MODELLING DEATHS ASSOCIATED WITH ROAD TRAFFIC ACCIDENTS AND RELATED FACTORS ON GREAT NORTH ROAD IN ZAMBIA BETWEEN THE YEARS 2010 AND 2016 USING POISSON MODELS.

By

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DECLARATION

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APPROVAL

This dissertation of Ronald Fisa has been approved as partial fulfilment of the requirements for the award of Master of Science in Medical Statistics by the University of Zambia.

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ABSTRACT

World Health Organization reports that about 1.24 million people die annually on the world's roads, with 20–50 million sustaining non-fatal injuries. More than 85% (1.05 million) of the global deaths due to injuries occur in the developing world.

Statistical techniques known and applied to model these scenarios are limited to basic statistics such as linear and Poisson regression that do not account for over dispersion. Further, Road Traffic Accident data violates assumptions that standard Poisson regression models is based. Appropriate extensions of this model, even though available, are rarely used by most applied statisticians.

Data was collected from Zambia Police, Traffic Section on accidents that occurred on the Great North Road (GNR) highway between Lusaka and Kapiri-Mposhi in Zambia from January 1, 2010 to December 31, 2016. Results from standard Poisson regression were compared to those obtained using the Negative Binomial (NB), Zero-Truncated Negative Binomial (ZTNB) and the Zero-Truncated Poisson (ZTP) regression models. Diagnostic tests were used to determine the best fit model. The data was analysed using STATA software, version 14.0 SE (Stata Corporation, College Station, TX, USA).

A total of 1, 023 Road Traffic Accidents (RTAs) were analysed in which 1, 212 people died. Of these deaths, 82 (7%) were Juveniles and 1, 130 (93%) were adults. Cause of accident such as pedestrians crossing the road accounted for 30% (310/1,023) while 29% (295/1,023) were as a result of driver's excessive speed. The study revealed that driving in the early hours of the day as compared to driving in the night had a significant increase in the incidence rate of death from RTAs, Incident Rate Ratio (IRR) of 2.1, (95% CI={1.01-4.41}), p-value=0.048, further, public transport as compared to private transport had an increased incidence of death from RTAs (IRR=5.65, 95% CI={2.97-10.73}), p-value<0.0001.

There is a reduced incidence of dying if one is using a private vehicle as compared to a public vehicle or a truck. Driving in the early hours of the day (between 1AM and 7AM) had an increased incidence of death from RTAs. This study suggests that when dealing with counts in which there are a few zeros observed such as in serious and fatal RTAs, ZTNB fits the data well as compared to other models.

Key words: Road Traffic Accidents, Poisson, Zero Truncated Poisson, Negative Binomial, Zero Truncated Negative Binomial, Number of deaths.

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DEDICATION

I dedicate this work to my loving wife Yakiwe Kauluka Fisa and my three children Michelle S. Fisa, Ryan C. Fisa and Abigail T. Fisa.

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ABBREVIATIONS AND ACRONYMS

AADT Average Annual Daily Time

AIDS Acquired Immunodeficiency Virus

CI Confidence Interval

DALYs Disability Adjusted Life Years

GNR Great North Road

HIC High Income Country

HIV Human Immunodeficiency Virus

IMF International Monetary Fund

INGOs International Non-governmental Organizations

LMIC Low and Middle Income Country

MOH Ministry of Health

MVC Motor Vehicle Collision

UN United Nations

UNICEF United Nations International Children's Emergency Fund

RDA Road Development Agency

RTA Road Traffic Accident

RTAs Road Traffic Accidents

RTI Road Traffic Injury

RTF Road Traffic Fatality

RTSA Road Transport and Safety Agency

SI Statutory Instrument

WHA World Health Assembly

WHO World Health Organisation

ZP Zambia Police

ZIPM Zero Inflated Poisson Model

ZTNB Zero Truncated Negative Binomial

ZTPM Zero Truncated Poisson Model

CHAPTER 1: INTRODUCTION

1.1 Overview

This chapter gives a background of the public health problem (Road Traffic Accidents) for which this study was conducted. This chapter also presents the statement of the problem, justification of the study and conceptual framework. This chapter also gives a detailed understanding of the factors associated with RTAs as documented by other researchers.

The World Health Organization (WHO) defines a Road Traffic Accident (RTA) as a collision involving at least one vehicle in motion on a public or private road that results in at least one person being injured or killed (WHO, 2004). A traffic collision, also known as a motor vehicle collision (MVC) among others occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or pole. These traffic collisions may result in injury, death and property damage. Globally, RTAs are one of the major causes of deaths, injuries and disabilities. According to WHO, the epidemic of road traffic injuries is increasing in most regions of the world (WHO, 2009). In fact it has a great impact on the disability-adjusted life years (DALYs). As a result, it is now a public health problem particularly in developing countries. The DALYs is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death (WHO, 2009).

The WHO reports that about 1.24 million people die on the roads annually, with 20-50 million sustaining non-fatal injuries (WHO, 2015). Globally, road traffic injuries are reported as the leading cause of death among young people aged 15–29 years and are among the top three causes of mortality among people aged 15–44 years (WHO, 2013). More than 85% of the global deaths due to injuries occur in the developing world, consuming substantial health sector resources (Nantulya, 2002). Further, road traffic deaths and injuries are a major but neglected public health challenge that requires concerted efforts for effective and sustainable prevention as the people dying on the roads keep increasing worldwide. The increased burden from road traffic injuries and deaths is partly due to economic development, which has led to an increased number of vehicles on the road (Nantulya, 2002).

The WHO (2013) indicates that road traffic injuries (RTI) cause considerable economic losses to victims, their families, and to nations as a whole. These losses arise from the cost of treatment (including rehabilitation and incident investigation) as well as reduced/lost

productivity (e.g. in wages) for those killed or disabled by their injuries, and for family members who need to take time off work (or school) to care for the injured. A Study by Goldsmith and Cwikel, (1993) revealed that for men in productive ages, RTI is considered to be the third most important cause of death in developing countries, after AIDS and tuberculosis. The dynamic nature of this multi-causal phenomenon affects victims to different degrees depending on the type of accident (run over pedestrian, motorbike accident or another type of accident involving a vehicle or motorbike) and demographic characteristics (sex, age, skin colour, marital status and level of education) (Blakely and Salmond, 2002; Bacchieri and Barros, 2011). Road traffic injuries (RTIs) have been neglected from the global health agenda for many years, despite being predictable and largely preventable. Evidence from many countries shows that dramatic successes in preventing road traffic crashes can be achieved through concerted efforts that involve, but are not limited to, the health sector (WHO, 2013).

The WHO (2002) reported that in 1990 Africa had lost 59,000 people in RTAs and the figure is expected to rise to 144,000 by the year 2020, if the situation is left to continue, while in developed countries the trend has been declining since the 1960s. Due to this alarming escalating situation the WHO in April 2001 conveyed a meeting on a 5 years strategy for road traffic injury prevention, and in the year 2003, the United Nations Secretary described RTIs as a global public health challenge and encouraged the member states to address it (WHO, 2002). The World Summit on Sustainable Development held in the year 2002 recommended that in developing countries where there is rapid motorization, urban development and transportation, planning is integrated and that reliance on mass transit and alternative modes of transport be increased. Such efforts should help to mitigate the adverse impacts of increased motorization.

The RTAs have claimed a lot of lives in Zambia especially on the highway roads (ZP, 2014). This has been on both public and private vehicles. It should be noted here that the accidents that are reported to the police and hospitals are not exhaustive as many of the accidents are not reported. In this regard, Museru (2002) observed that usually hospital based data is like a piece of floating ice berg, there are more injuries and deaths in the community than what we see at the reported health facilities.

Therefore the objective of this study was to model the number of deaths associated with RTAs and related factors on the Great North Road (GNR) in Zambia between the years 2010

and 2016 using Poisson Processes Models. The deaths in this case are deaths that occur at the scene of an accident and these are recorded by Road Transport and Safety Agency (RTSA) through Zambia Police (ZP) traffic division. The study does not take into account deaths that took place in the hospitals or other health facilities after the accident has happened.

This study was aimed at estimating the incidence rate of death from RTAs and identifying factors associated with fatal road traffic accidents. This study was necessitated due to the increased number of accidents on the highways in Zambia especially between Lusaka and Kapiri-Mposhi and these accidents result in a lot of deaths. The study therefore concentrated on the highway between Lusaka and Kapiri-Mposhi, and also examined on which stretch of the road and the period these accidents are most common.

1.2 Statement of the Problem

Globally, Zambia is ranked 29th in the world in road traffic accidents and has a death rate of 26.51 per 100, 000 of population (WHO, 2015). Statistics from Zambia Police (ZP, 2014) indicate that Road deaths in Zambia have increased by 85% between 2012 and 2014 from 1,000 to 1,858 respectively. These RTAs have enormous health, social and economic impacts on individuals, families, communities and nations. Besides the direct physical and psychological impact on those directly affected by RTAs also place a heavy burden on those involved with the victims. Family, friends and communities of those directly affected by RTAs can also experience short and long term adverse social, physical and psychological outcomes such as taking care of the injured. In line with this, a study carried out in Zambia by Hangoma et al. (2018) found that in urban areas, injury more than doubled medical spending after 2002 and injury was associated with a large increase in medical spending. The study further stated that health shocks (illness, injury and death) pose one of the biggest risks to economic wellbeing. The unpredictability of these shocks may impose unanticipated reduction in income because of possible increases in medical spending as well as reduced labour income.

In an attempt to address the rise in RTA**s** occurrence in Zambia, the government has prioritized the construction of roads in an effort to reduce the traffic accidents on the highway. The current projects Government is implementing include the Link 8000 Project which is a clear indication that Government is a major stakeholder in improving road safety (Mwape, 2014). The Ministry of Transport and Communication, through the RTSA has also tightened measures of assessing vehicle road worthiness and individual drivers' skill and

experience before they can be legally allowed on the road to improve the safety of road users (RTSA, 2015).

The growth in number of motor vehicles on the roads and growth in population means that there is need to transform and upgrade the road transport and road network systems in order to protect road users from preventable RTAs. The deaths among motorists and passengers between Lusaka and Kapiri-Mposhi may result from a series of factors such as human error, poor road network to mention just a few.

A study by Juillard et al, (2010) indicated that since air and rail transport are either expensive or unavailable in many African countries, the only widely available and affordable means of mobility in the region is road transport, of which Zambia is one of these African countries. In addition, WHO (2015) reports that the road infrastructure has not improved to the same level to accommodate the increased number of commuters and ensure their safety and as such many people are exposed daily to an unsafe road environment. In addition to all these, the Zambian government in the year 2016 signed a Statutory Instrument (SI) number 76 restricting night driving for public buses and trucks which was introduced in November, 2016 (RTSA, 2016). In this regard, this study will help the agencies involved to determine with evidence factors that are contributing to RTAs. To our knowledge, despite the high numbers of deaths and injuries recorded from RTAs on highways, little/no known research findings on RTAs on GNR highway in Zambia have been documented and published.

1.3 Justification of the Study

The number of accidents on the highways has been increasing and this is robbing the country of much needed human resource and negatively impacted on the economic growth of Zambia. Everyone killed, injured or disabled by a road traffic accident has a network of others, including family and friends, who are deeply affected. However, even though RTAs are claiming so many lives in Zambia, little/very few research work has been conducted to ascertain factors associated with these fatal accidents.

Further, due to the growing number of Road Traffic Accidents on the Great North Road (GNR) as documented by ZP (2014), in particular between Lusaka and Kapiri-Mposhi highway, this study was necessary to investigate factors associated with the fatal accidents. The study therefore aimed at modelling the number of deaths associated with road traffic accidents and related factors on the GNR between the years 2010 and 2016 using Poisson

processes models. The study gave the incidence rate ratios of deaths from RTAs by using exploring models for counts, deaths that are associated with RTAs in the past seven years together with associated factors. This study also determined which of the models explained the data well. The findings of this study may help the government and other stakeholders to know the factors associated with these fatal traffic accidents and come up with possible solutions to reduce the mortalities due to RTAs. The results of this study may also help the three government agencies, RTSA, ZP and RDA to come up with measures that can help in reducing these fatal accidents. The government through relevant authorities will also be able to equitably distribute the resources according to need.

1.4 Research Questions

The study answered the following research questions:

1. What is the incidence rate of death from RTAs?
2. What are the factors associated with deaths from RTAs on GNR highway?
3. Which of the models, Poisson model, Negative binomial model, Zero-Truncated Negative Binomial or the Zero-Truncated Poisson Model fit the accident count data better?

1.5 Research Objectives

General Objective

To model the number of deaths associated with road traffic accidents and related factors on the Great North Road in Zambia between the years 2010 and 2016 using Poisson Models.

Specific Objectives

1. To estimate the incidence rate of death from RTAs on the Great North Road highway between Lusaka and Kapiri-Mposhi.
2. To determine factors associated with death from RTAs on the Great North Road highway between Lusaka and Kapiri-Mposhi.
3. To determine which of the four models, Poisson regression model, Negative binomial model, Zero-Truncated Negative Binomial or the Zero-Truncated Poisson Model fit the accident count data well?

1.6 Conceptual Framework

The public health approach is a generic analytical framework that has made it possible for different fields of public health to respond to a wide range of health problems and diseases, including injuries and violence (Krug et al., 2000). This approach is not only helpful in the analysis of risk factors, but also provides a framework that guides decision making throughout the entire process, from identifying a problem to implementing and intervention. Analysis of risk factors is one of the components of this approach, and that is why we are able to apply to road traffic injuries.

As highlighted in the literature, several factors contribute to the occurrence of RTAs. Factors that contribute to accidents among others are socio-demographic factors such as the age of the driver and the sex of the driver. The vehicle condition also contribute to these accidents because a vehicle which is not roadworthy is prone to accidents. Driving under the influence of alcohol is also one factor that has been documented. There is also an appreciation that inclement weather is associated with more hazardous driving conditions. Various studies show that precipitation in the form of rainfall and snowfall generally results in more accidents (Edwards, 1999; Eisenberg, 2004). Those among others are some of the possible factors of road crashes. RTAs affect populations all over the world; different local factors influence the causes of RTA in specific regions. Another study by Bjerre et al., (2006) supports these findings and added that causes of RTAs' among others include human or driver errors, vehicle characteristics, traffic infrastructures including engineering design, road maintenance and traffic regulation. Driver attitude including road courtesy and behaviour, driving under the influence of drugs especially alcohol, male sex, use of seat belts, driver age (teenage drivers and elderly drivers), are among the recognised human factors (Smart and Mann, 2002). It is of importance to note that in these accidents, the most affected individuals are the pedestrians. Pedestrians are more affected in Africa due to bad road infrastructure, lack of pedestrian-friendly road signs, the way traffic is mixed with other road users and a general disregard for pedestrians by drivers (WHO, 2015).

William Haddon (Haddon, 1968) developed a matrix that identifies risk factors before the crash, during the crash and after the crash, in relation to the person, vehicle and environment. Haddon described road transport as an ill-designed "man machine" system in need of comprehensive systemic treatment. Each phase–pre-crash, crash and post-crash–can be analyzed systematically for human, vehicle, road and environmental factors. The Haddon

matrix is an analytical tool to help in identifying all factors associated with a crash. Once the multiple factors associated with a crash are identified and analyzed, countermeasures can be developed and prioritized for implementation over short-term and long-term periods. For the pre-crash phase, it is necessary to select all countermeasures that prevent the crash from occurring. The crash phase is associated with countermeasures that prevent injury from occurring or reduce its severity if it does occur. Finally, the post-crash phase involves all activities that reduce the adverse outcome of the crash after it has occurred. Based on the literature, and the cases presented, the Haddon Matrix provides a framework and structure for analysis to assist with developing potential objectives or courses of action. It has been utilised in a range of public health, injury prevention and safety management settings (Conroy and Fowler, 2000). Most of the factors that have been identified and found are also in this framework, hence it's a framework that includes most of the factors that lead to RTAs. In this study however, not all the factors depicted in the Haddon matrix will be used, this is because some of the factors such as the education level of the drivers is not documented by RTSA when an accident happens. The 1968 frame work is the basis of the transport system, it has been used because it encompasses all the stages of the Traffic accident, Pre-crush, during the crush and post-crush provides solutions on what to do at each stage. This framework is essential as it can be used for accident prevention and explores its application. The conceptual framework (Figure 1.1) below indicates some of the factors that lead to a traffic accident in the transport system.

Conceptual framework

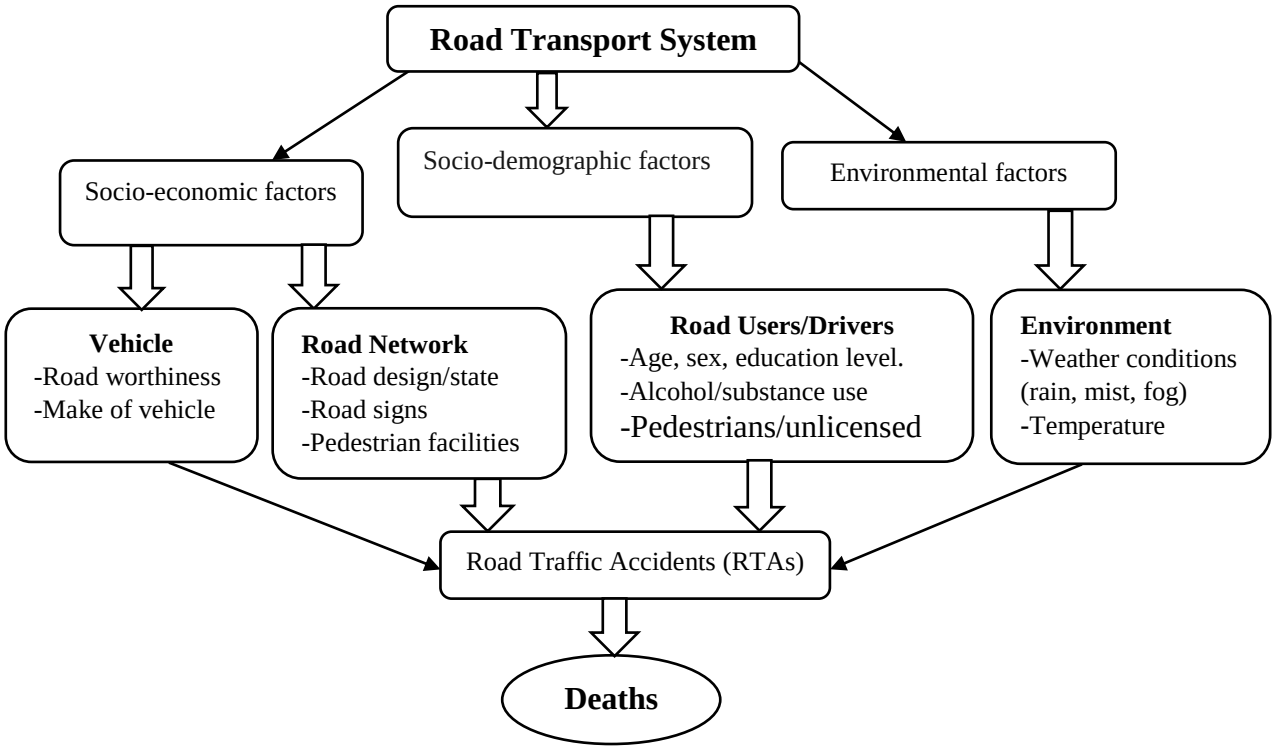

Figure 1.1: Conceptual framework indicating possible risk factors that lead to deaths from Road Traffic Accidents. Some of the factors are adopted from Haddon Matrix (Haddon, 1968) frame work.

1.7 Organization of the Dissertation

The organization of the dissertation is such a way that chapter one talks about the introduction in which the terms are defined such as Road Traffic Accident, Disability adjusted life years and the burden of this public health problem in the world, in Africa and also in our country Zambia. In chapter two, we present the literature on the incidence rate of death, the factors associated with RTAs and also the research questions and research objectives that were addressed. Chapter three presents the methodologies that were used to model the number of deaths which are recorded as a result of RTAs and it also indicate the sample size that was considered and the study site. Further the chapter also presents the study design and the inclusion and exclusion criteria. In chapter four, we present the results from different modelling approaches, these include the Poisson model, the Zero-truncated poisson, the negative binomial and the Zero-Truncated negative binomial. The tables with results from the best fit model are indicated in this particular chapter. In chapter five, we discuss the findings relating them with what other people have found elsewhere. In this chapter we give conclusions of the study and we also offer recommendations to the Zambian government and all agencies that are concerned with RTAs.

1.8 Summary

This chapter gave the background of the study area, defines the RTA, gives the statement of the problem justifying why it was important to carry out this research and also gives the conceptual framework which links the factors associated with RTAs and the outcome of interest which is death in this case. This chapter also utilised the Haddon matrix to visualise what happens during the three stages, these are pre-crash, during crash and post-crash.

The relevant studies that looked at RTAs were identified, the incidence rate of death from a RTA was also established from different studies, and this was done in Africa and around the world. The research questions were also presented.

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 Overview

This chapter will present studies that have been done on this public health problem (RTAs), it will give the findings from other studies regarding the incidence rate of death from RTAs, the factors associated with RTAs and also some of the models that have been applied to count data outcomes. The chapter will also give the burden of RTAs at global, Africa and National levels. It will also further outline the research questions and the research objectives that were investigated in this study.

2.2 Global burden of RTAs

RTAs are a routine occurrence on roads throughout the world. Thousands of people lose their lives on the roads every day. Many millions more are left with disabilities or emotional scars that they will carry for the rest of their lives. The WHO (2013) reported that worldwide, every year the lives of approximately 1.25 million people are cut short as a result of RTAs. This report further indicated that between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury. If left unchecked, by the year 2020, RTAs will rank third of all causes of morbidity and mortality globally (Peden, 2005).

The WHO has been concerned with RTAs for over four decades. In 1974, the World Health Assembly (WHA) adopted Resolution (WHA 27.59), declaring RTAs as a major public health issue and calling for member states to address the problem (WHO, 2000). As early as 1962, a WHO Report discussed the nature and dynamics of the problem. For the past two decades, the World Bank has encouraged its borrowers to include road safety components within most of their highways and urban transport projects (IMF Report, 2004). RTAs are the leading cause of death by injury, the 10th leading cause of all deaths and the 9th leading contributor to the burden of the disease worldwide (WHO, 2000).

According to a study done by Hijar et al. (1999) conducted in Mexico–Cuernavaca highway, the objective of the study was to identify risk factors related to the driver, the vehicle and the

environment, that are associated with motor vehicles accidents on highways. The study findings indicate that young people were at high risk of being involved in an accident, these results with respect to age coincide with those reported in other studies. The risk was higher for young people and lower for adults, increasing again in the older age group where accidents become more lethal. With respect to alcohol consumption, which has been broadly documented as a variable that increases the probability of an automobile accident (Beirness et al., 1994; Hijar et al., 1999) results obtained in these studies reinforce these statements.

Almost half of all deaths on the world's roads are among those with the least protection, these are motorcyclists, cyclists and pedestrians. These pedestrians are not well educated on the use of the roads. In terms of safety, it is also interesting to note that Jennings et al., (1977) found that pedestrians tended to only look prior to crossings when "DON'T WALK" signals were lit and concluded that pedestrians may depend too much on the signals to keep them safe from harm. Another study by Vorko-Jovic et al., (2006) looked at urban RTA risks for the city of Zagreb, Croatia, from 1999 through 2000. The accidents were analysed with the aim of reducing the increasing injury incidence. The results obtained were that more fatal accidents occurred during night hours, on urban road links, and at exceeding speed limit. RTAs happen as a result of so many factors and these include, the vehicle fitness, the condition of the road and the driver. Analyzing the factors which affect the occurrence of traffic accidents is a complex procedure as they are numerous and they are not independent (Gawryszewski et al., 2004). A Study by Hijar et al. (1999) was carried out in order to identify factors contributing to death or to the seriousness of injuries resulting from motor vehicle accidents, the factors were grouped as follows: driver related, vehicle related, environmental (climatological) conditions and the physical environment where these occur.

Lívia et al., (2013) analysed the characteristics of risk in the accident, considering the individuals and the roads where the vehicles drive was an important contribution for increasing the number of factors related to this phenomenon (RTA). The findings were that activities promoting the prevention of traffic accidents should primarily focus on accidents involving two-wheeled vehicles that most often involves a single person, unskilled, male, at night time, on weekends and on roads where they travel at higher speeds as these were found to be the main contributors of RTA.

Studies that have been conducted and used incident rate ratios as an effect measure are limited/few. An incidence rate ratio (IRR) is a meaningful effect measure in epidemiology if

it is adjusted for all important confounders. In this regard, a study by Guest et al. (2014) examined the effect of age on driver performance and safety in professional heavy vehicle drivers and to assist in the formulation of strategies to meet the looming shortage of skilled professional heavy vehicle drivers in Australia. In this study, the modelling of incidence rate ratios involving male drivers of rigid trucks compared to 45–54 year olds, older drivers 65 years of age and older were significantly less likely to have a crash. For drivers in the 55–64 age group there was no difference between their crash rate and their younger peers. This is likely to be true as elderly people tend to take their time when driving and as a result they tend to be more careful than their younger counterparts. A study by Sullivan et al. (2011) looked at all drivers aged 65 and over in Queensland Australia, they found that older drivers seek to avoid driving in the rain, at night and driving in peak hour.

2.3 The Burden of RTAs in Africa

Africa is the most affected with deaths from RTAs. Studies done in the region suggests that this is a problem in most countries in Africa. Studies done in Ghana, (Largade, 2007), noted that the problem of RTAs in Ghana is not typical of Ghana only, but a problem in the sub-region and Sub-Saharan Africa in general. Findings from a study by Coleman (2014) particularly stresses that the problem of RTA containment should primarily focus on prevention by utilising a multifaceted public health approach. An approach that draws on all the relevant public health disciplines of epidemiology, statistics, environmental sciences, behavioural sciences, safety and injury prevention, health services administration and others, as well as the incorporation of emergency and advanced trauma support services, to guide and formulate policies towards containing the scourge of the RTA problem currently confronting the country.

The death rate in African countries is high compared to European countries. In Africa the mortality rate is 28 per 100,000 populations while in Europe it is 11 per 100,000 people. Comparison of death vs number of vehicles, shows a higher ratio in Africa of 50 per 100,000 while in developed countries it is 1.7 deaths per 100,000 (Gul, 2013). Studies by Bradshaw et al. (2003), and Murray et al., (2001) found that the annual Road Traffic Fatality (RTF) burden of 43 deaths per 100 000 population in South Africa (SA) is disproportionately high in comparison to the world average of 22 per 100 000 population. Other studies in other African countries have recorded a slightly higher mortality rate, for instance a study by Mekonnen and Teshager (2014) in Ethiopia recorded the highest death rate at 81.6 per 100

000 population in 2011. The findings on the African continent are not consistent and they differ from country to country, a population-based study in Nigeria reported an estimate of 160 deaths per 100 000 population (Labinjo et al., 2009).

Developing countries are now in rapid urbanization, with high growth rate in traffic leading to congestion of traffic which causes increase in RTAs (Odero et al., 1997). Seventy percent (70%) of RTAs occur in developing countries, while there is a degree of decline of RTAs in developed countries. In Africa RTAs are on the increase especially in large cities. In countries such as Nigeria, Kenya, Malawi, Ethiopia, Zambia, Uganda and Tanzania, and South Africa there is also an increase in motorcycle accidents which have contributed to the rise in the death rate.

The economic impact of road traffic injuries is especially damaging, particularly for countries struggling with poverty alleviation and the overall challenges of development, because economically active age groups are the most vulnerable to such injuries. A study done in Sudan by Mofadal et al. (2016) found that road traffic accident costs the Republic of Sudan approximately US $391.31 million in 2010 and about US $413.06 million in 2011. The issue of road traffic safety is relevant to countries that are trying to achieve sustainable development of which Zambia is not an exception. Road traffic injuries place a heavy burden, not only on global and national economies but also household finances. Many families are driven deeply into poverty by the loss of breadwinners and the added burden of caring for members disabled by road traffic injuries (Gebru, 2017).

2.4 The Burden of RTAs in Zambia

According to the Auditor General's Report (2015), "Road Traffic Accidents are ranked third highest cause of death after HIV/AIDS and malaria and these accidents are the second leading cause of death in people aged between five (5) and twenty (20) years." The report further indicate that annually, approximately 2,000 fatalities are recorded as a result of road traffic accidents. Although road traffic injuries have been a leading cause of mortality for many years, most traffic crashes are both predictable and preventable. There is considerable evidence on interventions that are effective at making roads safer. In this vein, countries especially developed countries that have successfully implemented these interventions have seen corresponding reductions in road traffic deaths. Some of the interventions in high-income countries include management of road safety increase defined by activities such as setting appropriate speed limits according to those road functions, improving road layout and

design to encourage better use. These approaches can, in principle, be adapted to the contexts of middle-income and low-income countries (Murray et al., 1996). Rolling out these interventions globally offers huge potential to mitigate future damage and save lives at global level. To a large extent, large numbers of imported second hand cars has also contributed which in most cases are not roadworthy (Murray et al., 1996).

For modelling approaches in count data, several studies have used different models in different scenarios, in this regard Joshua and Garber (1990) studied the relationship between highway geometric factors and truck accidents in Virginia using both linear and Poisson regression models. In comparing these regression models, they concluded that linear regression techniques used in their research did not describe the relationship between truck accidents and the independent variables adequately but that the Poisson models did.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Overview

This chapter gives the methodological approach that was employed in this study. It will give detailed information regarding the study design, the study setting, the study variables, the study population, the inclusion and exclusion criteria that was used and also the analysis that was conducted.

3.2 Study Design

The study design was a cross-sectional study in which secondary data was used to model the number of deaths associated with road traffic accidents on the great north road between the years 2010 and 2016.

3.3 Study Setting

The study used secondary data on RTAs that had occurred between Lusaka and Kapiri-Mposhi highway. This data was obtained from Zambia Police traffic section at four police stations along the GNR road these include Emmasdale, Matero, Kabangwe, Chisamba, Prospect, Kasanda and Kapiri-Mposhi Police stations. The total distance from Lusaka to Kapiri-Mposhi is approximately 204 kilometres. This study site was selected due to the high number of deaths from accidents that have been recorded. The stretch on the GNR under study is a single carriageway, approximately 204 kilometres and was divided into five stretches (see Figure 2.1), this was done so as to determine which stretch of the road had a higher/lower incident rate of death as compared to others. The five stretches are Lusaka to Katuba, Katuba to Landless corner, Landless corner to ZNS, ZNS to Mulungushi and Mulungushi to Kapiri-Mposhi. The five stretches are not of equal distances as these mainly depended on the coverage of these different Police stations where the data was collected.

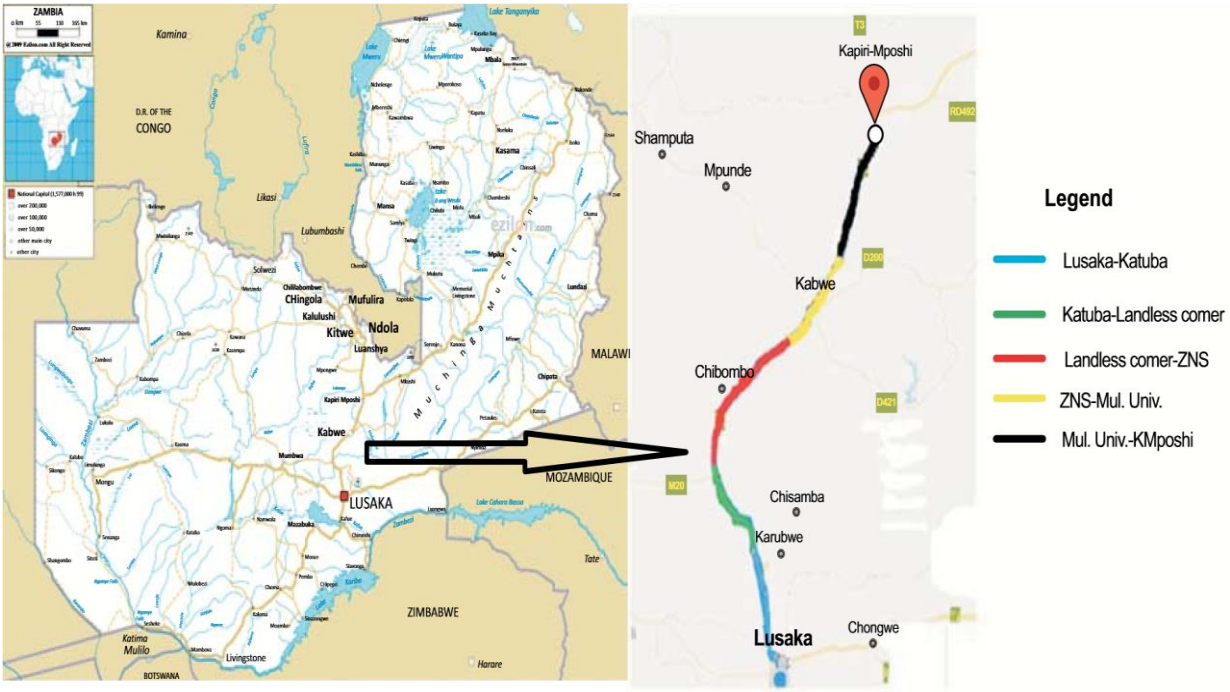

Figure 2.1: Figure showing a snap shot of the GNR stretch under study between Lusaka and Kapiri-Mposhi in Zambia (Source; Internet google).

3.4 Study Variables

The outcome variable in this study was number of deaths which is a count outcome. It is a count because number of deaths are non-negative and they take whole numbers only. The explanatory variables in the study included sociodemographic factors such as age of driver, gender of driver. Other variables included time of accident, quarter of the year, vehicle type, cause of the accident and stretch of the road where an accident happened. For the purposes of this study, cause of accident in this paper refers to the fault that gave rise to a particular accident.

3.5 Study Population

The study population was serious and fatal RTAs that had occurred on the GNR between Lusaka and Kapiri-Mposhi in the past Seven (7) years (2010 to 2016), on all vehicles both public and private vehicles.

3.5.1 Inclusion Criteria

All accident cases (resulting in deaths and/or serious injuries) that have happened on this stretch of the road (Lusaka to Kapiri-Mposhi) were considered as part of the study. Foreign vehicles such as trucks and buses were also included in the study. Road deaths that involve pedestrians were also included in this study.

3.5.2 Exclusion Criteria

Road traffic deaths that occurred in specific towns for instance Kabwe town or Kapiri-Mposhi town as a result of vehicle(s) that operate within the local towns and not on the highway were not considered in this study as these could have happened due to other factors which this study is not aimed at investigating. In this study, the deaths that happened in hospitals after the accident had happened were not included.

3.6 Sampling and Sample size

All accidents that have occurred on this stretch were considered to be part of this study. As a result, the whole population of fatal and serious accidents were considered. This means that all the accidents that have occurred between the years 2010 and 2016 along the GNR (Lusaka to Kapiri-Mposhi) were included in this study. This large sample size in turn increased the power of the study to detect the effect size. As a result of this complete enumeration, the study sample size was 1, 023 RTAs.

3.7 Data Extraction

The data used in this research was collected from ZP. The data extraction checklist was used to collect the data which was entered in excel and then exported to STATA version 14.0. The checklist used in collecting the data is attached in the appendices.

3.8 Data Analysis

Firstly, normality for the continuous variable age was checked using the histogram. The variable age was normally distributed and thus in the descriptive statistics we reported the

mean and standard deviation. For categorical variables such as sex, frequencies and percentages were reported. The models used in this study included the Poisson, Negative Binomial (NB), ZTNB and ZTP regression models. The aim of regression analysis in such instances is to model the dependent variable (deaths) as the estimate of outcome using some or all of the explanatory variables (in mathematical terminology estimating the outcome as a function of some explanatory variables). In order to model these traffic deaths there was need for a careful selection of one or more models that may provide a good description of the traffic type, estimation of parameters such as mean and variance for the selected models and statistical testing for selection of one of the considered models and analysis of its suitability to describe the traffic type under analysis.

For model selection, since road traffic accidents are non-negative, integer, and random event count, the distribution of the traffic deaths followed a Poisson distribution. In this study, the mean deaths was 1.2 and variance was 4.6 and due to this over-dispersion (variance>mean), Poisson cannot be used and hence the negative binomial was used as supported by other authors (Abdel-Aty and Radwan, 2000; Lord, 2000; Ivan et al., 2000). Therefore, statistical models to be used in this study are the Poisson model NB, ZTNB and ZTP**.** The results from models were compared to come up with the best fit model for this data using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Incidence rate ratios were reported, this is because in terms of generic count models, there was need to look at the difference in incidences over a period of time that is equal for all observations. If it was not equal, then that can be accounted for within the model. Among the various categories of a categorical variable, the modelling was with respect to the difference in incidence rate to the base category. This was looked at as the number of deaths over a specified period in this case from 2010 to 2016 for instance, it can be deduced if males have a higher incident rate of dying than females in that period. All analyses were performed using STATA software, version 14.0 SE (Stata Corporation, College Station, TX, USA).

3.9 Ethical Considerations

The study involved accessing the record books from Zambia Police, these books can only be accessed by Police officers and other senior officers in the ministry of home affairs. In an effort to uphold the respect of persons, principle of ethics, permission was sought from the Inspector general of Police (ZP, Headquarters) and the central division in Lusaka and Kabwe.

The police officers helped in the extraction of the data and only numbers not names of the deceased were indicated on the extraction tool. In addition, Ethical clearance was sought from the University of Zambia Biomedical Research and Ethics committee (UNZABREC) reference number 021-06-17.

3.10 Dissemination Plan

The research forms part of the key concerns for public health and the development of the country. The dissemination of findings has been done through publication in peer reviewed journal, in the public health Library of the University of Zambia, ridgeway campus. The findings of this research will be shared with key line agencies and ministries these include RTSA, ZP, MOH and RDA which have been concerned about the subject in the past years. The research findings will also be shared with other key INGOs such as the United Nations (UN), the World Bank and UNICEF are among other key UN agencies that will benefit from the results of the study to inform their future programming in the area of road traffic deaths.

3.11 Study Limitations

The research had limitations as the data used was collected for different purposes and not specifically for this research question. The fact that secondary data was used, there were problems that were encountered and these problems included having inaccurate/missing data on the observations. Administrative data, which is not originally collected for research, were not available in the usual research formats and in this case the variables to consider were limited to the variables that were found as recorded by the ZP traffic division. Despite these limitations, the study sample was large enough to make inferences and also considering the years of these accidents, most of the accidents were captured in this study. The methodologies that were employed in this study were robust methods and they are the most appropriate methods for modelling count data.

3.12 Summary

This chapter gave the methodology that was employed in this paper, it also gave a clear indication of where the study will be conducted and the type of accidents that were included in the study. It also tried to explain the procedure on the way data was analysed. The figure indicated in this chapter shows the diagram of the road that is under consideration (GNR). This is from Lusaka to Kapiri-Mposhi

CHAPTER 4: PRESENTATION OF RESULTS

4.1 Overview

The results of the study are given in this chapter, all the findings are presented in both text and table format. The chapter gives the results on all the variables that were considered in the study such as age of driver, sex of driver to mention but a few. It also gives the procedure on how the best fit model was arriving at.

4.2 Descriptive Statistics

A total of 1, 023 RTAs were analysed in which 1, 212 people died, 7 percent of 1, 212 deaths were Juveniles and 93 percent of the deaths were adults. For the purposes of this study a Juvenile is a person who is under the age of 17 years and an adult is over the age of 18 years. Accidents that happened as a result of pedestrians crossing the road accounted for 30 percent (310/1,023), while 29 percent (295/1,023) of the RTAs were as a result of driver's excessive speed. The mean age of the drivers was 37 years and standard deviation of 9.7 with minimum age 15 years and maximum 76 years. The mean deaths was 1.2 and variance was 4.6 (variance>mean). More descriptive statistics of these accidents are indicated in table 4.1.

Table 4.1: Characteristics of the accidents

Continuous variables		**Total**
Number of deaths-Median (IQR)	1 (1, 1)	1, 023
Drivers age, mean-SD)	37.1 (9.7)	800*
Categorical Variables	**Frequency (%)**	**Total**
Driver's sex: Male	803 (96.7)	830*
Female	27 (3.3)	
Quarter: Jan-Mar (1st)	231 (22.6)	
April-June (2nd)	251 (24.5)	
July-Sept (3rd)	277 (27.1)	
Oct-Dec (4th)	264 (25.8)	1, 023
Time of accident: Early morning 1/6	161 (15.8)	
Morning 7/12	157 (15.4)	
Afternoon 13/18	300 (29.4)	
Night 19/24	403 (39.5)	1,021*
Vehicle type: Private	466 (54.31)	
Public	134 (15.62)	858*
Truck	258 (30.07)	
Cause: Crossing road	310 (30.30)	
Excessive speed/overtaking	295 (28.84)	
Cutting in/FTKNS	175 (17.11)	1,023
Unlicensed/Inexperienced	22 (2.15)	
Hit & Run/Unknown	221 (21.60)	
Adults: Juveniles (0-17years)	82 (6.77)	
Adults (18-76years)	1,130 (93.23)	1,212[b]
Stretch: Lusaka-Katuba	217 (21.21)	
Katuba-Landless corner	87 (8.50)	
Landless corner-ZNS	150 (14.66)	
ZNS-Mul. University	168 (16.42)	
Mul. Univ.-K/Mposhi	401 (39.20)	1,023

*Missing values encountered. Ref: Reference/comparison group, FTKNS: Failure to keep near side, ZNS: Zambia National service, Mul. Univ.: Mulungushi University. [b]Total number of deaths.

4.3 Socio-demographic and Social-economic Factors

The social demographic factors that were considered in this study included age of the driver, sex of the driver and adults whereas the accident related factors included quarter of the year

in which the accident happened, time of accident, vehicle type, cause of accident and stretch of the road. The description of each of these factors is given in the next sub-sections.

4.3.1 Sex and age of driver

In this study, a total of 830 drivers information was abstracted of which, 803 (96.7%) were male drivers and only 27 (3.3%) were female drivers. In an event where the driver died on the spot, the sex of the driver could be indicated but the age of the driver was usually missing. This is because it is easy to identify the sex of the deceased individual but difficult to know the age of the deceased. As a result of this, more observations had the variable sex of the driver whereas some observations did not have age of the driver. It must be noted that for this variable, there were a lot of missing values as a result of hit and run RTAs. A driver would hit a person especially pedestrians and do not stop, in such instances the sex and age of the driver of that particular motor vehicle is not recorded. Due to the missing data problem encountered as a result of hit and run in this study, the complete case analysis that was used had 800 drivers' information. The mean age of the drivers was 37 years and standard deviation of 9.7 with minimum age 15 years and maximum 76 years.

4.3.2 Quarter of the year

The accidents in the study were evenly distributed throughout the year, 27.1 percent (277) of the accidents happened in the third quarter July-Sept the accidents 25.8 percent happened in the fourth quarter (October to December). Further, 251 (24.5%) accidents out of 1, 023 happened in the first quarter of the year (January to March).

4.3.3 Time of accident

Time of the accident in this study was categorised as Early morning, Morning, afternoon and night (that is between 1 AM and 6 AM, between 7 AM and 12 PM, between 1 PM and 6 PM and between 7 PM and 12 AM, respectively). With this time of the accident variable, 403 out of 1,021 (39.50%) of the accidents happened in the night between 7 PM and 12 AM, 29.4 percent of the 1, 021 accidents happened in the afternoon between 1 PM and 6 PM, 15.8 percent of 1,021 accidents happened in the early morning (between 1AM and 6AM) and 15.4 percent of these happened in the morning (between 7AM and 12PM).

4.3.4 Vehicle type

The vehicle type (mode of transport) on this road was categorized as private vehicle, trucks and public transport (buses and minibuses). Out of all the accidents that happened in this period, the majority 466 out of 858 (54.31%) were from private transport whereas trucks accounted for 30.30 percent of the 858 accidents and public transport accounted for 15.6 percent of the 858 of the accidents.

4.3.5 Cause of Accident

For the purposes of this study, cause of accident in this paper refers to the fault that gave rise to a particular accident. This cause of accident included pedestrians crossing the road inappropriately, excessive speed/overtaking inappropriately by the driver, cutting in or failure to keep near side (FTKNS), unlicensed or inexperienced driver and unknown causes or cause not traced due to hit and run cases. The majority of these accidents were as a result of pedestrians crossing the road inappropriately at 30.30 percent of the 1, 023 RTAs. Road traffic accidents that were as a result of excessive speed and overtaking inappropriately accounted for 28.84 percent of the 1, 023 RTAs.

4.3.6 Year of Accident

The study considered all the accidents that happened on this stretch between the years 2010 and 2016 (a seven year period) and the distribution of the deaths in this period are as shown in the bar chart in Figure 4.1. The year 2016 recorded the highest number of deaths from RTAs, as shown in the bar chart below.

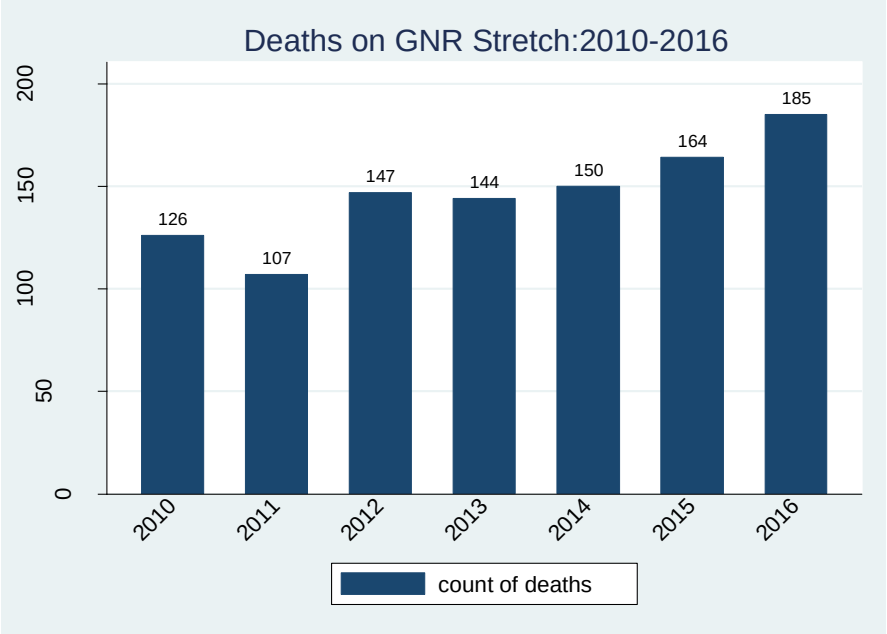

Figure 4.1 Distribution of Deaths between Lusaka and Kapiri-Mposhi on the GNR from years 2010 to 2016.

4.3.7 Age of passengers

This variable was included so as to investigate how many juveniles and adults are dying from RTAs. A juvenile in this context is an individual who is below the age of 18 years. From the descriptive statistics, a lot of adults died in this period out of 1, 212 deaths 1,130 (93.23%) were adults and 82 were children representing 6.77 percent of the total deaths.

4.3.8 Stretch of the Road

A high proportion of the accidents (39.20%) occurred on the stretch between Mulungushi University and Kapiri-Mposhi with the lowest proportion (8.50%) occurred being between Katuba and Landless corner (see Table 4.1).

The mean deaths was 1.2 and variance was 4.6. The accident data in this study was overdispersed (Variance greater than the mean), and as such the NB model was favoured over the Poisson model. The equi-dispersion of crash data is unlikely to be truly observed, as crash-frequency data are typically overdispersed. Unobserved dispersion arises when the covariates are not fully capable of capturing the heterogeneity across the cities in the country (Garnowski and Manner, 2011). The variance for the number of deaths (the outcome) was greater than the mean of these deaths, hence the number of deaths was over-dispersed.

Further the number of zeroes in the data was very minimal as most of the accidents were fatal, this is another problem often faced with count data and a more robust models such as the ZTNB model was employed. Table 4.1 gives the characteristics of the accidents that were analysed.

4.3.9 Model explorations

In order to model these traffic deaths there is need for a careful selection of one or more models that may provide a good description of the traffic accident type, estimation of parameters such as mean and variance for the selected models and statistical testing for selection of one of the considered models and analysis of its suitability to describe the traffic type under analysis.

Since road traffic accidents are non-negative integer, and random event count, the distribution of such events follow a Poisson distribution. The methodologies to model accident counts are well developed. Due to over-dispersion that was encountered in this study, we therefore applied a negative binomial (NB) regression model which is a Poisson-gamma mixture (Abdel-Aty et al., 2000, Lord, 2002, Ivan, 2000). In our serious and fatal traffic accidents considered, the numbers of Zeros were very minimal as most of the accidents had at least one person dying (fatal). We then applied the Zero-Truncated Poisson and the Zero-Truncated Negative binomial models. The results from all these models were compared to select the best fit model for this data using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) diagnostics. The ZTNB was the best fit model which gave the lowest values of AIC and BIC. These models were not nested models therefore the use of AIC and BIC diagnostics was preferred to other tests like the likelihood ratio test.

The two competing models were the ZTP and the ZTNB. The ZTP had an AIC=1304.55, BIC= 1336.55 whereas the ZTNB had AIC=742.25 and BIC=819.69. This indicated that the ZTNB was the best fit model for this data. Table 4.3 therefore shows crude estimates from the best fit model, the ZTNB.

4.3.10 Fitting a model with all covariates

Univariate analysis using the ZTNB was performed first in which the dependent variable was fitted with each of the covariates (independent variables). At univariate analysis variables that were significantly associated with death from RTAs included the age of the driver, sex of the

driver (Male), quarter of the year, year of accident, time of accident, vehicle type and stretch of the road.

Table 4.2: Unadjusted estimates using the ZTNB model for number of deaths from RTAs.

		Unadjusted estimates	
Variable	**IRR**	**95% CI**	**P-value**
Driver's age (in years)	1.04	(1.03, 1.05)	**<0.0001**[a]
Sex of driver: Female	**Ref**		
Male	4.92	(1.07, 22.58)	**0.040**[a]
Quarter of year: Jan-Mar	**Ref**		
Apr-Jun	0.67	(0.44, 1.03)	<0.071
Jul-Sep	0.22	(0.13, 0.36)	**<0.0001**[a]
Oct-Dec	0.65	(0.42, 0.99)	**0.044**[a]
Year of accident: 2010	**Ref**		
2011	1.06	(0.53, 2.12)	0.871
2012	0.38	(0.18, 0.80)	**0.010**[a]
2013	2.93	(1.61, 5.32)	**< 0.0001**[a]
2014	0.57	(0.29, 1.13)	0.109
2015	0.79	(0.42, 1.49)	0.461
2016	1.21	(0.67, 2.19)	0.531
Time of accident: Night	**Ref**		
Morning	2.59	(1.58, 4.24)	**<0.0001**[a]
Early morning	5.03	(3.26, 7.74)	**<0.0001**[a]
Afternoon	1.17	(0.75, 1.84)	0.489

Vehicle type: Private	**Ref**		
Public	8.90	(5.66, 13.98)	**<0.0001**[a]
Truck	2.10	(1.37, 3.21)	**0.001**[a]
Cause of accident:			
Excessive speed/overtaking	**Ref**		
Crossing road	0.03	(0.01, 0.09)	**<0.0001**[a]
Cutting in/FTKNS	0.29	(0.16, 0.51)	**<0.0001**[a]
Unlicensed/Inexperienced	1.20	(0.41, 3.55)	0.738
Hit & Run/Unknown	2.04	(1.37, 3.04)	**<0.0001**[a]
Adult: Adult	**Ref**		
Juvenile	0.77	(0.43, 1.38)	0.381
Stretch: Lusaka-Katuba	**Ref**		
Katuba-Landless corner	4.93	(2.01, 12.10)	**<0.0001**[a]
Landless corner-ZNS	20.49	(9.57, 43.85)	**<0.0001**[a]
ZNS-Mul. Univ.	7.95	(3.63, 17.38)	**<0.0001**[a]
Mul. Univ. -K/Mposhi	8.64	(4.15, 17.98)	**<0.0001**[a]

[a]significant variables at **0.05** level of significance (Adjusted estimates), **Ref**: Reference/comparison group, **IRR**: Incident rate ratio, **95% CI**: 95% Confidence Interval. **FTKNS:** Failure to keep near side.

4.4 Multivariable Analysis with the ZTNB regression

A stepwise approach was used for the multivariable analysis with the ZTNB regression. The variables that had p-values greater than 0.05 were eliminated until we had a model with all variables significant. after controlling for all the confounding variables (adjusted), the only factors that were significantly associated with deaths from RTAs are sex of the driver, time of the accident, the vehicle type that was involved in the accident, the cause of the accident and the stretch of the road on which the accident happened.

4.5 The best Predictors Model for number of deaths from RTAs

After controlling for confounding in the ZTNB, the following was the best predictors' model giving the unadjusted and adjusted estimates (see Table 4.3).

Table 4.3: Multivariable analysis with the ZTNB model, Unadjusted and Adjusted estimates. The best predictors' model for number of deaths from RTAs.

	Unadjusted Estimates			**Adjusted Estimates**		
Variable	IRR	95% CI	p-value	IRR	95% CI	P-value
Driver's age (years):	1.04	(1.03,1.05)	<0.0001	1.01	(0.99, 1.03)	0.358
Sex of driver: Female	**Ref**			**Ref**		
Male	4.92	(1.07,22.58)	0.040	9.57	(0.96, 95.46)	**0.054**[a]
Time: Night 18/24	**Ref**			**Ref**		
Early morning 01/05	2.59	(1.58, 4.24)	**<0.0001**[a]	2.11	(1.01, 4.41)	**0.048**[a]
Morning 6/11	5.03	(3.26, 7.74)	**<0.0001**[a]	1.78	(0.91, 3.49)	0.094
Afternoon 12/17	1.17	(0.75, 1.84)	0.489	0.93	(0.51, 1.70)	0.805

Vehicle type:	Private	**Ref**			**Ref**		
	Public	8.90	(5.66, 13.98)	<0.0001	5.65	(2.97, 10.73)	**< 0.0001**[a]
	Truck	2.10	(1.37, 3.21)	0.001	2.19	(1.25, 3.82)	**< 0.0001**[a]
Cause of accident:							
Exces. speed/overtaking		**Ref**			**Ref**		
Crossing road		0.03	(0.011, 0.09)	< 0.0001	0.04	(0.01, 0.12)	**<0.0001**[a]
Cutting in/FTKNS		0.29	(0.16, 0.51)	< 0.0001	0.17	(0.07, 0.42)	**<0.0001**[a]
Unlicensed/Inexperienced		1.20	(0.41, 3.55)	0.738	1.29	(0.35, 4.83)	0.701
Hit&Run/Unknown		2.04	(1.37, 3.04)	< 0.0001	1.05	(0.60, 1.85)	0.860
Stretch:	Lusaka-Katuba	**Ref**			**Ref**		
Katuba-Landless corner		4.93	(2.01, 12.10)	< 0.0001	4.41	(1.39, 14.01)	**0.012**[a]
Landless corner-ZNS		20.5	(9.57, 43.85)	< 0.0001	9.01	(3.29, 24.62)	**< 0.0001**[a]
ZNS-Mul. Univ.		7.95	(3.63, 17.38)	< 0.0001	3.60	(1.33, 9.74)	**0.012**[a]
Mul. Univ.-K/mposhi		8.64	(4.15, 17.98)	< 0.0001	5.73	(2.23, 14.73)	**<0.0001**[a]

[a]significant variables at **0.05** level of significance (Adjusted estimates), **Ref**: Reference/comparison group, **IRR**: Incident rate ratio, **95% CI**: 95% Confidence Interval. **FTKNS:** Failure to keep near side.

4.5.1 Results from the best predictors' model

There was no evidence of an association in this study between the age of a driver and having a crush that will lead to death (IRR=1.01, 95% CI=0.99, 1.03), p-value=0.358. The sex of the driver is a crucial variable in the analysis of Road traffic crashes. Results from this study indicated that there is an increased incident rate of death if one is a male driver compared to female driver (IRR=9.57, 95% CI=0.96-95.46) with borderline evidence, P-value=0.054.

Results further show that driving in the early hours of the day (between 1 AM and 6 AM) was significantly associated with a high incidence rate of death (IRR=2.1, 95% CI=1.01-4.41), adjusting for all other variables in the model.

Results indicated that there was a statistically significant reduction in the incidence rate of death from RTAs for pedestrians crossing road compared to excessive speed (IRR=0.04, CI=0.01-0.12), p-value<0.0001. There was also a reduced incidence of death from RTAs when the driver is cutting in or fail to keep near side compared to driver's excessive speed (IRR=0.17, CI=0.07-0.42). This finding was statistically significant, p-value<0.0001.

The study found an increased incidence of death if one is driving between Katuba and Landless corner compared to driving between Lusaka and Katuba (IRR=4.41, CI=1.39-14.01) and this was statistically significant p-value 0.012. The results also revealed that there was an increased incident of death between Landless corner and ZNS as compared to driving between Lusaka and Katuba (IRR=9.06, CI=3.29-24.62) p-value<0.0001.Further there was about five times increase in the incidence of death if one is driving between Mulungushi

University and Kapiri-Mposhi compared to one driving between Lusaka and Katuba (IRR=5.73, CI=2.23-14.73), p-value<0.0001.

Results from the best fit model (ZTNB) revealed that public transport compared to private transport had a higher incidence of death from RTAs (IRR=5.65, 95% CI=2.97-10.73), this finding was statistically significant, p-value<0.0001.

4.6 Summary

The chapter presented the findings from the study and from the data that was collected on the Great North Road from Lusaka to Kapiri-Mposhi and variables that were associated with road traffic accidents on this particular stretch were identified. The descriptive statistics were presented and in this study we had 1,023 RTAs and in these accidents 1,212 people died on this stretch of the GNR between the years 2010 and 2016. The models under consideration were all compared and the best predictor's model was found to be the Zero-Truncated Poisson model. The interpretation of the findings were also given in this particular chapter.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1 Overview

In this chapter we discuss the findings that have been found in this study and we also discuss this in line with what other researchers have found in other countries and settings. The chapter also presents the conclusions from this study and we also give the recommendations based on the findings from this study.

5.2 Study Findings

The predictors leading to an increased incident rate of death from RTAs on the GNR were found to be male drivers, driving in the early hours of the day (1AM-6AM), driving along the stretch between Katuba and landless corner compared to driving along Lusaka and Katuba and ZNS. Similarly there was an increased incident of death if one is driving between landless corner and ZNS compared to driving along Lusaka and Katuba and also using public transport and trucks. The comparison of the models using the statistical diagnostics revealed that the Zero-Truncated Negative binomial fit the fatal and serious accidents better.

It has been shown in this study that the number of deaths on this stretch of the road (GNR) has been increasing over time from 2010 to 2016. This could have been due to the rapid motorization in the country but the road network has remained the same. Eksler et al., (2008) observed that an increase in population boosts the crash frequencies, whilst the number of crash counts decreases as GNP of a country rises (Anwaar et al., 2012; Grimm and Treibich, 2013). The anticipated effect of the GNP on crash frequencies can serve as surrogate to the level of urbanization, industrialization and safer motorization in a country along with reflecting qualities in infrastructures and transportation facilities (Anwaar et al., 2012).

A study by González-Sánchez (2018) documented a high likelihood of younger drivers being involved in RTAs and the study found that young people were at a high risk of RTIs among car and motorcycle users, while among bicycle and public transport users, the risk was greater in older people. However in this study, there was no evidence of an association between the driver's age and the incidence of death from RTAs. The minimum age of the drivers in the study was found to be 15 years and this is illegal in Zambia. An individual is only eligible to obtain a drivers licence at the age of 18 years Zambia.

The sex of the driver is a crucial variable in the analysis of Road traffic accidents. Results from this study indicated an increase in the incidence rate of death if one is a male driver compared to female driver. This finding is with borderline statistical evidence and we cannot rule out chance finding, further the wide confidence interval is an indication that this finding is not very reliable. This finding established here regarding greater risk of serious and fatal injuries in males is consistent with other studies that used travel time (Santamariña-Rubio et al., 2014) and found that males compared to females were more likely to be involved in road traffic accidents.

Driving in the early hours of the day (between 1 AM and 6 AM) as compared to driving in the night had a significant increase in the incidence rate of death from RTAs adjusting for all other variables in the model. This increase in the incidence at these hours could be due to driver's fatigue or excessive speed as there is less traffic in the early hours of the day.

Results indicated that there was a statistically significant reduction in the incidence rate of death from RTAs for pedestrians crossing road compared to excessive speed. There was also a reduced incidence of death from RTAs the driver is cutting in or FTKNS compared to excessive speed. The narrowness of the road could be one of the contributing factors as there

is heavy traffic on this road and drivers tend to overtake inappropriately leading to these RTAs.

The study found an increased incidence of death if one is driving between Katuba and Landless corner compared to driving between Lusaka and Katuba. The results also revealed that there was an increased incident of death between Landless corner and ZNS as compared to driving between Lusaka and Katuba. This increase in the incidence of death on this stretch could be as a result of the curvature, a blind spot. Several studies have analysed these accident-prone road sections and several methods as well been proposed to identify blackspots and these include accident frequency method, accident rate methods, quality control method, empirical Bayesian method, and many more (Gregoriades and Mouskos, 2013, Jurenoks et al., 2008). Further, Geographical Information Systems (GIS) have been incorporated in the analysis of blackspots (Chen et al., 2011) the effectiveness of blackspot programs has been evaluated in different countries (Meuleners et al., 2008) and it still remains as an active field of research. Further research is needed in Zambia to identify blackspots especially on the highway roads.

Further there was about five times increase in the incidence of death if one is driving between Mulungushi University and Kapiri-Mposhi compared to one driving between Lusaka and Katuba. These results could be as a result of the narrow road on this stretch. Other authors have revealed that the size of road network is also another crucial factor in reducing the number of crash frequencies. Kumara and Chin (2004) pointed out that a large road network could serve wider dispersal of traffic and therefore reduces the number of crash counts, conversely, a small network could be associated with more traffic congestion and thus reduces causalities with lower speed (Anwaar et al., 2012).

Results further revealed that Public transport compared to private transport had an increased incidence of death from RTAs, this finding was statistically significant. Similar Studies done in developing countries also show that public transport has serious safety concerns as a result of frequent involvement in severe accidents (Barua and Tay, 2010). In these countries, bus/minibus accidents are rampant with alarming consequences (Kaplan and Prato, 2013, Chimba et al., 2010). This could have been due to the fact that private vehicle owners tend to be more careful on the roads as compared to bus drivers. Another factor could be that drivers of public vehicles drive long distances, which may result in fatigue and in turn makes the drivers prone to accidents. This finding is important to influence government policy on

limiting the kilometres and number of hours public drivers should driver per day in order to reduce RTAs.

5.3 Conclusions

The study showed that there was an increased incidence of death if the driver is male, driving in the early hours (1am-6am) of the day and using public transport. There is an increased incidence of death if one is driving between landless corner and ZNS compared to driving between Lusaka and Katuba. The study further revealed that the ZTNB is the best fit model for data in which there are few zeros as is the case with fatal traffic accidents. The majority of these accidents on this particular stretch is as a result of human error such as excessive speed, FTKNS.

5.4 Recommendations

From the findings of this study, it is highly recommended to expand highways like the GNR as the number of vehicles in the country has been increasing while the roads have remained the same. As a result of this, there is heavy traffic on this stretch especially on peak hours and drivers tend to overtake unnecessarily especially on blind spots and this lead to RTAs. This high number of RTAs could be due to lack of enough pedestrian crossing on this highway especially in built up areas like Chibombo and Kabangwe areas. There is need for massive sensitization to citizens especially pedestrians as most of these deaths are as a result of pedestrians crossing the road inappropriately. There is need for the Road development Agency to put speed humps especially in built up areas such as Chibombo and Kabangwe areas. Government need to limit drivers on the number of kilometres one can drive per day as driving more kilometres result in RTAs.

5.5 Further Research

Future studies should focus on multivariate crash counts and possibly a spatial statistical modelling approach that incorporates effects of heterogeneity between space and time and correlation between them. For example, one can obtain more insight into the effects and factors that simultaneously determine the number of fatalities, injuries and vehicle body damaged only type crashes and introducing spatial correlation among cities along with space–time interaction to check the effect of heterogeneity over-time among cities. There is need to conduct a follow up research study to determine if the incidence rate of death has reduced from the year 2017 onwards.

5.6 Summary

This chapter summarises the findings of this study, it highlights what has been done elsewhere in the field of road traffic accidents and injuries. The conclusions from the research and the recommendations have been given in this chapter.

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APPENDICES

APPENDIX I: Letter to the Road Transport and Safety Agency

THE UNIVERSITY OF ZAMBIA
SCHOOL OF PUBLIC HEALTH

Telephone: 252641, P.O. BOX 50110

Fax: +260-1-250753 Lusaka, Zambia.
Email: commed@unza.zm

26th May, 2017.
The Chief Executive Officer,
Road Transport and Safety Agency
Lusaka.

Dear Sir/Madam,

RE: REQUEST FOR AUTHORITY TO UNDERTAKE A RESEARCH STUDY

The department of Epidemiology and Biostatistics wishes to introduce Mr. Ronald Fisa (2016144877) who is currently studying for Master of Science in Medical Statistics.

Mr. Fisa has completed the first part of the degree (coursework) and is now preparing to conduct research whose title is **"Modelling the number of deaths associated with road traffic accidents and other factors on the Great North Road between the years 2000 and 2016 using poisson processes Models".**

A research proposal has been developed to that effect. However, prior to submission of the proposal to the ethics committee for approval, authorisation from you is required indicating that you will allow our student to use your existing data on road traffic accidents.

Therefore this is to kindly request for your permission for him to use your data in his study.

We appreciate your support to our Masters programme and the student.

Yours Sincerely,

Dr. H. Halwiindi,

ASSISTANT DEAN-POSTGRADUATE.

APPENDIX II: Letter from RTSA

ROAD TRANSPORT AND SAFETY AGENCY

Head Office: P.O. Box 32167, Dedan Kimathi Road, Lusaka
Tel: +260 211 226 909 / 230 539 Fax: +260 211 231 601 Email: rtsa@zamnet.zm

RTSA 101/1/9

6th June 2017.

The University of Zambia,
School of Public Health,
Department of Epidemiology and Biostatistics,
P.O Box 50110,
Lusaka

Attention: The Assistant Dean - POSTGRADUATE

Dear Sir/Madam,

SUBJECT: REQUEST FOR AUTHORITY TO UNDERTAKE A RESEARCH STUDY

We acknowledge receipt of your letter dated 26th May 2017 requesting for authority to undertake a research study on the number of deaths associated with road traffic accidents.

We have no objection in releasing information to your student as long as the information provided is used for academic purposes only. We shall also be grateful if he could share the research findings with our Agency upon completion of his studies.

We would like wish Mr. Ronald Fisa good luck in his studies leading to Master of Science in Medical statistics.

Yours faithfully,

Zindaba Soko
Director and Chief Executive Officer
Road Transport and Safety Agency

All correspondence to be addressed to the Director

TO ATTAIN A SAFE AND EFFICIENT ROAD TRANSPORT SYSTEM FOR ALL ROAD USERS COUNTRYWIDE THROUGH STAKEHOLDER PARTICIPATION, EDUCATION, REGULATION AND TRAFFIC LAW ENFORCEMENT.

APPENDIX III: Extraction Tool

SERIOUS AND FATAL ROAD TRAFFIC ACCIDENTS ON THE GREAT NORTH ROAD BETWEEN THE YEARS 2010 AND 2016.

S/No.	Deaths		Sex & Age of Driver	Cause of accident	Vehicle type (Private/public/ Truck)	Date of Accident	Time of accident	Place of Accident
	Adults	Juvenile						
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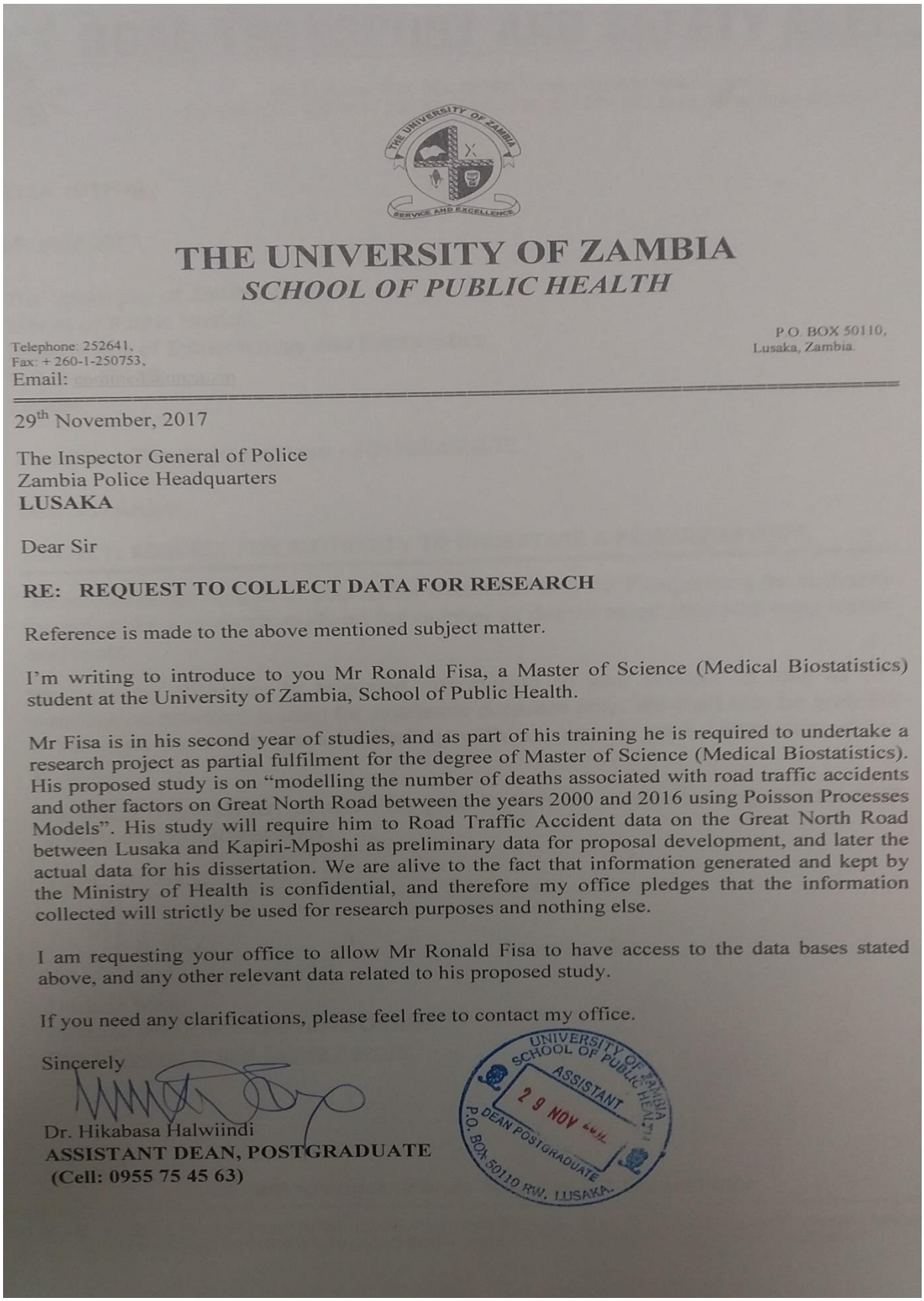
APPENDIX IV: Letter to the Inspector General of Police



THE UNIVERSITY OF ZAMBIA
SCHOOL OF PUBLIC HEALTH

Telephone: 252641,
Fax: + 260-1-250753,
Email:

P.O. BOX 50110,
Lusaka, Zambia.

29th November, 2017

The Inspector General of Police
Zambia Police Headquarters
LUSAKA

Dear Sir

RE: REQUEST TO COLLECT DATA FOR RESEARCH

Reference is made to the above mentioned subject matter.

I'm writing to introduce to you Mr Ronald Fisa, a Master of Science (Medical Biostatistics) student at the University of Zambia, School of Public Health.

Mr Fisa is in his second year of studies, and as part of his training he is required to undertake a research project as partial fulfilment for the degree of Master of Science (Medical Biostatistics). His proposed study is on "modelling the number of deaths associated with road traffic accidents and other factors on Great North Road between the years 2000 and 2016 using Poisson Processes Models". His study will require him to Road Traffic Accident data on the Great North Road between Lusaka and Kapiri-Mposhi as preliminary data for proposal development, and later the actual data for his dissertation. We are alive to the fact that information generated and kept by the Ministry of Health is confidential, and therefore my office pledges that the information collected will strictly be used for research purposes and nothing else.

I am requesting your office to allow Mr Ronald Fisa to have access to the data bases stated above, and any other relevant data related to his proposed study.

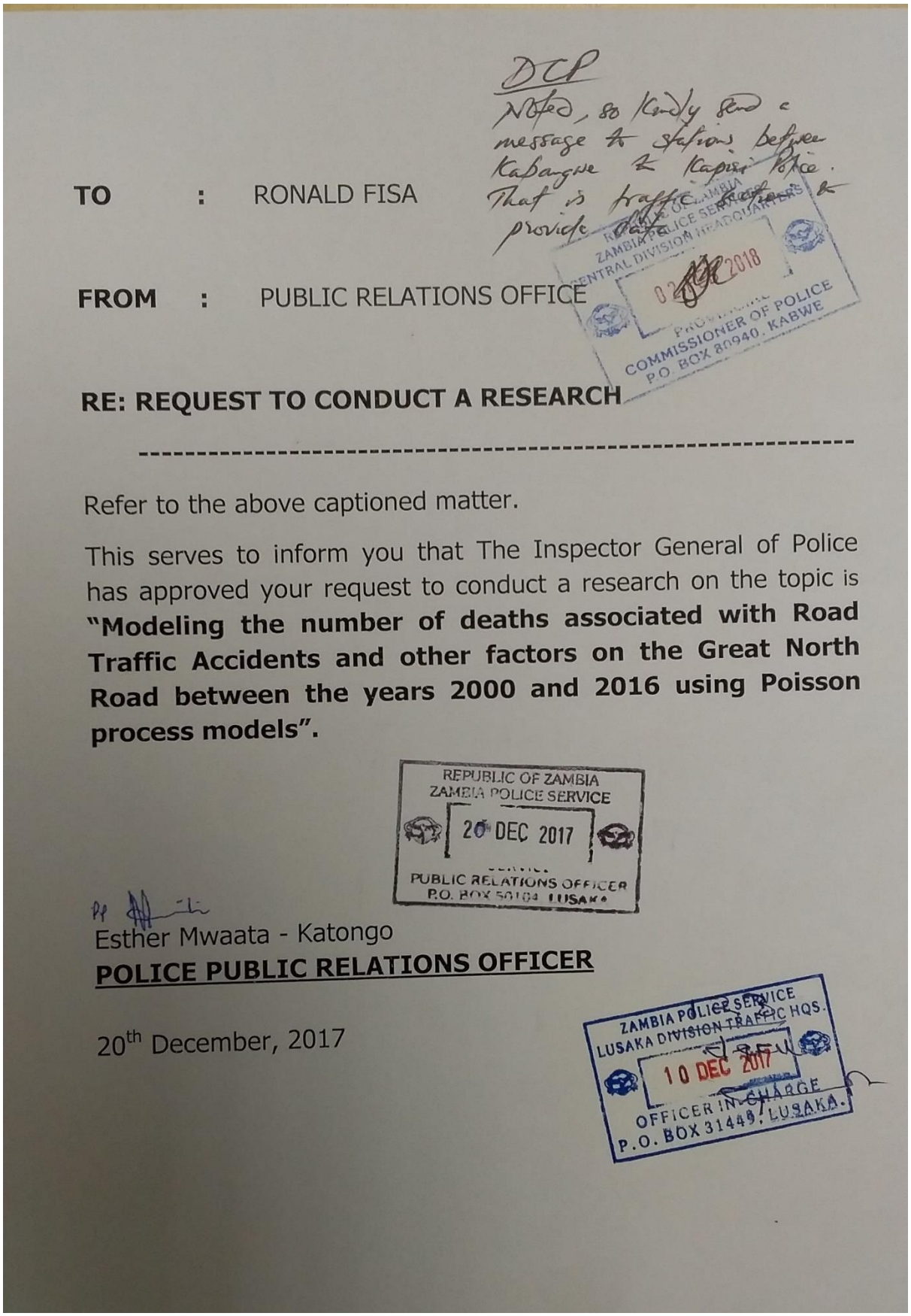
If you need any clarifications, please feel free to contact my office.

Sincerely

Dr. Hikabasa Halwiindi
ASSISTANT DEAN, POSTGRADUATE
(Cell: 0955 75 45 63)

UNIVERSITY OF ZAMBIA SCHOOL OF PUBLIC HEALTH ASSISTANT DEAN POSTGRADUATE 29 NOV 2017 P.O. BOX 50110 RW, LUSAKA

APPENDIX V: Letter from Inspector General of Police



DCP
Noted, so kindly send a message to stations between Kabanga & Kapiri Police. That is traffic matters & provide data

TO : RONALD FISA

FROM : PUBLIC RELATIONS OFFICE

REPUBLIC OF ZAMBIA ZAMBIA POLICE SERVICE CENTRAL DIVISION HEADQUARTERS 02 DEC 2018 COMMISSIONER OF POLICE P.O. BOX 80940, KABWE

RE: REQUEST TO CONDUCT A RESEARCH

Refer to the above captioned matter.

This serves to inform you that The Inspector General of Police has approved your request to conduct a research on the topic is **"Modeling the number of deaths associated with Road Traffic Accidents and other factors on the Great North Road between the years 2000 and 2016 using Poisson process models".**

REPUBLIC OF ZAMBIA ZAMBIA POLICE SERVICE 20 DEC 2017 PUBLIC RELATIONS OFFICER P.O. BOX 50104 LUSAKA

Pp
Esther Mwaata - Katongo
POLICE PUBLIC RELATIONS OFFICER

20th December, 2017

ZAMBIA POLICE SERVICE LUSAKA DIVISION TRAFFIC HQS. 10 DEC 2017 OFFICER IN CHARGE P.O. BOX 31449, LUSAKA.

APPENDIX VI: Ethical Approval Letter

THE UNIVERSITY OF ZAMBIA

BIOMEDICAL RESEARCH ETHICS COMMITTEE

Telephone: 260-1-256067
Telegrams: UNZA, LUSAKA
Telex: UNZALU ZA 44370
Fax: + 260-1-250753
E-mail: unzarec@unza.zm
Assurance No. FWA00000338
IRB00001131 of IORG0000774

Ridgeway Campus
P.O. Box 50110
Lusaka, Zambia

3rd November, 2017.

Your Ref: 021-06-17.

Mr. Ronald Fisa,
University of Zambia,
School of Public Health,
P.O Box 50110,
Lusaka.

Dear Mr. Fisa,

RE: RESUBMITTED RESEARCH PROPOSAL: "MODELLING THE NUMBER OF DEATHS ASSOCIATED WITH ROAD TRAFFIC ACCIDENTS AND OTHER FACTORS ON GREAT NORTH ROAD BETWEEN THE YEARS 2000 AND 2016 USING POISSON PROCESSES MODELS" (REF. 021-06-17)

The above-mentioned research proposal was presented to the Biomedical Research Ethics Committee meeting on 3rd November, 2017. The proposal is approved.

CONDITIONS:

- This approval is based strictly on your submitted proposal. Should there be need for you to modify or change the study design or methodology, you will need to seek clearance from the Research Ethics Committee.
- If you have need for further clarification please consult this office. Please note that it is mandatory that you submit a detailed progress report of your study to this Committee every six months and a final copy of your report at the end of the study.
- Any serious adverse events must be reported at once to this Committee.
- Please note that when your approval expires you may need to request for renewal. The request should be accompanied by a Progress Report (Progress Report Forms can be obtained from the Secretariat).
- Where appropriate, apply to National Health Research Authority for storage of samples before you embark on the study.
- **Ensure that a final copy of the results is submitted to this Committee.**

Yours sincerely,

Dr. S.H Nzala
VICE-CHAIRPERSON

Date of approval: 3rd November, 2017.

Date of expiry: 2nd November, 2018.

APPENDIX VI: My Published Paper

The Open Public Health Journal

Content list available at: https://openpublichealthjournal.com

RESEARCH ARTICLE

Modelling Deaths Associated with Road Traffic Accidents and other Factors on Great North Road in Zambia between the Years 2010 and 2016 Using Poisson Models

Ronald Fisa[1], Chola Nakazwe[2], Charles Michelo[1] and Patrick Musonda[1,3,*]

[1]*Department of Epidemiology and Biostatistics, School of Public Health, University of Zambia, Lusaka, Zambia*
[2]*Demography Section, Central Statistical Office, Lusaka, Zambia*
[3]*Centre for Intervention Science in Maternal and Child health (CISMAC), Centre for International Health (CIH), University of Bergen, Bergen, Norway*

Abstract:

Background:

According to the World Health Organization (WHO), 1.24 million people die annually on the world's roads, with 20-50 million sustaining non-fatal injuries. More than 85% (1.05 million) of the global deaths due to injuries occur in the developing world. Road traffic deaths and injuries are a major but neglected public health challenge that requires concerted efforts for effective and sustainable prevention. The objectives of the study were to estimate the incidence rate of death from RTAs, to determine factors associated with serious and fatal Road Traffic Accidents (RTAs) and to determine which of the poisson models fit the count data better.

Methods:

Data was collected from Zambia Police (ZP), Traffic Division on accidents that occurred on the Great North Road (GNR) highway between Lusaka and Kapiri-Mposhi in Zambia from January 1, 2010 to December 31, 2016. Results from standard Poisson regression were compared to those obtained using the Negative Binomial (NB), Zero-Truncated Negative Binomial (ZTNB) and the Zero-Truncated Poisson (ZTP) regression models. Diagnostic tests were used to determine the best fit model. The data was analysed using STATA software, version 14.0 SE (Stata Corporation, College Station, TX, USA).

Results:

A total of 1, 023 RTAs were analysed in which 1, 212 people died. Of these deaths, 82 (7%) were Juveniles and 1, 130 (93%) were adults. Cause of accident such as pedestrians crossing the road accounted for 30% (310/1,023) while 29% (295/1,023) were as a result of driver's excessive speed. The study revealed that driving in the early hours of the day (1AM-6AM) as compared to driving in the night (7PM-12AM) had a significant increase in the incidence rate of death from RTAs, Incidence Rate Ratio (IRR) of 2.1, (95% CI={1.01-4.41}), p-value=0.048. Results further showed that public transport as compared to private transport had an increased incidence rate of death from RTAs (IRR=5.65, 95% CI={2.97-10.73}), p-value<0.0001. The two competing models were the ZTP and the ZTNB. The ZTP had AIC=1304.55, BIC= 1336.55, whereas the ZTNB had AIC=742.25 and BIC=819.69. This indicated that the ZTNB with smaller AIC and BIC was the best fit model for the data.

Conclusion:

There is a reduced incidence of dying if one is using a private vehicle as compared to a public vehicle. Driving in the early hours of the day (1AM and 6AM) had an increased incidence of death from RTAs. This study suggests that when dealing with counts in which there are a few zeros observed such as in serious and fatal RTAs, ZTNB fits the data well as compared to other models.

Keywords: Road Traffic Accidents, Poisson, Zero truncated poisson, Negative binomial, Zero truncated negative binomial, Number of deaths.

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1. INTRODUCTION

The World Health Organization (WHO) defines a Road Traffic Accident (RTA) as a collision involving at least one vehicle in motion on a public or private road that results in at least one person being injured or killed [1]. A traffic collision, also known as a Motor Vehicle Collision (MVC) among others occurs when a vehicle collides with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree or pole. These traffic collisions may result in injury, death and property damage. Road Traffic Accidents (RTAs) are one

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Appendix VIII: Verdict Letter

The University of Zambia
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P O Box 32379
Lusaka, Zambia

19th February, 2019

Mr. Ronald Fisa
C/o School of Public Health
University of Zambia
LUSAKA

Dear Mr. Fisa

RE: EXAMINATION RESULTS OF YOUR MASTER OF SCIENCE IN EPIDEMIOLOGY AND BIOSTATISTICS

The examination results of your Master's Dissertation entitled: ***"Modelling Deaths Associated with Road Traffic Accidents and Other Factors on Great North Road in Zambia Between the Years 2010 and 2016 Using Poisson Models"*** was presented at the Board of Graduate Studies Meeting held on Friday 14th February, 2019.

The decision of the Board is: **Pass with Moderate Corrections.**

Therefore you are expected to attend to all the moderate corrections identified by the examiners. Your supervisor should certify in writing that all the corrections have been done before you deposit three copies of the Dissertation and a soft copy with the Directorate of Research and Graduate Studies.

Please note that depositing of the Dissertation and Soft Copy can only be done after showing proof of satisfying the Postgraduate Regulations as follows:

i. Given an Oral and Poster Presentation;
ii. A letter from Supervisor/Assistant Dean (Postgraduate) indicating that a paper has been submitted to a Journal (Taught Masters and Dissertation);
iii. A paper accepted in a Journal for publication (Masters by Research) and
iv. A paper already published in a Journal (PhD).

Yours sincerely

Prof. Henry M. Sichingabula
DIRECTOR

c.c. Dean, School of Public Health
Assistant Dean (PG), School of Public Health
Assistant Registrar (Graduate Studies)

Appendix IX: Supervisors Letter of Recommendation

THE UNIVERSITY OF ZAMBIA
SCHOOL OF PUBLIC HEALTH

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P.O. BOX 50110

Lusaka, Zambia

DATE: 03rd April 2019

The Assistant Dean (Post Graduate)
The University of Zambia
School of Public Health
Ridgeway Campus
LUSAKA, ZAMBIA

Dear Madam,

RE: Addressing concerns arising from examiners following the dissertation submitted by Mr Ronald Fisa

This letter serves to confirm that I have looked at the corrections made by Mr Ronald Fisa in his dissertation following the examiners comments. I would like to state that all corrections have been addressed and the dissertation has been revised accordingly. I am unreservedly recommending the work done that the candidate has addressed all the comments that were raised in his dissertation.

This work can proceed to the necessary required stage.

Kind regards,
Yours Sincerely,

Professor Patrick Musonda
(Head of Department and Supervisor of Mr Ronald Fisa)