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SCHOOL OF MATHEMATICS

PROJECT IN SOCIAL STATISTICS

EXPLORING THE MAJOR CAUSES OF ROAD TRAFFIC ACCIDENTS IN NAIROBI COUNTY

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DECLARATION

This is my original work and has not been presented for any academic award at the University of Nairobi or in any other University.

Signature……………………………………………………Date……………………..

Olemo Clifford Daniel

I56/75573/2014

This research project has been submitted for presentation with my approval as the university supervisor.

Signature……………………………………………………Date……………………..

Idah Orowe

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DEDICATION

This Research Project Report is dedicated to my late mother Mrs Joan Opado for believing in me. It is also dedicated to my late grandmother Mrs. Plister Opado and cousin John Bosco who were victims of road accidents.

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I thank the almighty God for granting me the strength and good health during the period of this study, and courage to complete this thesis.

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ABSTRACT

The road transport industry in Kenya plays a vital role in the life of a majority of its citizens. Many Kenyans utilizes different transport modes to reach their various destinations on a daily basis. Nearly 3000 people are killed on Kenyan roads annually. This translates to approximately 68 deaths per 10,000 registered vehicles, which is 30-40 times greater than in highly motorized countries. Nairobi County has one of the highest road fatality rates in relation to vehicle ownership in Kenya, with an average of 7 deaths from the 35 road crashes that occur each day. Despite the huge burden the major causes of accidents in Nairobi, have not been modeled so as to outline the major causes and their inter-relatedness. Current interventions are sporadic, uncoordinated and less effective despite the huge economic burden exerted by RTAs.

This study sought to explore the major causes that were likely to contribute to road traffic accidents in Nairobi County. This was to be achieved using suitable techniques whose performances were subsequently analyzed. The study utilized accident data between the years 2000-2014 obtained from Nairobi Traffic Police department. Poisson and the negative regression models were used to identify the main risk factors and model that performed better with the traffic data in Nairobi County. The results indicated that the negative-binomial model (R^2:0.6691, AIC: 1714.7) outperformed the Poisson model (R^2: 0.5991, AIC: 2433.1) as on this occasion was concluded as robust model for the prediction of RTAs in Nairobi County. In both models drivers, pedal. Cyclists, pedestrians and passengers significantly contributed to RTAs and thus policy measures should be formulated with them in mind.

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LIST OF ACRONYMS

KeNHA	-	Kenya National Highway Authority
KeRRA	-	Kenya Rural Road Authority
KRA	-	Kenya Revenue Authority
KRB	-	Kenya Roads Board
KURA	-	Kenya Urban Roads Authority
PSV	-	Public Service Vehicle
RTAs	-	Road Traffic Accidents
RTIs	-	Road Traffic Injuries

DEFINITION OF TERMS

Boda-boda: Popular name for motor-bicycle taxis in Kenya

GDP: Gross Domestic Product, is a measure of the economic production of a particular territory in financial capital terms over a specific time period

Matatu: A passenger service vehicle.

Road Traffic Accident (RTA): A collision between vehicles; between vehicles and pedestrians; between vehicles and animals; or between vehicles and fixed obstacle.

Road Traffic Injuries (RTI): Are injuries occurring as a result of RTA.

Road User: Pedestrians and vehicle users which include all occupants (i.e. driver or rider and passengers).

Road: Every public road system: state, regional or local road, or city street.

Vehicle: A machine that is used to carry people or goods from one place to another, it could be a bicycle, motor cycle or three and above wheeled machine.

Slight injury: Is an injury of minor character (i.e. bruise, sprain, cut or laceration) that is not judged to be severe and requires roadside attention.

Serious injury: Is an injury resulting to a person being detained in a health facility as an "in patient", or any of the following injuries whether or not detention result (i.e. fractures, internal injuries, crushing, severe cuts and concussions). They do cause death 30 or more days after the accident

Fatal injury: Is an injury resulting to death

Pedal-cycle: A vehicle operated solely by pedals and propelled by human power. This includes bicycle, tricycle, unicycle, sidecar or trailer attached to any of the above listed devices.

CHAPTER ONE

INTRODUCTION

This chapter provides the background to the study, context, problem statement and the objectives of the study. The purpose of this chapter is to provide an overview of the research that is presented through the body of this work.

1.1Background

1.1.1 Global State of Road Traffic Accidents

A road accident refers to a collision involving one or more vehicles on the road, or a pedestrian and results into death, injury or damage of property (Odhiambo *et al*, 2015). Road traffic injuries place a heavy burden on global and national economies and household finances. With more than 13 million deaths and 20 – 50 million injuries being directly linked to road traffic accidents in the world, the social and economic burden presents a compromising scenario for Kenya as a nation. Road accidents follow HIV/AIDS and malaria as the leading causes of deaths in Kenya according (Odero, Khayesi & Heda, 2003). This largely affects the economically productive population in the country. About 23% of them are motorists, while pedestrians and cyclists account for 22 and 5 percent respectively. Other victims are pedestrians, vehicle occupants, and other unspecified users who account for 31% and 19% of the rest of the deaths.

Most of the road accidents lead to fatalities or serious disabilities which disenfranchise many families. In addition, family members are plunged into poverty because of the loss of their usual breadwinner through death or the high costs incurred in medical costs (WHO, 2009). Therefore, relevant authorities in the transportation sector need to make an effort and enact policies or measures that would significantly reduce the impacts of road accidents including fatalities, disabilities, morbidity and the related costs of medical expenses associated with preventable road accidents.

Most players in the transport sector blame the bad state of the Kenyan roads for the numerous accidents. With the recent improvement of infrastructure however, fatal road accidents continue to be reported. This elicited varied reactions from transport authorities in Kenya including the ban on night travel on all Public Service Vehicles until they met the stated requirements of the government. Public Service Vehicles operators have protested this move claiming that the government has been insensitive about their needs. The blame game between transport authorities and PSV operators continues even though the much has been done to curb the number of road accidents. Traffic police has also been on the receiving end following their role in reducing road accidents. Corruption has been cited as one of the reasons the traffic police have failed to arrest the drivers found to have infringed on the regulations of road use. Policies developed based on the comprehensive statistical models are likely to lead to the development of a competitive transportation network that will enhance Kenya's role as a hub in East Africa.

1.1.2 Road Transportation in Nairobi County

Nairobi is the capital city of Kenya hosting national government ministries, businesses and numerous economic activities. It is also an important economic hub for Eastern and Central Africa. The population of Nairobi city has experienced a significant growth since the year 2009 when it was at 3,138,000 (Population and Housing Census, 2009). The city' population continues to grow at the rate of 4.0%. Nairobi City had 1, 214. 5 kilometers of roads in 2006 of which 972 kilometers were paved while the remaining 178 were earth gravel roads. Continued urban sprawl has increased transportation in the city with a large population relying on public transport system, which has been marked with unstructured operations due to poor monitoring.

Many organizations in Nairobi city structure their work hours between 8.00 a.m. and 5.00 p.m. This system has caused a scramble among the people trying to access their workstations or job opportunities within the set working hours. This has led to rapid growth in non-conventional means of public transport comprising of minibuses, taxis and more recently by commercial motorcycles. Most of these means are notorious for flouting traffic rules resulting to externalities such as accidents, congestion and corruption. KIPPRA (2015: 1) estimates that in 2013 there were 2 million registered vehicles in Kenya and 60% were used in Nairobi. The distance of the road network in Nairobi as in 2012 was about 58,000 kilometers long (KRB, 2012), with an approximate 1.2 million vehicles using these roads.

1.1.3 Road Transport Agencies

The Roads Act of 2007 enacted established three new agencies in charge of road infrastructure management, rehabilitation, maintenance and development. These are the Kenya National Highways Authority (KeNHA); Kenya Rural Roads Authority (KeRRA) and the Kenya Urban Roads Authority (KURA). The Kenya Roads Board (KRB) solicits and distributes funds for development of the road infrastructure while the Nairobi Traffic Department and City Inspectorate Department are responsible for enforcement duty to ensure compliance with traffic Act and County Government regulations. The National Transport and safety Authority (NTSA) whose vision is geared towards a sustainable, safe road transport system with zero crashes has been instrumental in the efforts to reduce road accidents and is responsible for registration, licensing and road safety. This informs us that the government appreciates the role of road transport and research geared towards addressing the influences of RTAs, which will foster a sound policy formulation framework.

1.2 Statement of the Problem

Road accidents are among the leading cause of death and disability in Kenya. Nearly three thousand people die annually because of accident related activities. This translates to approximately 68 deaths per 10,000 registered vehicles, which is 30-40 times greater than in highly motorized countries. Research indicates that about seven people die out of thirty-five road crashes that occur each day in Nairobi. Despite the huge economic burden exerted by RTAs, the major causes of accidents in Nairobi have not been descriptively analyzed and modeled to outline the major causes and their inter-relatedness. This emphasizes the need to comprehensively understand the major causes of these accidents. This study therefore intends to utilize generalized linear models to explore the major causes of road traffic accidents in Nairobi County that will help in minimizing loss of lives through road accidents.

1.3 Study Objectives

1.3.1General Objective

To explore major causes of road accidents in Nairobi county

1.3.2 Specific Objectives

i. To identify the suitable technique to model the injuries arising from road accidents in Nairobi County.
ii. To compare the results of models used in estimating the daily number of RTAs.

1.4 Significance

Researchers have been modeling RTAs with crash prevention models in various parts of the world. This has however not been done in Kenya. It is essential to conduct research to establish the main causes of Road Accidents and come out with the reality on the ground so that, policy makers can design strategies that will effectively reduce the numerous deaths caused by Road Traffic Accidents to the barest minimum in the country. It is necessary to develop better prediction mechanism to plan for future occurrence. This will help ensure that resources are channeled to the right direction geared towards addressing the major cause of Road Traffic Accidents (RTAs) as many causes have overtime been attributed to causing accidents in Nairobi. It will also aid in policy formulation that would address the major causes of accidents thus reducing the number of deaths resulting from RTAs in Kenya.

1.5 Scope

The study will be limited to roads in Nairobi County.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

In 2010, the United Nations General Assembly adopted resolution 64/255[1] proclaiming a Decade of Action for Road Safety so as to stabilize and reduce the increasing trend in road traffic fatalities. Interestingly RTAs in high income countries is expected to fall by 2020, while the converse is true for the developing countries (IRAP, 2009). More than 85% of RTAs occur in developing countries. The total number of losses realized in developing countries annually exceed the annual amounts of aid and loans received for the purpose of development. It has been suggested that the cost to the economy due to RTAs costs an approximately 1- 2% of a country's gross national product (WHO, 2012).

Road network in Kenya was historically developed as a subsidiary of the railway system up to 1963 when she attained her independence, to forge a link between the railways and the European-owned large-scale farmlands. Today road transport is the predominant mode of transport ferrying about 93% of all cargo and passenger transport. Furthermore, the government prioritizes road transport infrastructure as a leading developmental agenda in its total investments in fixed assets and serves the domestic and regional transport demand. The Northern Corridor is important as a freight transport corridor for both import and exports for the countries in Eastern and Central Africa. Modelling the major influences of RTAs will thus have a ripple effect on the neighboring economies.

2.1 Review of Previous Studies

A population based survey study on RTAs conducted in Nigeria, by Libinjo et al (2009) revealed that RTAs was a significant problem claiming approximately 200,000 Nigerian lives annually and injuring 4 million more. The loss to the economy was also considerably high at $25 million per annum. The study also found that men were more at risk of being involved in road accidents than women, while younger people, especially those aged 18- 44 years, formed the bulk of road accident victims.

Agoki (1992) indicates that RTAs causation factors may be traced to the road users, vehicles or the road environment; and in Kenya the proportion is 80% traceable to road users, 6% to vehicle and 14% to road environment. In Nairobi County the contribution by road user factors is as high as 94% and an analysis of road traffic accident characteristics revealed four major groupings of factors influencing RTAs namely; pedestrian factors; land use factors; road layout factors, vehicular factors and traffic control device factors (Agoki, 1992). These variables are also to be considered in our study.

Technical reports by the National Transport and Safety Authority recommends road safety be made an integral component in urban planning. Many stakeholders outline the importance of urban traffic planning for road safety and enforcement of traffic rules & regulations. This study will go further in addressing the missing link where all the road safety stakeholders are involved in formulating road safety programs and interventions in order to reduce the scale of RTAs in Nairobi County.

Kim et al (1995) utilized a log-linear model to explain the role of driver behaviors in the causal sequence that led to more severe injuries. They showed that behaviors of alcohol use and lack of seat belt use greatly increased the odds of more severe crashes and injuries. This was also employed by Akomolafe (2007) when he utilized the Artificial Neural Network using Multilayer perceptron to predict likelihood of accident happening at a particular location between the first 40 kilometers along Lagos-Ibadan Express road.

Statistical research on the causes and effects of RTAs in Nairobi County is a green field of research. This might be as a result of inadequate information and institutional framework dedicated to combating it. The Nairobi traffic department that is tasked with collecting data is the best equipped in the county when compared to the other departments. Despite the urgent need to combat death, injuries and costs affiliated to road traffic accidents, no statistical model has been developed to address the causative factors of RTAs in Nairobi. Instead, risk factors contributing to the accident like over-speeding, seat-belt use, alcohol use and old-age have been overemphasized at the expense of the direct accident causes.

2.2 Nairobi County Profile

Nairobi County has an area of 684 sq. km and is the only city in the world with a national park. It is the commercial hub of Eastern and Central Africa harboring close to over 100 international organizations and companies such as the United Nations Environmental programme (UNEP). The Nairobi Stock Exchange (NSE) is one of the biggest stocks markets in Africa. It has nine districts namely Kasarani, Dagoretti, Westlands, Starehe, Langata, Kamukunji, Njiru, Embakasi and Makadara. The major roads in the city are Thika road, Waiyaki road, Langata road, Uhuru highway, Mombasa road, Juja road, Jogoo road, Magadi road, Valley road and Limuru road.

Nairobi's high population density and expansion rate has outstripped the capacity of its road network as the county is unable to connect every locality. Approximately a great percentage of the city residents rely on a fleet of about twenty thousand personal minibuses known as matatus (KBNS, 2014). Nonetheless, Nairobi County roads are reported to be the world's fourth most congested (IBM, Commuter Pain Survey, 2011). The Kenyan government estimates that the traffic jams cost $578,000 a day, in terms of lost productivity to the County (Bloomberg Business, 2014). Notably, a faster means of transportation has become a necessity rather than a luxury as during peak hours many of the roads are rendered impassable by vehicles, elevating motorcycles as the quick and reliable form of transportation.

2.3 Understanding Road Traffic Accidents in Kenya

In 1986 a research study done by UK Transport Research Laboratory (TRRL) rated Kenya as 5th out of 29 worldwide selected countries in terms of highest number of accidents per licensed vehicles. Since then, the reported accidents continued to rise. In 1990, 10300 people were injured while in the year 2000, 13900 were injured. This translated to a 3 percent growth rate per annum. During the same period an average of 0.8 percent growth of vehicle population was realized rising from 350,000 vehicles to 530,000 vehicles, (Ministry of Transport, 2010). The Nation realized a road traffic fatality rate of 59.96 per 100,000 populations in 2009, with vehicle passengers being the most affected. This was much higher compared to the global figure of 21.5 per 100,000 populations for low-income countries and 10.3 per 100,000 for high income countries. However, recent statistics indicate that the number of reported accidents has decreased from 12,399, in 2004 to 6205 in 2013, but ironically the number of persons killed and those injured have increased.

A report by the Kenya Roads Board, 2009 indicates that 85.5% of all road accidents that occurred were as a result of human factors on the part of drivers and motorcyclists (43.6%), pedestrians (24.8%), passengers (4.8%) and pedal-cyclist (10.3%). According to (Ogendi et al, 2013), passengers on motorcycles, the elderly, children and pedestrians are among the most vulnerable road users. RTA fatalities have laid big burden to the victim's families, dependents, society and government at large. It has placed strain on health care services in terms of financial resources, bed occupancy, and demand placed on health professionals (WHO, 2009). In 1991, RTIs were estimated to cost Kenyans approximately US$3.8 billion annually, corresponding to 5 percent of the annual gross national product (Odero, et al., 2003). This was however thought to be a conservative estimate because it did not include costs associated with lost productivity and other related costs due to the years of life lost (William Maina & Kent A. Stevens 2012). Fatalities due to RTIs increased at an annual rate of 7 percent for the period 2004 to 2009. (Bachani, et al., 2012), therefore, a great relief would be realized if ways of minimizing these occurrences could be discerned.

2.4 Determinants of Road Traffic Accidents occurrence in Nairobi County

Understanding the effect of a risk factor is very important towards identifying the exact cause of an accident. Causation may be attributed to human related factors, road factors, environmental factors and vehicular factors. Human factors are triggered directly by the human behavior when in the vicinity of the road. According to the Kenya Traffic Police department pedal, driver, pedestrian, cyclist, passengers are categorized as the human factors directly responsible for accidents in Nairobi County. There are also different risk factors that are connected to immediate cause of accidents. Fatigues, overtaking improperly, negligence, inexperience, illness are some of the risk factors likely to result into the occurrence of an accident.

Road factors are risk factors that are associated with the road as an accident cause and include a slippery road surface, excessive dust obscuring road user view and dilapidated road surface. Environmental factors constitute weather and animals. Example of situations are fog or mist, torrential rain, glaring sun and animal in the carriage way. Vehicular factors are the mechanical defects on the vehicles and any vehicle feature that may contribute to an accident occurring.

2.5 History of Motorcycles in Kenya

Howe (2003) asserts that boda boda transport services originated from Ugandan as a new innovation. Initially this mode of transport was provided on a bicycle but the sector has now evolved in Kenya to include motorcycles. The motorcycle sector in Kenya is fast evolving and they are extensively utilized as the preferred mode of transport in the neglected rural villages and the otherwise inaccessible areas. According to the NTSA, 90% of the registered motorcycles are used for passenger transport. In the year 2014, the industry contributed close to 2.2 billion shillings to the economy. The rapid increase and use of motorcycles in Kenya is attributed to four factors first, the zero-rating of all motorcycles below 250cc by the Government in 2008. Second, the current transport system's inability to fully meet the commuters' transportation needs (Kumar & Barret, 2008). Third, the high levels of unemployment forcing mostly the young people to embrace the business as a form of employment (Nyachieo, 2012). It offers direct employment to close to 100,000 Kenyans with over 30,000 based in Nairobi. Fourth, entry into the motorcycle business is easy as there are fewer restrictions. One only needs to know how to ride a motorcycle (formally or informally) and they are in business. Notably in the case of motorcycle riding in Kenya, there is lack of documented information on motorcyclists formally trained through driving schools despite the increasing cases of motorcycle accidents among boda boda riders. Formal training is associated with acquisition of riding skills and safety knowledge. Therefore trained motorcycle riders are expected to have a certain level of road safety knowledge.

2.6 Motorcycle accidents

Kenya has reported a continuous increase in the number of motorcycles as is indicated by data from the Kenya Revenue Authority (KRA). For instance, annual registrations of motorcycles increased by 3730% from 3,759 in 2005 to 140,215 in 2011 (KRA, 2012). In the same way, accidents involving boda boda motorcycles have also exhibited an upward trend. For example nationally, deaths and injuries related to motorcycles accidents have increased by a factor of 4.4, from 451 in 2005 to 1,991 in 2013.

In 2010, a total of 3,055 road traffic deaths were reported by the Kenya Traffic Police of which approximately 7% were motorcyclists (World Health Organization, 2013). According to National Transport and Safety Authority, between 1st and 13th January 2016, the number of motorcyclist who died due to motorcycle accident have increased by 40% and the number could increase in the remaining months of 2016 if no interventions are made. Hurt, Quellet, & Thom, (1981) observe that riders of motorcycles received their raining from friends and family or unqualified trainers.

In spite of offering advantages such as affordability, availability, flexibility and even ability to travel on poorly maintained roads, safety concerns have emerged. The motorcycle taxis have been categorized as having a poor road safety record that increased by 58% during the first four months of 2015. Road traffic injury patients represent between 45-60% of all admissions to surgical wards. It is essential to note that Kenyatta National Hospital identified the need to have to improve its capacity to address accidents and converted some of its wards for emergency use. These wards include 6A, C, and D that receives the large number of motorcycle victims brought into the hospital. If nothing is done more accidents are likely to occur with serious socio-economic implications.

2.7 Causes of Motorcycle Accidents

According to the Kenya Traffic Police department different vehicles are primarily responsible for causing RTAs on the Kenyan roads. These have been classified as motor cars, Lorries, buses and taxis, motorcycles, pedal cycles, animals and matatus. About 582 cases people who were involved while using motorcycles accidents were recorded in high numbers. The number of cases has continued to sour with motorcycles accounting for 18% of annual road fatalities.

Rapid growth in the use of motorized two-wheeled vehicles in Kenya has been accompanied by increases in injuries and fatalities among its users. The problem of untrained riders has been a stubborn stain on the motorcycle industry resulting to its publicity. As a matter of priority the causes of RTAs in Kenya should thus be established in earnest.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

The goal of any robust model-building technique is to identify the best fitting and the most parsimonious model that describes the relationship between a given outcome (dependent or response) variable and a set of independent variables (covariates).

3.2 Study Variables

a. Dependent variable (Y) – Number of Injuries

b. Independent variables ($x_i's$)

i. Drivers
ii. Pedestrians
iii. Pedal Cyclists
iv. Passengers
v. Animals
vi. Obstruction
vii. Vehicle Defect
viii. Road Defects
ix. Weather

3.3 Poisson Regression Model

The Poisson modelling approach is often referred to as an ideal baseline model for modelling count data. It dominates the count data modelling activities as it suits the statistical properties of count data and is flexible to be parameterised into other form of distribution functions (Shanker, 1995; Cameron et al, 1998).

In this model, the number of accidents(Y) is the dependent variable and it is generated as:

$Y \sim Poiss(\mu)$

The primary equation of the model is:

$P(Y_i = y_i) = \frac{e^{-\mu}\mu^{y_i}}{y_i!}, y_i = 0,1,2, \ldots$

$Where\ \mu\ is\ the\ average\ number\ of\ occurences\ in\ a\ specified\ interval.$

The mean μ is let to depend on a given vector of explanatory variables x_i resulting to a simple linear model of the form: $\mu_i = x'_i\beta$

However, the linear predictor part can be taken to assume any value, whereas the Poisson mean μ_i is taken to be a non-negative since it represents the expected count.

The solution is to model the logarithm of the mean function using the linear model. The log-linear specification will be:

$$\log(\mu_i) = x'_i\beta = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n$$

According to G. Rodriguez, the log link function is advantageous as it stems from the empirical observations of the count data. The effects of the model predictors is considered multiplicative rather than additive. That is, one typically observes small effects for small counts and large effects for large counts.

Thus, expected number of accident is given by:

$E(y_i|x_i) = \mu_i = e^{x'_i\beta}$

Assumption of the Poisson Model

The major assumption of the Poisson model is:

$E(y_i|x_i) = \mu_i = e^{x'_i}\beta = Var(y_i|x_i)$

If $Var(y_i|x_i) > E(y_i|x_i)$ then there is over-dispersion.

$Var(y_i|x_i) < E(y_i|x_i)$ Then under-dispersion has occurred.

3.4 The Negative Binomial

The Poisson regression approach assumes a log linear relationship between its parameter λ_i and the explanatory variables.

$$\lambda_i = E(Y_i) = e^{\beta X_i}$$

Where;

$X_i - Is\ a\ vector\ of\ explanatory\ variables$

$\beta_i - Is\ a\ vector\ of\ unknown\ regression\ coefficients$

The negative binomial regression relaxes the assumption of equality of the mean and variance. By adding a gamma - distributed error term (ε_i), equation is rewritten as,

$$\lambda_i = E(Y_i) = e^{\beta X_i + \varepsilon_i}$$

The error term ε_i makes the variance to be distinct from the mean and is gamma-distributed with a mean of 1 and variance α^2. The addition of ε_i makes the variance to be different from the mean as follows:

$$Var(Y_i) = E(Y_i)[1 + \alpha E(Y_i)] = E(Y_i) + \alpha E(Y_i)^2$$

Where $\alpha - Dispersion\, parameter$ following a gamma distribution and $E(Y_i)$ is the mean from a Poisson process.

Therefore, the negative binomial is a mixture of two distributions (Poisson-Gamma) and was first derived by Greenwood and Yule (1920). It was developed to account for over-dispersion that is commonly observed in discrete or count data (Lord et al., 2005).

When the dispersion parameter α approaches zero, the variation of the model is almost equal to mean of the distribution, and can thus be modeled using the Poisson regression approach.

The primary equation of the negative binomial model is given as:

$$P(Y_i = y_i) = \frac{e^{(-\lambda_i)}(\lambda_i e^{\varepsilon_i})^{y_i}}{y_i!}, y_i = 0,1,2, ...$$

The formula integrating ε_i is as follows:

$$P(y_i) = \frac{\Gamma\left((1/\alpha) + y_i!\right)}{\Gamma(1/\alpha) y_i!} \left(\frac{1/\alpha}{(1/\alpha) + \lambda_i}\right)^{1/\alpha} \left(\frac{\lambda_i}{(1/\alpha) + \lambda_i}\right)^{y_i}$$

; Where, $\Gamma(.)$ is a gamma function.

The model is estimated by the standard maximum likelihood method. The corresponding likelihood function is outlined in equation

$$L(\lambda_i) = \prod_i \frac{\Gamma\left((1/\alpha) + y_i!\right)}{\Gamma(1/\alpha) y_i!} \left(\frac{1/\alpha}{(1/\alpha) + \lambda_i}\right)^{1/\alpha} \left(\frac{\lambda_i}{(1/\alpha) + \lambda_i}\right)^{y_i}$$

This function is maximized to obtain coefficient estimates for β and α

3.5 Performance Measures

We employ root mean squared error (RMSE) (Ghaffari *et al*, 2006)

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (y_i - y_{di})^2$$

$where\ y_i - predicted\ value$

$y_{di} - actual\ value$

$$RMSE = (MSE)^{\frac{1}{2}}$$

The coefficient of determination R^2 reflects the degree of fit for the mathematical model (Sin et al, 2006). The model with the highest R^2 is considered best.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - y_{di})^2}{\sum_{i=1}^{n}(y_{di} - y_m)^2}$$

$where\ y_i - predicted\ value$

$y_{di} - actual\ value$

$y_m - average\ of\ the\ actual\ values$

Absolute average deviation (AAD) could also be used to the output error between the actual and predicted output (Bas & Boyaci, 2007)

$$AAD = \{[\sum_{i=1}^{n}(y_i - y_{di}/y_{di})]/n\} \times 100$$

Where:

$\hat{y}$ - predicted value

y_i – actual value

$\bar{y}_n$ – average of the actual values

CHAPTER FOUR: DATA ANALYSIS AND RESULTS

4.1 Introduction

This chapter briefly describes our study area and details the results generated from data analysis.

4.1.1 Description of the Study Area

Figure 4.1. Map of Nairobi County

Nairobi county is situated at 1 ^{o} 17’S 36^{o}49’E in south central Kenya, 140 kilometers south of the equator. The county is surrounded by 113 sq.km of cliffs, plains and forest. It is adjacent to the eastern edge of the Rift Valley, and to the west are the Ngong hills. Nairobi is the capital and largest city of Kenya with a population of approximately 3 million people living in 17 constituencies.

4.2 Descriptive Statistics

Monthly data, from the Nairobi traffic department was collected from 2002 to 2014 and it comprised of nine variables namely drivers, pedal cyclist, pedestrians, passengers, animals, obstruction, vehicle defects, road defects and weather.

Variables	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Driver	156	130	57	187	122.19	28.037	786.066
Pedal. Cyclist	156	78	2	80	12.26	8.027	64.439
Pedestrians	156	183	16	199	78.86	33.943	1.15E+03
Passengers	156	52	0	52	11.34	7.726	59.692
Animals	156	3	0	3	0.21	0.655	0.428
Obstruction	156	11	0	11	0.85	1.611	2.595
Vehicles. Defects	156	13	0	13	1.97	2.278	5.187
Road. Defects	156	5	0	5	0.36	0.889	0.791
Weather	156	14	0	14	0.29	1.385	1.918

Table 4.1. Descriptive statistics of variables

4.3 Data Pre-processing

The data used in modeling was normalized to prevent and overcome the problem associated with extreme values:

i.e. $Y_{norm} = \frac{Y_i - Y_{min}}{Y_{max} - Y_{min}}$

Where;

$Y_{norm} - Nomalized\ dimensionless\ variable$

$Y_i - \quad Nomalized\ dimensionless\ variable$

$Y_{min} - Minimum\ value\ of\ the\ \ variable$

$Y_{max} - Maximum\ value\ of\ the\ \ variable$

4.4 Normality Test

The Kolmogorov - Smirnov test was conducted to determine the normality of our data distribution.

$$H_0: Accident\ data\ is\ normally\ distributed$$

$$vs$$

$$H_0: Accident\ data\ is\ not\ normally\ distributed$$

Results:

D-value	0.6994
P -value	<0.001

Table 4.2. Kolmogorov-smirnov test results

The D-value was 0.6994 with an associated p-value < 0.001, the study rejected the null hypothesis, and thus the data is non-normal.

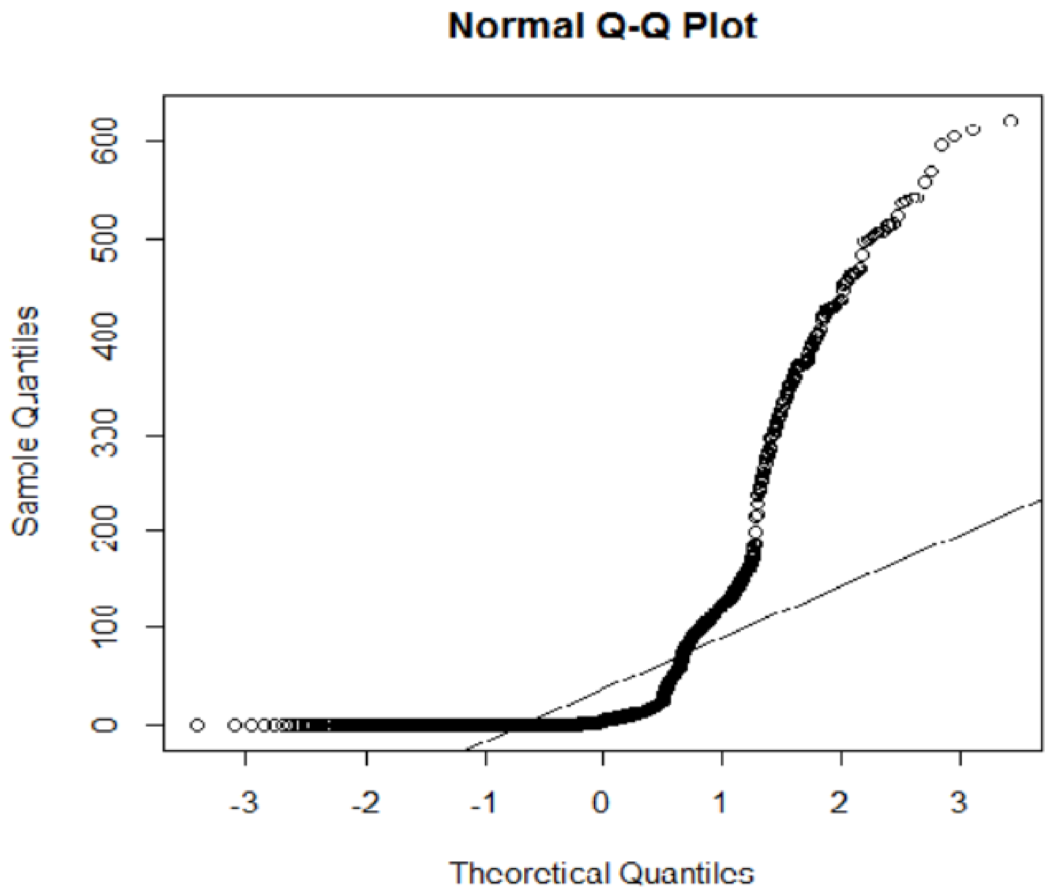

Figure 4.2. Normal Q-Q plot

4.5 Durbin-Watson Test

4.5.1Assumptions of the Durbin-Watson test:

The regression model includes an intercept term. The repressors are fixed in repeated sampling. The error term of the regression follows the first-order autoregressive (AR1) scheme. The error term is normally distributed. The repressors do not include the lagged value(s) of the dependent variable (Kramer, 2011).

Autocorrelation is a relationship, between values separated from each other by a given time lag; in this case, our data has been separated by months. Residuals are the prediction errors in our model.

$$e_t = \rho e_{t-1} + V_t$$

Where;

$e_t - error\ term$

$\rho - autocorrelation\ co-efficient, \qquad -1 < \rho < 1$

$V_t - random\ error\ with\ E(V_t) = 0\ and\ var(V_t) = {\delta_v}^2$

Our accident data is a time series, and so we need to test for stationarity

$$H_0 : \rho = 0\ vs\ \ H_a : \rho \neq 0$$

Null hypothesis: There is no lag one autocorrelation in the residuals (Errors are serially uncorrelated)

Alternative hypothesis: There is lag one autocorrelation in the residuals. If there is no autocorrelation, the Durbin-Watson distribution is symmetric around 2.

4.5.2 Durbin-Watson test results

DW (d-value)	1.7687
p-value	0.1095

Table 4.3. Durbin – Watson test results

A two-sided test was used to check for negative as well as positive autocorrelation. The d-value is 1.7687, which implies that there was no correlation in the residuals. Our p-value was 0.1095, thus there is no significant auto correlation remaining in the residuals. The Durbin-Watson test was utilized in this study, to test whether errors had autocorrelation or not. The study concluded with 95% certainty that there was no significant evidence of autocorrelation.

4.6 Over-dispersion test results

In a Poisson model, the mean and variance are equal. This test, tests this assumption as a null hypothesis against an alternative where $Var[Y_i] = E[Y_i] + \propto *\ g(E[Y_i])$

The constant α takes values greater than zero or less than zero, which results to over dispersion and under-dispersion respectively.

z-value	4.3073
P -value	8.2×10^{-6}
α	6.337604

Table 4.4. Over-dispersion test results

The study concluded that there was significant evidence of over dispersion ($\propto$ was estimated to be 6.337604), which is against the assumption of equi-dispersion i.e. $\propto \neq 0$

4.7 Poisson regression model results

The study fitted a Poisson regression as its baseline model and the following output was recorded.

	Estimate	**Std. Error**	**Z-value**	**Pr (>|z|)**
Intercept	5.0190	0.2025	247.8890	0.0000
Driver	0.0047	0.0002	28.6500	0.0000
Pedal. Cyclist	0.0051	0.0006	8.9200	0.0000
Pedestrians	0.0024	0.0002	15.6050	0.0000
Passengers	0.0080	0.0007	7.6330	0.0000
Animals	0.0036	0.0063	0.5660	0.5717
Obstruction	0.0075	0.0027	2.8250	0.0047
Vehicles. Defects	-0.0050	0.0018	-2.7150	0.0066
Road. Defects	-0.0004	0.0056	-0.0690	0.9453
Weather	-0.0140	0.0029	-4.7860	0.0000

Table 4.5. Poisson regression results

Injuries = 5.0190+0.004732(Drivers) +0.0051(Pedal. Cyclists) +0.0024(Pedestrians) +0.0080(Passengers) +0.0036(Animals) +0.0075(Obstruction) -0.005(Vehicle. Defects) -0.0004(Road. Defects) -0.0140(Weather)
AIC: 2433.1

4.8 Negative binomial regression model results.

	Estimate	**Std. Error**	**Z-value**	**Pr (>|z|)**
Intercept	4.9975	0.0570	87.6040	0.0000
Driver	0.0049	0.0005	10.0610	0.0000
Pedal. Cyclist	0.0049	0.0018	2.7460	0.0060
Pedestrians	0.0026	0.0005	5.5370	0.0000
Passengers	0.0045	0.0020	2.2840	0.0224
Animals	0.0034	0.0187	0.1800	0.8574
Obstruction	0.0084	0.0084	0.9910	0.3215
Vehicles. Defects	-0.0054	0.0056	-0.9560	0.3391
Road. Defects	0.0029	0.0165	0.1770	0.8593
Weather	-0.0155	0.0094	-1.6550	0.0980

Table 4.6. Negative-Binomial regression results

Injuries=4.9975+0.0049(Drivers) +0.0049(Pedal. Cyclists) +0.0026(Pedestrians) +0.0045(Passengers) +0.0034(Animals) +0.0084 (Obstruction) -0.0054(Vehicle. Defects) +0.0029(Road. Defects) -0.0155(Weather)

AIC: 1714.7

The study noted from the results in that drivers, pedal cyclists, pedestrians and passengers significantly determined the total number of injury occurrence in Nairobi county. The positive regression estimates indicated that the number of injuries was directly influenced by the significant variables.

4.9 Performances Measures

The objective of each of the methods used was to fit an accurate model of the accidents for use to predict future injuries. The adequacy of the negative binomial model and the poisson is assessed based on MSE, coefficient of determination (R^2) and RMSE.

Model	R- Squared	Mean – Squared Error	Root Mean Squared Error (RMSE)
Poisson	0.5991	164.76	12.8359
Negative Binomial	0.6691	148.3875	12.1814

Table 4.7. Performance measures results

The negative binomial technique out-performed the Poisson regression technique, since it had the minimal values of the mean-squared error and the root mean squared.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

Based on study results, there is an urgent need to address the root causes of accidents in Nairobi County. Laws and regulatory frameworks should be formulated and enforced promptly to avoid losses caused by the occurrence of an accident.

5.2. Summary of Findings

The results attest that a robust model will be beneficial in so far as RTAs mitigation and prevention is concerned. Given the nature of data being handled, a parsimonious model should always be chosen. In this study the negative binomial was chosen given that our data was over-dispersed.

The study also concluded that the causes of RTAs in Nairobi County are multi-factorial and can be categorized into driver factors, vehicle factors and roadway factors. Driver factors relates to all proximate factors affiliated to the diver that may result to an accident occurring. Speeding is a leading cause of accidents and policy should be geared towards addressing driver behavior as it predisposes the driver and other road users to injury.

5.3. Recommendations

From the results and finding in the study this recommendations if implemented will significantly reduce the number of accidents in Nairobi County. Additionally, motor cyclists should undergo formal training on road safety; increase levels of road use awareness among pedestrians, enforce use of seatbelts and discourage carrying excessive passengers.

5.3.1. Recommendation to Nairobi City County

The public should be sensitized on safe practices on the roads. Bumps should be erected in regions with a high population density.

5.3.2. Recommendation to planners and policy makers

RTAs require a collaborative approach in from different sectors so as to address RTAs in a holistic manner. Pedestrian's walkways and pedal-cyclists lanes should be factored in road design. The government, the police, the health personnel and general public should be incorporated into preventive measures to be formulated. Road safety professionals should be trained, to monitor the magnitude, severity and burden resulting from RTAs in Nairobi County to counteract the paucity of evidence occasioned by insufficient data handling skills. City planning should incorporate all road users in mind and should focus more on the behavior and the setting. Law enforcement officers should also be trained on different important aspects of road safety.

5.3.3. Recommendations for scholars

Future research should focus on the spatial modeling of road traffic accidents.

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