JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HIGHWAY ENGINEERING STREAM

INVESTIGATING FACTORS AFFECTING THE OCCURRENCE AND SEVERITY OF REAR END CRASH AT SIGNALIZED AND UNSIGNALIZED INTERSECTIONS :ACASE STUDY OF KIRKOS SUB-CITY, ADDIS ABABA, ETHIOPIA.

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER'S OF SCIENCE (MSc) IN CIVIL ENGINEERING (HIGHWAY ENGINEERING STREAM).

BY:

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May,2020

Jimma, Ethiopia

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June, 20
Jimma, Ethiopia

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By:

Kifle Tadesse

APPROVED BY BOARD OF EXAMINERS

DECLARATION

I, Kifle Tadesse Nreae, declare that this thesis work titled "**Investigating Factors Affecting The Occurrence And Severity Of Rear end Crash At Signalized and Unsignalized Intersections In Addis Ababa Kirkos Sub City**" is my original work. The work has not been presented elsewhere for assessment and award of any degree or diploma. Where a material has been used from other sources, it has been properly acknowledged/referred.

Candidate:

Kifle Tadesse(BSc)

______________ ______/___/_____

Signature Date

As Master research Advisors, we hereby certify that we have read and evaluated this MSc research prepared under our guidance, by Kifle Tadesse entitled: Investigating Factors Affecting The Occurrence And Severity Of Rear end Crash At Signalized And Unsignalized Intersections. A case study of Kirkos Sub City, Addis Ababa, Ethiopia.

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Main Advisor

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Oluma Gudena (Eng.)

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Signature Date

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ABSTRACT

To reduce injuries in rear end road crashes, better understanding is needed between the relationship of rear end injury severity and risk factors. Factors such as driver-related, time related, environment-related and intersection type related were considered when developing statistical models to predict the effects of these factors on the severity of rear end crashes at intersections.

The purpose of this study is to investigate factors affecting occurrence and severity of rear end crash at signalized and unsignalized intersections in Kirkos Sub City, Addis Ababa. The target population was considered all rear end accidents occurred in Addis Ababa kirkos sub city signalized and unsignalized intersections, during the period 2015/16-20117/18 were included. The pivotal data necessary for the study was collected from the daily Road Traffic Accident records format of the Kirkos Sub city and Addis Ababa Police Commission. Descriptive stastics and ordred logit model is developed to investigate and identifying significant contributing factors for rear-end crash injury severities classified into four categories: pdo (no injury), slight injury, severe injury, and fatality.

The results of the proportional odds model show that vehicle service age, day of crash (thursday), light condition (day light), driver vehicle relationship (hired) and educational level (preparatory school) were found to be significant predictors for severity levels of rear end crash at signalized intersections. Similarly the time of rear end crash, experience of drivers (less than one year ,1-2 year) and vehicle driver relationship (owner) were found to be significant predictors for severity level of rear end crash at unsignalized intersections.

Specifically the study showed that severity levels of rear end crash at signalized intersections is more likely for vehicle service age (<1 year, 1-2 year, 2-5 years, 5-10 year) than vehicle service age > 10 years. Hired drivers are more likely to commit fatal accident than others (reference group) and drivers whose educational level preparatory school are less likely to commit severe outcome than those vehicles whose educational level are above preparatory school (reference group) at signalized intersections. Similary the study showed that severity levels of rear end crash at unsignalized intersections (12 am-6 am, 6 am-12 pm, 12 pm-6 pm) is more likely for time of rear end crash 6 pm-12 am (refernce group). Similary drivers whose driving experience are (<1 year, 1-2 year) are less likely to commit severe outcome than those drivers whose driving experience above 10 years (reference category). Drivers who drives their own vehicle and hired drivers are more likely to commit fatal accident than drivers who drives others (reference group) at unsignalized intersections. The developed methodology and estimation results provide insights for developing effective countermeasures to reduce rear-end crash injury severities and improve traffic system safety performance.

Keywords: Rear end crash, crash severity, Signalized intersection, Unsignalized intersections , ordinal logistic regrression , Proportional Odds (PO) Model and odds ratio.

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ACRONYOMS

AADT: Annual Average Daily Traffic

AATPRO: Addis Ababa Traffic Police Report Office

ANSID16.1-1996:American National Standard

AU: Africa Union

CI: Confidence Interval

DI: Disabling Injury

FHWA: Fedaeral Highway Adminstration

JIT: Jimma Institute of Technology

MI: Minor Injury

NHTSA: National Highway Traffic Saftey Admnistration

OLR: Ordinal Logistic Regression

OR: Odds Ratio

PDO: Property Damage Only

POM: Proportional Odds Model

RTAs: Road Traffic Accidents

SPSS: Statistical Package for the Social Sciences

US: United State

VMT: Vehicle Miles Travel

WHO: World Health Orgaization

CHAPTER ONE

INTRODUCTION

1.1. Back ground

The problem of morbidity and mortality from motor vehicle crashes is now acknowledged to be a global phenomenon. Traffic accidents represent a worldwide major problem over 1.2 million people died each year on the world's roads, and between 20 million to 50 million suffer non-fatal injuries. Over 90 percent of the world's fatalities on the roads occur in low-income and middle-income countries**.** The global losses due to road traffic injuries are estimated to be US$ 518 billion and cost government's between 1 percent to 3 percent of their gross national product (1).

About half of all crashes and half of all injury crashes occur at intersections (2). The federal highway administration (FHWA) reported in the year 2013 that the highest no of vehicle crashes in the United States happens at intersections. Over 2.8 million intersection related crashes occur each year and these account for about 40% of all types of reported crashes. A comprehensive analysis of accidents at intersection would help to find viable solutions to reduce the probability and severity of crashes (3).

Vehicle to vehicle crashes have been classified based on the collision type into four categories: Rear-end, side sweep, head-on and right angle collisions. Rear-end crashes occur when the front of a vehicle strikes the rear of a leading vehicle. They are common in road net-works. Rear-end crashes are one of the frequently occurring types of crashes, accounting for almost one-third of all reported crashes in the US and 11.8 percent of multivehicle fatal crashes (4). Moreover, signalized intersections are accident-prone areas especially for rear-end crashes due to the diversity of the braking behaviors of drivers increases due to signal change (5). In the U.S., there were approximately 1.89 million rear-end crashes in 2004 (constitute about 30.5% of all police-reported crashes) resulting in 2083 fatal crashes and 555,000 injury crashes. Rear-end crashes are the leading crash type occurring at signalized intersections (5). They represent 40.2 percent of all reported intersection crashes based on the crash history of 1531signalized intersections in the state of Florida (6), and 42% according to FHWA (7). Of all accidents in Japan, about 60% of the total, and 45% of the fatal accidents occur at intersections. Rear-end accidents are the most common type at signalized intersections in Japan, accounting for 35.4% of intersection accidents and 21.3% of all vehicular accidents (8).

Significant research effort have been undertaken to analyze the characteristics and causes of the rear-end crashes in different parts of the world. Several statistical modeling techniques were utilized to investigate the contribution factors affecting the occurrence and severity of rear-end crashes (9). The majority of the researchers applied linear regression analysis bases in the analysis and modeling process. The risk of rear-end crashes at signalized intersections was investigated by Yan, et al. (10) using the multiple regression modeling. The model showed that seven road environment factors (number of lanes, divided/undivided highway, accident time, road surface condition, highway character, urban/rural, and speed limit), five factors related to striking role (vehicle type, driver age, alcohol/drug use, driver residence, and gender), and four factors related to struck role (vehicle type, driver age, driver residence, and gender) are significantly associated with the risk of rear-end accidents.

In addition, Wang and Abdal-Aty (11) applied negative binomial link function for risk analysis at signalized intersections. It was found that traffic volumes, speed, number of legs, right and left-turn proportion are significantly affect the occurrence of the rear-end crashes. Kim et al. (12) estimated rear-end crash risk at freeways using a modified negative binomial regression. The results showed that urban area, curvature, off-ramp and merge, shoulder width, and merge section are factors found to increase rear-end crash probabilities. Harb et al. (13) used a conditional logistic regression model to estimate rear-end crash risk in work zone. This model showed that roadway geometry, weather condition, age, gender, lighting condition, residence code, and driving under the influence of alcohol and/or drugs are significant risk factors associated with work-zone crashes.

The situation of road traffic accidents is most severe in Sub-Saharan Africa where the lives of millions are lost and significant amount of property is damaged. In Ethiopia, the situation has been worsened as the number of vehicles has increased and consequently due to increased traffic flow and conflicts between vehicles and pedestrians. Despite government efforts in the road development, road crashes remain to be one of the critical problems of the road transport sector in Ethiopia. Every year many lives are lost and much property is destroyed due to road traffic accidents in the country (14). According to Person (15), Ethiopia has the highest rate of traffic fatalities per vehicle in the world. This calls for a comprehensive analysis of highway crashes at the stage of planning and designing; in a way that safety is considered as one aspect of performance assessment of roads.

Now a day, road traffic accidents are the major problems in Addis Ababa. Because, RTAs was increasing from year to year, these affect the economic growth of Addis Ababa. Currently, in Addis Ababa, at least one person dies and eight persons are injured every day (16). According to the police reports, motor vehicle traffic accidents in Kirkos Sub city during the year 2000 – 2005 are about 44,000 and are relatively less compared to more than 50,000 crashes during the period between 1985 and 1997, and an average 3000 crashes are reported to the police each year (17). Each year, therefore, there were 300 people killed and 1500 slight and serious injuries in Addis Ababa (17). As data from (18), indicated, in Kirkos sub-city during the year 2013/14, there were 31 deaths, 333 injuries and 2,586 property damages. In this sub-city, the road traffic accidents were increasing from year to year and time to time.

However, no information about the rear-end crashes in Ethiopia has been published before. Thus, significant efforts are needed to investigate and identify the contributing factors of rear end crash severity occurrence at signalized and unsignalized intersections for more understanding of its characteristics and to develop the proper countermeasures in order to reduce its occurrence and severity. Thus, methods to reduce accident severity are of great interest to traffic agencies and the public at large.

1.2.Statement of the Problem

Intersections are the most risky locations of a roadway system. Intersections contain a major safety challenge due to their large numbers and increasing complexity with many potential conflicting movements. Actually intersections constitute a small portion of the overall highway system, but injury crashes happening at intersections represent more than a half of the total injury crashes in road network. According to Wang, “the percentage of injury crashes at intersections was 68.9 percent, which was much higher than that for all other entities (example road sections) (19).

Engineers and researchers in the automobile industry have tried to design and build safer automobiles, but traffic accidents are unavoidable. The cost of deaths and injuries due to traffic accidents have a great impact on society (20). Traffic accidents and their severity are resulted from several factors ranging from driver behavior, roads characteristics, vehicles types, weather conditions, to cite few of them.

Ethiopia contributes much to the misery of RTA in Africa. At least one person is killed from every five car coincidences occurring in Ethiopia. Eventually the most shocking and terrible impact of RTA in Ethiopia is also stated in (21), as over half of RTA deaths in Ethiopia involve pedestrians, of whom 20% are children younger than 18 years old. In Ethiopia, the rate of road traffic accidents (RTAs) is very high; because road transport is the major transportation mechanism along with poor road infrastructure, poor traffic laws enforcement and other factors.

According to (22), Addis Ababa Ethiopia's capital city –shares 60% out of the total number of vehicles in the country while its population is only about 3.2% of the total population for the country. Other reports showed that a lack of advanced technology for controlling road crashes in Addis Ababa, a disproportionally low number of traffic police officers per number of vehicles and roads, bad crossing behaviours of pedestrians, ineffective or nominal road traffic laws and regulations were risk factors of road traffic crashes in Addis Ababa, Ethiopia (23).

In Addis Ababa, the rate of traffic accidents goes up together with the increase of motor vehicles and population size. The rise in automobile ownership together with the poor condition of the roads has resulted in the high level of traffic safety and congestion problems. In year, 2015/16, in Addis Ababa 439 people were dead, 3,089 people were injured and 19, 411 property damage were occurred in road traffic accidents (18).

Traffic accident in Kirkos sub-city of Addis Ababa accounts nearly 20.5 percent of total crashes and is quite high compared with that of the other sub-cities of Addis Ababa (24).

At signalized intersections, rear-end accidents are frequently the predominant accident type. These accidents result from the combination lead-vehicle deceleration and the ineffective response of the following vehicle's driver to this deceleration. Rear end accident is one of the most frequently occurring collision types in Kirkos Sub-City. In year 2013/14, 651 and 2012/13, 542, Rear end accidents were occurred at intersections in this sub-city (18). This problem started to alarm the need for undertaking coordinated effort to curb the problem. However, no information about the rear-end crashes severiy in Ethiopia has been published before. Thus, significant efforts are needed to investigate and identify the contributing factors of rear-end crash severity at signalized and unsignalized intersections for more understanding of its characteristics and to develop the proper countermeasures in order to reduce its occurrence and severity.

This paper mainly aims to investigate factors affecting the occurrence and severity of rear end crash at signalized and unsignalized intersections in Kirkos Sub City, Adiss Ababa based on data collected from the daily Road Traffic Accident records format of the Kirkos Sub City and Addis Ababa Police Commission.

1.3. Research Questions

In light of the above statement of the problem, the research was conducted to answer the following basic research questions.

- What are the general characterstics of rear end crash severity at signalized and unsignalized intersections ?
- What is the application of ordinal logistic regression in rear end crash severity investigation ?
- What are the main risk factors affecting the severity of rear end crash at signalized and unsignalized intersections?

1.4. Objective

1.4.1. General Objective

The general objective of this research was to investigate factors affecting the occurrence and severity of rear end crashes at signalized and unsignalized intersections in Kirkos Sub City, Addis Ababa.

1.4.2. Specific objective

The specific objectives of this study were:-

- To describe the general characterstics of rear end crash severity at signalized and unsignalized intersections.
- To show the applications of ordinal logistic regression models for rear end crash severity investigation.
- To identify main risk factors affecting the severity of rear end crash at signalized and unsignalized intersections.

1.5.Significance of the Study

However, no information about the rear-end crashes has been published before in Ethiopia .

- ✓ The study will help to create awareness for road user about severity of traffic problems.
- ✓ The study will have paramount importance to the government, municipal authorities and the community in the city to determine the need for road improvements.
- ✓ The study will be used as a bench mark information to those scholars who want to conduct future detailed studies on rear end severity crashes and offering information regarding the basic Factors Affecting The Severity of Rear End Crashes in the Sub-City.
- ✓ It can be used also as one source of information for those institutions concerned with road safety management and helps to improve the quality of decision-making in urban road transport safety planning.
- ✓ The study will supplement the existing literature of road traffic accidents that will work to assess the situation of road traffic accidents in Ethiopia.
- ✓ The study will add knowledge on understanding what factors contribute to the occurrence and severity of rear end crash at signalized and unsignalized intersections.

1.6.Scope of the study

The study confined to one of the major cities in Ethiopia, in Kirkos Sub-City Addis Ababa. The study area contains different types of land uses i.e. road network, business districts, administrative area, several educational institutions, residential area and others. The research also basis its invesigation on the data collected for the period of three years since July 2008-July 2010 E.C. This study mainly focuses on investigating factors affecting severity of rear end carshes at signalized and unsignalized intersections.

1.7.Limitations of the Study

- Since Traffic Police Officers were engaged in many tasks and were usually out of their offices, it was difficult to get them.
- The data on RTA of the offices were not available in electronic data base and had to be collected manually from handwritten day registration books. This took more time than is needed and cost more than expected.

1.8.Organization of the study

This research work has been classified into five chapters. The chapter hierarchy is aimed at making the paper to have scientific format. The general description of each chapter is summarized as follows.

The first chapter is related with the study on general introduction starts by discussion from global perspective to local scenario related with the research title (i.e. investigation of factors affecting the occurrence and severity of rear end crashes at signalized and unsignalized intersections in Addis Abeba : Case study Kirkos Sub City), statement of the problem, objective of the study, Basic research questions, Significance of the study, Scope of the study and limitation of the study. The chapter closes its discussion by stating the objectives of the study and how the paper is organized.

The second chapter discusses about the review of related literatures. The discussion of this chapter mainly focused on the global and regional trend of RTA, Factors affecting road traffic accident, factors Affecting Crashes At Intersections, Definition of Rear end crash, Factors contributing for rear end crash severity, Crash severity, Current Accident Severity Definition in Ethiopia, Road Accident Modeling.

The third chapter comprises methods applied in steering the entire work. It describes in detail how the selected methodology is adopted to come up with, in addition to methodology the chapter also explains about the data type, data source, from where the data obtained and required what for what purpose data use, and finally how it is collected and analysed.

The fourth chapter presents detailed results and discussions of the study. Finally the fifth chapter embraces conclusion and recommendations. In brief the chapter presents what conclusions can be drawn from this study and what lessons can be gained from the study for different stakeholders who directly or indirectly are affected by rear end road accident.

CHAPTER TWO

REVIEW OF RELATED LITERATURES

2.1. Introduction

According to the WHO Global Burden Of Disease project in 2004, nearly 1.3 million people of all ages were killed in road traffic crashes around the world and up to 50 million, more were injured or disabled. The South-East Asia and the Western Pacific Regions of WHO together accounted for two third of all road traffic deaths. However, the highest rates of road traffic death were in the African and Eastern Mediterranean Regions. To reduce or eliminate traffic fatalities and serious injuries, it is important to understand the factors that affect traffic crash severities.

In the area of accident severity research, continuous efforts have been conducted in order to investigate the relationship between the level of severity (dependent variable) and a set of explanatory variables, which usually include: driver attributes (e.g., age and gender), vehicle features (e.g., body type, vehicle age and number of vehicles involved in the accident), road characteristics (e.g., number of lanes, road surface conditions, intersection control and types of road), and accident characteristics (e.g., accident's main cause). Occasionally, the influence of other variables on accident severity like speed limit, day of the week, time of the day, average traffic characteristics (AADT), weather and traffic conditions have also been scrutinized (25) (26). Mao et al. (27) assessed the factors affecting the severity of motor vehicle crashes involving young driver in Ontario, Canada, using the population based case-control study. It is found in this study that, the following factors can significantly increase the risk of fatal injury crashes: drinking and driving (with an odds ratio (OR) of 2.3), impairment by alcohol (OR 4.8), exceeding speed limits (OR 2.8), not using seat belts (OR 4.7), full ejection from vehicle (OR 21.3), intersection without traffic control (OR 2.2), bridge or tunnel (OR 4.1), road with speed limit 70-90 kph (OR 5.6) or 100 kph (OR 5.4), bad weather (OR 1.6), head-on collision (OR 80.0), and overtaking (OR 1.9). Zhang (28) identified and quantified the factors affecting highway crash severity in Louisiana. Ordered Mixed Logit was used to predict the crash severity. The factors identified include, age and gender of the driver, vehicle speed, alcohol assumption, seatbelt usage, whether the driver was ejected from the vehicle, whether the crash was a head-on collision, whether an airbag was deployed, and whether one of the vehicles was following too close behind another vehicle. Ratanavaraha & Suangka (29) evaluated the factors that affect the accident severity on expressways in Thailand. The independent variables evaluated include, average speed on road section, average traffic volume per day, period of time, weather conditions, physical characteristics of accident area, and cause of accident. The study results found that speed limit was the only factor that affects the accident severity on expressway.

Intersections are one of the most dangerous locations of a roadway network, since they are not only a convergence point for vehicles and pedestrians travelling on conflicting paths, but also often impose significant responsibility on road users to make successful gap judgements. Furthermore, intersections are a source of traffic congestion, and have a prevalence of severe side-impact crashes. Therefore, intersection crashes not only comprise a substantial portion of traffic crashes, but also comprise a considerable portion of traffic crash casualties. There have been a number of studies carried out focusing on the frequency of intersection crashes. Wang and Nihan (30) created negative binomial crash models to predict the number of angle crashes occurring at signalized intersections in Tokyo. Chin and Quddus (31) applied the random effect negative binomial model to examine the occurrence of signalized intersection crashes in Singapore.

Several factors such as vehicle type, geometric attributes, collision pattern and driver 's characteristics had been found to be important correlates of intersection crash severity. For instance, Tay and Rifaat (32) reported that the fatality risk of motorcyclists and cyclists involved in an intersection crash was much higher than for car occupants.

Huang et al. (2008) identified the factors that affected the driver injury severity and vehicle damage. They concluded that severity was less for crashes that occurred in peak period and in good street lighting condition compared to crashes that occurred at night, T -intersections, vehicles traveling in the right-most lane, and for intersections equipped with red light running cameras. They also found that heavy vehicle drivers were less likely injured when compared with two-wheeler riders because of the better resistance of heavy vehicles.

Significant research effort have been undertaken to analyze the characteristics and causes of the rear-end crashes in different parts of the world. Wang and Qin (33) studied driver mistakes that occurred at uncontrolled, stop-controlled, and signalized intersections. The authors also identified potential countermeasures and concluded that running stop signs, high speed, driving under the influence of alcohol or drugs, and poor visibility can cause more crash severity.

Chen et al., (34) developed a multinomial logit model (BN approach) to investigate the contributing factors of rear-end crash severity. The results showed that truck-involvement, inferior lighting conditions, windy weather conditions, the number of vehicles involved, etc. could significantly increase driver injury severities in rear-end crashes. Lao et al. (9) applied the generalized nonlinear modeling approach to investigate the relationship between risk of rear-end crashes and independent variable. The results showed for example that truck percentage and grade have a parabolic impact: they increase crash risks initially, but decrease them after the certain thresholds. Other approaches were applied to quantify the risk of rear-end crashes. Oh et al. (35) utilized inductive loop detector data to determine the potential of rear-end collision based on fuzzy-clustering algorithm. The results showed that six categories were more appropriate to establish collision risk criteria.

Ethiopia is one of the worst countries in the world where road transportation kills and injuries are in large number of road users every year. In Ethiopia, traffic police reports are the official sources of data for road-related accidents. In Ethiopia, the rate of road traffic accidents is very high; because of road transport is the major transportation mechanism along with poor road infrastructure, poor enforcement of traffic laws and other factors (14). In Ethiopia each year more than two thousand people die and ten thousand people injured in road traffic crashes (36).

The rate of traffic crashes and pollution in Addis Ababa goes up together with the increase of motor vehicles and population size. The rise in automobile ownership together with the poor condition of the roads has resulted in the high level of traffic safety and congestion problems. Despite it has low level of motorization; the share of the city in the total number of crashes was 60 percent in 1989 and 55 percent on the average from 1986-2002. During this period, annual average traffic crash growth had been 31.4 percent. Besides, the increase in car traffic has resulted in an increase in air and noise pollution of the city. As the data from Addis Ababa police commission during the year 2008E.C there were 463 deaths,1996 serious injuries, 973 slight injuries, 23,550 property damages. Rear end accident is one of the most frequently occurring collision types in Kirkos sub-city. In year 2013/14, 651 and 2012/13, 542, rear end accidents were occurred at signalized and unsignalized intersections in this sub-city (18).

2.2.Factors affecting road traffic accident

Traffic crash may have many contributing factors, such as those related to driver behavior, road geometry, traffic volumes, vehicle, and environment. The influence of such variables on crash occurrence could significantly vary on a case-by-case basis, but in general, both behavioral factors related to the driver’s errors, and non-behavioral factors related to road geometry, traffic flow conditions, vehicle, and environment are thought to significantly affect traffic crashes (37).

Research have revealed that there are generally six major groups of risk factors affecting traffic crash occurrence (38; 25) :

1. **Driver behavior**: Alcohol and drug use, reckless operation of vehicle, failure to properly use occupant protection devices, the use of cell phones or texting, and fatigue.

2. **Vehicle factors**: Vehicle type, and the engineering and the safety design standards for vehicle performance. For example, the design of windshield glass and the location and durability of gas tanks can increase safety. Passenger protection systems in vehicles (i.e. airbags, safety belts), if used, can eliminate injuries or reduce their severity.

3. **Roadway characteristics**: Road geometries and road side conditions, such as well-designed curves and grades, wide lanes, adequate sight distance, clearly visible

striping, flared guardrails, good quality shoulders, roadsides free of obstacles, well-located crash attenuation devices, and well-planned use of traffic signals.

4. **Traffic volumes**: Average annual daily traffic (AADT) or the vehicle miles travelled (VMT). AADT is the average number of vehicles passing a point along a particular road section each day. Thus, AADT represents the vehicle flow over a road section on an average day of the year. VMT refers to the distance travelled by vehicles on roads. It is often used as an indicator of traffic demand and is commonly applied to evaluate mobility patterns and travel trends.

5. **Environmental factors**: Weather conditions, and light conditions.

6. **Time factors**: The season of the year, the month of the year, weekdays, and the hour of crash occurrence

2.3.Intersections

Intersections are among the most dangerous roadway facilities due to the complex traffic conflicting movements and frequent stop and go traffic. Crashes often occur at intersections because these are the locations where two or more roads cross each other and activities such as turning left, crossing over, and turning right have the potential for conflicts resulting in crashes. Traffic crashes at intersections cause huge cost to society in terms of death, injury, lost productivity, and property damage. A number of recent studies of crashes for North American urban roads suggest that over 50% of reported road crashes take place in the proximity of intersections (39). A study conducted by [39] estimated that one third of crashes occur at intersections or the approach to intersections. In Florida, in 1995, 101,311 crashes occurred at intersections. These intersection crashes resulted in 530 fatalities and 79,646 injuries (40). The most common roadway related accidents at intersections are crossing collisions. A crossing collision can happen while attempting to go through an intersection or while trying to turn into a lane. If a drivers' view obstructed they will unable to ascertain whether it is safe to cross or not. According to NHTSA (41) says that about 40 percent of car crashes in the U.S. happen at intersections and according to (42) says also more than 94,800 car accidents occurred at intersections across the state in 2011 alone. Car drivers, passengers, pedestrians and bicyclists are all subject to being seriously hurt in car accidents at intersections. Speeding is recognized as a major contributing factor in traffic crashes, specifically for intersections (42).

2.3.1. Factors Affecting Crashes At Intersections

The NHTSA, is a major study of intersection accidents, found that turning left, crossing over or turning right at an intersection creates a potential for conflicts that result in literally millions of collisions each year. The Federal Highway Administration (FHWA) reported in the year 2013 that the highest number of vehicle crashes in the United States happens at intersections. Over 2.8 million intersection-related crashes occur each year and these account for about forty percent of all types of reported crashes. These crashes had a detrimental effect on loss of about 8500 lives and more than a million injuries. A comprehensive analysis of accidents at intersections would help find viable solutions to reduce the probability and severity of crashes (3). The NHTSA report said 96 percent of intersection accidents actually caused by driver error. The most frequent driver mistakes before an intersection accident were inadequate surveillance (inattention), false assumption of other driver's action, turning with obstructed view, illegal maneuver, internal distraction (distracted driving) and misjudgment of gap or other car's speed etc. Accidents that happen while simply crossing an intersection most often caused by inattention or an illegal maneuver, the NHTSA said. Rear-end accidents are the most common accident type at signalized intersections since the diversity of actions taken increases due to signal change. Specific causes of rear-end accidents include the following drivers' inattentive driving and following too closely. A proper space cushion is needed to provide a driver enough reaction time to recognize a hazardous situation and make a stop decision. Typically, driver, vehicle, and roadway/environment characteristics influence accident occurrence and injury severity. Moreover, since a rear-end accident is related to both driving behaviors and performances of the leading (struck) vehicle and the following (striking) vehicle, the accident risk is possibly associated with struck or striking role that a driver or vehicle would assume in a rear end accident (10). The NHTSA study also said intersection accidents involving drivers ages 24 years old and younger are more likely to be caused by "internal distraction" (i.e., distracted driving), "false assumption of other's action," "going too fast for conditions (speeding) or aggressive driving," or "external distraction" (41). According to the

North Calorina (42), major "contributing circumstances" for accidents statewide in 2011 included circumstances commonly found at intersections, such as: Disregarded stop sign (3,315 crashes), disregarded traffic signals (6,395), disregarded yield sign (442) and right turn on red (224) and another 6,686 car accidents in North Carolina in 2011 were attributed to an improper turn by the driver.

2.3.2. Factors Affecting Crashes At Signalized Intersections

Signalized intersections are where most vehicle accidents happen. According to the Federal Highway Administration (FHWA) report, over 2.8 million intersection-related crashes occur each year in the United States of America. It accounts for over 40 percent of all reported crashes. Vehicle movements at signalized intersections have many distinct conflicting patterns which contribute to the number of crashes. At signalized intersections, differences exist in traffic volumes, travel speeds, traffic signal operations, intersection geometry, and vehicle-bicycle-pedestrian interactions which affect the safety performance on various approaches. Traffic conflicts that take place at a signalized intersection can be significantly reduced by studying the factors such as the geometry design and the signal timing which is calculated according to the number of lanes and the annual average daily traffic (3). Crashes related to signalized intersections also tend to be more severe: 30% of intersection-related fatalities occurred at signalized intersections while only 10% of intersections are signalized Rice (43).

Table 2.1 : Rear end Crash Contributing Factors at Signalized Intersections

Rear-end or Sideswipe	Inappropriate approach speeds
	Poor visibility of signals
	Unexpected lane changes on approach
	Narrow lanes
	Unexpected stops on approach
	Slippery pavement
	Excessive speed

source (44)

2.3.3. Factors Affecting Crashes At Unsignalized Intersections

Unsignalized intersections are those intersections with stop control, yield control and no traffic control. Unsignalized intersections can be differentiated from their signalized counterparts in that their operational functions take place without the presence of a traffic signal (45).

Table table 2.2 : Possible Rear end Crash Contributing Factors at Unsignalized Intersections.

Rear-end	Pedestrian crossing
	Driver inattention
	Slippery pavement
	Large number of turning vehicles
	Unexpected lane change
	Narrow lanes
	Restricted sight distance
	Inadequate gaps in traffic
	Excessive speed

source (44)

2.4. Definition of rear end crash

Rear-end crashes occur when the front of a vehicle strikes the rear of a leading vehicle. They are common in road net-works. In the U.S., there were approximately 1.89 million rear-end crashes in 2004 (constitute about 30.5% of all police-reported crashes) resulting in 2083 fatal crashes and 555,000 injury crashes (5). Rear-end crashes are the leading crash type occurring at signalized intersections. According to The National Highway Transportation Safety Administration (NHTSA), rear end accidents account for 28% of all accidents on US roads costing $164 billion in losses. These incidents range from minor “fender benders” to accidents that result in major property damage, injury and death. NHTSA estimates that a rear end accident occurs every eight seconds in the United States. As one might suspect, young males have the highest indecent rates relative to this type of accident.

Most common causes include combinations of speeding/driving too fast for conditions, tail-gating (following too close), aggressive driving and inattentiveness. These causes are often compounded by a change in weather conditions and a lack of vehicle maintenance (brakes). However, more than 60% of these collisions are due to driver inattention (46). Rear-end crashes are the most frequently occurring type of collision, accounting for approximately 29 percent of all crashes and resulting in a substantial number of injuries and fatalities each year. Rear-end collisions in which the lead vehicle is stopped or moving very slowly prior to the crash account for the majority of these crashes. Over the years several initiatives have addressed the problem of rear-end crashes, with limited success (47). A proper space cushion is needed to provide a driver enough reaction time to recognize a hazardous situation and make a stop decision. Typically, driver, vehicle, and roadway/environment characteristics influence accident occurrence and injury severity. Moreover, since a rear-end accident is related to both driving behaviors and performances of the leading (struck) vehicle and the following (striking) vehicle, the accident risk is possibly associated with struck or striking role that a driver or vehicle would assume in a rear-end accident. The driver age and gender were considered as main driver characteristics that might be associated with a rear-end accident. However, the younger drivers, especially under 25 years, are more likely to be involved in aggressive attitude and inattentive driving. A previous study on rear-end accident indicated that drivers younger than 18 years were most vulnerable to roadway accidents followed by 18–24-year-old drivers; the propensity of drivers involved in accidents showed a decreasing trend with increasing age until the age of 69, after which the drivers again showed a higher accident involvement propensity as compared to the drivers who were 25–69 year old (48). How ever no information about rear end crash in Ethiopia has been published before. Thus, significant efforts are needed to investigate and identify the contributing factors of rear-end crashes severirty for more understanding of its characteristics and to develop the proper countermeasures in order to reduce its occurrence and severity.

2.4.1. Factors contributing for rear end crash severity

Significant research effort have been undertaken to analyze the characteristics and causes of the rear-end crashes in different parts of the world. Several statistical modeling techniques were utilized to investigate the contribution factors affecting the occurrence and severity of rear-end crashes (49). The majority of the researchers applied linear regression analysis bases in the analysis and modeling process. The risk or rear-end crashes at signalized intersections was investigated by Yan, et al. (50) using the multiple regression modeling. The model showed that seven road environment factors (number of lanes, divided/undivided highway, accident time, road surface condition, highway character, urban/rural, and speed limit), five factors related to striking role (vehicle type, driver age, alcohol/drug use, driver residence, and gender), and four factors related to struck role (vehicle type, driver age, driver residence, and gender) are significantly associated with the risk of rear-end accidents.

In addition, Wang and Abdal-Aty (11) applied negative binomial link function for risk analysis at signalized intersections. It was found that traffic volumes, speed, number of legs, right and left-turn proportion are significantly affect the occurrence of the rear-end crashes.

Table 2.3 :Example Haddon Matrix for Rear-End Crash

Period	**Human Factors**	**Vehicle Factors**	**Roadway Factors**
Before the Crash (Causes of the Hazardous situation)	distraction, fatigue, inattention, bad judgment, age, cell phone use, impaired cognitive skills, deficient driving habits	bald tires, worn brakes	wet pavement, polished aggregate, steep downgrade, poor signal coordination, limited stopping sight distance, lack of warning signs
During the Crash (Causes of crash severity)	vulnerability to injury, age, failure to wear a seat belt	bumper heights and energy absorption, headrest design, airbag operations	pavement friction and grade
After the Crash (Factors of crash outcome)	age, gender	ease of removal of injured passengers	the time and quality of the emergency response, subsequent medical treatment

2.5.Crash severity

Crashes vary in the level of injury or property damage. The American National Standard ANSI D16.1-1996 defines injury as “bodily harm to a person”. The level of injury or property damage due to a crash is referred to in the HSM as “crash severity.” While a crash may cause a number of injuries of varying severity, the term crash severity refers to the most severe injury caused by a crash.

Crash severity is often divided into categories according to the KABCO scale, which provides five levels of injury severity. Even if the KABCO scale is used, the definition of an injury may vary between jurisdictions. The five KABCO crash severity levels are:

K - Fatal injury: an injury that results in death;

A - Incapacitating injury: any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury occurred;

B – Non-incapacitating evident injury: any injury, other than a fatal injury or an incapacitating injury, which is evident to observers at the scene of the accident in which the injury occurred;

C - Possible injury: any injury reported or claimed which is not a fatal injury, incapacitating injury or non-incapacitating evident injury and includes claim of injuries not evident;

O – No Injury/Property Damage Only (PDO).

When the dependent variable (accident severity) is discrete and contains more than two categories, the multinomial logistic regression(logit) model is a well-established method to use (51). The multinomial logit model combines the independent variables to estimate the probability that a particular event will occur; in this case the probabilit of an accident to be slight, serious, or fatal. When the order of the values is taken into consideration, thus hierarchy has a natural meaning such as in this study, the commonly used model is an ordered logistic regression (52).

2.5.1. Current accident severity definition in Ethiopia

In Ethiopia, even though a documented definition of different accident severity levels was not obtained for this study, but from the data base of Addis Ababa police commission the the crash severity is divided in to the following.

1. A fatal accident : is the one in which one or more individuals die as a result of traffic accident within the same reporting 30 days of the occurrence of the accident.

2. A serious injury: is one in which a victim sustains severe cuts, bleeding, breaks, and other damages which requires a medical treatment as "in-patient" in hospital.

3. A slight injury : is the one as a result of which the victim sustains only small cuts, scratches, and other small damages which may be treated as an out-patient without requiring admission to a hospital.

4. Property damage only accident: is the one as a result of which no person is injured only one or more vehicles involved in the accident are damaged.

2.6.Road Accident Modeling

Road accident modeling is the way of developing accident predicting equation to forecast the future demand of the road accident based on the current crash information. So it is advisable to understand accident variables characterized as dependent (response) and independent (explanatory).

2.6.1. Types of Variables

Variables may take several forms, and it will be important later that someone aware of, and understand the nature of variables. The following variables are those which are most likely to encounter in deferent research.

1. Categorical Variables

Such variables include anything that is "qualitative" or otherwise not amenable to actual quantification. There are a few sub classes of such variables.

➢ **Dummy variables**: take only two possible values, 0 and 1. They signify conceptual opposites: war vs. peace, fixed exchange rate vs. floating exchange rate, etc.

➢ **Nominal variables:** can range over any number of non-negative integers. They signify conceptual categories that have no inherent relationship to one another: red vs. green vs. black, Christian vs. Jewish vs. Muslim, etc.

➢ **Ordinal variables:** are like nominal variables, only there is an ordered relationship among them: no vs. maybe vs. yes, etc.

2. Numerical variables

Such variables describe data that can be readily quantified. Like categorical variables, there are a few relevant subclasses of numerical variables.

- **Continuous variables** can appear as fractions; in reality, they can have an infinite number of values. Examples include temperature, GDP, etc
- **Discrete variables** can only take the form of whole numbers. Most often, these appear as count variables, signifying the number of times that something occurred: the number of firms invested in a country, the number of hate crimes committed in a county, etc.

The main goal of developing accident model is to predict the future outcomes based on the existing data of traffic accident in specified road section. Prediction of accidents is performed by analyzing the various factors (variables) responsible for accidents and quantifying their effect on the accidents using statistical techniques.

Several global studies have been carried out in the field of accident prediction modeling in the past few decades. Beginning with the pioneering effort conducted by popularly known as the Smeed's law developed in the year 1968; this is an empirical equation that relates the vehicle registration and population to the number of fatalities (53). The stability of the Smeed model for application to the various states over time was also investigated. The various models developed were compared based on the coefficients of variation (CV) using the Statistical Package for Social Science (SPSS) software. It was found that the original Smeed model overestimated the fatality rate per vehicle when applied to the Indian conditions.

To account for the probabilistic nature of accident occurrence Saccomanno and Blower have used a Poisson log linear model to explain variations in accident rates. This Poisson regression model is especially suitable for handling data with large numbers of zero counts. However, this model could be inappropriate for road accident counts, since it fails to account for extra-Poisson variation (the value of the variation could exceed the value of the mean) in the observed accidents counts. Accident severity is of special concern to researchers in traffic safety since this research is aimed not only at prevention of accidents but also at reduction of their severity. One way to accomplish the latter is to identify the most probable factors that affect accident severity.

2.6.2. Models for Polytomous Dependent Variables

Since the real traffic data nature for dependent variables is polytomous, evaluation was made to justify which model is more preferable for accident data registered by Ethiopia crash data. Of course, many dependent variables of accident will have more than two possible categories. These categories might be unordered or ordered. On the basis of the survey data,overall dependent variables have polytomous nature with unordered categories (54).

Fernando states that to select a model that fits for specific data, it is necessary to consider the nature or property of the data. According to his logic different models fits different data series. In line with this fact the following models are identified with their nature as follow:

A) Ordinal Logistic Regression:- It is used when a dependent variable has more than two categories and the values of each category have a meaningful sequential order. It is applied where a value is indeed 'higher' than the previous one.

B) Multinomial Logistic Regression:- It is used when dependent variable has more than two categories and the variable is purely nominal, we can extend the dichotomous logit model, using one of the categories as reference and modeling the other responses j=1, 2, m-1 compared to the reference. Based on the above investigation and model result the overall analysis is not significant and Standardized coefficient cannot obtain.

C) Multinomial Probit Regression: - It is used when a dependent variable has more than two categories and the variable is really nominal, we use multinomial probit (probit). The probit in this model are for cumulative categories at each point, contrasting categories above with categories below. This model provides standardize estimated coefficient.

2.6.3. Ordinal logistic regression

Logistic regression model can be classified as multinomial, ordinal and binary. In this investigation Ordinal logistic regression model was used. The ordinal logistic regression procedure empowers one to select the predictive model for ordered dependent variables. It describes the relationship an ordered response variable and a set of explanatory variables. The explanatory variables may be continuous or discrete (or any type). The responses are discrete or qualitative (which is ordered in nature) rather than continuous or quantitative in nature. Many such analyses involve an outcome or dependent variable that is ordinal and in these studies the logistic regression model has become the statistical model of choice (55). Logistic regression may be useful when we are trying to model a categorical dependent variable as a function of one or more independent variables being the dependent variable has two outcomes. Ordinal logistic regression (OLR) is a type of logistic regression analysis when the response variable has more than two categorizes with having natural order or rank. In statistics, the ordered logit model (also ordered logistic regression or proportional odds model), is a regression model for ordinal dependent variable. It is natural to consider methods for more categorical responses having more than two possible values. Rear End accident severity is the dependent variable. The original data has four categories of severity. They are Property Damage Only (PDO), Minor Injury (MI), Disabling Injury (DI) and Fatal.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1.Description of the study area

Addis Ababa, the seat of the Federal government of Ethiopia and Oromia regional state, is located at 9°3′ N and 38°42′E. It holds a position very close to the geographical centre of the country. The city stretches for more than 20 km East-West and over 25 km North-South direction. The northern limit is Entoto Mountain, to the south; it extends to the plains of Akaki river. The western limits are the flanks of mount Wechecha and the eastern limit climbs up to the plateau of Showa (56).

Addis Ababa lies at a maximum altitude of 2900 meters above sea level. Because of having the highest altitudinal position, Addis Ababa ranks the fourth highest capital city in the world and takes the first rank from African cities. There is a great variation of height within the city, so that much of it is built on the slope (57).

The city has an expanded area of 540 sq. km and divided into 10 sub-cities and 100 woreda for administrative purpose. The city has experienced spatial spread mostly towards the southern, eastern and south western parts. The spatial spread is mainly guided by topography and road network development. The topography of Addis Ababa is not suitable for the transport network development point of view (57). The city's landscape is very sloppy and mostly exposed to flooding.

It has a population of 3,384,569 according to the 2007 population census, with annual growth rate of 3.8%. This number has increased from the originally published 2,738,248 figure and appears to still largely underestimate. The city is populated by people from different regions of Ethiopia (58). More than 50% of the city"s residents live under poverty line and 80% of the built up urban area is categorized as slum according to UN criteria. Addis Ababa is the 4th largest diplomatic center in the world as it is a headquarter of UN Economic Commission for Africa (UNECA), African Union (AU) and a home of more than 90 embassies and various international organizations (59). Addis Ababa therefore often referred to as "the political capital of Africa" for its historical, diplomatic and political significance for the continent. The

Federation of African Societies of Chemistry and Horn of Africa Press Institute also headquartered in Addis Ababa (60).

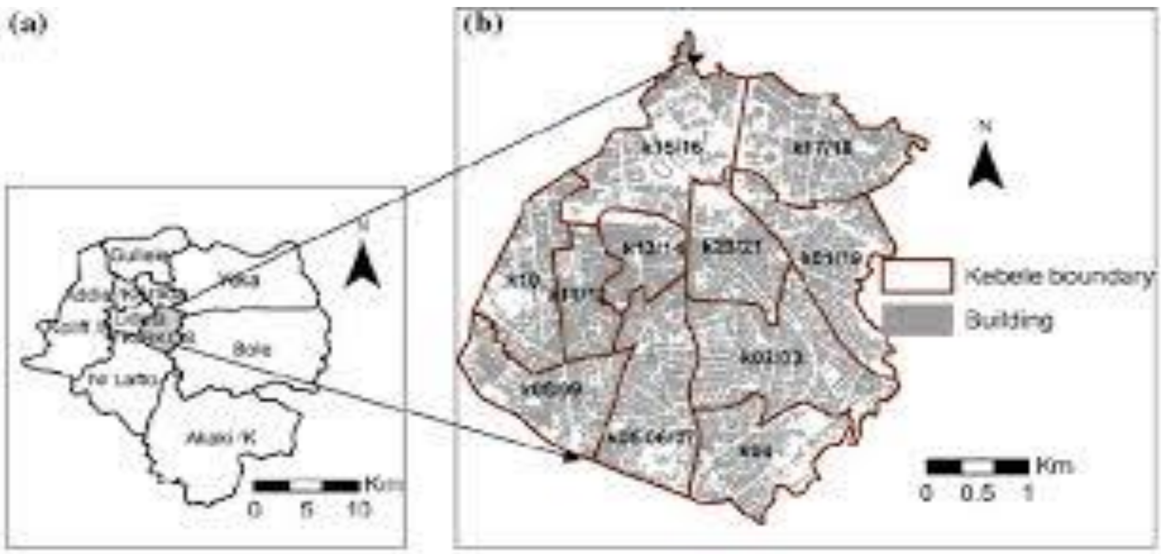
Out of all the crashes registered in Ethiopia, Addis Ababa holds about 60% on average. This is partly because the city has great contact through its all gates with different regions every day. In addition to this, of the registered motor vehicles in Ethiopia, the city takes about 77% of it. All these facts reveal that Addis Ababa, having a great deal of concentration of vehicles and traffic, takes the lion's share in car crashes also. Statistical data from the office depicts that Addis Ababa is experiencing around 700 crashs per month and the costs of such fatalities and injuries due to traffic crashs have a great impact on various aspects of the society (61).

Addis Ababa City Administration is divided into ten sub-cities: namely, Addis Ketema, Akaki-Kaliti, Arada, Bole, Gulelle, Kirkos, Kolfie-Keraniyo, Lideta, Nefas Silk-Lafto and Yeka Sub-city. The study area is in the kirkos sub-city (Figure 3.1).

Traffic accident in Kirkos sub-city accounts nearly 20.5 percent of total crashes in Addis Ababa and is quite high compared with that of the other sub-cities.

More specifically, Kirkos sub-city is geographically located at 9°2′6″N 38°45′28″E. It covers an area of 1464.72 hectares. The sub-city is roughly situated in the central part of Addis Ababa, nearby the center, bounded from the South by Nifase silik lafto, from West by lideta, from East by Bole and from North by Arada sub-cities (Figure 3.1). It is divided into 11 woredas, 31 sub-woredas, 111 sefers, and 316 blocks.

There are several features which makes the sub city differs from other sub city. It is the sub city where the National Palace and international organizations like African Union, which made Ethiopia the seat of Africa, Economic Commission of Africa and 23 embassies are located. In addition to this, international features like the first National Stadium, the railway station, Addis Ababa museum, Red Terror Martyrs Memorial Museum, Mesqel Square: which is multipurpose square; Exhibition center and National Theater are located in this sub city. Moreover, Filwuha spa which is unique features for the establishment of Addis Ababa, and the Gottera interchange the first modern and sophisticated road section as well as nations and nationalities square are also located in the sub city. Beside these, Kirkos is the most commercially vibrant subcity with several commercial center centers like 25 Star hotels including Sheraton Addis and Hilton, 161 financial instuitions including commercial bank of Ethiopia head office and Awash international bank and insurance. Minster and government offices such as Minister of Justice and road authority are found in this sub city (62).



source (63)

Figure 3.1 Kirkos sub city map(study area)

According to the 2007 census, the total population within this sub city is 220,991 which are 8.07% of the entire population of the city. From the total population 103,314 are males while 117,677are females. Lots of people live in Wereda 04 with population number of 28450 which is 12.87% of the sub city population. And relatively few people live in Wereda 06 with population number of 11,042-which is 5% of the sub city population.

The densely populated Wereda in the sub city is Wereda 10 with population density of 331.83 peoples /hectare and the least dense Wereda is Wereda 07 with population density of 90.6 peoples /hectare. Averages of 150.88 people live in each hectare area of the sub city which makes (64).

In Kirkos sub-city there are a lot of unsignalized and signalized intersections. This study includes all signalized and major unsignalized intersections. There are only ten signalized intersections in kirkos sub city and many unsignalized intersections. This study includes ten signalized and ten unsignalized intersections. The unsignalized intersections are selected by intersections having higher traffic accident. The signalized intersections are, such as intersections, near to Estifanos church, Meskel Square, Legahar, near to Tell Bar, near to Buna Ena Shaye Building, near to Commerce, near to National Theater, Bulgaria intersection, tobacco monopole intersection and near to Harambe Hotel and unsignalized intersections are, such as intersections near to Ureal Church, near to kasnches Sunday market, near to upper Grand Palace, near to Filwoha, near to AU, near to bête mengste, Dembell seti ruondaboutt, Olompia intersection , Kera serawoch and Kera intersection.

3.2.Research design

This study involved the following steps: First problem was identified then a detailed review of past research in rear ends accident severity next collecting rear end accidents data for signalized and unsignalized intersection. After collecting the data, then transferred to computer for statistical analysis. Then the models were developed to estimate the factors contributing for rear end accident severity. Finally, the finding of the statistical analysis was interpreted. The figure below shows the research design.

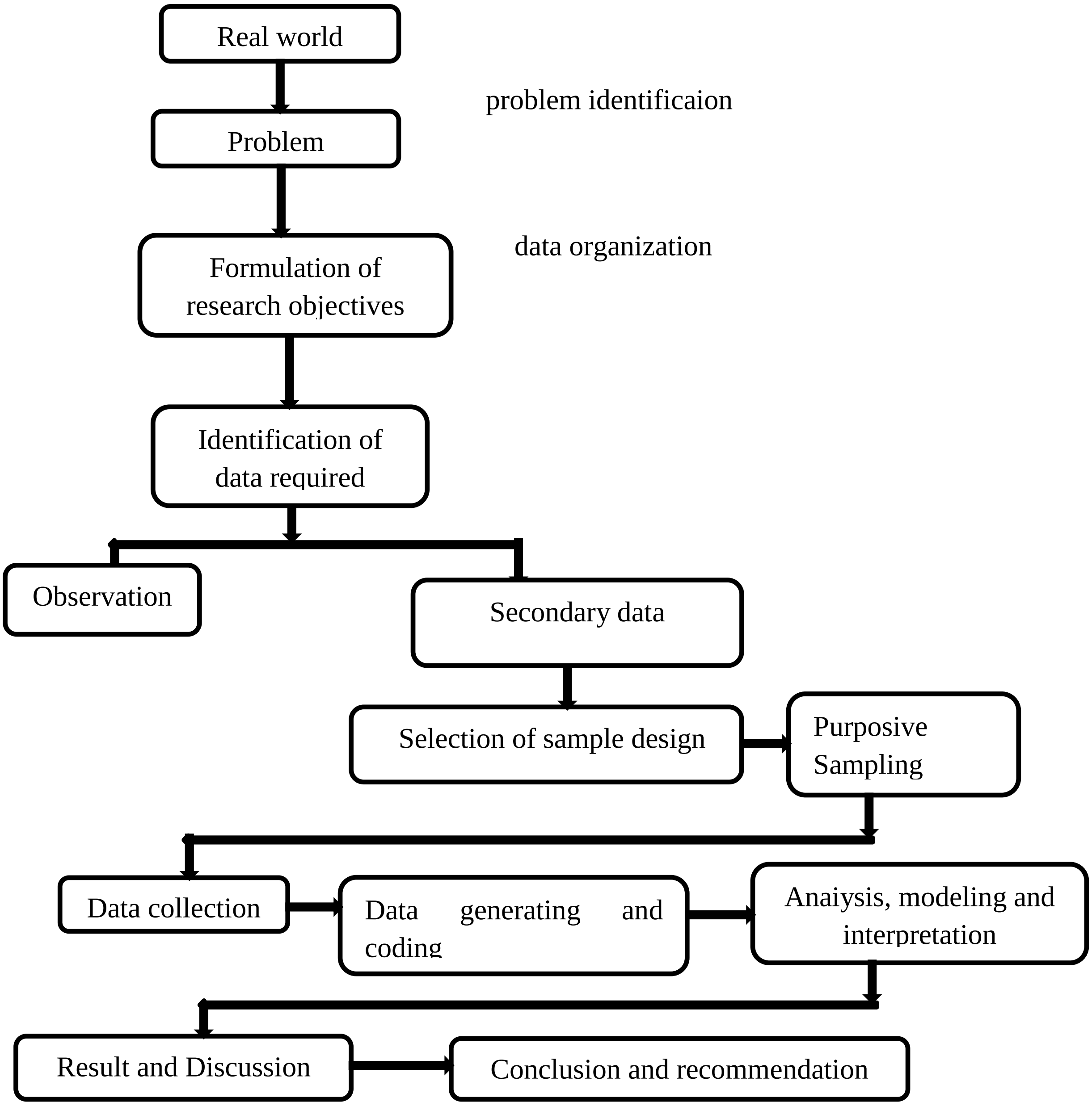


Figure 3.2. Research study design flow chart.

3.3.Target population

All rear end accidents occurred at kirkos sub city roads recorded in Addis ababa police commission and kirkos subcity traffic police from 2008-2010 E.C.

3.4.Sample size and sampling technique

3.4.1. Sampling technique

The sampling technique that used to get the necessary data for this research was purposive sampling.

3.4.2. Sampling Sizes

The sample inspections selected is provided by using purposive sampling. All registered rear end crash at signalized and unsignalized intersections in kirkos sub city covering the period from 2015/16-2017/18.

3.5.Study variables

The following dependent and independent variables considered for this study:

3.5.1. Dependent Variable

Dependent variables in the statistical process were:

- ✓ Rear end crash severity (fatal,serious injury,slight injury,PDO).

3.5.2. Independent Variables

The independent variables were:

Socio demographic and other variables related to the driver like:

- ➢ Age
- ➢ Sex
- ➢ Educational background
- ➢ Driver vehicle relationship
- ➢ Driving experience

Vehicle related variables:

- ➢ Vehicle type
- ➢ Vehicle years of service

Time related variables:

Intersection type related variables:

Light condition related variables:

Weather condidtion related variables:

Primary cause of accident:

3.6.Nature and source of data

3.6.1. Primary data collection

The major primary data collection was site visit and observation of intersections.

3.6.2. Secondary data collection

In Ethiopia, the police service is the main organization that is responsible for road crash data collection and storage. Secondary data for rear end crash were obtained from the daily RTA police files of Kirkos sub-city traffic police report office and Addis Ababa police commission. The crash data set contains time of crash, day of crash, year of crash, sex of driver, age of driver, weather condition, light condition, crash location, type of crash, level of injury etc.

Rear end accident data:- Rear end accident data for signalized and unsignalized intersections were collected from Addis Ababa Police Commission booklet and Kirkos-sub city police stations that were recorded during 2015/16-2017/18. From these, the collected data include;

- Location, name and classification of the road & intersection;
- Date, month, years, day of the week, time.
- Light conditions (day light, dark hour with good, street, dark hour with poor street light, dark hour with no street light);
- Weather condition (fine, mist/fog, cloudy, light rain, heavy rain, hot, cold wind, other);
- Classification of the accident (fatal, serious injury, light injury, property damage only);
- Type of the vehicle and manufacture years;
- Nature of the accident (over turning, head-on collision, rear-end collision);
- Name, sex, age, education, address of the driver, type and license number.
- Vehicle involved (load, vehicle defect / brake, steering tyres and other);and
- Other than drivers involved in accidents (age, status).

3.7.Data collection method

Data were collected using a structured checklist which was developed based on daily RTA registration book format. The rear end accident data provided by the Police Agency, consists of the data happening on the road from 2008-2010 E.C were collected from from Addis Ababa Police Commission booklet and Kirkos-sub city police stations book let.

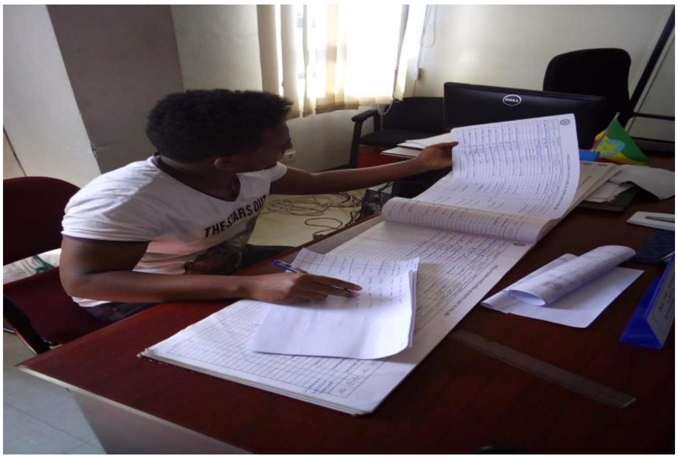


Figure: 3.3 A photograhe taken by Ashenafi Tesfay during data collection.

3.8.Method of data analysis

Data were entered, cleaned and analyzed using SPSS version 20. First Descriptive statistics of percentages and frequency distribution using tables and figures were carried out to explore the socio demographic characteristics related to the driver, vehicle, intersection, time, day, weather condition, light condition and characteristics related to direct or in direct cause of the accident occurrence of rear end crash severity at signalized and unsignalized intersections. Data analysis is the process of observing the data, transforming it, and modeling it to obtain useful information. This modeling process allows the identification of statistically significant factors that contribute to rear end crash severity at signalized and unsignalized intersections. Regression Analysis is a statistical process of estimating relationships between variables. There are different types of regression analysis for different type of data. The methodology used to model the rear end crash severity data was Ordinal Logistic Regression (OLR). Ordinal logistic regression was used to assess the association between the dependent and independent variables, outcome of rear end crash with socio demographic characteristics related to driver (age, sex, educational background, driving experience and driver vehicle relationship and characteristics related to direct(in direct) cause of the accident (year of accident, road user, road condition, vehicle service years, reason of accident, time of the accident, day of accident, location of accident, type of vehicle involved, vehicle years of service and reason of injury). Adjusted odds ratio (OR) with 95% confidence interval (CI) and P values were calculated. P< 0.05 was considered statistically significant.

Afour-point ordinal scale was used to classify the severity of rear end crashes occurred in kirkos sub city signalized and unsignalized intersections, including a. 0= fatal there is at least one person killed immediately or dying within 30 days as a result of the crash. b. 1 = severe injury : is one in which a victim sustains severe cuts, bleeding, breaks, and other damages which requires a medical treatment as "in-patient" in hospital but no person is killed; c. 2 = slight injury: is the one as a result of which the victim sustains only small cuts, scratches, and other small damages which may be treated as an out-patient without requiring admission to a hospital. D. 3 = PDO (property damage only). Therefore, injury severity can be regarded as the dependent variable in the proposed model with pdo (3) slight injury (2), heavey injury (1) and fatality (0).

According to the vehicles involved during the injury, the explanatory variables reflecting the vehicle profiles include vehicle type and vehicle service age. Further more, the crash data collected involve either two vehicles or more than two vehicles, in which the vehicle with main responsibility is named as vehicle1, and those with minor responsibility is neglected.

3.8.1. MODEL

In order to meet the objective set up on this study ordinal logistic regression model and tests related are employed as a general methodology.

Logistic Regression Model

Logistic regression is used to predict the probability of dependent variable on the basis of independent variables and to determine the effect size of the independent variables on the dependent; to rank the relative importance of independents; to assess interaction effects; and to understand the impact of covariate control variables. The impact of predictor variables is usually explained in terms of odds ratio and hence the name logistic regression, also called the log-odds function. This model applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not).

Rear end accident severity is, usually, defined as a categorical variable; the values of which vary according to the method being officially suggested by the authority designing and collecting accident data. These values represent the‘level of severity’ in an ordinal scale (e.g., no injury, slight injury, serious injury, fatality). In the case of road accident severity models, researchers are trying to explore the factors that can be related to road characteristics, the users, the vehicles, or the conditions on the road at the time of the accident.

3.8.2. Ordinal logistic regression model

Logistic regression model can be classified as multinomial, ordinal and binary. In this investigation Ordinal logistic regression model was used. The ordinal logistic regression procedure empowers one to select the predictive model for ordered dependent variables. It describes the relationship an ordered response variable and a set of explanatory variables. The explanatory variables may be continuous or discrete (or any type).

Ordinal response models have major importance in social sciences as well as demography and many social phenomena. The responses are discrete or qualitative rather than continuous or quantitative in nature. Many such analyses involve an outcome or dependent variable that is ordinal and in these studies the logistic regression model has become the statistical model of choice. The most popular model in ordinal logistic is the Proportional Odds model.

3.8.3. Proportional Odds (PO) Model

Proportional Odds Model is used as a tool to model the ordinal nature of a dependent variable by defining the cumulative probabilities differently instead of considering the probability of an individual event. It considers the probability of that event and all events that are ordered before it. When response categories are ordered, logits can directly incorporate the ordering.

The cumulative probabilities are the probability that the response Y falls in category i or below, for each possible i the i^{th} cumulative probability is py(y≤i) = p_1 +p_2 +………p_i.

The proportional odds model assumes that the cumulative logits can be represented as parallel linear functions of independent variables. That is, for each cumulative logit the parameters of the models are the same, except for the intercept. Consequently, according to the proportional odds assumption, odds ratio is the same for all categories of the response variable.

The PO model, however, has some appealing features. At first, it is invariant under several categories, as only the signs of the regression coefficients change. Secondly, it is invariant under collapsibility of the ordered categories, as the regression coefficients do not change when response categories are collapsed or the category definitions are changed. Thirdly , it produces the most easily interpretable regression coefficients, as exp(β) is the homogenous odds ratio over all cut-off points summarizing the effects of the explanatory factor X on the response Y in one single frequently used measure. Due to these reasons, the PO model is by far the most used regression model for ordinal data.

Let Y takes categorical response variable with c ordered categories and assume pr(Y=1) is p_1 , pr(Y=2) is p_2 ,….. pr(Y=i) is p_i : for i= 1……..c. Cumulative probability reflect the ordering, with pr(y≤1) ≤ pr(y≤2) ≤ …..pr(y≤c) =1 and let the cumulative probability of the first c-1 of Y is pr(y≤i) = π_i ,i =1……c-1.

Then the odds of the first c-1 cumulative probabilities are

$$odds\ pr(Y \leq i) = \frac{pr(Y \leq i)}{1 - pr(Y \leq i)} = \left[\frac{\pi_i}{1 - \pi_i}\right] \qquad i = 1 \ldots .c - 1 \ldots \ldots \ldots (3)$$

The proportional Odds model models the log odds of the first c-1 cumulative probabilities as:

$$logit[pr(Y \leq i)] = log\left[\frac{pr(Y\leq i)}{1-pr(Y\leq i)}\right] = log\left[\frac{\pi_i}{1-\pi_i}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

And the relationship between the cumulative logits of Y is:

$$log\left[\frac{\pi_i}{1-\pi_i}\right] = log\left[\frac{\pi_i}{\pi_{i+1}+\cdots\pi_c}\right] : i = 1 \ldots\ldots\ldots\ldots\ldots. c-1.$$

Consider a collection of P explanatory variables denoted by the vector x′ =(x_1, x_2, x_3 …, x_p). The relationship between the predictor and response variables is not a linear function in logistic regression; instead, the logistic regression function is used, which is the logit transformation of π.

$$\pi_i = \frac{exp(\alpha_i+\beta_1X_1+\cdots\beta_pX_p)}{1+exp(\alpha_i+\beta_1X_1+\cdots\beta_pX_p)} \qquad (5)$$

Then the logit or log-odds of having pr(Y≤i) = π_i is modeled as a linear function of the explanatory variables as:

$$log\left[\frac{pr(Y\leq i)}{1-pr(Y\leq i)}\right] = log\left[\frac{\pi_i}{1-\pi_i}\right] = \alpha_i + \beta_1X_1 + \cdots\beta_pX_p. \ \ equinalent\ with$$

$$log\left[\frac{\pi_i}{1-\pi_i}\right] = \alpha_i + \sum_{j=1}^{p}\beta_jX_j \ ; 0 \leq \pi_i \leq 1 \ ; there\ for$$

$$logit[pr(Y \leq i)] = \alpha_i + \sum_{j=1}^{p}\beta_jX_p \ ; \ i = 1, \ldots\ldots c-1\ and\ j = 1 \ldots\ldots. p \qquad (6)$$

The model assumes a linear relationship for each logit and parallel regression lines. Equation (6) is called proportional odds model and it estimates simultaneously multiple equations of cumulative probability. An equation is solved for each category of the dependent variable except the last one.

In this model each logit has its own α_i term called the threshold value and their values do not depend on the values of the independent variable for a particular case. Logistic regression coefficients indicates the direction and strength of the relationship between independent variable and the log odds of dependent variable. However, these logistic regression coefficients are a little bit more complicated to intuitively gauge, as they present the influence of a unit change in the independent variable on the log odds of the dependent variable. The influence determines the rate of increase or decrease in the log odds of dependent variable. This means that the effect of the independent variable is the same for different logit functions, that's also the reason why the model is called the proportional odds model.

Testing of Parallel Lines

The assumption that all logit surfaces are parallel must be tested. The effect of x is the same for each pair of categories in y. Test of parallel lines helps to determine whether it is reasonable to assume that the values of the location parameters are constant across categories of the response. The test of parallelism contains: –2 log-likelihood for the constrained model, the model that assumes the planes or surfaces are parallel and –2 log-likelihood for the General model, the model that assumes planes or surfaces are separated.

The chi-square statistic is the log-likelihood difference between the two models. If the lines or planes are parallel, the observed significance level for the change should be large, since the general model doesn't improve the fit very much and the parallel model is adequate. If there is evidence to reject the null hypothesis, it is possible that the link function selected is incorrect or that the relationships between the independent variables and logits are not the same for all logits.

3.8.4. Odds Ratio

The odds ratio is a value which measures the strength effect of each independent variable in the model on the log odds of the dependent variable.

The odds of some event happening is defined as the ratio of the number of occurrences to the number of non occurrences. That is, the odds of the event E is given by:

$$odds(E) = \frac{pr(E)}{pr(not\ E)} = \frac{pr(E)}{1-pr(E)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(8)$$

The odds of the response are multiplied by e^{β} for every unit increment of x. That is, the odds at level x +1 equal the odds at x multiplied by e^{β} and odds less than one indicate the occurrence is less likely than non occurrence.

Test of Overall Model Fit

For the selected model before proceeding to examine the individual coefficients, we should look at an overall test of the null hypothesis that the location coefficients for all of the variables in the model are 0.

It can base this on the change in –2 log-likelihood when the variables are added to a model that contains only the intercept. The change in likelihood function has a chi-square distribution even when there are cells with small observed and predicted counts. This value provides a measure of how well the model fits the data. The log likelihood statistic is analogous to the error sum of squares in multiple linear regressions. As such it is an indicator of how much unexplained information remains after fitting the model. The larger the value of the log likelihood the more unexplained observations there are and a poorly fitting model. Therefore, a good model means a small value for −2LL. If a model fits perfectly, the likelihood is 1, and $-2 \times \log 1=0$.

3.8.5. Goodness-of-Fit Measures

A good-fitting model has several benefits. The structural form of the model describes the patterns of association and interaction. The sizes of the model parameters determine the strength and importance of the effects. Inferences about the parameters evaluate which explanatory variables affect the response variable Y, while controlling effects of possible confounding variables. Finally, the model's predicted values smooth the data and provide improved estimates of the mean of Y at possible explanatory variable values.

For logistic regression, the model coefficients are estimated by the maximum likelihood method and the likelihood equations are non-linear explicit function of unknown parameters. The ordinal logistic regression model is fitted to the observed responses using the maximum likelihood approach. In general, the method of maximum likelihood produces values of the unknown parameters that best match the predicted and observed probability values. Therefore, it usually used a very effective and well known fisher scoring algorithm to obtain ML estimates.

A model for logit $pr(Y \leq i)$ alone is ordinary logit model for a binary response in which categories 1 to i form one outcome and categories i+1 to c form a second outcome.This shows that c categories of response collapsed in to binary out come. Again let (Y_{J1}.......Y_{Jc}) be binary indicators of the response for subject j.

The likelihood function L is viewed as a function of α and β parameters. The parameters are estimated by maximizing the likelihood, or more usually, by maximizing the logarithm of the likelihood. The likelihood function is given by the equation:

$$l = \prod_{j=1}^{n}\left[\prod_{i=1}^{c}\pi_i(X_j)^{Y_{ij}}\right] = \prod_{j=1}^{n}\left[\prod_{i=1}^{c}\left(p(Y \le i/X_j) - p(Y \le i-1/X_j)^{Y_{ij}}\right)\right]$$

$$= \prod_{j=1}^{n}\left[\prod_{i=1}^{c}\left(\frac{exp(\alpha_i + \beta' X_j)}{1+exp(\alpha_i + \beta' X_j)} - \frac{exp(\alpha_{i-1} + \beta' X_j)}{1+exp(\alpha_{i-1} + \beta' X_j)}\right)^{Y_{ij}}\right]$$

$$l(\beta)^* = \prod_{j=1}^{n}\left[\pi_1(X_j)^{Y_{1j}}\pi_2(X_J)^{Y_{2j}}\, x \dots . x\pi_c(X_j)^{Y_{cj}}\right]$$

Here β^* use somewhat imprecisely to denote both the slope coefficients and intercept coefficients. It follows that the log-likelihood function is:

$$l(\beta)^* = \sum_{j=1}^{n} Y_{1j}\, ln[\pi_1(X_j)] + Y_{2j} ln[\pi_2(X_j)] + \cdots Y_{cj} ln[\pi_c(X_j)] \dots\dots\dots\dots\dots\dots (10)$$

The maximum possible value of the likelihood for a given data set occurs if the model fits the data exactly. This occurs if observed counts are close with predicted. The difference between the log-likelihood functions for two models is a measure of how much one model improves the fit over the other. A special case of this was defined as the deviance. The deviance is defined as minus twice the log of the ratio of the likelihood for a model to the maximum likelihood. Deviance for model comparison is:

$D = -2LOG\left[\frac{likelihood\ of\ the\ current\ model}{likelihood\ of the\ saturated\ model}\right]$,this simplify to

D= -2[log(likelihood of the current model) – log(likelihhod of saturated model]

={(-2log(likelihood of the current model)- (-2loglikelihood of saturated model)}

This deviance is also used to construct a goodness-of-fit test for the model. The goodness of fit statistics for ordinal logistic regression has a form:

$$D = 2\sum\sum o_{ij} log\left(\frac{o_{ij}}{E_{ij}}\right)$$

Likewise, the Pearson chi-square statistic also compares the model fit to the actual data, defined by:

$$x^2 = \sum\sum \frac{\left(o_{ij} - E_{ij}\right)^2}{E_{ij}}$$

E_{ij} is the expected value for the i^{th} observation.

Both goodness-of-fit statistics should be used only for models that have reasonably large expected values in each cell. If the model fits well, the observed and expected cell counts are similar, the value of each statistic is small, and the observed significance level is large. As usual large X^2 and D value provide the evidence of lack of fit . When the fit is poor, residuals and other diagnostic measure describes the influence of individual observation on the model fit and highlight reason for the inadequacy.

3.9.Ethical consideration

The data was collected after ethical permission is given from Jimma University. Jimma Institute of Technology before continuing the study acceptance should be given from different responsible organs and local authorities in order to follow the research. Make sure the confidentiality of data, Approve of research by an ethics review committee to make sure the study is not contradicting any of the above considerations; follow the procedure that is required with the concerned organization. This study was conducted in a manner that was consistent with ethical issues that need to be considered in conducting a research.

3.10. Data quality assurance

In my study the data was collected from secondary source of data collection (record of an event or circumstance). An initial letter of cooperation was written to Addis Ababa police commission. Addis Ababa police commission, in turn, wrote a letter of support to kirkos sub city of police station. Therefore; the assurance of those data to be highly recognized and those data are true. The checklist were prepared first in English, then translated to Amharic, and translated back to English by experts and checked before the actual data collection started. Data collectors were supervised by supervisor and checked for completeness and coherence. Data were checked and cleaned for completeness and consistency.

3.11. Operational definitions

RTA: A road traffic accident is defined as any motor vehicle accident occurring on a public highway. It includes collisions between vehicles and animals, vehicles and pedestrians, or vehicles and fixed obstacles. Single vehicle accidents, which involve a single vehicle that means without other road user, are also included (Safe car guide 2004).

Slight injury: an injury which requires medical care, but no injuries requiring hospitalization.

Severe injury: an injury, which results hospital admission.

Death: a death that occurs immediately after traffic accident injury.

Outcome of road traffic accident: outcome/result of the accident whether it is injury or death.

Driving experience: This is the number of years the driver drove since receiving a driving license. The information obtained from the driver is recorded under one of the following six categories: <1 year,1-2 years, 2-5 years ,5-10 years > 10years and unknown.

Vehicle type: type of the vehicle, which caused the accident.

Vehicle years of service: This is the number of years from date of manufacture.The categories are: 1 year, 1-2 years, 2-5 years, 5-10 years,> 10 years and unknown.

Road surface Type: condition of the road asphalt or gravel "pista"

CHAPTER FOUR
RESULT AND DISCUSSION

4.1.General characteristics of rear end crash severity in Kirkos Sub City signalized intersections (descriptive stastics).

4.1.1. Time and rear end crash severity at signalized intersections

4.1.1.1 Temporal variation of rear end crash severity

This study used rear end crash data which is collected from Kirkos Sub City Addis Ababa at signalized and unsignalized intersections. The occurrence of rear end crash can vary within the 24 hours of a day. As discussed in the previous chapters, the environmental factors like the availability of light, the time of crash, the experience of drivers have a greater impact in the variation of rear end crash distribution with in a day. A total of 483 rear end crashes occurred at signalized intersections during the year from 2015/16-2017/18 from the total 11518 crashes occurred at kirkos sub city. The table below show the amount of the rear-end crashes, fatalities, severe injury and PDO from year 2015/16- to 2017/18 how ever rear end crashes and related fatalities are in increasing trend..

Table 4.1: Temporal variation of rear end crash year at signalized intersections in kirkos sub city from 2015/16-2017/18.

Time interval	**Rear end Crash year**				
	2015/16	2016/17	2017/18	Total	Percent
12am-6am	12	15	19	46	9.5
6am-12pm	39	48	52	139	28.78
12pm-6pm	57	74	93	224	46.4
6pm-12am	21	24	29	74	15.32
Total	129	161	193	483	100

Source (65)

The variation in the hours of a day exhibits the difference in rear end crash occurrences in Kirkos Sub City (Table 4.1). The time between 12 pm to 6 pm reveals the largest proportion (46.4%) of all the rear end crash scenes in kirkos sub city between the years 2015/16 to 2017/18. The frequency of occurrence of rear end crash in this time interval even exhibited a continuous increase from the years 2015/16 to 2017/18. Ironically, the time between 12 am to 6 am contributes only for 46 (9.5%) of rear end crashes records in the sub city with in the study time. Generally rear end crashes in Kirkos Sub City are frequently observed in the day time than in the night time between 6 am to 6 pm. About 363(75%) of all the rear end crash accidents recorded in the study period have been observed in the day time.The rest 120 (24.80%) rear end crash incidences have been recorded in the night time between 6 pm to 6 am. This means, driving or travelling on the roads of signalized intersections Kirkos Sub City between 12 pm to 6 pm is five times more precarious for being engaged in rear end crash than driving or travelling between 12 am to 6 am.

Table 4.1.1: Time and rear end crash severity at signalized intersections in kirkos subcity from 2015/16-2017/18.

Time interval	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
12am-6am	1	4	3	38	46
6am-12pm	1	14	7	117	139
12pm-6pm	5	19	12	188	224
6pm-12am	2	5	2	65	74
Total	9	42	24	408	483

source (65)

4.1.1.2 Daily Temporal Variation of rear end crashes severity

Like the variation in the distribution of RTAs within the 24 hours of a day, there is disparity of rear end crash severity frequencies between the different days of a year in kirkos sub city signalized intersections.

Table 4.2:Temporal variation of rear end crash severity by day of week at signalized intersections in kirkos sub city from (2015/16-2017/18).

Day of crash	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Monday	1	6	3	56	65
Tuesday	1	5	2	54	62
Wednesday	1	6	3	51	61
Thursday	2	7	6	60	75
Friday	2	8	5	71	86
Saturday	1	6	3	63	73
Sunday	1	4	2	53	61
Sum	9	42	24	408	483

Source (65)

Table 4.2 describes that, there is a slight variation in the occurrence of rear end crashes among the days in the sub city. Comparatively, Thursday and Friday were the days of highest rear end crashes at signalized intersections panorama in the sub city where they contribute 75 (15.34%) and 86(17.9%) respectively of the total rear end crash during the study period.

4.1.2. Drivers Characteristics and rear end crash severity

4.1.2.1. Drivers age and rear end crash severity

Human beings are the primary causes of rear end crash.Several studies have witnessed that the age of drivers have a greater impact over the occurrence of rear end crashes.This is due to the fact that, the age of drivers affects their driving behavior, concentration, sense of responsibility and patience.

Table 4.3: Driver’s age and rear end crash severity at signalized intersections in kirkos sub city from (2015/16-2017/18).

No	Age of driver	Rear end crash severity level				Total
		Fatal	Severe injury	Slight injury	PDO	
1	<18	0	0	0	1	1
2	18-30	4	18	11	186	219
3	31-50	3	16	10	168	197
4	>51	2	8	3	53	66
Sum		9	42	24	408	483

Source (65)

Drivers between the ages of 18 and 30 are more frequently engaged in rear end crash than drivers in the other age groups (Table 4.3). Drivers aged 18 to 30 contribute 219 (45%) of all the rear end crash in the study period. These age boundary are also more in fatality rate and heavey injury. Followed by age groups between 31 - 50 which contributes 197(40.79%) to the misery. Driver age group above 50 years contributes 66 (13.86%) rear end road crashes in Kirkos Sub City during the study period but are the thired highest in fatality rate in the group. The underage car drivers/riders contribute for (0.2%) of total rear end crashes during the study period since acquiring driving license considers at minimum of 18 years.

4.1.2.2.Drivers sex and rear end crash severity

Most of the time, the major contributing factor in the majority of traffic accidents is the behavior of the drivers; hence, worldwide studies show that about 80-90% of the road traffic accidents are attributed to the fault of the drivers, and majority of them are male drivers (66). Similarly the occurrence of rear end crash severity in Kirkos Sub City at signalized intersections shows a greater variation in terms of drivers' sex. As shown in table 4.4, the number of male drivers' involvement in rear end crashes greatly out numbers females in Kirkos Sub City signalized intersections.The outstrip number of male drivers could result in more frequencies of engaging in rear end crash events. From july 2015/16 to july 2017/18 male drivers cause 426 (88.19%) rear end crashes in Kirkos Sub City at signalized intersections. In contrary, female drivers caused 57 (11.80%) rear end road crashes. In a very similar result Mekonnen (67) have proved that, male drivers are the main contributors to RTAs than females in Addis Ababa. However, with this, conclusive remarks cannot be made due to the different proportions of male against female drivers.

Table 4.4: Driver's sex and rear end crash severity at signalized intersections in kirkos sub city from (2015/16 - 2017/18).

No	Drivers sex	Rear end crash severity level				Total
		Fatal	Severe injury	Slight injury	PDO	
1	Male	8	35	22	361	426
2	Female	1	7	2	47	57
3	Sum	9	42	24	408	483

Source (65)

4.1.2.3.Drivers driving experience and rear end crash severity

It is believed that the experience of drivers plays a paramount role in road crashes. The distributions of rear end road crashes in Addis Ababa Kirkos Sub City are also affected by the driving experience.

Table 4.5: Drivers experience and rear end crash severity occurrences in kirkos sub-city signalized intersections (2015/16 - 2017/18).

No	Experience of drivers in years	Rear end crash severity level				Total
		Fatal	Severe injury	Slight injury	PDO	
1	No license	1	1	0	1	3
2	<1 year	0	3	2	32	37
3	1-2 year	1	6	4	57	68
4	2-5 year	2	10	7	112	131
5	5-10 year	3	12	7	106	128
6	>10 year	2	10	4	100	116
7	Sum	9	42	24	408	483

Source (65)

Table 4.5, illustrates 131(26.91%) rear end crashes incidences have been exhibited by drivers whose driving experience is between 2 to 5 years. The drivers with driving experience between 5 and 10 years have caused 128 (26.49%) rear end road crashes in the study period. Drivers having 5 to 10 years experience more engaged in fatal , heavey injury and light injury.

4.1.2.4. Driver vehicle relationship

The incident of rear end accident was evaluated against driver and vehicle ownership. Table 4.6 below illustrates how far the drivers' vehicle ownership relationship contributes to rear end accident occurrences in Kirkos Sub City of signalized intersections. About 314 (65%) of accidents are recorded from employed drivers. Whereas, 142 (29.4%), 27 (5.6%) were accompanied by owners of vehicle while driving their own vehicle, others respectively. In addition to this driver vehicle relationship is significantly associated with the level of injury in the given year.

Table 4.6: Driver vehicle relationship and rear end crash severity occurrences in kirkos sub-city signalized intersections (2015/16 - 2017/18).

Vehicle driver relationship	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Owner	3	12	7	120	142
Hired	5	24	15	270	314
Others	1	6	2	18	27
Sum	9	42	24	408	483

source (65)

4.1.2.5.Educational level of the drivers and rear end crash severity

Among the seven categories of educational background depicts Table 4.6, those drivers with Primary, secondary, Preparatory and Above Preparatory level of education are responsible for the largest share of rear end crashes (20.29%, 31.26%, 28.36% and 19.050%) respectively and basic education level are responsible for the smallest share of severity (1.05%). There is no recorded rear end crash in Kirkis Sub City signalized intersections with illiterate educational level.

Table 4.7: Eductional level and rear end crash severity in kirkos sub-city signalized intersections (2015/16 - 2017/18).

No	Educational level of drivers	Rear end Crash severity level				Total
		Fatal	Severe injury	Slight injury	Pdo	
1	Illiterate	0	0	0	0	0
2	Read and write	0	1	1	3	5
3	Primary education	1	8	5	84	98
4	Secondary education	3	14	9	125	151
5	Preparatory school	3	12	5	118	138
6	above preparatory	2	7	4	78	91
7	Sum	9	42	24	408	483

source (65)

4.1.3. Vehicle Characteristics and rear end crash severity at signalized intersections

4.1.3.1 Vehicle Service Age and rear end crash severity

The vehicle service age determines the fate of the vehicle to be engaged in RTA Crashes. The rear end crash data collected from Addis Ababa Kirkos Sub City Traffic office, as shown in table 4.8 reveals that the vehicle service age determines the variation in the distribution of rear end crash severity throughout the study period.

Vehicles with service age between 2 and 5, and 5 to 10 years caused more rear end crashes 135 (27.9%) and 145 (29.81%) respectively. Generally as the service age of vehicles is high, for example, above ten years, the probability of rear end road crashes in the city decreases (0-5,5-10 and >10years).

Table 4.8: vehicle service age and rear end crash severity in kirkos sub city at signalized intersections (2015/16 - 2017/18).

No	Vehicle service age	Rear end crash severity level				Total
		Fatal	Severe injury	sLight injury	Pdo	
1	<1 year	0	3	2	16	21
2	1-2 year	1	8	4	70	83
3	2-5 year	2	10	5	118	135
4	5-10 year	3	12	7	123	144
5	>10 year	3	9	6	81	100
6	Sum	9	42	24	408	483

Source (65)

4.1.3.2 Vehicle category and rear end crash severity

Table 4.9: Vehicle category and rear end crash severity in kirkos sub city signalized intersections (2015/16 -2017/18).

No	Rear end crash severity	Type of vehicle										total
		Automobile	Mini bus	Mid bus	bus	Truck	Trailer truck	Three wheeler	Motor cycle	bicycle	Note stated	
1	Fatal	3	2	1	1	1	1	0	0	0	0	9
2	Severe injury	18	8	2	1	9	2	1	1	0	0	42
3	Slight injury	11	5	1	1	5	1	0	0	0	0	24
4	PDO	176	77	19	14	79	19	7	12	3	3	408
Sum		208	92	23	17	94	23	8	13	3	3	483

Source (65)

Here the result shows car (automobile, taxis, pickups and Land Cruisers, Land Rovers, etc) have the highest rear end crash comprised only 36% of in property damage and 6% in slight and severe injuries.

4.1.4. Road charactersics and rear end crash severity at signalized intersections

4.1.4.1 Road surface condition and rear end crash severity

Road pavement is found as the major contributing variable for the occurrence of rear end crashes since it is directly related to the speed of the vehicle. Drivers prefer to drive in higher speeds in smoother road pavements like in asphalt roads. Consequently, in the study areas almost all rear end crashes occur on asphalt roads.

4.1.4.2 Junction type and rear end crash severity at signalized intersections

The signalized intersections at Kirkos Sub City are two types T-junction caused (9.5%) rear end crashes and cross junction types (90.5%). This is also stated by Hanna, Flynn et al (68) found that accident rates at four leg rural intersections 69% higher than at T intersections.

Table 4.10: Junction type and rear end crash severity at signalized intersections in kirkos sub city from (2015/16 -2017/18).

Junction type	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
T- junction	1	4	2	39	46
†-junction	8	38	22	369	437
Sum	9	42	24	408	483

source (65)

4.1.5. Weather Condition and rear end crash severity at signalized intersections

The weather condition of the moment in rear end crashes plays an important role in varying the frequency and risk of rear end crashes. According (69) and (70) stated that the climatic and environmental conditions can be a factor in RTAs.

Experiences show that several crashes occur during conditions of smoke or fog, which reduces visibility. Rear end crashes in Kirkos Sub City signalized intersections frequently occur during good weather conditions than during rainy and drizzle falling events. Accordingly 424 (87.8%) rear end crashes in the city have been recorded in good weather conditions but only 34 (7.03%) and 11 (2.27%) accidents recorded in drizzle and cloudy weather conditions respectively. Bright and dry weather of the city which covers the longer days of the year in the city produces greater number of rear end crashes than the rainy and drizzle falling weather conditions.

Table 4.11: weather condition and rear end crash severity in kirkos sub city at signalized intersections (2015/16 - 2017/18).

No	weather condition	Rear end crash severity level				Total
		Fatal	Severe injury	Slight injury	Pdo	
1	Good	8	38	18	360	424
2	Cloudy	0	1	3	7	11
3	Drizzle	0	2	2	30	34
4	Rainy	0	0	0	3	3
6	Hot	1	1	1	3	6
7	Cold	0	0	0	5	5
Sum		9	42	24	408	483

Source (65)

4.1.6. Lighting condition and rear end crash severity

Even though the existence of light is very important for the reduction of RTAs significantly, the analysis shows that most of the rear end crash i.e. 348 (72%) occurred during the day light at signalized intersection from 2008-2010 E.C. The accidents in sun set takes the next rank which accounts 65 (13.5%) this the reason might be the pedestrian volume increases at this time. Rear end accidents those happened in sunrise, night with street light and dark with out street light were relatively very low and shares magnitude (see table 4.12. for the detail).

Table 4.12: Lighting condition and rear end crash severity in kirkos sub city at signalized intersections (2015/16 - 2017/18).

Light condition	Rear end Crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Day light	6	26	14	302	348
Sunset	1	8	4	52	65
Sun rise	1	3	2	21	27
Dark with street light	1	3	2	30	36
Dark no street light	0	2	2	3	7
Sum	9	42	24	408	483

source (65)

4.1.7. Primary Causes and contributing factors to severity of rear end crashes at signalized intersections.

Table 4.13: Main causes and rear end crash severity in kirkos sub city signalized intersections (2015/16-2017/18.

No	Main causes of accident	Rear end crash severity level				Total
		Fatal	Severe injury	Slight Injury	Pdo	
1	Tailgating	4	7	5	150	166
2	Speeding	2	10	3	39	54
3	Improper turns	0	2	4	17	23
4	Running red light	0	4	3	14	21
5	Running traffic police	0	0	2	23	25
6	Lack of visual attention	0	5	1	10	16
7	Drunk driving	1	4	2	17	24
8	Defects of automobile	0	0	2	10	12
9	Not giving priority	2	10	2	128	142
10	Sum	9	42	24	408	483

source (65)

4.2.General characterstics of rear end crash severity at unsignalized intersections

4.2.1. Time and rear end crash severity at unsignalized intersections

4.2.1.1.Temporal variation of rear end crashes

A total of 260 rear end crashes occurred at unsignalized intersections in Kirkos Sub City during the year 2015/16-2017/18.

Table 4.14: Temporal variation of rear end crash by hours of a day in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

No	Time interval	Rear end accident year			Total	Percent
		2015/16	2016/17	2017/18		
1	12 A.M – 6 A.M	6	7	10	23	8.85
2	6 A.M – 12 P.M	17	24	31	72	27.69
3	12 P.M – 6 P.M	38	36	48	122	46.92
4	6 P.M – 12 A.M	8	14	21	43	16.54
Sum		69	81	110	260	100

source (65)

The variation in the hours of a day exhibits the difference in rear end crash occurrences in Kirkos Sub City (Table 4.14). The time between 12 p.m to 6 p.m reveals the largest proportion (46.92%) of all the rear end crashes scenes in Kirkos Sub City unsignalized intersections between the years 2015/16 to 2017/18. The frequency of occurrence of rear end crash in this time segment even exhibited a continuous increase from the years 2015 to 2018.

Table 4.15: Temporal variation of rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 -2017/180.

Time interval	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
12 A.M-6 A.M	0	1	0	22	23
6 A.M – 12 P.M	1	4	1	66	72
12 P.M – 6 P.M	3	3	7	109	122
6 P.M – 12 A.M	1	3	1	38	43
Sum	5	11	9	234	260

source (65)

4.2.1.2.Daily temporal variation of rear end crash severity at unsignalized intersections

Like the variation in the distribution of rear end crashes within the 24 hours of a day, there is disparity of rear end crash severity frequencies between the different days of a year in kirkos sub city unsignalized intersections. Table 4.16 below describes that, there is a slight variation in the occurrence of rear end crashes among the days in the sub city. Comparatively, saturday ,Thursday and Friday are the days of highest rear end crashes at unsignalized intersections panorama in the sub city where they contribute 40(15.38%), 46(17.7%) and 39(15%) respectively of the total rear end crashes during the study period.

Table 4.16 : Temporal variation of rear end crash severity by day of week in kirkos sub city unsignalized intersections (2015/16- 2017/18).

Day of rear end crash	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Monday	1	2	1	32	36
Tuesday	1	1	1	31	34
Wednesday	1	2	1	29	33
Thursday	1	2	2	35	40
Friday	1	2	2	41	46
Saturday	0	2	1	36	39
Sunday	0	0	1	31	32
Sum	5	11	9	235	260

source (65)

4.2.2. Drivers Characteristics and rear end crash severity at unsignalized intersections

4.2.2.1. Drivers age and rear end crash severity

Drivers between the ages of 18 and 30 are more frequently engaged in rear end crashes than drivers in the other age groups at unsignalized intersections (Table 4.17). Drivers aged 18 to 30 contribute 125 (48.08%) of all the rear end crashes in the study period followed by age groups between 31 and 50 which contributes 83 (31.9%) to the misery. Driver age group above 51 years contributes only 48(18.46%) rear end crashes in Kirkos Sub City during the study period. The underage car drivers/riders contribute for 4(1.54%) of total rear end crashes during the study period. Likewise, David et al. (71) suggested that, young drivers are significantly more likely to be involved in a fatal crash than aged drivers.

Table 4.17: Drivers age and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 -2017/18).

Driver age in crash	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
<18	0	0	0	4	4
18-30	2	5	4	114	125
31-50	2	4	3	74	83
>51	1	2	2	43	48
Sum	5	11	9	235	260

source (65)

4.2.2.2.Drivers sex and rear end crash severity

The occurrence of rear end crash at unsignalized intersections in Kirkos Sub City shows a greater variation in terms of driver sex. As shown in figure 4.18, the number of male driver‟s involvement in rear end crash at unsignalized intersections greatly out numbers females in Kirkos Sub City. The outstrip number of male drivers could result in more frequencies of engaging in rear end crashes events. From 2015/16 to 2017/18 male drivers cause 220(84.6%) rear end crashes. In contrary, female drivers caused 40 (15.38%) crashes.

Table 4.18: Drivers sex and rear end crash severity in kirkos sub city at unsignalized intersections from 2015/16 to 2017/18

Sex of driver in rear end crashes	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Male	4	9	7	200	220
Female	1	2	2	35	40
Sum	5	11	9	235	260

source (65)

4.2.2.3.Drivers driving experience and rear end crash severity

It is believed that the experience of drivers plays a paramount role in rear end road crashes. The distributions of rear end crashes at unsignalized intersections in Kirkos Sub City are also affected by the driving experience. Table 4.19 summarizes the difference in rear end crash occurrences in relation to driving experience.

Table 4.19 illustrates 51 (19.62%) rear end incidences have been exhibited by drivers whose driving experience is between 1 to 2 years. The drivers with driving experience between 2 and 5 years have caused 90 (34.62%) rear end crashes in the study period.

Table 4.19: Driving experience and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 -2017/18).

Driving experience in years	Rear end crash severity level				Total
	fatal	Severe injury	Slight injury	Pdo	
No Driving license	0	0	0	3	3
<1 years	1	1	1	13	16
1-2 years	1	2	2	46	51
2-5 years	1	3	3	83	90
5-10 years	1	3	2	53	59
>10 years	1	2	1	37	41
Sum	5	11	9	235	260

source (65)

4.2.2.4.Driver vehicle relationship and rear end crash severity at unsignalized intersections

The incident of rear end crash severity was evaluated against driver and vehicle ownership. Table 4.20 Illustrates how far the drivers – vehicle ownership relationship contributes to rear end crash occurrences at unsignalized intersections in Kirkos Sub City. About 172 (66%) of rear end crashess recorded from hired drivers. Ironically, 74 (29%) of accidents were accompanied by owners of the vehicle while driving their own vehicles. Similar to this finding, Mekonnen (67) argued that hired drivers were engaged in frequent RTAs in Addis Ababa when compared to the vehicle owners. The low accident caused by own drivers" is mainly attributed to the strong sense of ownership feeling, belongingness and responsibility.

Table 4.20: Hired Drivers – own drivers vis-à-vis rear end crash severity in kirkos sub city at unsignalized intersections from 2015/16 to 2017/18.

Driver vehicle relationship	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Owner	2	4	3	80	89
Hired	2	6	5	146	159
Others	1	1	1	9	12
Sum	5	11	9	235	260

source (65)

4.2.2.5.Educational level of the drivers and rear end crash severity at unsignalized intersections

Among the five categories of educational background depicts table 4.21, those drivers with Primary, secondary, Preparatory and Above Preparatory level of education are responsible for the largest share of severity crashes 37(14.23%), 99 (38.08%), 73(28.06%) and 49(18.85%) respectively and basic education level are responsible for the smallest share of severity 2 (0.77%). There is no recorded rear end crash in Addis Ababa Kirkis Sub City unsignalized intersections with illiterate educational level.

Table 4.21: Eductional level and rear crash severity in kirkos sub city at unsignalized intersections (2015/16 -2017/18).

No	Educational level of drivers	Rear end crash severity level				total
		Fatal	Severe injury	Slight injury	Pdo	
1	Read and write	0	0	0	2	2
2	Primary education	1	2	2	32	37
3	Secondary education	1	4	3	91	99
4	Preparatory school	1	3	3	66	73
5	above preparatory	2	2	1	44	49
Sum		5	11	9	235	260

source (65)

4.2.3. Vehicle Characteristics and rear end crash severity at unsignalized intersections

4.2.3.1.Vehicle service age and rear end crash severity

The vehicle service age determines the fate of the vehicle to be engaged in rear end crashes. The rear end crash data collected from Kirkos Sub City Traffic office, as shown in table 4.22 reveals that the vehicle service age determines the variation in the distribution of rear end crash severity throughout the study period. Vehicles with service age less than 1, and 1 to 2 years caused rear end crashes 11 (4.23%) and 44 (16.9%), respectively. Vehicles with service age 5-10 years and 2-5 years cause 79 (30.38%) ,74 (28.46%) respectively.

Table 4.22: Vehicle service age and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

Vehicle service age in years	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
<1 year	0	1	1	9	11
1-2 year	0	2	2	40	44
2-5 year	1	3	2	68	74
5-10 year	2	3	3	71	79
>10 year	2	2	1	47	52
Sum	5	11	9	235	260

source (65)

4.2.3.2.Vehicle category and rear end crash severity

Several vehicle categories have been involved in rear end crashes scenes in the city in the last three years. The entire types or model of vehicles in the city in relation to their contribution to rear end crashes in the last three years is given below.

Table 4.23: Vehicle Category and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

No	Rear end crash severity level	Vehicle type								total
		Automobile	Mini bus	Mid bus	Bus	Truck	Trailer truck	Three wheeler	Motor cycle	
1	Fatal	2	1	1	1	0	0	0	0	5
2	Severe injury	5	2	1	0	2	1	0	0	11
3	Slight injury	4	2	0	0	3	0	0	0	9
4	PDO	101	44	11	8	46	11	4	10	235
Sum		112	49	13	9	51	12	4	10	260

source (65)

4.2.4. Road charactersics and rear end crash severity in kirkos sub city unsignalized intersections

4.2.4.1.Road Pavement and rear end crash severity

Road pavement is found as the major contributing variable for the occurrence of rear end crashes in Kirkos Sub City since it is directly related to the speed of the vehicle. Drivers prefer to drive in higher speeds in smoother road pavements like in asphalt roads. Consequently, of all the rear end accidents has occurred on asphalt roads unsignalized intersections.

4.2.4.2.Intersection type and rear end crash severity

The unsignalized intersections at Kirkos Sub City includes T-junction (24.6%), Y junction (9.23%) , cross junction types (21.5%) and roundabout (44.6) rear end accidents occur. But there are four round about, three cross junction types , two T-junction and one Y - junction unsignalized intersections.

Table 4.24: Intersection type and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

Junction type	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
T- junction	1	3	2	56	64
(╬)-junction	2	4	2	48	56
Roundabout(o)	1	2	2	111	116
Y-junction	1	2	1	20	24
Sum	5	11	9	235	260

source (65)

4.2.5. Weather Condition and rear end crash severity at unsignalized intersections

The weather condition of the moment in rear end crashes plays an important role in varying the frequency and risk of rear end crash severity. Experiences show that several crashes occur during conditions of smoke or fog, which reduces visibility. Rear end traffic accidents at unsignalized intersections in Kirkos Sub City frequently occur during good weather conditions than during rainy and drizzle falling events. Accordingly Table 4.24, 249 (95.77%) rear end crashes in the city have been recorded in good weather conditions but only 5 (1.92%) and 6 (2.31%) rear end accidents recorded at unsignalized intersections in drizzle falling and warm weather conditions respectively. Bright and dry weather of the city which covers the longer days of the year in the city produces greater number of rear end crashes than the rainy and drizzle falling weather condition.

Table 4.25: Weather condition and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

No	Air condition	Rear end crash severity level				Total
		Fatal	Severe injury	Slight injury	Pdo	
1	Good	3	9	7	230	249
3	Drizzle	1	1	1	2	5
6	Hot	1	1	1	3	6
Sum		5	11	9	235	260

source (65)

4.2.6. Lighting condition and rear end crash severity

Even though the existence of light is very important for the reduction of RTAs significantly, the analysis shows that most of the rear end crash i.e. 187 (71.9%) occurred during the day light in the years 2015/16-2017/18 at unsignalized intersection in Kirkos Sub City. The accidents in sun set takes the next rank which accounts 35 (13.47%). Rear end accidents those happened in sunrise, night with street light and dark with out street light were relatively very low and shares magnitude (see Table 4.26. for the detail).

Table 4.26: Lighting condition and rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

Light condition	Rear end crash severity level				Total
	Fatal	Severe injury	Slight injury	Pdo	
Day light	4	7	6	170	187
Sunset	0	2	2	31	35
Sun rise	0	0	0	14	14
Dark with street light	1	2	1	19	23
Dark no street light	0	0	0	1	1
Sum	5	11	9	235	260

source (65)

4.2.7. Primary Causes and contributing factors to severity of rear end crashes

There are several causes that result RTAs across all roads in the world. According to Mebrahtu (72; 73) the major causes of RTA in Ethiopia and its cities include lack of driving skills, poor knowledge of drivers and pedestrians over traffic rules and regulations, violating speed limits by drivers, insufficient traffic law enforcements, lack of timely vehicle maintenance, driving under the influence of drugs and alcohol, failure to observe and respect road traffic signs, failure to give way for pedestrians, failure to give way for vehicles, lack of sidewalks, lack of road traffic signs, improper overtaking, improper turning and excessive loading. Most common causes of rear end include combinations of speeding/driving too fast for conditions, tail-gating (following too close), aggressive driving and inattentiveness. These causes are often compounded by a change in weather conditions and a lack of vehicle maintenance (brakes). However, more than 60% of these collisions are due to driver inattention (46). In addition to this, the common and frequently observed causes of rear end crashes at unsignalized intersections in Kirkos Sub City are also similar to the aforementioned reasons. Seemingly, with some additional variables of causes of rear end crashes, table 4.27 as shown below describes the current staple reasons of rear end crashes occurrences at unsignalized intersections in Kirkos Sub City.

Table 4.27 : Causes of rear end crash severity in kirkos sub city at unsignalized intersections (2015/16 - 2017/18).

Causes of rear end end Accidents	Rear end crash severity level				total
	Fatal	Severe injury	Slight injury	pdo	
Following too closely	1	3	2	50	56
Failure to give way for vehicle	2	3	3	77	85
Failure to respect the right-hand rule	0	1	0	10	11
Improper Turning	0	0	0	8	8
Improper driving	1	1	1	18	21
Speed Driving	0	0	0	18	18
Un Safe Driving & Driving without attention	1	2	2	39	44
Failure to respect stop rule	0	1	1	15	17
Sum	5	11	9	235	260

source (65)

4.3. Logistic regression analysis

4.3.1. Factors affecting rear end crash severity at signalized intersections.

In this study ordinal logistic regression is selected for analyzing the rear end crash severity data using the explanatory variables associated with the dependent variable.

Accordingly, time of crash (TC), day of crash (DC), Age of driver (AD), Sex of driver (SD), drivig experience (DE), Driver vehicle relationship (DR), Educational Background (EB),Vehicle service age (AV), Vehicle category (VC), Juction type (JT), Weather condition (WC), Light condition (LC), Primary cause (PC) are included in the model.

Table 4.28: Description of explanatory variables

Variable name	Categories	Coding
Time	12 am-6 am	1
	6 am-12 pm	2
	12 pm-6 pm	3
	6 pm-12 am	4
Driver age	<18	1
	18-30	2
	31-50	3
	>51	4
Driver sex	Male	1
	Female	2
Driver experience	No license	1
	<1 year	2
	1-2 year	3
	2-5 year	4
	5-10 year	5
	>10 year	6
Educational level of driver	Illiterate	1
	Read and write	2
	Primary education	3
	Secondary education	4
	Preparatory school	5

		above preparatory	6
Vehicle service age		<1 year	0
		1-2 year	1
		2-5 year	2
		5-10 year	3
		>10 year	4
Vehicle category		Automobile	0
		Mini bus	1
		Mid bus	2
		Bus	3
		Truck	4
		Trailer truck	5
		Three wheeler	6
		Motor cycle	7
		Biycle	8
Junction type	Signalized inte	T-junction	0
		†-junction	1
	Unsignalized inte	T- junction	0
		(╬)-junction	1
		Roundabout(o)	2
		Y-junction	3
Weather condition		Good	0
		Cloudy	1
		Drizzle	2
		Rainy	3
		Hot	4
		Cold	5
Primary Causes of accident as identified by police		Tailgating	0
		Speeding	1
		Improper turns	2

	Running red light	3
	Running traffic police	4
	Running stop sign	5
	Drunk driving	6
	Defects of automobile	7
	Not giving priority	8
Vehicle driver relationship	Owner	0
	Hired	1
	Others	2
Light condition	Day light	0
	Sunset	1
	Sun rise	2
	Dark with street light	3
	Dark no street Light	4
Day	Monday	0
	Tuesday	1
	Wednesday	2
	Thursday	3
	Friday	4
	Saturday	5
	Sunday	6

The model takes Y values: 0(Fatal accident), 1(Severe injury), 2(Slight injury) and 3(PDO). Assume $\pi_0 = pr(y \le 0), \pi_1 = pr(y \le 1), \pi_2 = pr(y \le 2)\ and\ \pi_3 = pr(y \le 3)$. The fitted proportional odds model of rear end crash severity is given as follows:

$$\log\left[\frac{\pi_0}{1-\pi_0}\right] = \alpha_0 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{5}\beta_{5n}\ EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{1}^{2}\beta_{9e}JT_e + \sum_{f=1}^{9}\beta_{10f}CA_f + \sum_{g=1}^{4}\beta_{11}LC_g + \sum_{h=1}^{5}\beta_{12}WC_h + \sum_{l=1}^{9}\beta_{13}VT_L$$

$$\log\left[\frac{(\pi_0+\pi_1)}{1-(\pi_0+\pi_1)}\right] = \alpha_1 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{5}\beta_{5n}\,EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{e=1}^{2}\beta_{9e}JT_e + \sum_{f=1}^{8}\beta_{10f}CA_f + \sum_{g=1}^{4}\beta_{11}LC_g + \sum_{h=1}^{5}\beta_{12}WC_h + \sum_{l=1}^{9}\beta_{13}VT_L$$

$$\log\left[\frac{(\pi_0+\pi_1+\pi_2)}{1-(\pi_0+\pi_1+\pi_2)}\right] = \alpha_2 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{5}\beta_{5n}\,EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{e=1}^{2}\beta_{9e}JT_e + \sum_{f=1}^{8}\beta_{10f}CA_f + \sum_{g=1}^{4}\beta_{11}LC_g + \sum_{h=1}^{5}\beta_{12}WC_h + \sum_{l=1}^{9}\beta_{13}VT_L$$

$log\left[\frac{\pi_0}{1-\pi_0}\right]$, $log\left[\frac{(\pi_0+\pi_1)}{1-(\pi_0+\pi_1)}\right]$ and Log $\left[\frac{(\pi_0+\pi_1+\pi_2)}{1-(\pi_0+\pi_1+\pi_2)}\right]$ are the log odds for respective cumulative logit model.

α_0 , α_1 and α_2 are threshold values for each model respectively.

4.3.1.1.Overall Test of the relationship for signalized intersections

Model Fitting Information:

Table 4.29 : Model Fitting Information.

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	&Sig.
Intercept Only	450.559			
Final	264.245	186.314	54	.000

Link function: Logit.

The first analysis of Ordinal Logistic Regression is to describe the overall test of the relationship i.e. the relationship between the dependent and the independent variable. This relationship is based on the statistical significance of the final model Chi-Square. Chi-Square Statistic is the difference in -2 Log-Likelihood between the final model and the reduced model.The Final Log Likelihood value (-2Log Likelihood) decreases and the significant value of chi-square is 0.00 i.e. less than 0.05. So, the null hypothesis that there is no significant difference between the model without independent variables and the model with independent variables is rejected. The existence of a relationship between the dependent and independent variables is supported.

Goodness of Fit:

Table 4.30: Goodness of fit table.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	240.026	231	.653
Deviance	227.555	231	.552

Link function: Logit.

Pearson and Deviance Goodness of Fit measure how the model adequately fits the data.

The null hypothesis in this case is given by-H0: There is no difference between observed and expected Frequencies, i.e. the model is good fit. If the significance value is >0.05, it is not statistically Significant and the model is good fit. In table 4.27 the significant value of Chi-Square is greater than 0.05. So, we can say that, the data are consistent with the model assumptions i.e. the model adequately fits with the data.

pseudo R- square:

Table 4.31 : pseudo R- square

Pseudo R-Square

Cox and Snell	.320
Nagelkerke	.567
McFadden	.334

Link function: Logit.

For logistic and ordinal regression models, it not possible to compute the same R^2 statistic as in linear regression so three approximations are computed instead.

What constitue a good R^2 value depends upon the nature of the outcome and the explanatory variables. Here the pseudo R^2 values (e.g. Nagelkerke = 56.7%) indicates that there is relatively small proportion of the variation in rear end crash severity between rear end accidents. The R^2 value ranges between 0 and 1 – a higher value means a higher amount of explained variation.

Parameter Estimates:

In the Parameter Estimates table we see the coefficients, their standard errors, the Wald test and associated p-values (Sig.), the 95% confidence interval of the coefficients and odds ratios. Since p-values less than alpha level they are statistically significant; otherwise not. The thresholds are shown at the top of the parameter estimates output, and they indicate where the latent variable is cut to make the four groups that we observe in our data. The threshold coefficients are representing the intercepts, specifically the point (in terms of a logit) where crash severity might be predicted into the four categories.

The results displayed in table 4.17 show that vehicle service age, day of crash, light condition, driver vehicle relationship and educational level were found to be significant predictors for severity levels of rear end crash at signalized intersections.

$$\log\left[\frac{\pi_0}{1-\pi_0}\right] = -50.082 + 4.386\ vehicle\ serviceage_{<1} + 4.930\ vehicle\ service\ age_{1-2\ years} + 5.221 vehicle\ service\ age_{2-5 years} + 2.525\ vehicle\ service\ age_{5-10\ years} + -2.755\ educational\ level_{preparatory\ school} - 7.929\ day\ of\ crash_{thursday} + 3.427\ driver\ vehicle\ relationship_{hired} + 8.02\ light\ condition_{day\ light}$$

$$log\left[\frac{(\pi_0+\pi_1)}{1-(\pi_0+\pi_1)}\right] = -47.375 + 4.386\ vehicle\ service\ age_{<1} + 4.93\ vehicle\ service\ age_{1-2\ years} + 5.221\ vehicle\ age_{2-5 years} + 2.525\ vehicle\ service\ age_{5-10\ years} - 2.755\ educational\ level_{preparatory\ school} - 7.929\ day\ of\ crash_{thursday} + 3.427\ driver\ vehicle\ relationship_{hired} + 8.02\ light\ condition_{day\ light}$$

$$log\left[\frac{(\pi_0+\pi_1+\pi_2)}{1-(\pi_0+\pi_1+\pi_2)}\right] = -46.543 + 4.386\ vehicle\ service\ age_{<1\ year} + 4.93\ vehicle\ service\ age_{1-2\ years} + 5.221\ vehicle\ age_{2-5\ years} + 2.525\ vehicle\ age_{5-10\ years} - 2.755\ educational\ level_{preparatoey\ school} - 7.929\ day\ of\ crash_{thursday} + 3.427\ driver\ vehicle\ relationship_{hired} + 8.02 light\ condition_{day\ light}$$

In this coefficients the negative sign indicates that those variables have negative effects on rear end crash severity from table 4.28.

Table 4.32 : Parameter Estimates:

		Estimate	Std. Error	Wald	Df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[crash_sev = 1]	-50.082	10205.365	.000	1	.996	-20052.229	19952.065
	[crash_sev = 2]	-47.375	10205.365	.000	1	.996	-20049.522	19954.772
	[crash_sev = 3]	-46.543	10205.365	.000	1	.996	-20048.690	19955.604
Location	sex_drive	.635	2.129	.089	1	.765	-3.538	4.808
	jun_type	-14.686	3644.590	.000	1	.997	-7157.952	7128.580
	[exp_drive=1]	-10.237	3842.864	.000	1	.998	-7542.112	7521.639
	[exp_drive=2]	-4.456	3842.864	.000	1	.999	-7536.330	7527.419
	[exp_drive=3]	12.330	1218.425	.000	1	.992	-2375.739	2400.400
	[exp_drive=4]	14.285	1218.425	.000	1	.991	-2373.783	2402.353
	[exp_drive=5]	15.551	1218.424	.000	1	.990	-2372.516	2403.617
	[exp_drive=6]	0[a]	.	.	0	.	.	.
	[edu_level=2]	-1.502	2.964	.257	1	.612	-7.310	4.307
	[edu_level=3]	-1.518	2.474	.376	1	.539	-6.368	3.331
	[edu_level=4]	-3.055	2.047	2.227	1	.136	-7.067	.957
	[edu_level=5]	-2.755	1.795	2.357	1	.012	-6.273	.762
	[edu_level=6]	0[a]	.	.	0	.	.	.
	[veh_seve=1]	4.386	1.783	6.053	1	.014	.892	7.879
	[veh_seve=2]	4.930	1.670	8.714	1	.003	1.657	8.204
	[veh_seve=3]	5.221	1.685	9.599	1	.002	1.918	8.524
	[veh_seve=4]	2.525	1.261	4.012	1	.045	.054	4.996
	[veh_seve=5]	0[a]	.	.	0	.	.	.
	[veh_type=1]	-17.734	7142.622	.000	1	.998	-14017.016	13981.548
	[veh_type=2]	-17.598	7142.622	.000	1	.998	-14016.880	13981.684
	[veh_type=3]	-18.454	7142.622	.000	1	.998	-14017.736	13980.827
	[veh_type=4]	-19.096	7142.622	.000	1	.998	-14018.377	13980.186
	[veh_type=5]	-19.975	7142.622	.000	1	.998	-14019.256	13979.306
	[veh_type=6]	-23.183	7142.621	.000	1	.997	-14022.464	13976.098

	[veh_type=7]	-21.618	7142.621	.000	1	.998	-14020.899	13977.663
	[veh_type=8]	-19.225	7142.621	.000	1	.998	-14018.505	13980.056
	[veh_type=9]	-1.884	8061.046	.000	1	1.000	-15801.244	15797.476
	[veh_type=10]	0[a]	.	.	0	.	.	.
	[causes_ac=1]	-16.333	1218.425	.000	1	.989	-2404.403	2371.736
	[causes_ac=2]	-20.025	1218.425	.000	1	.987	-2408.093	2368.044
	[causes_ac=3]	-19.740	1218.425	.000	1	.987	-2407.810	2368.329
	[causes_ac=4]	-19.088	1218.425	.000	1	.988	-2407.157	2368.982
	[causes_ac=5]	-17.697	1218.425	.000	1	.988	-2405.767	2370.372
	[causes_ac=6]	-19.891	1218.424	.000	1	.987	-2407.959	2368.177
	[causes_ac=7]	-17.819	1218.423	.000	1	.988	-2405.884	2370.247
	[causes_ac=8]	-3.573	3.857	.858	1	.354	-11.132	3.987
	[causes_ac=9]	0[a]	.	.	0	.	.	.
	[day_crash=1]	-7.322	4.385	2.788	1	.095	-15.916	1.272
	[day_crash=2]	-7.070	4.297	2.707	1	.100	-15.493	1.352
	[day_crash=3]	-7.297	4.141	3.104	1	.078	-15.414	.821
	[day_crash=4]	-7.929	3.972	3.985	1	.046	-15.714	-.144
	[day_crash=5]	-6.538	3.757	3.028	1	.082	-13.903	.826
	[day_crash=6]	-3.461	2.167	2.551	1	.110	-7.708	.786
	[day_crash=7]	0[a]	.	.	0	.	.	.
	[wea_condition=0]	-1.976	3.144	.395	1	.530	-8.137	4.186
	[wea_condition=1]	.044	2.186	.000	1	.984	-4.242	4.329
	[wea_condition=2]	1.721	1.806	.908	1	.341	-1.819	5.262
	[wea_condition=3]	16.332	5831.917	.000	1	.998	-11414.014	11446.679
	[wea_condition=4]	0[a]	.	.	0	.	.	.
	[wea_condition=5]	0[a]	.	.	0	.	.	.
	[dri_veh=0]	2.539	1.986	1.634	1	.201	-1.354	6.432
	[dri_veh=1]	3.427	1.661	4.255	1	.039	.171	6.683
	[dri_veh=2]	0[a]	.	.	0	.	.	.
	[light_cond=0]	8.020	3.995	4.030	1	.045	.190	15.850
	[light_cond=1]	4.693	3.738	1.576	1	.209	-2.634	12.020

[light_cond=2]	3.627	2.643	1.884	1	.170	-1.553	8.806
[light_cond=3]	2.893	1.554	3.465	1	.063	-.153	5.938
[light_cond=4]	0[a]	.	.	0	.	.	.
[time_inte=1]	-.325	3.470	.009	1	.925	-7.126	6.476
[time_inte=2]	-2.760	2.274	1.473	1	.225	-7.217	1.697
[time_inte=3]	.030	1.862	.000	1	.987	-3.620	3.680
[time_inte=4]	0[a]	.	.	0	.	.	.
[age_driv=0]	26.433	.000	.	1	.	26.433	26.433
[age_driv=1]	4.098	2.936	1.948	1	.163	-1.657	9.852
[age_driv=2]	3.110	2.494	1.556	1	.212	-1.777	7.998
[age_driv=3]	0[a]	.	.	0	.	.	.

Link function: Logit.

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

Interpretation of the Results:

When the proportional odds model is used in the analysis of ordinal data, the coefficients of the explanatory variables in the model is interpreted as logarithm of the ratio of the odds of response variable. The interpretation of parameters corresponding to different variables which are found significant in the model as shown in Table 4.17 is described in the following section and comparison is made with the reference category.

In this study 13 variables are considered as possible risk factor for severity levels of rear end crash at signalized intersections. Of 13 variables the 5 variable have statistically significant effect on severity levels of rear end crash at signalized intersections by applying multiple ordinal logistic regression. The results displayed in table 4.17 show that vehicle service age, day of crash, light condition, driver vehicle relationship and educational level were found to be significant predictors for severity levels of rear end crash at signalized intersections. The OR is interpreted in the following way: "for every one-unit increase in x, y increases/decreases by [the OR]". Accordingly, if you get a negative OR (below 1), you say: "for every one-unit increase in x, y decreases by [the OR]", and if you get a positive OR (above 1), you say: "for every one-unit increase in x, y increases by [the OR]".

The increment to log odds of severe outcome (severe outcome stands for fatal, severe injury and slight injury) for vehicle service age 2-5 year is 5.221. The estimated odds ratio (OR =184.946) indicates that vehicle service age whose age are 2-5 year are 184.946 times more likely to commit fatal accident than those vehicles whose age are greater than10 years (reference group). Similarly , vehicles whose service year is 2- 5 years are 184.946 times more likely to attain severe out come(to commit fatal, severe injury and slight injury) than those vehicles whose service are above 10 years holding other predictors effects are constant. The increment to log odds of severe out come (severe out come stands for fatal, severe injury and slight injury) for vehicle service age 1-2 year is 4.93. The estimated odds ratio (OR=138.341) indicates that vehicle service age whose age are 1-2 year are 138.341 times more likely to commit fatal accident than those vehicles whose age are greater than10 years (reference group). By the same taken, vehicles whose service year is 1-2 years are 138.341 times more likely to commit fatal accidents than those vehicles whose service year are more than ten years (reference group). The increment to log odds of severe (severe out come stands for fatal, severe injury and slight injury) for vehicle service age less than one year is 4.385. The estimated odds ratio (OR = 80.261) indicates that vehicle service age whose age are less than one year are 80.261 times more likely to commit fatal accident than those vehicles whose age are greater than 10 years (reference group). By the same taken vehicles whose service year is less than one year is 80.261 times more likely to commit fatal accident than vehicles whose service year is greater than 10 years (reference group). The increment to log odds of severe(severe out come stands for fatal, severe injury and slight injury) for vehicle service age 5-10 year is 2.525. The estimated odds ratio (OR =12.495) indicates that vehicle service age whose age are 5-10 year are 12.495 times more likely to commit fatal accident than those vehicles whose age are greater than 10 years (reference group).

The log odds of severe outcome (severe outcome stands for fatal, severe injury and slight injury) for Thursday is decreased by -7.931. The estimated odds ratio (OR = 0.0004) indicates that Thursday contributes 0.0004 times less to commit severe outcome (fatal, severe injury, slight injury) than Sunday (reference group).

The increment to log odds of severe outcome for day light condition is 8.020. The estimated odds ratio (OR = 3041.177) indicates that drivers who drives during the day light are 3041.177 times more likely to commit fatal accident than drivers who drives during dark with no street light (reference group). By the same token, drivers who drives during the day light are 3041.177 times more likely to attain severe outcome (to commit fatal, severe injury and slight injury) than drivers who drives during the dark night with no street light (reference group).

The increment to log odds of severe outcome for hired vehicle relationship is 3.427. The estimated odds ratio (OR = 30.774) indicates that hired drivers are 30.774 times more likely to commit fatal accident than others (reference group).

The log odd of severe outcome for preparatory school of educational level is decreased by -2.755. The estimated odds ratio (OR = 0.064) indicates that drivers whose educational level preparatory school are 0.064 times less likely to commit severe outcome than those vehicles whose educational level are above preparatory school (reference group).

Table 4.33:Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Null Hypothesis	264.245			
General	170.048[b]	94.196[c]	108	.826

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

b. The log-likelihood value cannot be further increased after maximum number of step-halving.

c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.

One of the assumptions underlying ordinal logistic regression is that the relationship between each pair of outcome groups is the same. This is commonly referred to as the test of parallel lines because the null hypothesis states that the slope coefficients in the model are the same across response categories (and lines of the same slope are parallel). If we fail to reject the null hypothesis, we conclude that the assumption holds. From the above table shows parallel line test for general model with chi square value 94.196 and p-value = 0.826 which is greater than the 5% level of significance, fail to reject the null hypothesis. Therefore, there is no enough evidence to reject the null hypothesis for general model. Thus, the proportional odds assumption appears to have held for general model.

4.3.2. Factors affecting rear end crash severity at unsignalized intersections.

$$\log\left[\frac{\pi_0}{1-\pi_0}\right] = \alpha_0 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{4}\beta_{5n}\;EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{1}^{3}\beta_{9e}JT_e + \sum_{f=1}^{7}\beta_{10f}CA_f + \sum_{g=1}^{3}\beta_{11}LC_g + \sum_{h=1}^{2}\beta_{12}WC_h + \sum_{l=1}^{7}\beta_{13}VT_L$$

$$\log\left[\frac{(\pi_0+\pi_1)}{1-(\pi_0+\pi_1)}\right] = \alpha_1 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{4}\beta_{5n}\;EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{e=1}^{3}\beta_{9e}JT_e + \sum_{f=1}^{7}\beta_{10f}CA_f + \sum_{g=1}^{3}\beta_{11}LC_g + \sum_{h=1}^{2}\beta_{12}WC_h + \sum_{l=1}^{7}\beta_{13}VT_L$$

$$\log\left[\frac{(\pi_0+\pi_1+\pi_2)}{1-(\pi_0+\pi_1+\pi_2)}\right] = \alpha_2 + \beta_{1k}SD_K + \sum_{i=1}^{3}\beta_{2i}\,TC_i + \sum_{j=1}^{6}\beta_{3j}DC_j + \sum_{m=1}^{3}\beta_{4m}\,AD_m + \sum_{n=1}^{4}\beta_{5n}\;EB_n + \sum_{c=1}^{4}\beta_{6c}DE_c + \sum_{d=1}^{2}\beta_{7d}DR_d + \sum_{t=1}^{4}\beta_{8t}VA_t + \sum_{e=1}^{3}\beta_{9e}JT_e + \sum_{f=1}^{7}\beta_{10f}CA_f + \sum_{g=1}^{3}\beta_{11}LC_g + \sum_{h=1}^{2}\beta_{12}WC_h + \sum_{l=1}^{7}\beta_{13}VT_L$$

4.3.2.1.Overall Test of the relationship

Table 4.34: Model Fitting Information

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	188.611			
Final	71.012	117.599	46	.000

Link function: Logit.

The first analysis of ordinal logistic regression is to describe the overall Test of the relationship i.e. the relationship between the dependent and the independent variable. This relationship is based on the statistical significance of the final model Chi-Square. Chi-Square Statistic is the difference in -2 Log-Likelihood between the final model and the reduced model. The Final Log Likelihood value (-2Log Likelihood) decreases and the significant value of chi-square is 0.00 i.e. less than 0.05. So, the Null Hypothesis that there is no significant difference between the model without independent variables and the model with independent variables is rejected. The existence of a relationship between the dependent and independent variables is supported.

Goodness of Fit:

Table 4.35: Goodness-of-Fit.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	133.429	134	.498
Deviance	58.644	134	1.000

Link function: Logit.

Pearson and Deviance Goodness of Fit measure how the model adequately fits the data.

The Null Hypothesis in this case is given by-H0: There is no difference between observed and expected frequencies, i.e. the model is good fit. If the significance value is >0.05, it is not statistically significant and the model is good fit. In table 4.27 the significant value of chi-square is greater than 0.05. So, we can say that, the data are consistent with the model assumptions i.e. the model adequately fits with the data.

Table 4.36: Pseudo R-Square

Pseudo R-Square

Cox and Snell	.364
Nagelkerke	.643
McFadden	.542

Link function: Logit.

What constitue a good R^2 value depends upon the nature of the outcome and the explanatory variables. Here the pseudo R^2 values (e.g. Nagelkerke = 64.3%) indicates that there is relatively small proportion of the variation in rear end crash severity between accidents.

Parameter Estimates:

In the parameter estimates table we see the coefficients, their standard errors, the wald test and associated p-values (Sig.), the 95% confidence interval of the coefficients and odds ratios. Since p-values less than alpha level they are statistically significant; otherwise not. The thresholds are shown at the top of the parameter estimates output, and they indicate where the latent variable is cut to make the four groups that we observe in our data. The threshold coefficients are representing the intercepts, specifically the point (in terms of a logit) where crash severity might be predicted into the four categories.

The results displayed in table 4.33 show that time of rear end crash, experience of driver and driver vehicle relaionship were found to be significant predictors for severity levels of rear end crash at unsignalized intersections.

$$log\left[\frac{\pi_0}{1-\pi_0}\right] = -23.671 + 11.107\ time\ of\ rear\ end\ crash_{12am-6am} + 5.807\ time\ of\ rear\ end\ crash_{6am-12pm} + 2.052\ time\ of\ rear\ end\ crash_{12pm-6pm} + -24.046\ driving\ experience\ of\ drivers_{<1\ year} - -18.941\ driving\ experience\ of\ drivers_{1-2\ years} + 6.843\ driver\ vehicle\ relationship_{owner} + 7.87\ driver\ vehicle\ relationship_{hired}$$

$$log\left[\frac{(\pi_0+\pi_1)}{1-(\pi_0+\pi_1)}\right] = -20.845 + 11.107\ time\ of\ rear\ end\ crash_{12am-6am} + 5.807\ time\ of\ rear\ end\ crash_{6am-12pm} + 2.052\ time\ of\ rear\ end\ crash_{12pm-6pm} - 24.046\ driving\ experience\ of\ drivers_{<1\ years} - 18.941\ driving\ experience\ of\ drivers_{1-2\ years} + 6.843\ driver\ vehicle\ relationship_{owner} + 7.87\ driver\ vehicle\ relationship_{hired.}$$

$$log\left[\frac{(\pi_0+\pi_1+\pi_2)}{1-(\pi_0+\pi_1+\pi_2)}\right] = -19.568 + 11.107\ time\ of\ rear\ end\ crash_{12am-6am} + 5.807 time\ of\ rear\ end\ crash_{6am-12pm} + 2.052\ time\ of\ rear\ end\ crash_{12pm-6pm} - 24.046\ driving\ experince\ of\ drivers_{<1years} - 18.941 driving\ experience\ of\ drivers_{1-2\ years} + 6.843\ driver\ vehicle\ relationship_{owner} + 7.87\ driver\ vehicle\ relationship_{hired}$$

Table 4.37: Parameter Estimates.

Parameter Estimates

		Estimate	Std. Error	Wald	Df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[crash_sev = 0]	-23.671	8699.135	.000	1	.998	-17073.663	17026.321
	[crash_sev = 1]	-20.845	8699.135	.000	1	.998	-17070.837	17029.147
	[crash_sev = 2]	-19.568	8699.135	.000	1	.998	-17069.560	17030.424
Location	sex_drive	-1.697	4234.546	.000	1	1.000	-8301.255	8297.861
	[wea_con=0]	14.940	4477.309	.000	1	.997	-8760.423	8790.304
	[wea_con=1]	-.660	3294.690	.000	1	1.000	-6458.134	6456.814
	[wea_con=2]	0[a]	.	.	0	.	.	.
	[pri_cause=0]	-20.265	8025.564	.000	1	.998	-15750.081	15709.552
	[pri_cause=1]	-20.850	8025.564	.000	1	.998	-15750.666	15708.966
	[pri_cause=2]	-24.044	7559.439	.000	1	.997	-14840.271	14792.183
	[pri_cause=3]	-24.044	7535.593	.000	1	.997	-14793.535	14745.447
	[pri_cause=4]	-10.665	6759.678	.000	1	.999	-13259.390	13238.061
	[pri_cause=5]	-12.752	5113.464	.000	1	.998	-10034.957	10009.453
	[pri_cause=6]	-12.324	3598.787	.000	1	.997	-7065.818	7041.170
	[pri_cause=7]	0[a]	.	.	0	.	.	.
	[time_cras=0]	11.107	3.844	8.346	1	.004	3.572	18.641
	[time_cras=1]	5.807	3.269	3.156	1	.050	-.600	12.213
	[time_cras=2]	2.052	2.734	.563	1	.045	-3.306	7.409
	[time_cras=3]	0[a]	.	.	0	.	.	.
	[day_crash=0]	-12.460	5849.642	.000	1	.998	-11477.549	11452.628
	[day_crash=1]	-11.418	5849.641	.000	1	.998	-11476.504	11453.669
	[day_crash=2]	-10.673	5849.641	.000	1	.999	-11475.758	11454.413
	[day_crash=3]	-9.429	5849.640	.000	1	.999	-11474.514	11455.655
	[day_crash=4]	-3.211	3823.807	.000	1	.999	-7497.735	7491.312

[day_crash=5]	-2.938	1922.520	.000	1	.999	-3771.009	3765.132
[day_crash=6]	0[a]	.	.	0	.	.	.
[inte_type=0]	-11.977	9504.506	.000	1	.999	-18640.466	18616.512
[inte_type=1]	-10.934	9504.506	.000	1	.999	-18639.422	18617.555
[inte_type=2]	2.409	8855.702	.000	1	1.000	-17354.448	17359.266
[inte_type=3]	0[a]	.	.	0	.	.	.
[type_veh=0]	-4.893	8256.142	.000	1	1.000	-16186.635	16176.848
[type_veh=1]	9.727	7459.715	.000	1	.999	-14611.046	14630.500
[type_veh=2]	-21.317	6123.685	.000	1	.997	-12023.519	11980.885
[type_veh=3]	-21.198	5649.534	.000	1	.997	-11094.081	11051.685
[type_veh=4]	-17.606	2950.118	.000	1	.995	-5799.731	5764.518
[type_veh=5]	-16.719	3667.950	.000	1	.996	-7205.768	7172.330
[type_veh=6]	-27.907	5576.860	.000	1	.996	-10958.351	10902.537
[type_veh=7]	0[a]	.	.	0	.	.	.
[light_con=0]	2.576	5385.837	.000	1	1.000	-10553.470	10558.622
[light_con=1]	.680	4560.597	.000	1	1.000	-8937.927	8939.286
[light_con=2]	0[a]	.	.	0	.	.	.
[light_con=3]	-.904	8151.487	.000	1	1.000	-15977.525	15975.718
[light_con=4]	0[a]	.	.	0	.	.	.
[age_drive=0]	16.965	8405.849	.000	1	.998	-16458.197	16492.126
[age_drive=1]	1.523	3593.715	.000	1	1.000	-7042.030	7045.075
[age_drive=2]	-17.024	4321.780	.000	1	.997	-8487.557	8453.510
[age_drive=3]	0[a]	.	.	0	.	.	.
[exp_drive=0]	-24.046	10746.489	.000	1	.998	-21086.779	21038.686
[exp_drive=1]	-24.046	3.467	48.098	1	.000	-30.842	-17.251
[exp_drive=2]	-18.941	2.933	41.699	1	.000	-24.690	-13.192
[exp_drive=3]	-19.965	.000	.	1	.	-19.965	-19.965
[exp_drive=4]	-2.419	3528.713	.000	1	.999	-6918.569	6913.731
[exp_drive=5]	0[a]	.	.	0	.	.	.
[relation=0]	6.843	2.147	30.414	1	.000	7.634	16.052
[relation=1]	7.870	.000	.	1	.000	13.870	13.870

[relation=2]	0[a]	.	.	0	.	.	.
[educati=0]	14.515	9383.319	.000	1	.999	-18376.453	18405.483
[educati=1]	14.515	1196.419	.000	1	.990	-2330.423	2359.452
[educati=2]	13.965	1196.417	.000	1	.991	-2330.968	2358.899
[educati=3]	-1.573	.000	.	1	.	-1.573	-1.573
[educati=4]	0[a]	.	.	0	.	.	.

Link function: Logit.

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

Table 4.38: Test of Parallel Lines[a]

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	71.012			
General	.000[b]	71.012	92	.949

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

b. The log-likelihood value is practically zero. There may be a complete separation in the data. The maximum likelihood estimates do not exist.

Interpretation of the Results:

When the proportional odds model is used in the analysis of ordinal data, the coefficients of the explanatory variables in the model is interpreted as logarithm of the ratio of the odds of response variable. The interpretation of parameters corresponding to different variables which are found significant in the model as shown in Table 4.33 is described in the following section and comparison is made with the reference category.

In this study 13 variables are considered as possible risk factor for severity levels of rear end crash at unsignalized intersections. Of 13 variables the 3 variable have statistically significant effect on severity levels of rear end crash severity at un signalized intersections by applying multiple ordinal logistic regression. The results displayed in table 4.33 show that driver vehicle relationship , experience of driver and time of rear end crash were found to be significant predictors for severity levels of rear end crashes at unsignalized intersections. We can get odds ratio by exp^{B}.

The increment to log odds of severe outcome (severe outcome stands for fatal, severe injury and slight injury) for the time of rear end crash 12 am- 6 am is 11.107. The estimated odds ratio (OR = 66635) indicates that time of crash whose time are12 am-6 am are 66635 times more likely to commit fatal accident than those time of crash whose time are 6 pm- 12 am (reference group). By the same taken the time 12 am -6 am is 66635 times more likely to commit severe out come (severe out come stands for fatal, severe injury and slight injury) than the time 6 pm - 12 am (reference group). Similarly the increment to log odds of severe out come (severe out come stands for fatal, severe injury and slight injury) for the time of rear end crash 6 am - 12 pm is 5.805. The estimated odds ratio (OR = 331.9) indicates that time of crash whose time are 6 am - 12 pm is 331.9 times more likely to commit fatal accident than those time of crash whose time are 6 pm- 12 am (reference group). By the same taken the time 6 am-12 pm is 331.9 times more likely to commit fatal accident than the time 6 am -12 pm. The increment to log odds of severe outcome for the time of rear end crash 12 pm -6 pm is 2.052. The estimated odds ratio (OR = 7.78) indicates that time of rear end crash 12 pm - 6 pm is 7.78 times more likely to commit fatal accident than whose time of crash is 6 pm -12 am (refernce group).

The log odd of severe out come for driving experience for less than one years is decreased by -24.06. The estimated odds ratio (OR =0.0000000000356) indicates that drivers whose driving experience are less than one years are 0.0000000000356 times less likely to commit severe outcome than those drivers whose driving experience above 10 years (reference category). Similary the log odd of severe out come for driving experience for 1-2 years is decreased by -18.941. The estimated odds ratio (OR = 0.0000000059) indicates that drivers whose driving experience are 1-2 years are 0.0000000059 times less likely to commit severe outcome than those drivers whose driving experience are above 10 years (reference category).

The increment to log odds of severe outcome for owner drivers is 6.843. The estimated odds ratio (OR = 937.29) indicates that drivers who drives their own vehicle are 937.29 times more likely to commit fatal accident than others (reference group).

Similarly The increment to log odds of severe outcome for hired drivers is 7.87. The estimated odds ratio (OR = 2617.57) indicates that drivers who are hired are 2617.57 times more likely to commit fatal accident than others drivers (reference category).

CHAPTER FIVE

5. CONCULUSION AND RECOMMENDATION

5.1.Conclusions

Both statistical descriptive analysis and modeling approaches were applied in order to investigate the contribution variables affecting the severity of rear-end crash by using data collected from Addis Ababa police commission and kirkos sub city signalized and unsignalized intersections between year 2015/16 and 2017/18.

The time 12pm - 6pm:Thursday and Friday were responsible for the largest number of rear end crash severity at signalized and unsignalized intersections. Drivers with age group of 18-30 years: educational background those who completed secondary school and those who have driving experience of 5-10 years were highly responsible for the largest number of rear end crash severity at signalized intersections. Drivers having driving experience 2- 5 years caused high rear end crash at unsignalized intersections. Vehicle service age 5-10 years: Automobile vehicle type and hired vehicle relationship were highly engaged in highest number of rear end crash severity at signalized and unsignalized intersections. (†)-type of intersection were engaged highest severe rear end accident at signalized intersection but roundabout junction at unsignalized intersections. Besides, highest severe rear end accidents were recorded in good asphalt: in good weather condition: during day light followed by sunset at signalized and unsignalized intersections.

The contributing factors of rear-end crash severity have been investigated by applying ordinal logistic regression model technique. The model had been developed by using 483 crash records at signalized intersection and 260 crash records at unsignalized intersections. Thirteen predictors were selected for the study and ordinal logistic regression model was developed to assess the relation between severity levels of rear end crash and the selected variables.

Based on the results, the multiple ordinal logistic regression analysis was applied to select the most important determinants for severity levels of rear end crash at signalized and unsignalized intersections. The results of the proportional odds model show that vehicle service age, day of crash (thursday), light condition (day light), driver vehicle relationship (hired) and educational level (preparatory school) were found to be significant predictors for severity levels of rear end crash at signalized intersections. Similarly the time of rear end crash, experience of drivers (less than one year ,1-2 year) and hired ,owner vehicle driver relationship were found to be significant predictors for severity level of rear end crash at unsignalized intersections.

Specifically the study showed that severity levels of rear end crash at signalized intersections is more likely for vehicle service age (<1 year, 1-2 year, 2-5 years, 5-10 year) than vehicle service age > 10 years. Also it was found that Thursday contributes less than Sunday for rear end crash severity and drivers who drives during the day light are more likely to attain severe outcome (to commit fatal, severe injury and slight injury) than drivers who drives during the dark night with no street light (reference group). Hired drivers are more likely to commit fatal accident than others (reference group) and drivers whose educational level preparatory school are less likely to commit severe outcome than those vehicles whose educational level are above preparatory school (reference group) at signalized intersections.

Similary the study showed that severity levels of rear end crash at unsignalized intersections (12 am-6 am, 6 am-12 pm, 12 pm-6 pm) is more likely for time of rear end crash 6 pm-12 am (refernce group). Similary drivers whose driving experience are (<1 year, 1-2 year) are less likely to commit severe outcome than those drivers whose driving experience above 10 years (reference category). Drivers who drives their own vehicle and hired drivers are more likely to commit fatal accident than drivers who drives others (reference group) at unsignalized intersections.

5.2 Recommendation

Based on the core findings of this study, the following are recommended.

- New vehicles are highly increased rear end crash severity and drivers must take care when driving new vehicles at signalized intersections.
- Drivers who drives during the day light are more likely to commit fatal accident than drivers who drives during dark with no street light at signalized intersections traffic polices must give special attention for day light.
- Majority of the rear end crashes in Kirkos Sub City are occurring in the day time especially between 12 pm to 6 pm. Hence, Traffic polices should be assigned at intersections .
- The prevalence of rear end accident casualties is increasing in terms of number and severity form time to time in the sub city. Therefore, it is recommended that hospitals must be more equipped with an emergency vehicle /Ambulances/ to minimized rear end crash severity.
- An effort has to be made to compile and organize RTA data of the city in database software or at least in application software programs like Microsoft office Access or Microsoft office Excel for data retrieval and analysis.
- Futher study is needed for improving the model specification by including additional variables, such as AADT, no of lanes, road alignment, grades, road curvature, detailed roadway geometrics, and average speeds at the location of crash (rather than speed limits).

REFERENCES

1. WHO. *global status report on road saftey supporting adecade of action.* World Health Organization. geneva : s.n., 2013.

2. US Department Of Transportation Federal Highaway Adminstration. *Saftey at unsignalized intersection.* 2010.

3. Nasima B, EmelindaM. Parentela and Venkata S. Analysis of Signalized Intersection Crashes. 2006.

4. National Transportation Safety Board (NTSB). *Special Inves-tigation Report—Vehicle- and Infrastructure-Based Technology forthe Prevention of Rear-End Collisions,.* 2001.

5. Yan, Xuedong and Radwan, Essam. Analyses of Rear-End Crashes Based on Classification Tree. *Traffic Injury Prevention.* 2010, Vol. 7: 3.

6. Abdel-Aty, M., Keller, J., Brady, P., 2005a. Analysis of the types of crashesat signalized intersections using complete crash data and tree-basedregression. Transport.

7. Federal Highway Administration,2004. *Signalized Intersections: InformationalGuide (Rep. No. FHWA-HRT-04-091).* Washington, D.C : USDOT, 2004.

8. Institute for Traffic Accident Research and Data Analysis. *Traffic Statistics.* Tokyo (in japan) : s.n., 1997.

9. Lao, Y., Zhand, G., wang, Y., Milton, J. General Nonlinea Models for Rear-end Crashes Analysis. *Accident Analysis and Pervination.* 2014, Vols. 48, p. 254-263.

10. Yan X., Radwan E and Abdel-Atay M. Characteristics of Rear-end Accidents at Signalized Intersections using Multiple Logistic Regression Model. *Accident Analysis and Pervination.* 2005, Vols. 37p. 983-995.

11. Wang, X., Abdal-Aty, M. Temporal and spatial analyses of rear-end crashes at signalized intersections. *Accident Analysis and Pervination.* 2006, Vol. vol 38, p. 1137-1150.

12. Kim, J., Wang, Y., Ulfarsson, G. Modeling the Probability of Freeway rear-end Crash Occurrence. *ASCE J. Transp. Eng.* Vol. 133, (1).

13. Harb, R., Radwan, E., Yan, X., Pande, A., Abdel-Aty, M. Freeway Work Zone Crash Analysis and Risk Identification using Multiple and Conditional Logistic Regression. *ASCE J. Transp. Eng.* 2008, Vol. 34 (5), 203–214.

14. United Nations Economic Commission forAfrica,. *Case Study: Road Safety in Ethiopia.* Unite Nations Economic Commission for Africa. sep 2009.

15. person, A. Road Traffic Accidents in Ethiopia:magnitude, causes, and possible interventions. *Advances in Transportation Studies an international Journal.* section A, march 18, 24 appril, Vol. 15;5.

16. Federal Police Commission Of Ethiopia. *Traffic Accident Data,.* Addis Ababa,Ethiopia : s.n., 2013.

17. Fanueal, S. Analysis of Traffic Accident in Addis Ababa: Traffic Simulation; Unpublished MA Thesis Addis Ababa University (AAU),. 2006.

18. Addis Ababa Police Commission. *Anual Road Crash Stastics.* 2011-2016.

19. Wang, X. Saftey At Signalized Intersections Considering Spatial, Temporal and Site Correlation. *PhD Dissertation,.* 2006.

20. Peltzman, S. The effects of automobile safety regulation. *Journal of Political Economy.* 1975, Vol. 83, pp.677-725.

21. United Ntions Economic Commission For Africa. *Road Saftey In Ethiopia.* 2009.

22. Tariku A., Belay H.,Adal T.and Van gelder P. Road Crashes in Addis Ababa, Ethiopia: Empirical Findings between the Years 2010 and 2014. 2017, Vol. 11(2), ISSN 2070-0083.

23. *Ministry of Infrastructure,Roads Authority 2004,.*

24. Addis Ababa Sub-City Administration, Traffic Crash (2008/09-2011/12).

25. Delen, D., Sharada, R., & Bessonov, M. dentifying significant predictors of injury severity in traffic accidents using a series of artificial neural networks. *Accident Analysis and Prevention.* 2006, 38, 434–444.

26. Manner, H., & Wünsch-Ziegler, L. Analyzing the severity of accidents on the German Autobahn. *Accident Analysis and Prevention.* 2013, 57:40-48.

27. Mao, Y., J. Zhang, G. Robbins, K. Clarke, M. Lam, and W. Pickett. Factors Affecting the Severity of Motor Vehicle Traffic Crashes Involving Young Drivers in Ontario. *Injury Prevention.* 1997, 3: 183- 189.

28. Zhang H. Identifying and Quantifying Factors Affecting Traffic Crash Severity in Louisiana. *A dissertation submitted to Louisiana State University.* 2010.

29. Ratanavaraha, V. and Suangka, S. Impacts of Accident Severity Factors and Loss Value of Crashes on Expressways in Thailand. *International Association of Traffic and Safety Science Research* . 2014, Vols. 37, 130-136.

30. Wang Y, Nihan N. *Quantitative analysis on angle-accident risk at signalized intersections.Presented at 9 World Congress on Transport Research.* Korea : s.n., 2001.

31. Chin H, Quddus M. Applying the random effect negative binomial model to examine traffic accident occurrence at signalized intersections. *Accid Anal Prev.* Vol. 35, 2: p 253-259.

32. ifaat, S.M., Tay, R. Effects of street patterns on injury risks in two-vehicle crashes. *Transportation Research Record.* 2009, 2102: 61–67.

33. Wang, K., & Qin, X. Exploring Driver Errors at Intersections:. *Exploring Key Contributors and Solutions.* 2002, 2514, 1-9.

34. Chen, C., Zhang, G., Tarefder, R., Ma, J., Wei, H. A Multinomial Logit Model-Bayesian Network Hybrid Approach for Driver Injury Severity Analyses in Rear-end Crashes. *Accident Analysis and Pervination.* 2015, Vols. 80:p 76-88.

35. .Oh, C., Park, S., Ritchie, S. G. A Method for Identfying Rear-end Collision Risks Using Inductive Loop Detectors. *Accident Analysis and Pervination.* 38: p 295-301, 2006, 2006.

36. Ethiopian Federal Police Report, Adiss Ababa. 2010-2011.

37. Caliendo, C., Guida, M., & Parisi, A. A crash-prediction model for multilane roads. *Accident Analysis and Prevention.* 2007, Vol. 39, 4 :657-670.

38. Greibe, P. Accident prediction models for urban roads. *Accident Analysis and Prevention.* (2003), 35, 273–285.

39. Wets, A. Pirdavani T. Brijs T. Bellemans G. Evaluation of traffic safety at un-signalized intersections using microsimulation: a utilization of proximal safety indicators. 2010, Vol. section A 22.

40. Dedeitch B. *Reducing Crashes at Urban Intersections through Engineering:Traffic Safety Summit.* 2002.

41. National Highway Traffic Safety Administration. *Crash Factors in Intersection-Related Crashes: An On-Scene Perspective.*

42. Department of Transportation, ". *NORTH CAROLINA 2011 TRAFFIC CRASH FACTS.*

43. E., Rice. Taking action to reduce intersection fatalities. *Safety Compass.* 2007, Vol. 1(2), 1-3.

44. *high way saftey manual.* AASHTO. s.l. : FHWA, appril 6, 2006.

45. Maged K. *COMPREHENSIVE ANALYTICAL INVESTIGATION OF THE SAFETY OF UNSIGNALIZED INTERSECTIONS.* Orlando, Florida : s.n., 2009.

46. We are on the road with you. Vehicle Rear end Collisin Avoidance.

47. Suzan E, Lianeras E,Klauer S and Sudweeks J. *Analyses of Rear-End Crashes and Near-Crashes in the 100-CarNaturalistic Driving Study to Support Rear-SignalingCountermeasure Development.* s.l. : USDOT/National Highway Traffic Safety Administration Office of Advanced Vehicle Safety Research, NVS-331 1200 New Jersey Avenue SEWashington, DC 20590, 2007. DOT HS 810 846.

48. Santokh, S. *Driver Attributes and Rear-end Crash InvolvementPropensity, National Highway Traffic Safety Administration.* 2003. DOT HS 809 540..

49. Lao, Y., Zhand, G., wang, Y., Milton, J. General Nonlinea Models for Rear-end Crashes Analysis. *Accident Analysis and Pervination.* 2014, Vol. 62, p 9-16.

50. Yan, X., Rdwan, E., Abdel-Aty, M. Characteristics of Rear-end Accidents at Signalized Intersections using Multiple LogisticRegression Model. *Accident Analysis and Pervination.* 2005, Vol. vol 37, p 983-995.

51. Khorashadi, A., Niemeier, D., Shankar, V., & Mannering, F. Differences in rural andurban driver-injury severities in accidents involving large-trucks an exploratory analysis. *accident analysis and preventation.* 2005, Vol. 37(5), 910-921.

52. Quddus, M. A., Wang, C., & Ison, S. Road traffic congestion and crash severity: An econometric analysis using ordered response models. *ASCE Journal of Transportation enginnering.* 2010, Vol. 136(5), 424-435.

53. *Variations in the pattern of accident rates in different countries and their causes.* Smeed, R. 1968, Vol. 10.

54. *Logit, Probit and Tobit, Models for Categorical and Limited.* Fernando, R. march 23,2011.

55. Harrell, Jr., F. E,. *Regression modeling strategies, with applications to linear modelslogistic regression,and survival analysis.* New York : Springer-Verlag, 2001.

56. Institute., Ethiopian Mapping. *National Atlas of Ethiopia, Addis Ababa:.* s.l. : EMA, 1988).

57. Tesfaye, T. The Journey to Work Pattern in Addis Ababa. *Addis Ababa University (Thesis M.A. in Geography),*. 1986.

58. Central Statistical Authority,. *Household income consumption and expenditure survey*. Addis Ababa: : CSA publication, 2005.

59. UN-HABITAT. *Slum of the world:The face of urban poverty in the new millennium.* 2008.

60. United Nations Economic Commission for Africa. [Online] [Cited: May 05, 2012.]

61. Tesema, T. et al. *Rule Mining And Classification Of Road Traffic Crashs Using Adaptive Regression Trees.International Journal of Simulation Systems. Science & Technology Special Issue on Soft Computing for Modeling and Simulation.* Adiss Ababa : s.n., 2005. 10-11.

62. governmen, Addis Ababa city. kirkos sub city administration. [Online] february today, 2017. [Cited: February 29, , 2020 .] http://www.addisababa.gov.et/de/web/guest/kirkos-sub-city.

63. *Addis Ababa City Web Site.* [Online] september 01, 2004. [Cited: march 29, 2017.]

64. CSA. *Population and Housing census of Ethiopia.* 2007.

65. Addis Ababa and Kirkos sub-city police commission traffic accident report office," 2014-2018.

66. Bitew, M. *Taxi Traffic Accidents in Addis Ababa: Causes, Temporal and Spatial Variations and Consequences; Unpublished MA Thesis, Addis Ababa University(AAU), Ethiopia.* 2002.

67. *Emprical Analysis on Traffic Accidents involving human injuries.* Mekonnen, T. MSc, The case of Addis Ababa : Addis Ababa University, 2007.

68. Hanna, J.T.,Flynn,T.E. and Tyler,W.L. *Characterstics of intersection accidents in rural municipalities,Transportation research Board,Transportation Record 601.,PP.7.* Washington D.C. : s.n.

69. Lisa, K. S., B. David, et al. *Evaluation of Traffic Crash Fatality Causes and Effect.* Florida State, : s.n., 2005.

70. Alister, C., OBE and B. Simon. *Licensed to Skill. England and Wales, Institute ofAdvanced Motorists Limited.* 2011.

71. *Development of Assessment Techniques and Tools for Rural Accessibility, Final Report.* al., David et. sydney,Austraila : s.n., 1998.

72. Mebrahtu, B. Taxi Traffic Accidents In Addis Ababa. *Causes, Temporal And Spatial Variations And Consequences.* 2002.

73. *The Extent, Variation and Causes of Road Traffic Accidents in Bahir Dar.* Addis, Y. Addis Ababa : Addis ababa university, 2003.

74. Chen, C., Zhang, G., Tarefder, R., Ma, J., Wei, H. A Multinomial Logit Model-Bayesian Network Hybrid Approach fo rDriver Injury Severity Analyses in Rear-end Crashes. *Accident Analysis and Pervination.* 2015, Vol. Vol. 80 (2015), p. 76-88.

75. Delen, D., Sharda, R., & Bessonov, M. Identifying significant predictors of injury severity in traffic accidents using a series of artificial neural networks. *Accident Analysis and Prevention.* 2006, Vol. 38(3):, 434 - 444.

76. Tesfay.T. The Journey to Work Pattern in Addis Ababa. . *Addis Ababa University (Thesis M.A. in Geography.* 1986.

APPENDICES

APPENDICE A

1.1 Ordinal logistic regression output for signalized intersections.

Case Processing Summary

		N	Marginal Percentage
crash severity	Fatal	9	1.9%
	severe injury	42	8.7%
	slight injury	24	5.0%
	Pdo	408	84.5%
time interval	12 am-6 am	46	9.5%
	6 am-12 pm	139	28.8%
	12 pm-6 pm	224	46.4%
	6 pm -12 am	74	15.3%
age of at fault driver	<18 year	1	0.2%
	18-30 year	219	45.3%
	31-50 year	197	40.8%
	>51 year	66	13.7%
experience of driver	no license	3	0.6%
	<1 year	37	7.7%
	1-2 year	68	14.1%
	2-5 year	131	27.1%
	5-10 year	128	26.5%
	>10 year	116	24.0%
educational level of driver	read and write	5	1.0%
	primary education	98	20.3%
	secondary education	151	31.3%
	preparatory school	138	28.6%
	above preparatory school	91	18.8%
vehicle service age	<1 year	21	4.3%
	1-2 year	83	17.2%
	2-5 year	135	28.0%
	5-10 year	145	30.0%
	>10 year	99	20.5%
type of vehicle	Automobile	208	43.1%
	mini bus	92	19.0%
	mid bus	23	4.8%
	Bus	17	3.5%

	Truck	94	19.5%
	trailer truck	23	4.8%
	three wheler	8	1.7%
	motor cycle	13	2.7%
	Bicycle	3	0.6%
	Missing	2	0.4%
causes of accident severity	Tailgating	166	34.4%
	Speeding	54	11.2%
	improper turns	23	4.8%
	running red light	21	4.3%
	running traffic police	25	5.2%
	lack of visual attention	16	3.3%
	drunk driving	24	5.0%
	defects of automobile	12	2.5%
	not giving proririty	142	29.4%
day of crash	Monday	66	13.7%
	Tuesday	62	12.8%
	Wednesday	61	12.6%
	Thursday	75	15.5%
	Friday	86	17.8%
	Saturday	73	15.1%
	Sunday	60	12.4%
weather condition	Good	424	87.8%
	Cloudy	11	2.3%
	Drizzle	34	7.0%
	Rainy	3	0.6%
	Hot	6	1.2%
	Cold	5	1.0%
driver vehicle relationship	Owner	142	29.4%
	Hired	314	65.0%
	Others	27	5.6%
light condition	day light	348	72.0%
	Sunset	65	13.5%
	sun rise	27	5.6%
	dark with street light	36	7.5%
	dark no street light	7	1.4%
Valid		483	100.0%
Missing		0	
Total		483	

1.2 Ordinal logistic regression output for unsignalized intersections

Case Processing Summary

		N	Marginal Percentage
crash severity	Fatal	5	1.9%
	severe injury	11	4.2%
	slight injury	9	3.5%
	Pdo	235	90.4%
day of rear end crash	Monday	36	13.8%
	Tuesday	34	13.1%
	Wednesday	33	12.7%
	Thursday	40	15.4%
	Friday	46	17.7%
	Saturday	39	15.0%
	Sunday	32	12.3%
time of rear end crash	12 A.M-6 A.M	23	8.8%
	6 A.M – 12 P.M	72	27.7%
	12 P.M – 6 P.M	122	46.9%
	6 P.M – 12 A.M	43	16.5%
age of driver in crash	<18	4	1.5%
	18-30	125	48.1%
	31-50	83	31.9%
	>51	48	18.5%
experience of driver	No Driving license	3	1.2%
	<1 years	16	6.2%
	1-2 years	51	19.6%
	2-5 years	90	34.6%
	5-10 years	59	22.7%
	>10 years	41	15.8%
driver vehicle relationship	Owner	89	34.2%
	Hired	159	61.2%
	Others	12	4.6%
educational level of driver	Read and write	2	0.8%
	Primary education	37	14.2%
	Secondary education	99	38.1%
	Preparatory school	73	28.1%
	above preparatory	49	18.8%
type of vehicle in crash	Automobile	112	43.1%

	Mini bus	49	18.8%
	Mid bus	13	5.0%
	Bus	9	3.5%
	Truck	51	19.6%
	Trailer truck	12	4.6%
	Three wheeler	4	1.5%
	Motor cycle	10	3.8%
intersection type	T- junction	64	24.6%
	+ junction	56	21.5%
	o roundabout	116	44.6%
	Y junction	24	9.2%
weather condition	Good	249	95.8%
	Drizzle	5	1.9%
	Hot	6	2.3%
light condition	day light	187	71.9%
	Sunset	35	13.5%
	Sun rise	14	5.4%
	Dark with street light	23	8.8%
	Dark no street light	1	0.4%
primary cause of rear end crash	Following too closely	56	21.5%
	Failure to give way for vehicle	85	32.7%
	Failure to respect the right-hand rule	11	4.2%
	Improper Turning	8	3.1%
	Improper drivin	21	8.1%
	Speed Driving	18	6.9%
	Un Safe Driving & Driving without attention	44	16.9%
	Failure to respect stop rule	17	6.5%
Valid		260	100.0%
Missing		0	
Total		260	

APPENDEX B

1. Accident data collections methods

1.1 Drivers age and rear end crash severity

ተ/ቁ	ዕድሜ	አደጋው ያስከተለው ጉዳት				ድምር
		ሞት	ከባድ የአካል ጉዳት	ቀላል የአካል ጉዳት	የንብረት ጉዳት	
1	ከ18 ዓመት በታች					
2	ከ18-30 ዓመት					
3	ከ31-50 ዓመት					
4	ከ51 ዓመት በላይ					
5	ያልታወቀ					
ድምር						

1.2 Drivers driving experience and rear end crash severity

. የአሽከርካሪው የማሽከርከር ልምድ

ተ/ቁ	የማሽከርከር ልምድ	አደጋው ያስከተለው ጉዳት				ድምር
		ሞት	ከባድ የአካል ጉዳት	ቀላል የአካል ጉዳት	የንብረት ጉዳት	
1	መንጃ ፈቃድ የሌለው					
2	ከ1 አመት በታች					
3	ከ1-2 አመት					
4	ከ2-5 አመት					
5	ከ5-10 አመት					
6	ከ10 አመት በላይ					
7	ልታወቀ					
	ድምር					

1.3 Gender and rear end crash severity

ተ/ቁ	ፆታ	አደጋው ያስከተለው ጉዳት				ድምር
		ሞት	ከባድ የአካል ጉዳት	ቀላል የአካል ጉዳት	የንብረት ጉዳት	
1	ወንድ					
2	ሴት					
3	ያልታወቀ					
ድምር						

1.4 vehicle service age and rear end crash severity

. የተሽከርካሪው የአገልግሎት ዘመን

ተ/ቁ	የአገልግሎት ዘመን	አደጋው ያስከተለው ጉዳት				ድምር
		ሞት	ከባድ የአካል ጉዳት	ቀላል የአካል ጉዳት	የንብረት ጉዳት	
1	እስከ 1 ዓመት					
2	ከ1-2 ዓመት					
3	ከ2-5 ኣመት					
4	ከ5-10 ኣመት					
5	ከ10 ዓመት በላይ					
6	ያልታወቀ					
ድምር						

APPENDEX C

1. Name of intersections

1.1 signalized intersections

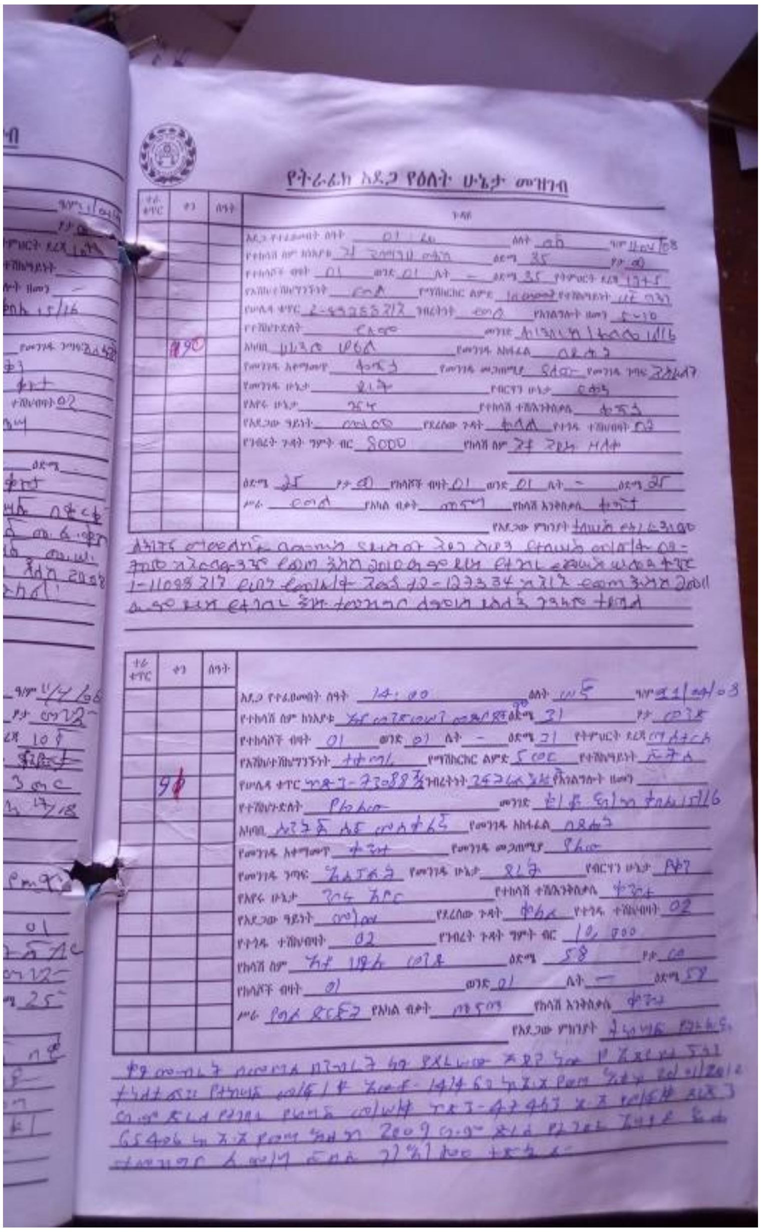
N0	Name of signalized intersections	Intersection type	Rear end crash
1	Meskel square	Crossing(╬)	81
2	Near Estifanos	Crossing(╬)	73
3	Leghare intersection	Crossing(╬)	64
4	Near to tell bar	T –Crossing	46
5	Buna ena shaye intersection	Crossing(╬)	58
6	Near to commerce	Crossing(╬)	23
7	Near to national theater	Crossing(╬)	37
8	Near to harambe hotel	Crossing(╬)	33
9	Bulgarya intersection	Crossing(╬)	45
10	Timbaho monopole	Crossing(╬)	23
sum	Sum		483

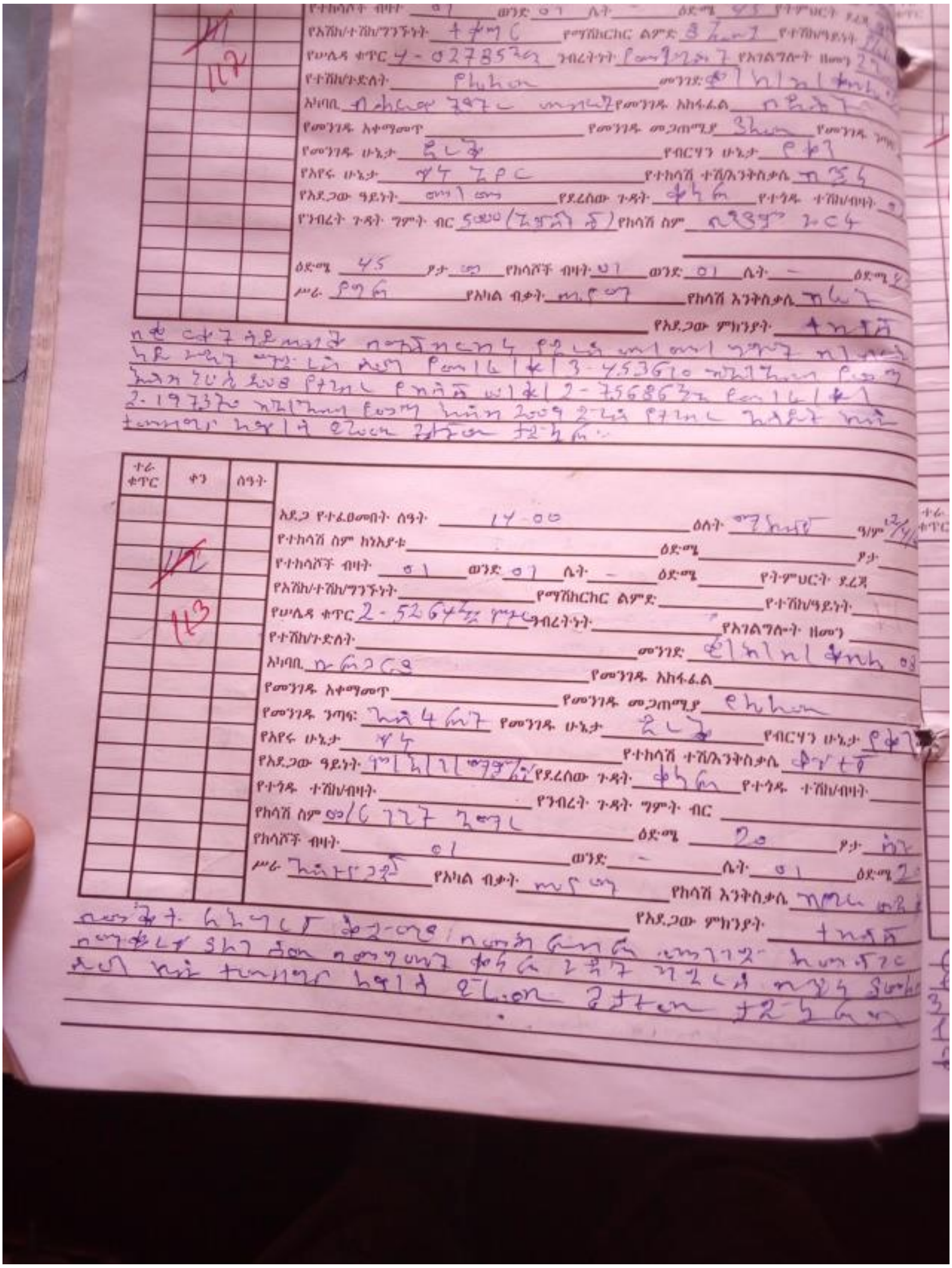
1.2 unsignalized intersections

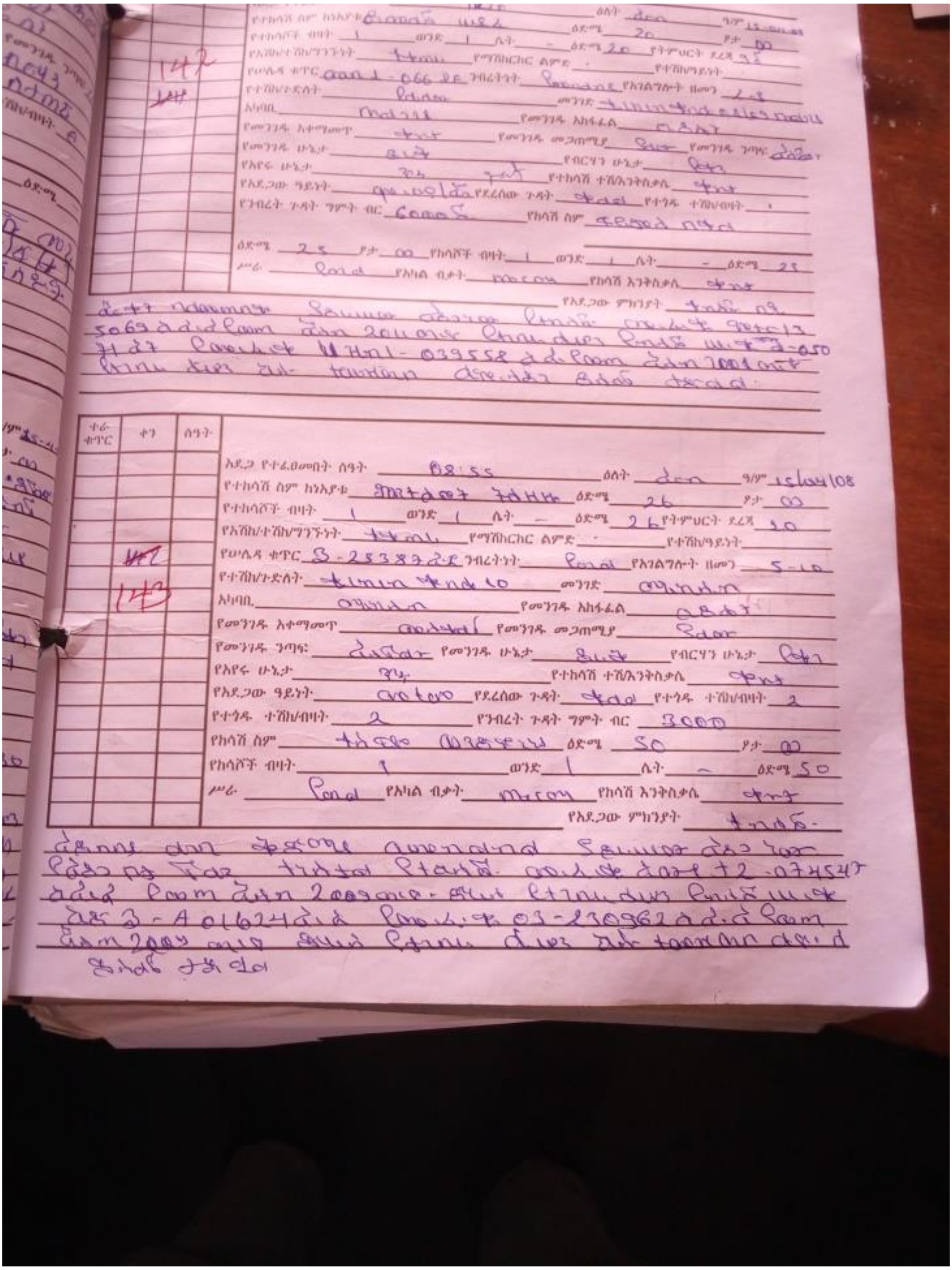
No	Name of unsignalized intersections	Intersection geometry	Rear end accident
1	Near to Ureal church intersection	O-roundabout	29
2	Kasanches Sunday market	(╬) crossing	18
3	upper grand palace intersection	T- crossing	31
4	Filwoha intersection	T- crossing	33
5	Bête mengst intersection	(╬) crossing	21
6	Kera serawoch intersection	Y-intersection	24
7	Olympia roundabout	O-roundabout	23
8	Dumbbell seti roundabout	O-roundabout	32
9	AU roundabout	O-roundabout	32
10	Kera intersection	(╬)Crossing	17

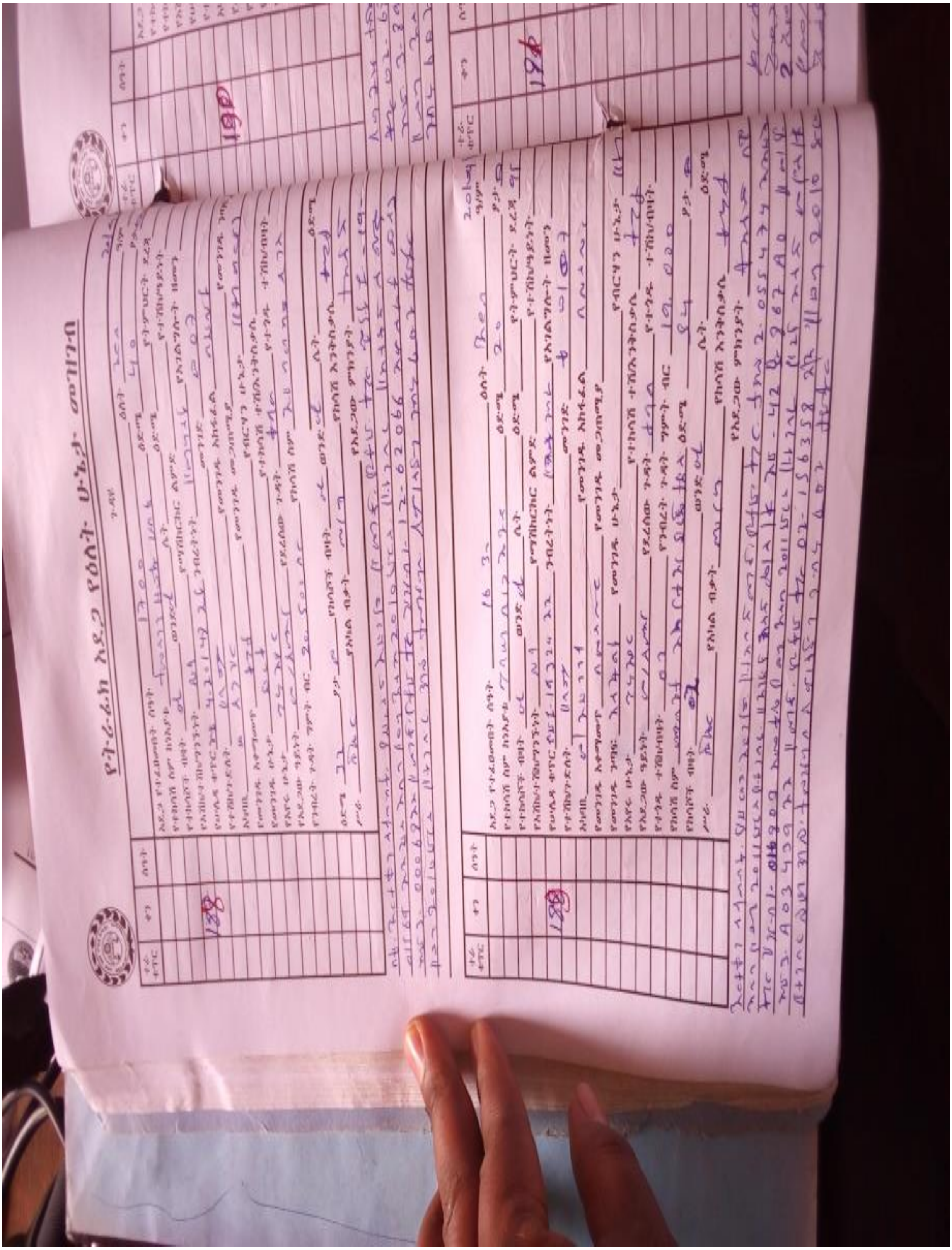
APPENDEX D

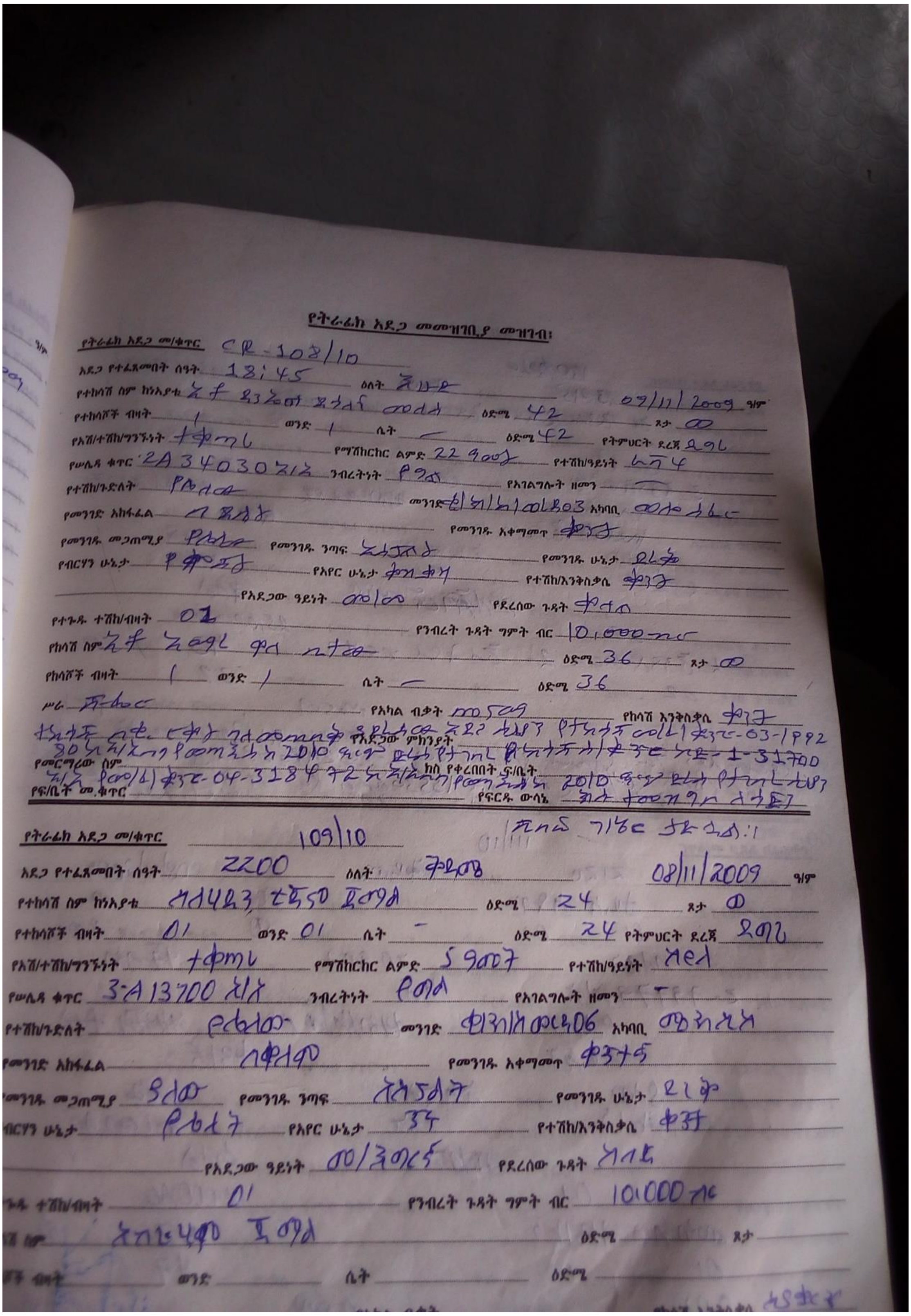
Samples of accident data



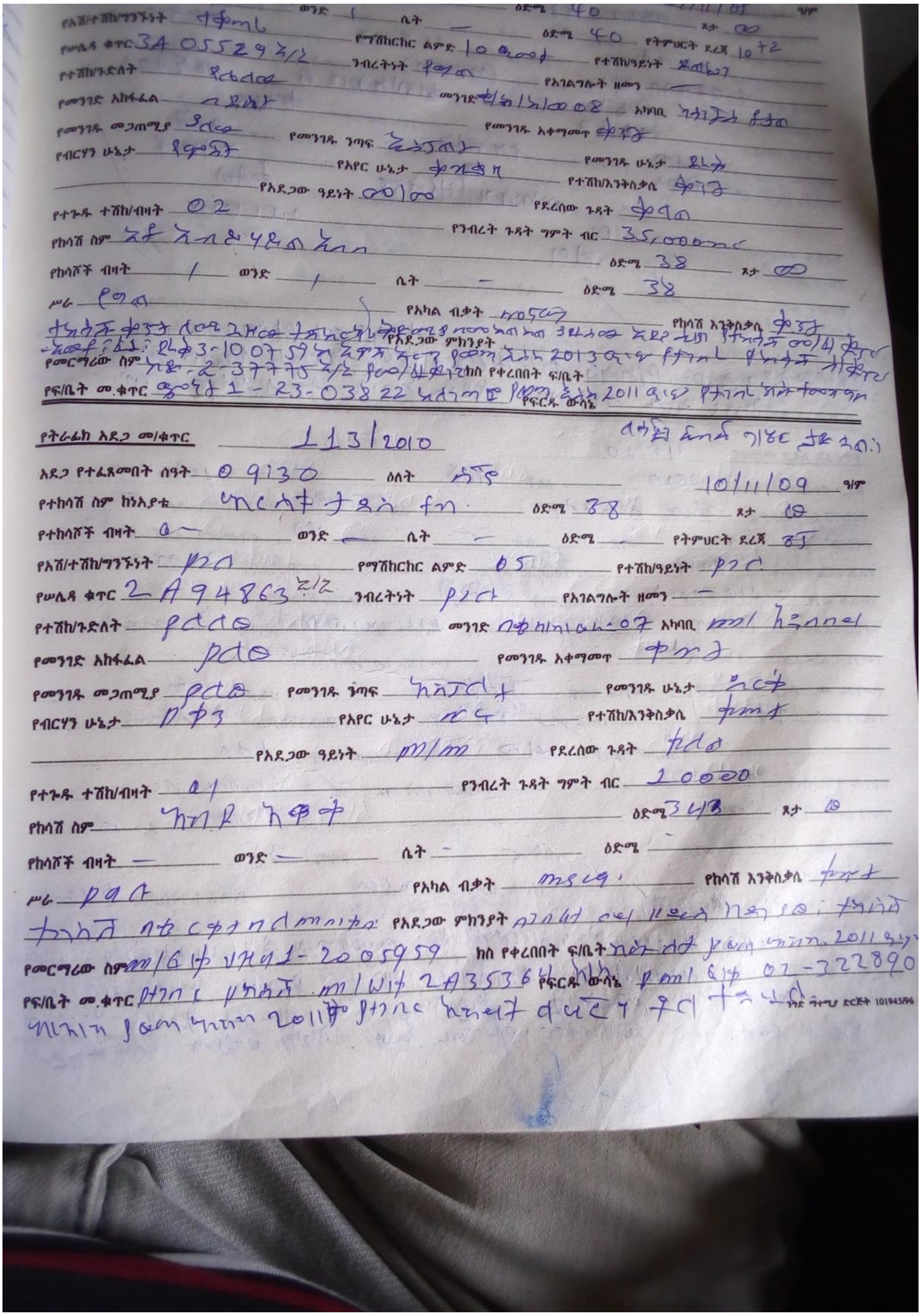


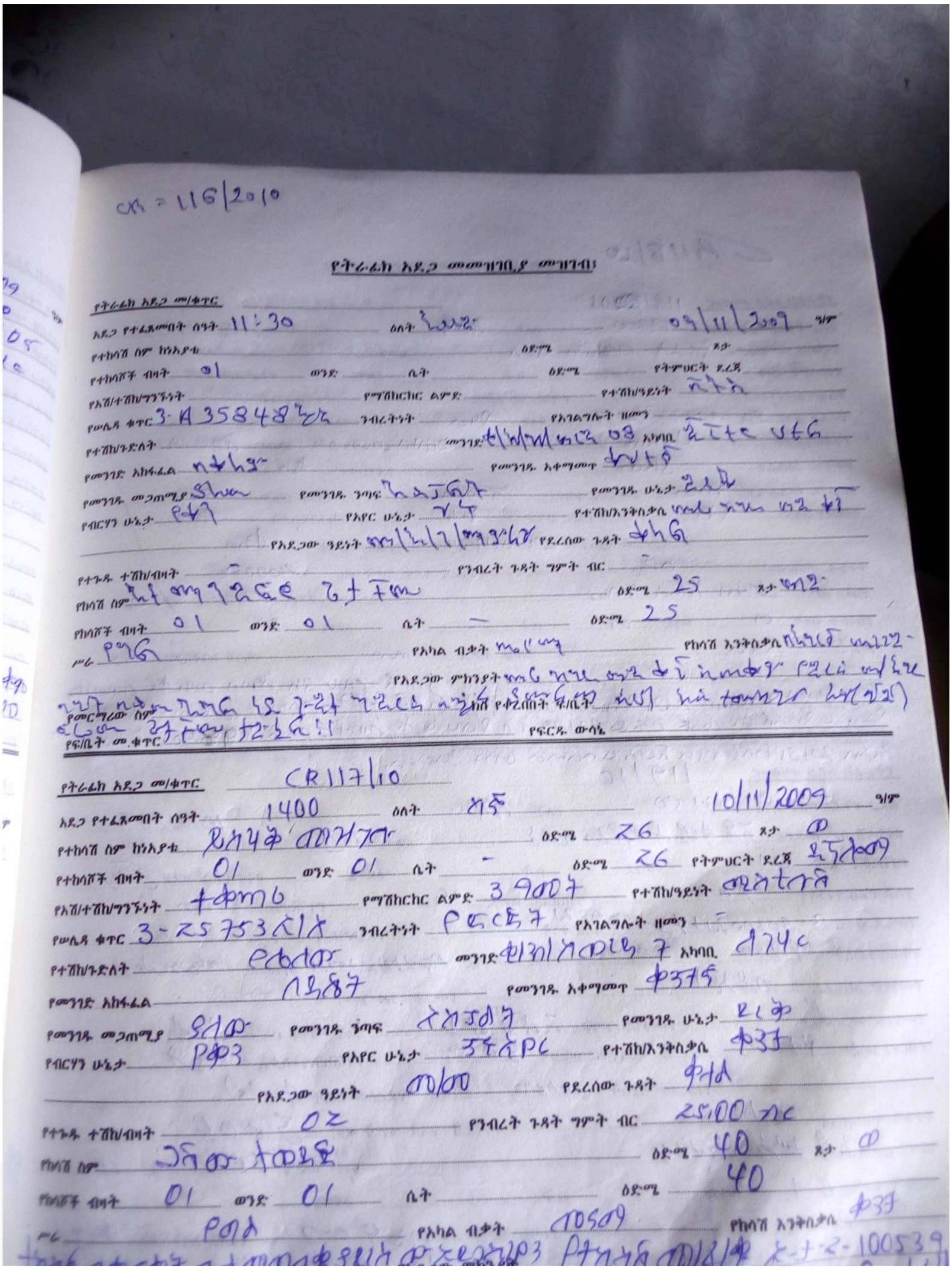






የትራፊክ አደጋ መመዝገቢያ መዝገብ፡
የትራፊክ አደጋ መ/ቁጥር CR-108/10
አደጋ የተፈጸመበት ሰዓት 18:45
07/11/2009 ዓ/ም
የትራፊክ አደጋ መ/ቁጥር 109/10
አደጋ የተፈጸመበት ሰዓት 2200
08/11/2009 ዓ/ም
የንብረት ጉዳት ግምት ብር 10,000




CR = 116/2010
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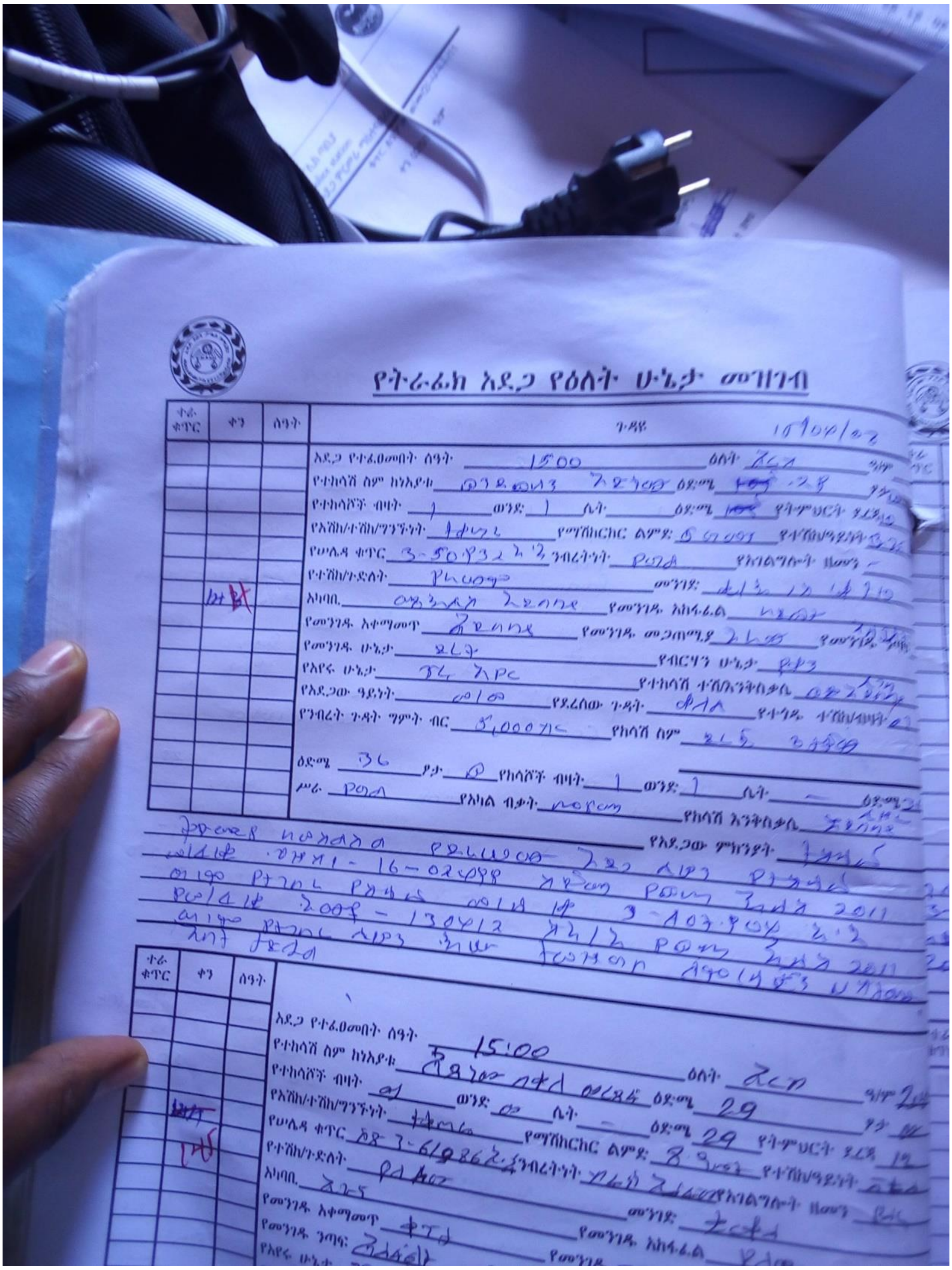
CR117/10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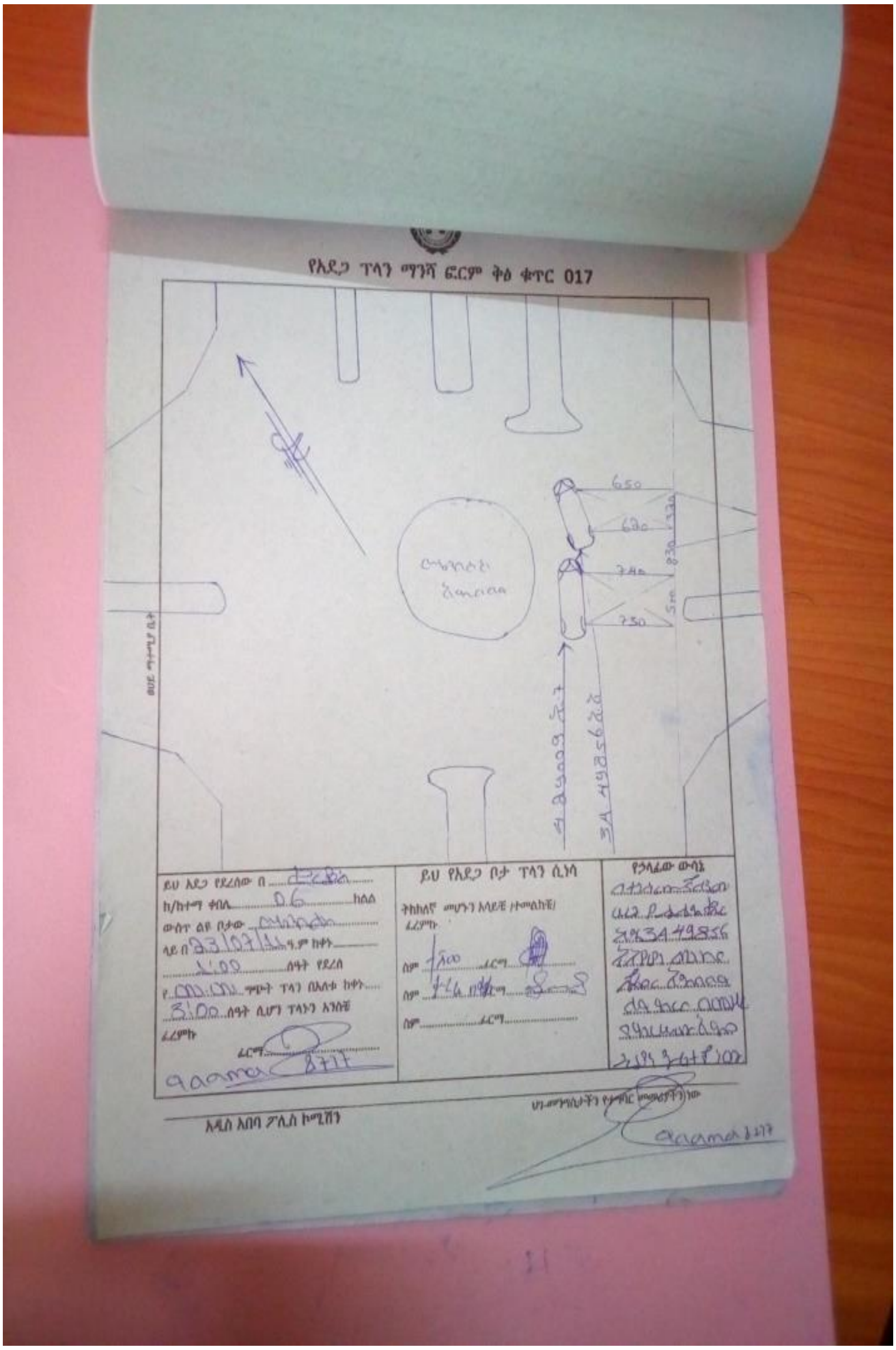
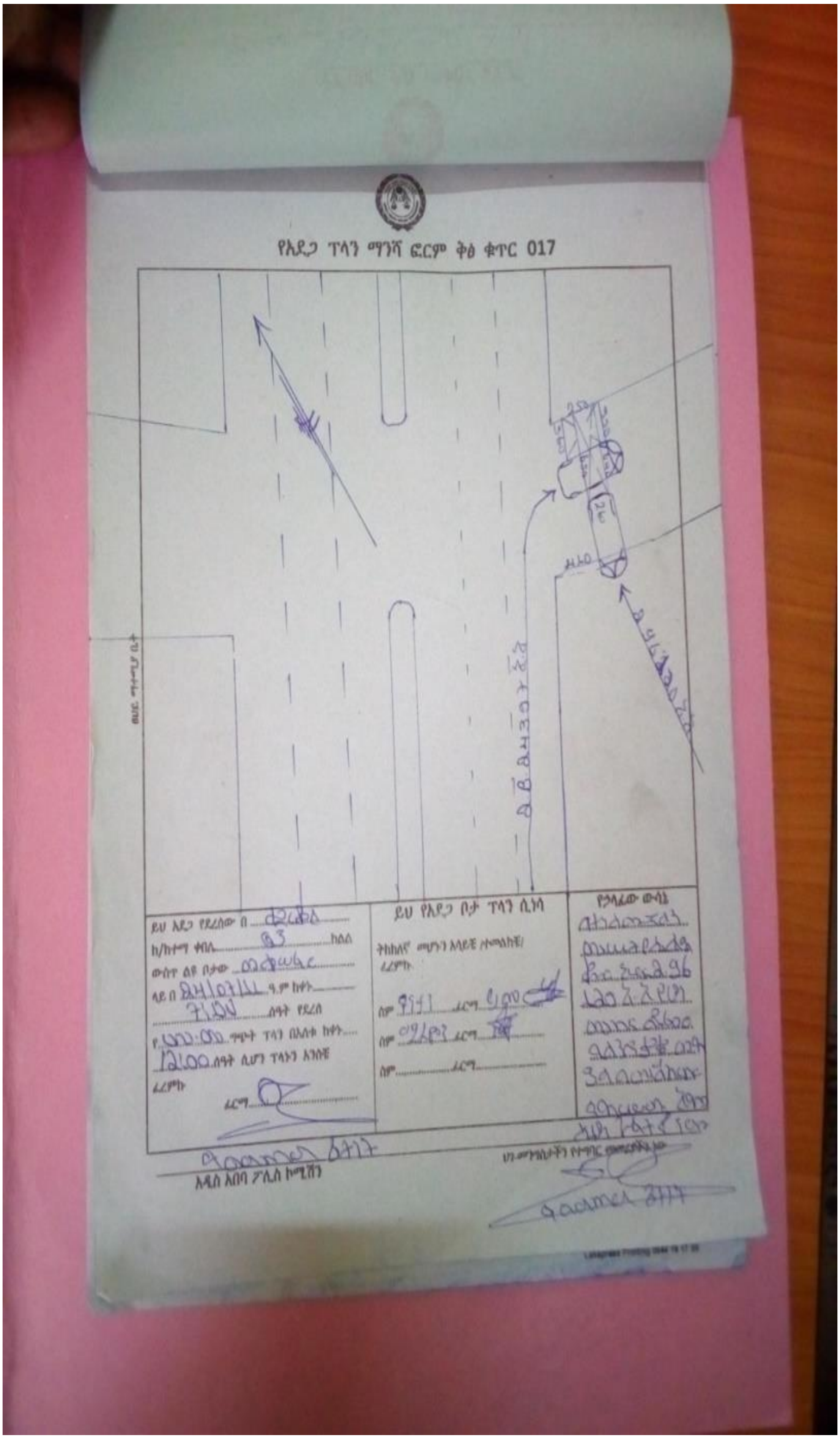



አዲስ አበባ ፖሊስ ኮሚሽን


የአደጋ ፕላን ማንሻ ፎርም ቅፅ ቁጥር 017
ይህ የአደጋ ቦታ ፕላን ሲነሳ
አዲስ አበባ ፖሊስ ኮሚሽን

APPRNDX E

Photo taken during observation


Kool


Eyes on your
Money
24
7
INTERNET & MOBILE BANKING
Wegagen Bank