ANALYSIS OF THE EFFECT OF WEATHER ON THE OCCURRENCE OF ROAD TRAFFIC ACCIDENTS IN ZARIA, KADUNA STATE, NIGERIA

BY

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DECLARATION

I declare that this thesis entitled **“Analysis of the Effect of Weather on the Occurrence of Road Traffic Accidents in Zaria, Kaduna State, Nigeria”** has been carried out by me in the Department of Geography and Environmental Management under the supervision of Professor I.J. Musa, Professor E.O. Iguisi and Professor A.A. Ibrahim. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

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CERTIFICATION

This thesis entitled **''Analysis of the Effect of Weather on the Occurrence of Road Traffic Accidents in Zaria, Kaduna State, Nigeria''**by Hamza MOHAMMED meets the regulations governing the award of the degree of Doctor of Philosophy (Ph.D) Geography of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to Almighty Allah, Prophet Muhammad (SAW), my supervisors, Alhaji U.U. Mohammed's family, late Alhaji Yusuf Danmallam's family, Department of Geography and Environmental Management, A.B.U, Zaria, A.B.U. Staff School, Demonstration Secondary School, A.B.U, Zaria and the entire university.

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In the name of Allah, the Beneficent, the Compassionate. All praise, honour, adoration and glory are due to Allah, who 'taught by the pen and teaches man that which he knows not'. May the peace and blessings of Allah (SWA) continue to be upon the noble prophet Muhammad (SAW), his household, companions and the rightly guided servants of Allah. Indeed, I am grateful to Allah (SWA), my Sustainer, and Cherisher who gave me the opportunity, privilege, wisdom and strength to undertake this study.

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ABSTRACT

This thesis assessed the effect of weather on the occurrence of road traffic accidents (RTAs) within Zaria unit command of the Federal Road Safety Commission (FRSC). Thus, data for the selected weather elements which include rainfall, temperature, visibility, relative humidity, wind speed and evaporation rate and RTAs were obtained from Nigerian Meteorological Agency and FRSC respectively. Time series analysis, Pearson's product moment correlation coefficient, T-test, Fisher's method, bar graphs, multiple linear regression, one-way ANOVA were the analytical methods used. A range of statistical methods used in this study were adopted from Mondal *et al.* (2011c) which include rain-crash-index, wet-crash-rate, dry-crash-rate, rain-crash-effect, dry spell effect and rain-class-crash-rate. This study revealed a general increase in the amount of rainfall, number of wet days, air temperature, visibility and relative humidity and a decrease in wind speed and evaporation rate. It also showed that Zaria-Kaduna route recorded more RTA cases and casualties, dangerous drivingwas the leading causes of RTAs in Zaria and there was a general increase in the number of RTA cases and casualties in Zaria.The highest number of RTA cases recorded in a year was in 2013 and for casualties, it was in 2012. The highest number of RTA cases and casualties were recorded in July and January respectively. Furthermore, of the seven RTA variables which include fatal, serious, minor, total cases of RTA, number of passengers injured or killed and total casualties that each of the weather parameters was tested against annually and monthly for relationship, both positive and negative associations were observed showing that the relationship is not vary from one weather element to another and from one RTA parameter to another. The most predominant cause of RTAs in the study area which is dangerous driving was tested annually against the selected weather parameters and their resulting relationship showed that where DGD was found to have caused fatal RTAs, rainfall, number of wet days and wind speed were found to have influenced it positively. However, when monthly analysis was carried, the resulting relationship showed that where DGD was found to have caused fatal RTAs, rainfall, air temperature, visibility and relative humidity were found to have influenced it positively. There is a general tendency in Zaria for greater amount of rainfall to lead to more RTAs and lesser rain-crash-index, the probability that a RTA will occur on any wet day is 0.24 while it is 0.28 on any dry day while the probability that a RTA will occur on a no dry spell wet day is 0.39, 0.55 on a small dry spell wet day and 0.06 on a large dry spell wet day. Zaria revealed a negative rain-crash-effect showing that more RTA cases occur per unit dry day than unit wet day.The amount of rainfall recorded three, four or five days before any RTA had a significant positive relationship with fatal, minor and the number of passengers killedin RTAs while the amount of rainfall recorded three days before any RTA has a significant negative association with the number of serious cases and total RTA cases. Finally, class two rainfall (>1 to 2mm) has the highest rain-class-crash-rate in the study area. In conclusion, there exist a complex relationship between weather and the occurrence of RTAs and secondly, this study has proven scientifically that weather (poor or conducive) contributes to the occurrence of RTAs. It may not be a proximate factor but it combines with other factors to cause RTAs and this study went a long way to show how. Generally, it was observed that the attitude of most drivers towards driving does change significantly between the wet and dry seasons as wet crash rate and dry crash rate were 28 per cent and 24 per cent respectively. This could be due to poor understanding of drivers with regards to either the effect of weather on the occurrence of RTAs directly or the influence of weather on other causes of RTAs. Thus, all the stakeholders in the transport sector must show commitment towards reducing RTAs in Nigeria.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Road traffic accidents (RTAs) and their related deaths have become a major health problem and concern worldwide. Road traffic injuries are the eighth leading cause of death globally (WHO, 2013). In Nigeria, road traffic safety has been a subject of considerable public debate. However, studies on RTAs have generally focused on issues such as spatio-temporal analysis of RTAs (Filani and Gbadamosi, 2007); variability in RTAs (Atubi, 2010a, 2012a); safety issues and socio economic cost of RTAs (Aderamo, 2012); traffic regulations and RTAs (Gbadamosi, 2002). Missing from these studies is a study on the contribution of weather and climate to RTAs. Available studies on weather and RTAs in Nigeria are recent and very few as compared to many studies on the subject in the developed countries (Enente and Igu, 2011).

Road traffic accidents (RTAs) which in this study is defined as accidents that take place on the road between two or more vehicles of which one must be a moving vehicle (World Health Organization, 2013) started in 1906 in Lagos, Nigeria. Ever since, it has been a public health concern based on the number and magnitude of persons killed and injured. Between 1960 through to 2006, a total of 969,618 RTAs were reported leading to a casualty figure of 1,159,642 persons, distributed as 292,703 persons killed and 866,939 persons injured (Arosanyin, Olowosulu and Oyeyemi, 2012). A comparative assessment of the causes of deaths in Nigeria has placed RTAs as the most important killer of Nigerians than a combination of 35 noticeable diseases including malaria and HIV/AIDS. This burden is more than what the estimate covers as it covers mainly the casualty component (Arosanyin, 2008). In the year 2012, at the special marshal workshop held in Kaduna sector command, Kaduna state, it was announced that between January and July 2012, a total of 2,200 traffic offenders were apprehended while 597 RTAs were recorded in Kaduna state. Out of these accidents, 125 fatal cases, 389 serious cases and 58 minor cases occurred while 297 persons were killed and 2,239 persons were injured (Federal Road Safety Commission, 2012). RTAs may be fatal resulting in death of the road users (passengers, drivers or pedestrians), serious if injury is sustained by at least a road user or minor when it is not severe enough as to cause substantial hardship such that neither death nor injury is reported (Agbonkhese *et al.*, 2013).

Weather parameters on the other hand have been found to be related to RTAs. Rainfall is said to be related to RTAs due to factors such as skidding due to wetness of road surfaces, poor visibility, wet pavement exposure, surface runoff to mention a few as reported by Burns (1976), Rohde (1977), Andreescu and Frost (1998), Yannis and Karlaftis (2007), Mondal, Sharma, Kumar, Vigay, Bhangale, and Tyagi (2011) among others. A classic example among other effects of rainfall is the case of a vehicle running on a wet road at high speed. Rainwater will flow through the tyre tread grooves giving rise to hydrodynamic pressure. The occurrence of this hydrodynamic force deteriorates the tyre traction efficiency because it decreases the tyre contact force so that the driving controllability and the braking performance become worse than those on the dry roads (Cho, Lee and Yoo, 2006; Mondal, Dalela, Balasubramanian, Sharma, and Singh, 2008).

Furthermore, just as rainfall is said to be related with RTAs, temperature likewise. Chen (2010) reported that temperature affects man (driver) in several ways such as the effect of high temperature on man leading to heat exhaustion of which dizziness is one of its symptoms. The researcher also stated that vehicles are affected by temperature in several ways such as its effect on the pressure of tyres as it makes the air in the tyre to expand, drying up of fluids in the battery, failing of fuel pumps due to drying up of petro blended with ethanol before it reaches the engine making the car to stall. High temperature in addition to large volume of goods transported on roads which lead to the deformation of these roads shows how temperature is related to roads. Visibility, relative humidity, wind speed and evaporation rate are related to rainfall and temperature (Garg and Nayar, 2007; Wooden, 2011; Umoh, Akpan and Jacob, 2013) and by extension, also lead to the occurrence of RTAs.Thus, road safety is treated as a transportation issue not a public health issue. However, road traffic injuries called “accidents,” are mostly preventable. As a result, many countries put far less effort into understanding and preventing road traffic injuries than they do into understanding and preventing diseases that do less harm.Every day, as many as 140,000 people are injured on the world’s roads of which more than 3,000 die and some 15,000 are disabled for life. Each of those people has a network of family, friends, neighbors, colleagues or classmates who are also affected emotionally and otherwise (Dinesh, 2004). Worldwide, nearly 1.24 million people die in Traffic fatalities annually (World Health Organization, 2013).

As in other developing countries, RTAs in Nigeria is one of the most serious problems in need of pragmatic solution. Yet, this problem has been difficult to address probably because of the country’s level of development. Nigeria is said to have the highest RTAs rates in Africa and the second in the world (Akpogomeh, 1998; Obinna, 2007; Atubi, 2012c). In support of this, it was said that the proportion of deaths from RTAs in Nigeria increased from 38.2 percent to 60.2 percent in the ten years from 1991 to 2001 (Obinna, 2007). Road traffic accident situation over three decades has been particularly disturbing. In 1976, there were 53,897 RTAs resulting in 7,717 deaths. Although in 1981, the magnitude reduced to 5,114 accidents, but the fatality increased to 10,236. The number of people killed in road accidents between 1990 and 2005 kept rising and the fatality rate remained consistently high (Atubi, 2009b).

Thus, Nigeria's annual report of 8,000 to 10,000 RTAs deaths between 1980 and 2003 resulted in waste of human resources. This was confirmed by Filani and Gbadamosi (2007) and Atubi (2012b) who reported that Nigeria in particular Lagos is a high risk region with an average of 32 traffic deaths per 1,000 people. This is very high compared with the United States' 1.6 traffic deaths per 1,000 populations and with the United Kingdom's 1.4 deaths per 1,000 people (Trinca, 1988). In terms of traffic safety, there are on average 23 accidents per 1,000 vehicles in Nigeria (that is 230 per 10,000 vehicles) far in excess of the accident rates in the USA (2.7 RTAs per 10,000 vehicles) and the UK (3.2 RTAs per 10,000 vehicles).

According to data from the Nigerian Federal Road Safety Commission (FRSC), the country has the highest rate of death from RTAs in Africa; leading 43 other nations in the number of deaths per 10,000 vehicle crashes (Obinna, 2007). Nigeria is followed by Ethiopia, Malawi and Ghana respectively (Daramola, 2004). Thus, in an effort to check this alarming trend, the Nigerian Federal Government inaugurated the Federal Road Safety Commission in 1988. The commission's functions include among others, the regular patrol of the highways with the aim of checking reckless driving. But for this function to be performed effectively the FRSC and the police have to be familiar with the temporal distribution of road traffic accidents in the country that is, they must know where road traffic accidents are most frequent in addition to identifying those factors that are responsible for RTAs.

Hence, the climate of any study area must be well understood in order to have a clearer understanding of its relationship with the occurrence of RTAs. Nigeria enjoys the humid tropical climate type with a consistent high temperature all year round. The seasonal pattern of climatic conditions over Nigeria gives rise to four seasons in the south and two in the north where the study was carried out which are the long dry season (October – mid May) and the wet season (June –September) (Ekpoh and Nsa, 2011).

1.2 Statement of the Research Problem

In Nigeria, the pattern of RTAs seems to suggest that the better the roads, the higher the accident and fatality rate as well as the severity and non-survival indices because of drivers' non-compliance with speed limits (Filani and Gbadamosi, 2007). Most RTAs in Nigeria today occur on federal roads and the roads topping the list include Benin-Ore, Lagos-Ibadan Expressway, Abuja-Lokoja-Okene, Kaduna-Zaria-Kano, Okigwe-Umuahia, Kaduna-Abuja, Enugu-Awka-Onitsha and Otukpo-Otukpa among others (Godwin, 2012). Since Zaria links different parts of the country to other northwestern and northeastern part of the country, the probability that RTAs will occur in Zaria, where urbanization is also visible, will be very high.

According to Welch, Vaughan, Andréa send and Foldvary (1972) from their study in Australia using a nonlinear representation for weather conditions revealed a highly significant association between the weather and RTA statistics. On the average, their study revealed that dry- bulb and wet-bulb temperature at 3:00 p. m. seems a better predictor of accidents than daily rainfall or time of sunset. Furthermore, theyfound out that the prevailing weather could affect the yearly number of accidents by about plus or minus 5 percent and that the lowest RTA rates occurred on mild days with 3:00 p.m dry-bulb air temperature between 21.1 and 26.1^{0}C.

Andreescu and Frost (1998) analyzed the effects of rain, mean temperature and snow on RTAs in Montreal, Canada, from 1990 to 1992. Three time frames were used, monthly, annual and the entire study period. Aggregate daily numbers of RTAs were obtained in addition to meteorological data. Correlation coefficients and regression equations were calculated for each year with the number of RTAs as the dependent variable. Monthly scatter grams of number of RTAs versus the meteorological variables were plotted. Finally, the 'difference of means' test was used to compare mean RTA rates on dry days and days with precipitation. The significance of the difference between means was established by the t-test.The monthly scatter grams showed a strong positive relationship between number of RTAs and amount of snow in late winter and early spring, and between number of RTAs and amount of rainfall in summer months.

Keay and Simmonds (2006) carried out an investigation into the effect of weather variables on traffic flow at a site in Melbourne, Australia, for the period 1989–1996. Using rain-class-crash-rate, they found out that rainfall was the strongest correlated weather parameter with traffic flow with its greatest impact in winter and spring, thus reducing traffic volume on wet days. There are statistically significant decreases of 1.35 and 2.11% in traffic volume on wet days in winter and spring respectively. The reduction increases to 2–3% over the 2–10mm range, the largest being 3.43% for the 2–5mm class in spring. Their study for the first time considered daytime and nighttime periods separately. They found a reduction of 1.86% in winter and 2.16% in spring during daytime rainfall. The reduction at nighttime is significant over all seasons, ranging from 0.87% in winter to 2.91% in spring.

Yannis and Karlaftis (2007) studied the impact of weather conditions on traffic safety.The study used an integer autoregressive model (INAR) was used to estimate the effects of weather conditions on four traffic safety categories: vehicle accidents, vehicle fatalities, pedestrian accidents and pedestrian fatalities, using 21 years of daily count data for Athens, Greece. The results suggested that the most consistently significant and influential variable was mean daily precipitation height along with its lagged value. It was found that, contrary to many previous researches, increases in rainfall reduced the total number of RTAs and fatalities as well as the pedestrian accidents and fatalities while temperature increase was found to lead to increased RTAs.

Mondal *et al.* (2011c) in their work on weather and wet road related crashes presented a critical analysis on wet road driving conditions due to rainfall.RTA data was provided by Delhi Traffic police. A range of statistical techniques were used ranging from rain-crash-index to rain-crash-effect. The results showed that about 19% of RTAs took place in wet days. This could be due to physical or psychological factors like the build-up of oil and dirt on the road surface or the slow mental realignment to wet conditions.

Atubi (2012a) studied road traffic accident variations in Lagos state. The data used in the study were collected from Lagos State Police command, Ikeja and the FRSC, Lagos for 32 years (1970-2001). The monthly variations of RTA cases were presented in tables and analyzed with the aid of time series and averaging models. Nine Local Government Areas of Lagos State were selected. July recorded the highest number of RTAs accountingfor about 27% of all the road traffic accidents recorded; February, 23%; April, 22% and December, 22% as well. These four months alone accounted for 94 percent of all the accidents in Lagos State over the thirty two year period. July falls under the long rainy season in southern Nigeria.

Aderamo (2012) examined the spatial variation of road traffic accident casualties in Nigeria for the period 2004 to 2007. The study used multiple regression analysis to model the spatial pattern of road accident casualties in Nigeria. The result of the study revealed a spatial variation of road traffic accident casualties across the 36 states and the Federal Capital Territory. The study showed that Kaduna State was the only state with relatively high level of RTA deaths in the country.

Ayeni and Oni (2012) examined RTAs in Lagos State, Nigeria in relation to seasonal climatic variations for 6 years (2005 - 2010). In order to generate the total monthly occurrence of RTAs, the number of RTAs that occurred in each month was summed while monthly climatic variables average was determined using Arithmetic mean. Correlation analysis was also used. The results revealed that on the average, 46.7% RTAs occurred in dry season as against 53.31% in the rainy season. The casualty cases was about 45.6% during the dry season which increased by 8.6% in the raining season. Correlation analysis showed strong positive relationship between rainfall and RTAs while temperature and RTAs revealed a negative relationship.

Olawole (2016) examined impact of rainfall and temperature on RTAs in Ondo State, Nigeria. Secondary data on monthly RTAs, rainfall and temperature were derived from FRSC and Nigerian Meteorological Agency (NIMET). Pearson's product moment correlation coefficient was used to test the relationship between RTAs and elements of weather. Both rainfall and temperature were negatively and positively correlated on yearly bases. Similarly, multiple linear regression models between RTAs and the weather elements on yearly bases showed that the variations in RTAs accounted for by rainfall and temperature were equally low never exceeding 25.7%.

Thus, many studies have been conducted on RTAs in Nigeria like Akpogomeh (1998), Daramola (2004), Obinna (2007), Filani and Gbadamosi (2007), Atubi (2009a, 2009b, 2010a, 2010b, 2012a, 2012b and 2012c) and Aderamo (2012) but the focus was never on the relationship between weather and RTAs except for Ayeni and Oni (2012) and Olawole (2016) whose focus was on Lagos and Ondo States in Southwest zone of Nigeria. Furthermore, not even a single RTA case was attributed to weather by FRSC who listed poor weather among the probable causes of RTAs. Thus, the paucity of knowledge on the relationship between RTAs and elements of weather and the increase in fatality and injuries associated with RTAs has necessitated this study. In fact, available studies on weather and RTAs in Nigeria are recent and very few as compared to many studies on the subject in the developed countries (Enente and Igu, 2011). The need for this study cannot be overemphasized due to the growing interest in understanding the relationship between climate change and transportation worldwide.In fact, the consequences of climate change and changing weather conditions for the transport sector have not received much attention in literature (The Stern, 2007; IPCC, 2007a).

Thus, this study attempted to answer the following research questions:

1. What are the monthly and annual rainfall (number of wet days inclusive), temperature, visibility, relative humidity, wind speed and evaporation trends in Zaria?
2. Is there spatial variation in RTA cases and casualties in Zaria?
3. Is there temporal variation in RTA cases and casualties in Zaria?
4. What is the nature of association between rainfall, temperature, visibility, relative humidity, wind speed and evaporationrate and RTAs in Zaria?
5. What is the occurrence rate of RTAs on wet and dry days and during dry spell respectively?
6. How can the rain-class-clash-rate of the study area be derived?

1.3 Aim and Objectives

The aim of this study is to analyze the effect of weather on the occurrence of RTAsin Zaria, Kaduna State. In order to achieve the aim of this study, the specific objectives are to:

i. examine the monthly and annual trends of rainfall (number of wet days inclusive), temperature, visibility, relative humidity, wind speed and evaporationratein the Zaria from 1979 to 2014;
ii. analyze the spatial variation of RTAs along six major routes in Zaria;
iii. analyze the temporal variation of RTAs in Zaria from 2001 to 2014;
iv. assess the nature of association between rainfall, temperature, visibility, relative humidity, wind speed and evaporationrate and RTAs in the study area;
v. examine the occurrence rate of RTAs on wet and dry days and during dry spell in Zaria; and
vi. derivea rain-class-crash-rate (RCCR) for Zaria.

1.4 Hypothesis

This study tested the following hypothesis which was stated as follows:

There is no significant association between weather and the occurrence of road traffic accidents within the Zaria Unit Command of FRSC, Nigeria.

1.5 Scope of the Study

This study focused on Zaria Unit Command in Kaduna State made up of five local government areaswhich are Giwa, Kudan, Makarfi, Sabon Gari and Zaria LGAs to investigate the effect of weather on RTAs. Thus, the major road networkshere which include road networks within Zaria Township, Zaria-Kaduna, Zaria-Kano, Zaria-Sokoto, Old Zaria-Kano and Zaria-Jos routes were studied. Rainfall, temperature, visibility, relative humidity, wind speed and evaporation rate were the weather parameters that were studied in order to examine the nature of association between weather and the occurrence of RTAs. The nature of association between these weather elements and the occurrence of RTAs in Zaria unit command was studied from 2001 to 2014.

1.6 Justification of the Study

In spite of the importance of transportation as a key driver and enabler of the economy, little research has been conducted around the world into how vulnerable it will be to climate change. This is surprising as lack of efficient and reliable transportation can severely impact on economic growth given that the influence of meteorological effects on RTAs and traffic disruption will have a negative impact on any economy. In fact, the global costs of road injuries are enormous; one report estimates the global costs of RTAsat about $518 billion annually in US dollars, and ranges in percentage of GNP from 0.3% in Vietnam to almost 5% of GNP in the USA, Malawi and South Africa (Jacobs, Aaron-Thomas and Astrop, 2000). The true costs to society are probably much greater since these estimates are based on direct costs only.

North-central and northwest geopolitical zones stand out as the first and second high risk zones in the country of which Zaria is located in the Northwest zone. However, little has been done to have an in-depth understanding of the circumstances surrounding the occurrence of RTAs here. Furthermore, little has also been done to understand the impact of weather on the occurrence of RTAs. In fact, available studies on weather and RTAs in Nigeria are recent and very few as compared to many studies on the subject in the developed countries as reported by Enente and Igu(2011). The need for this study is also due to the growing interest in understanding the relationship between climate change and transportation worldwide. In fact, the consequences of climate change and changing weather conditions for the transport sector have not received much attention in literature (The Stern, 2007; IPCC, 2007a).

CHAPTER TWO

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 System Theory of Accidents

Road accidents are seen as failures of the whole traffic system. It arises from interactions among humans, machines and the environment. It is not simply chains of events or linear causality, but more complex types of causal connections because under normal circumstances, chances of an accident are low. Road traffic accidents are seen as failures of the whole traffic system (interaction between the three elements) rather than a failure of the driver only. Under normal circumstances, chances of an accident are low. Rather than looking at the environment as being full of hazards and people prone to errors, system safety assumes that harmony (steady state) exists between individuals and the work environment. Thus, the driver is a victim as this assumes that the demands that the traffic system put on the driver is too complex for the driver's limited capacity to process information.

As a result of this assumption, the system must be designed to be less complex, which preventserrors from occurring. The system must also reducethe negative consequences of errors; introduce safety margins that allow the driver to incur an error without being hurt too seriously. This theory therefore enhances our understanding of the three major contributory factors of road accident including human, mechanical and environment. Thus, system theory is based on man-environment adjustment and maladjustments (Muhlrad and Lassarre, 2005) and the components of the theory are the environment, means of transportation (vehicles) and the behavior of man (Krug, Sharma and Lozano, 2000) enhancing our understanding of the major contributory factors leading to road traffic accidents.

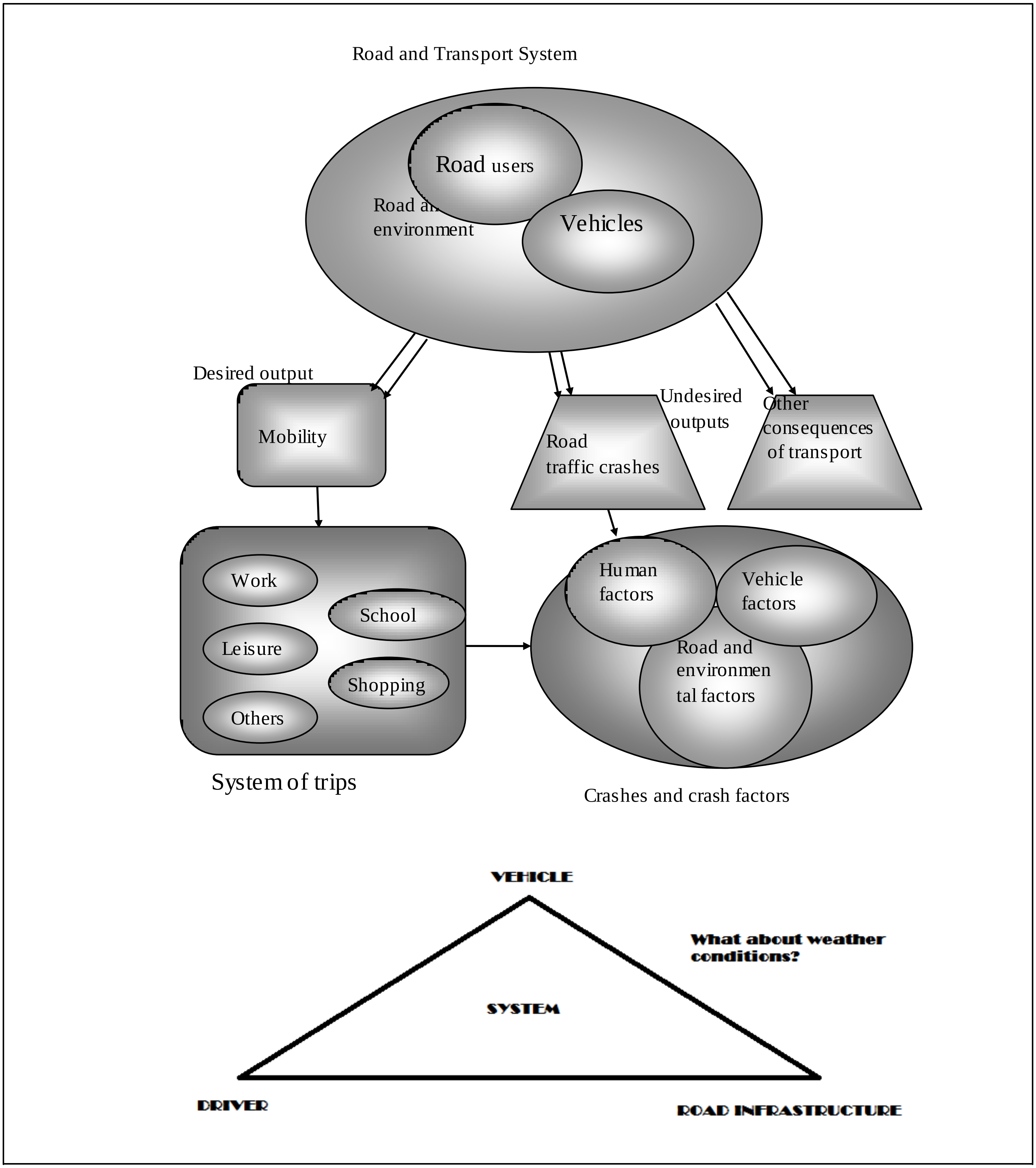


Figure 2.1: The System Theory Approach

Source: Road Traffic Injury Prevention Training Manual-WHO and New Delhi.

2.1.2 Jorgensen and Abane Model for Traffic Accidents

A model for traffic accident as inspired by the ecological model of a disease was developed by Jorgensen and Abane (1999) to suit road traffic accident analysis. This model is characterized by three main components:

i. The vehicle (corresponding to the vector in disease ecology) which describes vehicles into its composition, age, technical conditions and safety equipment like seat belts in a car

ii. The environment consisting of the road system and the wider physical and built up environment. The physical environment splits further into different aspects such as daylight and climate (weather conditions and road conditions), spatial conditions, settlement pattern, situation of areas of residence and work areas, principle of traffic separation, topology and road construction qualities.

iii. The behavior of the population including its characteristics such as sex ratio as well as attitude and general traffic behavior.

2.1.3 The Single Event Theory

This theory is based on the ‘assumption that an accident consists of a single event that has a cause. Find the cause, and you have explained the phenomenon. The investigative task is easy: find the cause and correct it and you will prevent accidents. This perception seems rooted in primitive history. If an unusual phenomenon occurred and there was no ready explanation for it, the survivors sought a scapegoat as the “cause” of the occurrence. Find the cause and the victims are satisfied. History offers numerous examples, including acts of God precepts which carry over into present day insurance policies. Anyone who has observed the media’s handling of an accident will recognize some evidence of this perception. While largely discredited by the scientific community, vestiges of this theory can be widely observed.

Accidents are still frequently defined as an “event” in safety publications and military investigation manuals, for example(National Safety Council, 1976). Many aspects of our legal system in the highway safety field also provide evidence of this perception, such as police citations for accidents, and some of the arguments about “no-fault” insurance legislation. Publication of accident cause statistics reinforces this view, and the use of these statistics in the media perpetuates it. It is a world-wide perception, as evidenced by the World Health Organization’s classification of the causes of death. The principal difficulty is that the view encourages an incomplete examination of the accident phenomenon.

2.1.4The Chain-of-Events Theory

The perception of sequential events is a popular perception of the phenomenon, widely recognized. Most of us have heard about the sequence that goes “for want of a nail the shoe was lost; for want of a shoe the horse was lost,” among others. The concept was adapted by Heinrich, who gave it the term “domino” theory in 1936 (Heinrich, 1936). His premise was that if a set of “unsafe conditions” (hazards) set up a row of vulnerable dominos, an “unsafe act” would start them toppling. Under this concept, the investigator looks for information that will help reconstruct the chain of events that constituted the accident. Then as now, the unsafe conditions lack criteria, as do the unsafe acts.

These terms represent the investigator’s conclusions, rather than observations of the phenomenon. How investigators arrived at these conclusions was not disciplined by principles or criteria that would provide consistent and reproducible findings. The conclusions were descriptive and usually symptomatic rather than etiologic (Haddon, 1968). The indiscriminate mixture of events, conditions, factors and other kinds of entries does not facilitate understanding of the accident phenomenon or development of countermeasures for this researcher.

2.1.5The Determinant Variable Theory

The work of Greenwood and Woods (1951) and Newbold (1951) suggested the factorial view of the phenomenon. Their “accident proneness” concept was statistically inferred by examination of available data. The focus on static conditions reflected the view expressed by Thorndike (1951) of the search for the experimental ideal of the single independent variable, and set the goal and ideal of an accident investigation as the gathering of data in such a way that statistical comparisons will permit fair estimates of the influence of variables in a particular factor on the probability of an accident. This included precursor conditions of the actors involved in the accident. The view assumes that some common factors are present in accidents, and that they can be discerned from the right accident data.

Therefore, this view led to the admonition to investigators to get all the facts about an accident. Hypotheses can only be generated after the fact. By not prescribing the scope, relevance tests and other data specifications, the theory and its operation require the investigator to make these decisions according to the investigator’s best judgment. The result is that no accidents are reported in a reproducible manner, even when trained investigators use reporting forms. Such reports are almost totally dependent on the conclusions from findings and judgments with respect to causes or causal factors.

These theories are important to the present study as they attempt to carry out accident investigation by trying to identify the causes and solutions of RTAs, therole of the environment being one of the components to be considered when dealing with RTAs, the gathering of data in such a way that statistical comparisons will permit fair estimates of the influence of various variables of a particular factor on the probability of an accident. However, system theory and the determinant variable theory were adopted, modified and used for this study owing to established facts stating that the occurrence of road accidents in hazardous weather conditions (rainfall, fog, snowfall and wind) broadly follows the regional weather patterns for those conditions.

2.2 Literature Review

Too often, road safety is treated as a transportation issue not as a public health issue, and road traffic injuries are called “accidents,” though most could be prevented. As a result, many countries put far less effort into understanding and preventing road traffic injuries than they do into understanding and preventing diseases that do less harm.Every day, as many as 140,000 people are injured on the world’s roads. More than 3,000 die and some 15,000 are disabled for life. Each of these people has a network of family, friends, neighbors, colleagues or classmates who are also affected emotionally and otherwise. Families struggle with poverty when they lose a breadwinner or have the added expense of caring for disabled family members (Dinesh, 2004).

Furthermore, urban transport problems remain one of the most nagging problems in urban centers today. All over the world, attempts have been made to tackle the problems, yet the situation seems to get worse as cities are known to be centers of economic, social, cultural and intellectual activities. Among the most notable urban transport problems are traffic congestion and parking difficulties; longer commuting; public transport inadequacy; difficulties for non-motorized transport, less of public space, environmental impacts and energy consumption, accident and safety, land consumption and freight distribution (Aderamo, 2012). With the rapid development of any economy comes road transportation system which is playing an increasing role in bringing about a comprehensive transportation system. However, the occurrence of traffic accident shows a rising tendency as a result of the quick growing of motor vehicles (Ali, Ieyla, Ahmad and Abdolreza, 2011).

Road Traffic accident can be said to be an unplanned occurrence of auto crash that may result in injuries, loss of lives and properties. RTA is having a worsening effect on our society and economy. RTA claims the largest toll of human life and tends to be the most serious problem all over the world (Kual *et al.*, 2005). Worldwide, the number of people killed in RTA each year is estimated at almost 1.2 million while the number of people injured could be as high as 50 million (WHO, 2004). Currently, motor vehicle accidents rank 9th in order of disease burden and are projected to be ranked 3rd in the year 2020. Nearly three-quarters of deaths resulting from motor vehicle crashes occur in developing countries (Odero, 1998) and this problem appears to be increasing rapidly in these countries (Jacobs, Aaron-Thomas and Astrop, 2000).

Both the World Bank and the World Health Organization, in independent studies, have calculated that, worldwide, there are around 500,000 fatalities and 15 million injuries per annum as a result of road accidents. Earlier estimates also suggest that about sixty percent of these deaths and injuries take place in those countries of Africa and Asia which are classified by the World Bank as low or middle income (WHO, 2004).

2.2.1 Observed Trends of Some Meteorological Parameters

Anyadike (1992) examined the variations of rainy season rainfall over the Southern, Middle Belt, and Northern regions of Nigeria as well as the country as a whole over a 72-year secular period (1916–1987). He investigated the extent and nature of nonrandom changes, such as fluctuations, trend and persistence. The trend analysis showed a tendency towards decreasing seasonal rainfall totals in all the regions. According to his evaluation, the Northern region and the country as a whole were significant; no significant persistence was evident in any of the regions during this secular period.

Ogolo (2002) studied the trend of Pan Evaporation in four different climatic regions (Sahel, Mainland, Guinea Savannah and Coastal/Tropical Rainforest) covering about twenty one Tropical stations in Nigeria (during the period 1970 to 2000). The influence of meteorological variables was tested and found to have significant impact on the spatial and temporal trends of pan evaporation for three consecutive decades across the different regions in Nigeria. Mann-Kendal Statistical Test was carried out to investigate the trend. A decade to decade trend analysis was carried out for three consecutive decades over all the regions. A general downward trend was observed in all the regions except Sahel region in the first decade under consideration. The decade (1970-1979) coincides with the period when there was a Global Solar Dimming.

However, the other decades witnessed an upward trend in PE for all the Climatic Regions across Nigeria. The general trend analysis of PE for Nigeria shows that about 80% of stations involved in the study experience upward trend (development of arid condition) out of which only 50% were significant. The other 20% showed a downward trend (creation of humid condition) with none significant. Further trend analysis was carried out on the seasonal months and this revealed that all the wet season months (April-October)exhibits downward trend for all the regions while similar trend regime was established for dry season months (December –March) in Sahel and Guinea Savannah and upward trend for Midland and the Coastal/Tropical Rainforest. Evidence of Pan Evaporation paradox was also established for a certain period in Nigeria. In addition, further investigation on the spatial variation of Epan revealed a gradual latitudinal increase from the coastal stations to the arid stations.

Akpodiogaga-a andOdjugo (2009) attempted to quantify the cost of climate change impact in Nigeria with emphasis on wind and rainstorms.Wind related hazards have not been adequately acknowledged as an environmental problem like flooding and gully erosion by the Nigerian Government. This is in spite of the fact that it claims lives, destroys buildings and social infrastructure annually. This prompted this study that dwell on quantifying the cost of climate change impact in Nigeria with special emphasis on wind and rainstorm hazards on building and infrastructures between 1992 and 2007. Climate data (air temperature, rainfall, wind speed) and cost of wind/ rainstorm damage were collected from 12 out of the 36 states in Nigeria. Time series, graphs and chi-square were the statistical tools used to evaluate the relationships between climate elements and rate of damage.

The results showed evidence of climate change with increasing temperature and wind speed and decreasing rainfall on the other hand. Wind and Rainstorm damage show evidence of seasonality, which is higher at the beginning and end of the rainy season, following the movement of the Inter Tropical Convergence Zone. Total lives lost were 199 persons and cost of property damaged worth N85.03 billion ($720.6 million). It was recommended that while causes of climate change should be minimized, adequate developmental policies and planning that focus on wind and rainstorm hazards' awareness and preparedness should be vigorously pursued by both individuals and the government.

Ogolo and Adeyemi(2010) studied the variations and trends of some meteorological parameters over a tropical-humid station, Ibadan (07026'N, 03˚ 54΄E) in the southwestern part of Nigeria have been observed using daily mean data of each of the parameters taken at the International Institute of Tropical Agriculture (I.I.T.A.), Ibadan, between 1988 and 1997. The meteorological parameters show a decreasing trend which is not statistically significant except those of rainfall and relative humidity data series that show an increasing trend which is statistically significant when the Mann-Kendall (τ) and Spearman rho statistics were applied. Thus, the yearly series of the parameters show that solar radiation and evaporation rate have significant decreasing trend, while other parameters show an increasing trend that is not statistically significant. It has also been found that the annual variations of the parameters are in synchronism with the North South movement of the surface Inter-tropical discontinuity (ITD).

Adaramola and Oyewola (2011) studied the wind speed distribution and characteristics in Nigeria. The aim of this research was to review wind speed distribution in Nigeria and discuss the potential of using this resource for generation of wind power in the country. The power output from a wind turbine is strongly dependent on the wind speed and accurate information about the wind data in a targeted location for wind turbine is essential. The wind speeds in Nigeria range from about 2 to 9.5 m/s based on recent reported data and the trend show that wind speeds are low in the south and gradually increases to relatively high speeds in the north. The areas that are suitable for exploitation of wind energy for electricity generation as well as for water pumping and small scale applications were identified. Also some of the challenges facing the development of wind energy and suggested solutions were presented.

Obasi and Ikubuwaje (2012) carried out an analytical study of rainfall and temperature trend in catchment states and stations of the Benin- Owena River Basin, Nigeria. The impact of climate change is felt worldwide, but the effects are more devastating in countries where flooding or drought has occurred. Therefore, in the Nigerian context, the impact of climate change is felt majorly in terms of rainfall and temperature. It is on the basis of their variations that the analytical study of their trend is carried out in some catchment states of Nigeria using the Benin-Owena River Basin as case study. Climatic data of rainfall and temperature for 35years were collected and subjected to Cumulative Summation (CU-SUM) and the rank-sum tests. The trend analysis shows that as temperature increases there is a corresponding increase in rainfall. The trend also indicates that no significant departure of these climatic parameters occurred. The least square regression (r2) and the trend as generated from the Microsoft Excel computations show that the temperature variation ranges from 0.4% in Delta to 3.5% in Edo, an indication that the temperature conditions in states understudy are not uniform even though the trend shows an increase. The rainfall least square regression variation ranges between 0.2% in Zaria and 2.7% in Plateau states, implying that the rainfall is varying in an upward trend.

Akinsanola and Ogunjobi (2014) investigated rainfall and temperature variabilities in Nigeria using observations of air temperature (^{o}C) and rainfall (mm) from 25 synoptic stations from 1971-2000. The data were analyzed for the occurrences of abrupt changes in temperature and rainfall values over Nigeria while temporal and spatial trends were also investigated. Statistical approach was deployed to determine the confidence levels, coefficients of kurtosis, skewness and coefficient of variations. Analysis of air temperature indicated that in the first decade of 1971-1980 anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations (Lokoja, Kaduna, Bida, Bauchi and Warri) shows positive anomaly while greater portion of the country were normal with evidence of warming in the third decade of 1991-2000. Results further indicated that there have been statistically significant increases in precipitation and air temperature in vast majority of the country. Analyses of long time trends and decadal trends in the time series further suggest a sequence of alternately decreasing and increasing trends in mean annual rainfall and air temperature in Nigeria during the study period.

Igwenagu (2014) studied the pattern of rainfall in Nigeria using data on the average rainfall for a period of eleven years was examined. The result showed a continuous increase in the pattern of rainfall for a period of five years within the period under study. However the pattern was inconsistence for the remaining year with some kind of fluctuations. Sequence plot showed a clear presence of trend with the peak period being the seventh year corresponding to 2008 within the period under study. Analysis result shows that the test is significance with p-value of 0.006 and coefficient of determination (R^2) value of 0.581. The model built was used to make predictions for a period of six years ahead; which shows continuous increase in the pattern of rainfall based on the available data. The irregularity in the pattern of rainfall calls for serious commitment in joining the force for climate change abatement process.

Oyewole, Thompson, Akinpelu and Jegede (2014) studied the variation of rainfall and humidity in Nigeria for thirty-one years (1979-2010).Annual rainfall and relative humidity for eight stations (Sokoto, Kano, Minna, Maiduguri, Lagos, Port-harcourt, Calabar and Ilorin) scattered over Nigeria were analyzed. The study was carried undertaken because rainfall is highly variable in both time and space, particularly in sub-humid tropical regions like West-Africa. The analysis was done using statistical package. The mean, standard deviation and coefficient of variation for both relative humidity and rainfall for the study area were calculated. The results shows that the range of the standard deviation for relative humidity for the study areas lie between7.0 and10.5 while its range of the coefficient of variation is between 0.02 and0.35.

Furthermore, coefficient of variation for the rainfall for the period of study is between 0.25and5.65, increasing from the coastal areas into the hinterland. The monthly analysis also show that period of highest rainfall falls between June or July and August or September for the locations nearest to the coast and those closer to the Sahara desert respectively. The trend of the rainfall in Nigeria within the study period is 0 .654per annum. This study showed that there is a direct relationship between rainfall and relative humidity throughout the months of the year and that the average yearly rainfall and relative humidity for all the study areas showed that rainfall and relative humidity are generally increasing in Nigeria.

Ekwe, Joshua, Igweand Osinowo(2014) carried out a mathematical study of monthly and annual rainfall trends in Nasarawa State, Nigeria.The research critically examined the monthly and annual rainfall patterns in Nasarawa State from 1993 to 2012 using data obtained from the archives of Meteorological Observatory at the College of Agriculture, Lafia, Nasarawa State. Statistical techniques like time series analysis, mean and standard deviation were employed to depict the temporal distribution of rainfall over the area. The study showed that 1996 was the wettest year while 2010 showed a year with the lowest negative rainfall deviation. In analyzing the months for the period, it was noticed that August recorded the highest rainfall value of 2498mm which is the month where clouds pervades the sky. The study also revealed a statistically significant stable decrease in annual rainfall in Nasarawa State.

Dammo, Yadima andSangodoyin(2016) studied the observed trend of changes in relative humidity Across North-East Nigeria from 1981 to 2010.Monthly relative humidity (RH) data for 6 stations in North-east Nigeria were provided by the Nigeria Meteorological Agencies. Mean RH variabilities, and trends calculated by the Mann-Kendal method are analyzed. The annual regional mean of RH ranged between 47.5±20.6%, with a clear maximum (62.5%) in Taraba and minimum (36.9%) in Borno. Extensive analyses of trends in mean monthly and annual relative humidity were examined also. Regression and analysis of variance were used to illustrate trends and calculate mean and annual rate of change. Results showed an inconsistent pattern of trend and a statistically significant stable increase in RH across these locations.

Nwokocha and Okujagu (2016) studied the atmospheric visibility trends in the Niger Delta region of Nigeria from 1981 to 2012.This study was undertaken because atmospheric pollution has been a serious threat in the Niger delta region that is the hub of oil production in Nigeria due to the rapidly expanding economic and industrial activities which has significant impacts on visibility. Visibility is a highly relevant factor indicating the level of air quality and inversely related to the optical extinction coefficient caused by gas and particle phases. Thus, a 31 years Horizontal visibility data for some coastal weather stations in the Niger delta region acquired from the Nigerian Meteorological Agency (NIMET) Abuja Nigeria was analyzed.

In this study, atmospheric visibility trends for six Niger delta cities (Akure, Warri, Owerri, Uyo, Calabar and Portharcourt) in Nigeria were evaluated for the period 1981-2012 using statistical techniques. It was observed that the yearly seasonal indices for the mean visibilities for the stations, Warri, Owerri, Akure, Uyo, Calabar and Portharcourt are 2.056817, 1.523725, 0.988518,-3.87354, -0.08079, and -0.6144 km respectively. Akure, Owerri and Warri have experienced a significant increase in visibility during the entire time series while for other three cities/stations Portharcourt, Uyo and Calabar shows decreasing visibility trends. The general dreadful conditions of visibility in these cities were probably due to the excess aerosol loading, oil exploration and exploitation in the region which leaves chunks of farmland, water bodies and the atmosphere severely polluted and degraded. Therefore, an urgent targeted reduction of atmospheric pollution may be needed to better air quality in the Niger delta region Nigeria.

The aforementioned studies helped the researcher achieve objective one of this research.

2.2.2 Traffic Flow and Road Traffic Accidents

A number of studies have been conducted to relate traffic flow with road crash propensity. Jean-Louis (2002) showed that damage-only and injury-involved incident rates are higher in light traffic than in heavy traffic conditions. He also compared the incident rates on the basis of time of the day and found that these rates do not depend on day time or nighttime traffic. Hasan, Bajwa, Horan and Chung (2011) have found that road accident probability on the freeway depends significantly on the traffic flow. They developed a regression tree by using traffic flow and speed at accident location, nearest upstream and downstream and concluded that road accidents depend more on traffic parameters: traffic flow and vehicle speed rather than weather condition.

On the contrary, Lord, Manar and Vizioli (2005) showed that the crash risk cannot be predicted perfectly only by traffic flow but adding traffic density so improves the prediction performance. Furthermore, they also described the comparative difference of crash density relationship between urban and rural freeways. For the same flow and density, it has been found that crash rates are much higher on urban freeways than the rural ones. Dickerson, Peirson and Vickerman (1998) revealed significant differences in accident - traffic flow relationship by road class and geography. Their outcomes are based on all types of accidents regardless of severity level. Accident probability also depends on type of vehicles (Ayati and Abbasi, 2011). Non-passenger car vehicles are found to cause more accidents on urban highways than other vehicle types. Interestingly, it was shown that heavy vehicles cause less accident than non-passenger cars including taxis and motorcycles.

2.2.3 Road Traffic Accident Fatality

Fatalities as a result of road accidents have become more significant in Less Developed Countries in recent years. For example, in Africa, road accident fatalities have risen by over 300 percent since 1968, while over the same time period road accident fatalities in industrialized countries have fallen. There we some 500,000 road accident fatalities per annum, worldwide, of which around 70% occur in the developing world. While for example developed countries have experienced a decreasing trend since the 1960s, the fatality rate in African countries ranges from 10-fold to more than 100-fold of those in the United States (Jacobs, Aaron-Thomas and Astrop, 2000; Peltzer and Renner, 2004; Chen, 2010). Lagarde (2007) also reported that while South-East Asia has the highest proportion of global road fatalities (one-third of the 1.4million occurring each year in the world), however, the road traffic injury and mortality rate is higher in Africa (28.3 per 100,000 population) compared with 11.0 per 100,000 persons in Europe. Indeed, if major challenges are not made to reverse the trend, it is feared that road traffic crash fatality rate in Africa as a whole is anticipated to increase by 80 per cent between 2000 and 2020.

Nigeria has the highest rate of fatalities from motor accidents in Africa according to statistics compiled by FRSC. Nigeria leads 43 other nations with 230 deaths Per 10,000 vehicle crashes followed by Ethiopia, Malawi and Ghana with 219, 183 and 178 deaths per 10,000 vehicles respectively (Daramola, 2004). International comparison indicates that the chance of a vehicle killing someone in Nigeria is 47 times higher than in Britain. The proportion of fatalities to injuries reported is also very high. For example, while Czech Republic has only one death in 197 accidents, France, one death in 175, South Africa, one death in 47 accidents, Nigeria has one death in 2.65 accidents (Atubi, 2010a).

Accidents may be fatal resulting to death of the road users (passengers, drivers or pedestrians), or minor when it is not severe enough as to cause substantial hardship (Agbonkhese *et al.*, 2013). Road accidents are usually classified as being fatal if a victim dies within 30 days of the accident occurring. The Fatality Index is usually defined as the percentage of fatalities out of the total number of road accident casualties; it is expressed in the following equation:

Fatality = Fatalities x 100 ⁄ Total Casualties

2.2.4 Causes of Road Traffic Accidents

Agbonkhese *et al.* (2013) opined that causes of road traffic accidents depend on a list of factors which can be broadly divided into:

i. Vehicle operator or driver factors
ii. Vehicle factors
iii. Road pavement condition factors
iv. Environmental factors.

2.2.4.1 Driver Factors

Driver factors in road traffic accidents are all factors related to drivers and other road users. In Nigeria, studies and road traffic accident records have clearly shown that the attitude of the Nigerian driver to driving code and etiquette is the single most important contributing factor as driver factors solely contributes to about 57 percent of road traffic accidents and 93 per cent either alone or in combination with other factors (Agbonkhese *et al.*, 2013). Driver-related issues include:

2.2.4.2 Speed and Indiscriminate Use of Sirens

An increase in average speed is directly related both to the likelihood of a crash occurring and to the severity of the consequences of the crash. Travelling too fast for prevailing conditions or above the speed limit contributes to road traffic accidents. The risk of being injured increases exponentially with speed much faster than the average speed. The severity of accident depends on the vehicle speed change at impact and transfer of kinetic energy. Though vehicles travelling slower than average speed are also at increased risk of road traffic accidents, most involved speed too fast for the conditions.

Aarts and Ingrid (2006) reviewed the literature on vehicle speed and road accident relationship and showed that road accidents increase significantly with an increase in speed on minor roads than on major roads. Similarly, Navon (2003) mentioned that excessive speed causes road crashes. He also described that the relationship between average speed and accident is not clear. Elvik, Christensen and Amundsen (2004) described that mean speed is positively related with frequency and severity of accidents since the number of road accidents increases with increase of speed. In order to develop the relationship between speed and safety, Aljanahi, Rhodes and Metcalfe (1999) found significant positive relationship between mean speed and accident rate. Similarly, Hasan, Bajwa, Horan and Chung (2011) also concluded that vehicle speed is a contributing factor to accident occurrence on freeway. Also, Taylor, Lynam and Baruya (2000) discussed the results of driver based and road based Previous studies, and mentioned that higher speed causes more accidents. The outcome of the study showed that approximately 1 km/h decrease in average speed can reduce accident occurrence rate by 2% - 7%.

In order to relate the speed limit and fatal crash, Ossaiander and Cummings (2002) found that in Washington (USA) speed limit and fatal crash occurrence have positive relationship, the higher is the speed, more number of fatal accidents occurs. However, the relationship between speed limit and all types of accident rate is not so clear. While aiming to assess the effects of traffic congestion on the frequency of crash rate by using spatial analysis approach, Wang, Quddus, Ison and Wang (2009) found that traffic congestion has no impact on the frequency of accident occurrence (either for fatal crash or slight injury crash).

2.2.4.3 Drunk–driving and Use of Drugs

Drinking and driving increases both the risk of a traffic accident and the likelihood that death or serious injury will result. The risk of being involved in a traffic accident increases significantly above a blood alcohol concentration (BAC) of 0.04 g/dl. Doctors often advise patients to abstain from driving vehicles or operation of machineries while under certain drugs as these drugs are known to cause side effects of sleepiness and fatigue thus leading to possible occurrence of accident.

2.2.4.4 Distracted Driving

There are many types of distractions that can lead to impaired driving, but recently there has been a marked increase around the world in the use of mobile phones by drivers that is becoming a growing concern for road safety. The distraction caused by mobile phones can impair driving performance in a number of ways, for instance, longer reaction time (notably braking reaction time, but also reaction to traffic signals), impaired ability to keep in the correct lane, and shorter following distances. Text messaging also results in considerably reduced driving performance, with young drivers at particular risk of the effects of distraction resulting from this use. Drivers using a mobile phone are approximately four times more likely to be involved in a traffic accident than when a driver does not use a phone. Hands-free phones are not much safer than hand-held phone sets as they too have been recorded to result in traffic accidents when shocking news is received while driving.

2.2.4.5 Inexperience and Unqualified Drivers

Majority of Nigerian drivers do not possess the right authorization from government authorized agencies like the Federal Road Safety Commission, FRSC and are unqualified before driving cars on road pavements. This is the major reason most Nigerian drivers are ignorant of highway codes or traffic orders. They put their lives and those of other road users at the risk of traffic accidents. As a result of their inexperience, since they were never given any tutorial or taught how to use their vehicles on highways by government accredited driving schools, their decision making ability and reaction speed to traffic is bad.

2.2.4.6 Nonuse of Safety Devices

Seat belts are safety device provided to safeguard a driver in the course of an accident. The use of vehicle seat belts also helps to ensure that the driver is in an upright and comfortable position thus enabling him/her to operate the vehicle properly. However, this safety device that has beenprovided by manufacturers has been grossly abused thus increasing the risk of fatality among front-seat and of rear-seat passengers. Also, majority of motorcyclists or their passenger do not wear helmets while plying the road thus exposing themselves and indeed other road users to road traffic accident.

2.2.5 Vehicle Factors that Encourage RTAs

The vehicle itself is a key factor when analyzing the remote causes of a traffic accident and it is incorporated with gadgets like, the horn, side mirrors, wipers, braking system, trafficators, headlights and break-lights (to mention just a few) so as to avoid road accident. Malfunction of any vehicle part such as tyres, engines, braking systems, light systems can cause road traffic accidents. The reliability of a vehicle is a function of the condition of the vehicle at any given time. Vehicle components and vehicle maintenance are the two main conditions which affect vehiclesand can easily cause road traffic accidents if not properly managed.

2.2.5.1 Vehicle Components

The assembled components of a vehicle working effectively uniformly or abnormally as a unit will determine the occurrence of a traffic accident.

2.2.5.2 Vehicle Design

The specific maximum load designed for a vehicle in its entire ramification goes a long way towards determining its stability on the road surface. When vehicles are subjected to stress over and above the provisions of the design specifications as is the case of a lot of vehicles plying the Nigerian roads, deterioration for the condition of the vehicle in accelerated wear and tear sets in. Design defects affect the subsequent condition of the vehicle once it is put on the road and operated either normally or otherwise which may result to possible road traffic accidents.

2.2.5.3 Vehicle Brake System

Brakes are generally applied to rotating axles or wheels. Vehicles use a combination of braking mechanisms which works jointly with the accelerator as the main synchronizer of the speeds of vehicles. Any malfunctioning of the brake sub-system should be taken very seriously as a potential source of unavoidable accident.

2.2.5.4 Vehicle Body and Tyres

The firmness of the structure of a vehicle is a less prominent attribute to some measure in causing road traffic accidents. One of the dominant factor in determining the stability and safety of vehicles on the road is the tyres. Tyres designed and specified for cold regions are not those specified for tropical regions like Nigeria. However, this is not the case of most tyres used in Nigeria as vehicle owners do not take the specification of tyres into consideration when buying and fixing tyres onto their vehicles and this has been known to cause tyre raptures thus leading to traffic accidents. Some other tyre related causes of road accidents could be due to one or a combination of overinflated tyres, underinflated tyres, or if the thread of tyres are thoroughly worn out.

2.2.5.5 Vehicle Lights

The failure of vehicle light is a major factor in road traffic accident. Failure of vehicle lights has a tendency to misinform and mislead other road users thereby providing a good opportunity for an accident to occur. Vehicle lights are very useful at all times during the daylight, in darkness and in poor/bad weather. For example, a failed trafficator light of a vehicle ahead of other vehicles will not provide the usual warning to those vehicles behind it that it is about to undertake or stop and if for instance the driver of the vehicle behind has not allowed for a sufficient stopping sight distance or the vehicle has a faulty brake sub-system, this could result in an accident occurring.

2.2.5.6 Vehicle Engine

The power house and heart of the vehicle is the engine sub-system.It is responsible for bringing other parts of the vehicle into motion and one whose sudden failure on a highway is more likely to cause an accident if the volume of traffic is sufficiently high at that point in time. Even when the traffic is reasonably low, its failure can lead an experienced driver to cause road traffic accident(s).

2.2.5.7 Vehicle Maintenance

Acquiring a well-designed vehicle and putting it onto road use is not enough to prevent the vehicle from causing road traffic accident. Actually, not performing routine maintenance and checks on the vehicle can lead to deterioration of the vehicle sub-systems and thus expose the vehicle to causing road traffic accident as a well maintained vehicle is less likely to be involved in accidents. For example, if the brakes and tires are good and the suspension well-adjusted, the vehicle is more controllable in an emergency and thus, better equipped to avoid accidents.

2.2.6 Cost of Road Traffic Accidents

The socio-economic costs of RTAs in Nigeria are immense and the direct cost of traffic casualties can perhaps, at best be understood in terms of the labour lost to the nation’s economy (Adekunle, 2010). It has been estimated that persons injured in accidents on Nigerian highways and streets no longer participate in the economic mainstream and this amounts to a loss of labour force which amount to millions of persons yearly in this nation (Pratte, 1998).

Adekunle (2010) opined that the cost to society such as loss of able bodied men and women who hitherto, would have been involved in productive economic activities, loss of intellectuals in our schools, loss of resources to government and families, to insurance companies and damage to properties among others are inestimable. Again, valuing the psychosocial impact on victims is another difficult task. Issues like suffering, injuries and loss of life associated with road traffic accidents is difficult to assign monetary value. According to Onakomaiya (1991), with injuries, people often suffer physical pain and emotional anguish that is beyond any economic compensation. Permanent disability such as paraplegia (paralysis of the lower half of the body), Quadriplegia (paralysis of all four limbs), loss of ability to achieve even minor goals that result in dependence on other people for economic support and routine physical care which may be although not in all cases for the rest of the victim's life.

2.2.7 Trend of Road Traffic Accidents in Nigeria

The world road accident problem dates back to 1863 when J.J. Lenoir built the first car in Paris, France. It was not until after 1896 that the first motoring facility was experienced. However, the first recorded death due to mechanical vehicle in the United States of America was in 1899 (Haddon, 1968). Nigeria recorded her first traffic accident in Lagos in 1906 (Oluduro, 1999). For more than half a century thereafter, accident rates in the country remained low due largely to low vehicular population (Ogunsanya, 2004). From the 1970s following remarkable improvements in the economic prosperity in the country arising from the oil boom, the magnitude of the accident problem increased.

According to Ogunsanya (2002), the period witnessed a substantial increase in private vehicle ownership (motor car fleet was reported to have increased by 183% between 1978 and 1987). This was followed by the economic recession of 1980s characterized by increasingly inadequate and poorly maintained road infrastructure. The situation today has been exacerbated by the near absence of alternative modes of transportation as an estimated 90% of passengers and freight in

Nigeria rely on the road network with the attendant challenge of increased number and incidence of road traffic crashes.

As in other developing countries, a road traffic accident in Nigeria is one of the most serious problems in need of pragmatic solution. Yet this problem has been difficult to address probably because of the country's level of development. Nigeria is said to have the highest road traffic accident rates in Africa and the second in the world (Obinna, 2007). In Nigeria, road traffic accident situation over the last three decades has been particularly disturbing. In 1976, there were 53,897 road traffic accidents resulting in 7,717 deaths (Atubi, 2010a). Although in 1981, the magnitude reduced to 5,114 accidents but the fatality increased to 10,236 which mean that there was an average of 96 accidents and the situation in subsequent years has not been any better. The number of people killed in road accident between 1990 and 2005 rose to 28,253 and the fatality rate remains consistently high (Atubi, 2009a).

In 1976, there were 53,997 road traffic accidents resulting in 7,717 deaths. In 1981, the magnitude reduced to 35,114 accidents but the deaths increased to 10,236, while in 1984, Nigeria was said to have the highest rate of road traffic deaths in Africa and indeed the world over with the chances of a vehicle killing someone in Nigeria being 47 times higher than Britain (Ogunsanya, 2004). In 1988, there were 25,292 road traffic accidents with as high as 9,077 deaths. From these statistics, it can be deduced that as the number of accidents reduced, the number of deaths increased. Secondly using the 1988 accident data alone, it was observed that on the average, there was an embarrassing rate of 69 accidents and 24 deaths every day of that year.

Sadly, the character of Road Traffic Accidents in terms of frequency of occurrence and fatality rate has not changed over the years in Nigeria. An annual average of 8,153 crashes was recorded with 5,084 annual deaths and an average fatality rate of 5 per 100,000 populations (FRSC, 2012). The highest number of cases which is 11,341 cases was recorded in 2008 as against the figure of 8,477 cases in the preceding year. Since 2008 however the trend has been a declining one. Perhaps one can safely conclude that this may be attributed to the activities of the Federal Road Safety Corps which assumed full road safety responsibilities in 2007. In terms of spatial spread, the FRSC has shown that about 50% of the total accidents and fatalities were recorded in most of the states that constitute the North Central and North-Western zones. They are therefore ranked respectively as the first and second high risk zones in the country of which Zaria in Kaduna State is situated in Northwestern zone.

The aforementioned studies helped the researcher achieve objectives two and three of this research.

2.2.8 Road Pavement Condition and Environmental Factors

Nigerian highways are arguably one of the worst and most dangerous in the world as they are often poorly designed, necessary important road facilities like drains are not adequately provided for and to top it up, they are rarely rehabilitated and are in dilapidated states. The deplorable states of the Nigerian highways create a scenario that makes vehicles and other road users susceptible to road traffic accidents. This further confirms that road traffic accidents are not just caused by human error or drivers' negligence.

Environmental related conditions such as fog, sunrays, mist and rain in no small measure contributes greatly to the rate of road traffic accident in Nigeria today. Having stated earlier that most vehicles on Nigerian roads are poorly maintained, a poorly maintained vehicle for example on a rainy day is most likely to cause road traffic accident if the wipers are faulty and not functioning as the driver will be unable to see ahead

Weather as an environmental factor creates driving hazard but weather hazard is complexly related with road crash and needs more specific and distinguished research (Mondal *et al.*, 2011c). Contrasting reports on the impact of temperature and rainfall on road accident like Atubi (2010a) versus Mondal *et al.* (2011) on one hand and Scott (1986), Brijs, Karlis and Wets (2008) versus Yannis and Karlaftis (2007) have been documented. Atubi (2010a) in his study discovered that the month of July which falls under the long rainy season of southern Nigeria recorded the highest number of accidents. Thus, rainfall and road accidents had a positive relationship in this study area. The result was the opposite in India according to the report by Mondal *et al.* (2011c). On the other hand, higher temperatures appear to have a decreasing effect on accident frequencies and severity both at daily, weekly and monthly bases according to Scott (1986) and Brijs *et al.* (2008). The result was the opposite in the report by Yannis and Karlaftis (2007). Thus, it became paramount to study weather-road traffic accident relationship in Zaria in North western zone of Nigeria.

2.2.9 Climate Change

Climate change is almost invariably considered an issue of global interest. However, the extentto which climate changerepresents a problem is still a heavily debated issue; calculations onfuture damages associated with climate change, andtherefore also judgments about mitigationand adaptation costs to be made now, differ widely. For example, the influentialStern reportclaims that ‘the benefits of strong, early action considerably outweigh the costs’ (Stern, 2007). Specifically, assuming no mitigation efforts, the report estimates that climate change may cause a permanent decrease in annual global GDP of between 5% and 20%, thereby claiming justification for large mitigation efforts right now. Although the report has received wide attention, substantial criticism has arisen. For instance, Tol (2006) argues that for ‘water, agriculture, health and insurance, the Stern review consistently selects the most pessimistic study in the literature’. Another point of criticism comes from Nordhaus (2006), who focuses on the unusually low social discount rate of 0.1% used in the report. Since a near-zero discount rate gives a large weight to climate change damages in the distant future, GDP losses are large even when distant future damages are small. Using a discount rate that is more generally accepted Nordhaus (2006) shows that the extremely low discount rate used in the Stern report is the main reason for the unusually large damage estimates.

The main consequences of climate change as predicted by most of the existing climate models are an increase in global temperatures, changes in precipitation patterns, and sea level rise. In general, climate models predict that increases in temperature will be higher over land areas than over oceans and seas, higher in interiors of continents than in coastal areas, and higher when going from the tropics to the polar region in the Northern Hemisphere. The potential consequences of climate change for precipitation patterns are more complex, and depend largely on continental geometry (vicinity of water) but also on the vicinity and shape of mountains and on wind flow direction. In general the existing climate models predict that precipitation will increase in areas adjacent to the Polar Regions, and will decrease in areas adjacent to the tropics. Furthermore, tropical precipitation is expected to increase especially during the rainy seasons. Global sea level rise in 2100 for the six SRES (Special Report on Emissions Scenarios) marker scenarios ranges between 0.18 and 0.59 m above 1990 levels (Intergovernmental Panel on Climate Change, 2007c). The six SRES marker scenarios do not include additional measures for mitigation of greenhouse gas emissions, e.g., Kyoto measures are not incorporated. Also these estimates do not include further acceleration in the melting of the Greenland and West Atlantic ice shelves.

The consequences for global temperatures and sea level rise are almost certain orvery likely. Uncertainty islargest with respect to the consequences for precipitation patternsand wind strengths, storms and hurricanes. Furthermore,the effects are qualitative innature; the level of uncertainty surrounding climate change increases substantiallywhenquantitative effects are considered. Moreover, climate changes and the degrees to which theywill occurare different for different regions.Given these differences in climate change, it isobvious that impacts of climate change onthe transport sector will also differ across regions. Thus, itshould be noted that due to differences across regions inthe vertical movement ofland and coastal erosion, local sea level rise can be quite different at different locations, withobviousconsequences for changes in flooding probabilities.

2.2.9.1 Climate Change Impact on Global Transport Patterns

a)Passenger Transport (Pattern of Tourism)

Nicholls and Amelung (2008) investigate to what extent the increase in temperature affects the touristic attractiveness of countries in Europe. Their analysis shows that during the summer months Northern parts of Europe become more attractive, while Southern parts become less attractive. Moreover, the length of the holiday season in Northern countries increases. We may therefore expect a decrease in tourism from North to South, and, especially during the summer months, an increase in tourism from South to North. However, during spring and winter, the Southern countries become more attractive which may increase tourism to this region in these periods. Hamilton, Maddison and Tol (2005) made use of data on arrivals and departures of tourists from 207 countries. They model the impact of climate change on tourism and also find a shift from Southern to Northern countries. Next to the associated changes in transport patterns they also find a slight decrease in tourism related vehicle kilometers. The underlying reason is that people from the area that produces most of the tourism kilometers (North-Western Europe) stay closer to home.

b) Freight Transport (Shift in Agricultural Production)

Regarding the production of goods and services, the sector that will probably be affected most isthe agricultural sector. Ona global scale, increase in temperature may have asubstantial impact on patterns in production and the associatedpatterns in trade and freighttransport. Results from a broad based research project into the effects of climate changeon foodproduction on a global scale show that especially countries at higher longitudes will becomemore suited for food production (Easterling *et al.*, 2007). The climate in countries at lower longitudesamong which is the largest part of developingcountries will become substantially lesssuited, however. This will likely result in an increase in freight flows from developed to developing countries. It is difficult to quantify the effects, however, largely because of uncertainty in the extent of climate change, both globally and regionally,uncertainty in adaptation potentialand technological change, and uncertainty regarding socio- economic developments. The shift of food production from southto north will likely also hold atthe regional level, for instance, from South- to North-Europe and from South America to North America.On this level, however, uncertainty on the consequences for transport patterns and demand areeven larger than on aglobal scale.

c)Inland shipping: Economic Loss due to Low Water Levels

An obvious consequence of increasing temperatures is reduced ice cover on rivers and lakes in various regions across the globe, e.g., Great Lakes in Canada, rivers in Russia. Although it is recognized that this opens up possibilities for increased transport by water, few studies actually assess this potential. For instance, Lofgren, Quinn, Clites, Asseland Eberhardt (2000) showed that a positive effect of climate change may be a substantial reduction in ice cover on the Great Lakes in Canada, but they do not assess the (potential) positive consequences for the commercial shipping sector (see also Permanent International Association for Navigation Congresses, 2008). Another consequence of increasing temperatures is the clearing of ice at and around the North Pole. This may open up the possibility for sea transport on the Northwest Passage during at least several months per year. This route may provide opportunities for more efficient transport between North-America, Europe and Russia and Asia

Changes in temperature and precipitation also have consequences for water levels in rivers and thereby for the inland shipping sector. Specifically, low water levels in rivers may disrupt transport by water in river basins such as the Mississippi and the Rhine where many goods (bulk freight) are transported by barges. Low water levels will force inland waterway vessels to use only part of their maximum capacity, which may considerably increase transportation costs. Not much research has been done in this area. In a recent study on the consequences of climate change for shipping in the Great Lakes river system, Millerd (2005) estimates that increases in average operating costs may indeed be substantially higher. Specifically, using climate change scenarios for 2030 and 2050 from the Canadian Centre for Climate Modeling and Analysis, he estimates that compared to 2001, the average operating costs in 2030 will increase by 3–14% depending on the industrial sector, with an average of approximately 8%. Estimate for 2050 range from 6% to 22% with an average of 13%. Results of a similar exercise for the Middle Mississippi River are reported in Olsen, Zeppand Dager (2005). They estimate losses in shipper savings, defined as the difference between costs of shipping and costs of the cheapest transport alternative, due to low water levels for the period 1933–2002. Losses over the entire period amount to $77 million per year on average. Because of wetter weather conditions, the annual losses in the 1968–2002 periods were substantially lower ($25 million).

Shifting our attention to Europe, Jonkeren, Rietveld and Van Ommeren (2007)analyzed freight prices of approximately 2800 shipping trips on the river Rhine in the period January 2003 to June 2005. Approximately 70% of inland shipping in the EU is transported on the Rhine. Applying regression analysis to explain freight prices per ton, the study clearly shows increasing freight prices at decreasing water levels. It is estimated that in the period 1986–2004 there has been an annual average welfare loss of €28 million due to low water levels in the river Rhine.

d)Rail Transport: Infrastructure Failure and Accidents

Studies that investigate the effects of weather or climate change on rail transport and infrastructure are scarce. Duinmeijer and Bouwknegt (2004) studied the frequency and distribution of rail infrastructure failures due to adverse weather conditions in the Netherlands in 2003 is reported. Weather appeared to cause approximately 5% of all rail infrastructure failures (i.e. 5% of 8279 failures in the Netherlands in 2003), which is limited but far from negligible. Most of the weather-related failures were caused by high temperatures, icing, storm and lightning.Furthermore, 66 out of 5700 accidents and incidents in the US between 1993 and 2002, the reported primary cause was weather, a figure much lower than that for the Netherlands. Alternatively, when looking at the weather conditions at the time of the accident, snow, fog and rain seem to account for 131, 81 and 411 accidents, respectively. This would amount to approximately 10% of all failures, which would be more in accordance with the Dutch situation.

e)Air Transport: Delays, Cancellations and Accidents

For the aviation sector, wind speedis important because of its impacts on safety. Extremewind speeds imply thataircrafts are not allowed to land at the designated airport and have to landat alternative airports. This has large cost implications both for the airlines and the travelers. In asimilar vein, high winds imply that the departure of aircrafts will be delayed.Wind speeds andtheir directions also have implications on the use of runways. Strong cross winds have an impactonthe probability of accidents. For example, one of the larger aviation accidents at Schipholairport was due to a landing of aTransavia plane in 1997 with very strong cross winds.Obviously, it is important for airports that sufficient runway capacityis available under variouswind directions. An underestimation of wind speeds and their directions may mean that wrongdecisionsare taken on the design of airports in terms of the capacity and orientation of runways.

The Netherlands Bureau for Economic Policy Analysis (2002) has estimated that in the case of Schiphol a ‘wrongly’ configured system of runways – implying that the number of hours that the airport cannot be used is unnecessarily long – may lead to a negative welfare effect in the range of 0.6 and 2.8 billion Euro (net present value in Euro for the period 2002 to 2040), where the variation depends largely on the underlying assumptions with respect to economic development and global competition. However, wind is not the only factor. A good example of economic loss due to other types of bad weather is San Francisco International Airport. A study by Eads, Kiefer, Mendiratta, McKnight, Laingand Kemp(2000)showed that poor visibility in the summer months and rain storms in the winter months lead to substantial delays and numerous cancellations. Compared to a good weather, cancellations per day increase by a factor 2–3 in the morning when the weather is bad and by a factor 3–4 when weather is bad all day. Similar figures hold for the number of delay minutes per flight operated. Although these figures are based on fairly simple counts, they were gathered over two entire years, thereby reducing the probability that the patterns were caused by other factors.

Changnon (1996) showed that rain had a substantial increasing effect on the number of departures with a delay of at least 30 minutes at Chicago O'Hare airport at the end of the 1970s. He also includes figures from the National Transportation Safety Board, which confirm that adverse weather has an increasing effect on aircraft accidents, especially those with fatalities. Annual monetary costs associated with weather-related accident damage and injuries, delays and unexpected operating costs are estimated at $3 billion in US aviation (Kulesa, 2002).

f)Road Traffic Accident Frequency and Severity

Weather conditions have an effect on road safety. Several weather variables appear to be important. Stern and Zehavi (1990) investigated the relationship between hot weather and traffic accidents. They conclude that the risk of an accident increases with increasing heat-stress conditions. The largest increase was found to be in the category of single-vehicle accidents (Maycock, 1995). Fog and wind may have an increasing effect on the number of accidents (Hermans, Brijs, Stiers and Offermans, 2006). Most of them indicate a positive relationship between precipitation and frequency of road accidents (Brodsky and Hakkert, 1988; Jones, Janssen and Mannering, 1991; Levine, Kim and Nitz,1995; Edwards, 1996; Eisenberg, 2004; Shankar, Chayanan, Sittikariya, Shyu, Juwa and Milton, 2004; Chung, Ohtani, Warita, Kuwahara and Morita, 2005). An issue that appears to mediate the impact of rain and snow on road accidents is lagged precipitation.

Eisenberg (2004) shows that lagged precipitationwhich is rainfall the day or days before, substantially increases the impact of precipitation on road safety, implying that rainfall leads to a stronger increase in the number of fatal accidents after a dry spell. This is most likely caused by the fact that precipitation clears the oil that accumulates on roads during dry periods, thereby making roads slippery. It is also possible that people adjust their driving behavior slowly, implying relatively risky driving behavior in rainy conditions after a dry spell. A similar lagged precipitation effect is found by Levine *et al*. (1995) and Brodsky and Hakkert (1988).

Using negative binomial regressions, Eisenberg and Warner (2005) stated that even though precipitation increases accident frequency, it appears to decrease accident severity. Andrey, Mills, Leahy and Suggett (2003)also found out that the increase in the probability of an injury due to rain and snow is lower than the increase in the probability of an accident. Most studies show a substantial reduction in traffic speed due to adverse weather, and especially precipitation. For example, results from a study by Martin, Perrin, Hansen and Quintana (2000)range from 10% speed reduction in wet conditions to 25% speed reduction in wet and slushy conditions. Hranac, Sterzin, Krechmer, Rakha and Farzaneh (2006)used detailed traffic and weather data from 2002 to 2004 for the Baltimore, Seattle and Minneapolis-St. Paul metropolitan areas. Light rain causes reductions in free-flow speed and speed-at capacity around 3% and 9%, respectively. Reductions generally increase with rain intensity, with maximum reductions around 6–9% and 8–14% respectively.

For snow, the effects are larger; light snow causes reductions in free-flow speed and speed-at-capacity of 5–16%. Maze, Agarwal and Burchett (2006)used a dataset including four years of traffic data from the freeway system in the Minneapolis/St. Paul metropolitan area and weather data from three weather stations nearby the freeway network. They show that rain, snow and reduced visibility because clear reductions in traffic speed; up to 6% for rain, up to 13% for snow, and up to 12% for reduced visibility.

2.2.9.2 Behavioral Responses in Passenger and Freight Transport

In transport, behavioral reactions to adverse weather may occur in various ways. We can order them according to the well-known basic dimensions of trip generation, trip distribution, modal choice, route choice, temporal choice and speed choice (De Dios Ortúzar and Willumsen, 2001). With respect to the former pair, it is plausible that under adverse weather conditions, certain trips are cancelled, that shopping occurs nearby rather than further away (distribution short run) and that average commuting distance declines (distribution long run). Regarding mode choice decisions, car drivers may, for instance, be inclined to shift to public transport when precipitation increases congestion on roads.

Furthermore, another possibility is that people adjust their route choice based on expectations about changes in generalized transport costs of route choice alternatives. Travelers may furthermore change their time of departure, for example postponing a trip until it stops raining. The last dimension of change concerns speed choice. This choice element, already addressed in the previous section, can be considered as an instrument for car users to correct for the risk changes that occur under extreme weather conditions. Despite the many possible behavioral responses by travelers to adverse weather, the available empirical evidence is relatively limited.

a)Traffic Volume on Roads

Changes in traffic-flow andvolume reflect changes in demand for transport, changes in route choice and postponement of trips. Parry (2000) notes that during days with snow, inessential journeys are postponed or curtailed. Keay and Simmonds (2005) find an overall reduction in traffic volume in Melbourne of 1.35% on wet days in winter and of 2.11% on wet days in spring. Fridstrøm (1999) analyzes determinants of vehicle kilometers in Norway and finds a strong seasonal impact. The more minutes of light per day on one hand and the higher the mean monthly temperature on the other hand, the higher the number of vehicle kilometers. The number of days of snowfall per month has a negative effect on the total number of vehicle kilometers.

Chung *et al.* (2005) analyze the impact of rainfall on travel demand on the Tokyo Metropolitan Expressway using traffic counts and rainfall measured on a daily basis for the period 1998–2004. They found out that travel demand on weekdays decreases on average by 2–4% as rainfall increases from 1 to 30 mm per day. The effects on Saturdays and Sundays are much larger, ranging approximately from 4% to 14% and from 4% to 8%, respectively. In conclusion that, on the one hand, increasing frequency of extreme precipitation events under climate change may substantially decrease the number of trips on specific days, especially those for leisure purposes. On the other hand, increasing average temperatures and a decrease in average rainfall (depending partly on the region) will likely increase leisure trips. Given the relatively limited changes in averages, these effects are likely small, however.

b) Bicycle Use

There is some evidence that changes in temperature, precipitation and wind affect utility attached to bicycle use. Richardson (2000) finds that rainfall and both low and very high temperatures decrease the number of cycling trips. This pattern appears to be fairly general; low temperatures, strong wind and precipitation have a negative impact on the use of the bicycle (Goetzke and Rave, 2006; Winters, Friesen, Koehoorn and Teschke, 2007; Sabir, Koetse and Rietveld, 2008b). Bergström and Magnusson (2003) performed a survey among a thousand employees of four major companies in two Swedish cities. They find that there is a large decrease in the number of bicycle trips (-47%) and a large increase in car use (+27%) for commuting purposes during winter. Moreover, temperature and precipitation were among the most important factors for those who cycled to work in summer but not in winter.

Although bad weather certainly causes a reduction in the number of people who use the bike for commuting purposes, there is strong evidence that recreational cycling is more affected by bad weather than utilitarian cycling. Whereas most studies use a time series approach, Rietveld and Daniel (2004) perform a cross section comparison. They find that wind speed affects bicycle use in The Netherlands; municipalities with strong winds are found to have lower annual bicycle use than municipalities with moderate wind speeds.

c)Mode Choice Decisions: Passenger Transport

The impact of climate change on modal choice through infrastructure disruptions are therefore equally uncertain and empirical insights on this particular issue are absent. However, there are some insights into short run mode choice decisions under different weather conditions. Khattak and De Palma (1997) conduct a stated preference study among Brussels commuters in 1992, assessing their mode choice decisions under various circumstances. The results show that 69% of the respondents, next to their primary transportation mode, have access to an alternative transportation mode, but that only 5% actually switches between transportation modes according to season. This suggests that changes in weather patterns from summer to winter have only a small impact on modal choice, and specifically points to a limited substitution between car and public transport. This is not to say that no behavioral change takes place.

Furthermore, more than half of the automobile users indicate that they would change mode, departure time or route under adverse weather conditions, of which changes in departure time appears to be the most popular option. Further analysis suggests that flexibility of the activity is a very important factor for a change in mode choice. Also worth noting is that the use of weather forecasts have only a small increasing and statistically insignificant impact on the probability of a change in mode choice. A similar pattern emerges from an ordered probit analysis on ‘changes in departure time due to adverse weather’, with the added feature that greater flexibility in arrival time and departure at work time has a large impact on changing departure time. Since the sample used for these ordered probit analyses is rather small (N = 166) and includes car users only (i.e. car is primary transport mode), caution is required in generalizing the results.

Results from a revealed preference study by Aaheim and Hauge (2005) on the impact of weather on travel habits in Bergen (Norway) in 2000 suggests that the impact of weather on substitution between public and private transport is relatively small. The study also shows that travel distance decreases with precipitation, except for trips with commuting purposes. Therefore, although precipitation has a direct negative effect on the proportion of walking and biking trips, it has an indirect positive effect because of its decreasing effect on trip distance. The authors conclude that in some cases the indirect positive effect outweighs the direct negative effect.

Finally, using detailed trip information from a national transport survey and local and hourly weather conditions, Sabir *et al.* (2008b) estimate a multinomial logit model to analyze the impact of weather on mode choice in the Netherlands. The results suggest that strong winds and low temperatures discourage bicycle use and stimulate the use of the car and public transport. The reverse appears to be true for high temperatures. Precipitation has the most substantial impact on bicycle and car use, decreasing bicycle use and substantially increasing the use of the car. Although the results are insightful, a disadvantage of this study is that its analysis is based on mode shares, and as such does not distinguish between transport demand and mode substitution. Shifts in mode shares are thus interpreted as modal shifts, while they may also reflect cancellation of certain trips.

d)Mode Choice Decisions: Freight Transport

Similar to passenger transport, the impact of climate change on mode choice decisions in freight transport through infrastructure disruptions are uncertain. Empirical insights on this particular issue are therefore also largely absent. An exception is a study by Jonkeren, Jourquinand Rietveld (2008) as climate change is expected to affect inland waterway transport in most main natural waterways in Europe. For the river Rhine it is expected that in summer, more and longer periods with low water levels will occur, which was shown to increase transport prices per ton. One possible consequence of these higher transport prices is a deterioration of the competitive position of inland waterway transport compared to rail and road transport and thus a change in modal split.

In order to study this issue,Jonkeren, Jourquinand Rietveld (2008)used a GIS based network model which provides a tool for detailed analysis of freight transportation over extensive multimodal networks. They assess the effect of low water levels on the cost functions of transport operations for inland waterway transport in North West Europe under several climate scenarios. Assuming no climate change consequences for road and rail transport, it turns out that the modal shift effect is limited. Under the most extreme climate scenario, inland waterway transport is estimated to lose about 3.2 million tons annually in the part of the European inland waterway transport market considered, which amounts to about 5% of the current amount transported by barge in this market. Ultimately, modal shifts depend on relative transport costs and more detailed insights into the climate change consequences for costs of rail and road transport are needed. However, given that the direction of net effects for these two modes is highly uncertain, it is not likely that, on average, changes in transport costs will be substantial enough to cause large long run changes in the modal split in freight transport.

Although several studies on behavioral responses to adverse weather are available, it is clear that the impact of weather conditions on destination choice, route choice and departure time are under researched. Also the empirical evidence is scarce, many studies have important drawbacks, and many insights are lacking, implying that strong inferences on behavioral change in transport due to climate change are not possible at this point in time. Furthermore, most available studies focus on current weather conditions. When one is interested in the potential long run effects of climate change for transport, the impact of seasonal patterns are probably more relevant. For example, studies that try to gain insight into instantaneous responses to adverse weather, for instance transport demand and mode choice responses to rain or snow, do not take on board the question whether the number of trips is actually reduced, or that people just make the trip at a later time during the day or the week. Clearly, more detailed research is needed to obtain the necessary insights into behavioral responses in transport to climate change related shifts in weather conditions. Thus, this present study focused on RTA and the likely association that exist between RTA and weather in Zaria.

2.2.9.3 Physics behind Wet Road Crashes

Short discussion of the physics behind the wet road accident will be interesting even to readers of medical journals. Many researchers stressed that wet road traction deserves special attention during accident analysis. When a vehicle is running on the wet road at high speed, the rainwater flow through the tire tread grooves gives rise to the hydrodynamic pressure. The occurrence of this hydrodynamic force deteriorates the tire traction efficiency because it decreases the tire contact force (Cho, Lee and Yoo, 2006; Mondal *et al.,* 2008), so that the driving controllability and the braking performance become worse than those on the dry road. Rohde (1977) presented a classical model of the thin film wet traction problem by considering the tire tread element to be rigid and the pavement to be smooth. Burns (1976) reported that differential friction should be given major consideration in any pavement friction analysis. Differential friction is a term derived to describe the condition that exists when the individual wheel paths on which a vehicle rides have different or unequal coefficients of friction. There are also strong indications that differential friction may be as important a cause of wet pavement accidents as low friction level.

Furthermore, Persson, Tartaglino, Albohr and Tosatti (2004) in an article in Nature journal proposed a novel theory of "sealing effect" to analyze the rubber friction on wet and dry road surfaces. The theory showed that this cannot be due to hydrodynamics and proposed an explanation based on a sealing effect exerted by rubber on substrate "pools" filled with water. Water effectively smoothen the substrate thus reducing the major friction contribution due to induced viscoelastic deformations of the rubber by surface asperities. Ali, Al-Mahrooqi, Al-Mammari, Al-Hinai and Taha (1998) studied the problems of skidding, particularly during the wet season. A predictive relationship between the friction coefficient and the skid length was obtained. Minimum required values of friction coefficient were recommended for safe performance. On the basis of criteria such as those proposed in that study, recommendations were made to improve the skid resistance. Open-graded friction courses are strongly recommended to reduce wet weather skidding.

Thus, common experience is that rainfall creates driving hazard. It is also common perception that rainfall increases road crashes. Many researchers proved the positive correlation between rainfall and road crash. Gothié (2000) reported that twice the proportion of accidents occur on wet pavements than dry. A study has been conducted to assess the seasonal and weather effects on the frequency of road accidents in California. The weather was found to be a major factor affecting accident numbers. On very wet days the number of accidents was often double that of corresponding dry days. Most of these researches are concentrating on general relationship of rainfall and crash. But critical analysis of rainfall related crashes are not much available. The aim of the present study is among other targets study the effect of rainfall on road crash by analyzing risk of rain, dry spell effect and rain class effect.

2.2.9.4 Temperature and Road Traffic Accidents

According to Chen (2010), the impact of temperature on human, vehicles and road pavements can be assessed at both the seasonal and daily level. The variability in occurrence of numerous illnesses is linked to somewhat predictable seasonal trends in temperature.Medical disorders such as bronchitis, peptic ulcer and adrenal ulcer glaucoma are related to seasonal variation in temperature. Complication from this disorder can be expected at higher temperatures since the body responds to thermal stress by forcing blood into peripheral areas to promote heat loss through the skin. Heat exhaustion is relatively common reaction to severe heat and can include symptoms such as dizziness, headache and fainting. Often accompanied by dry skin, a body temperature above 36.5^0Cleads to confusion and sometimes unconsciousness as this affects the brain.

Furthermore, just as high temperature affects man, it also affects vehicles. Temperature affects the pressure in tyres causing the air in tyres to expand. Itaffects the pavement making it extremely hot which in turn damages tyres making them flat. High temperature can cause battery life to shorten and its fluid to dry up. When this happens, the internal part of the battery gets damaged and since heat causes car fluids to dry up, then it is expected of the engine to overheat. Temperature of about 32^0C can cause the temperature under the hood to reach more than 60^0C. High temperatures also lead to the frequent use of car air conditioner leading to the use of more power and therefore heating up the vehicle. Fuel pumps also fail especially for vehicles using petro blended with ethanol as alcohol boil at lower temperatures compared to regular petrol during hot day causing fuel to aerate before it reaches the engine. If the fuel pump fails, certainly the car will stall.

Furthermore, weather has been one of the primary factors that affect the performance of both carriageway and footways. The extent at which climate affect the pavement also depends on a number of factors such as characteristics of the pavement, traffic, underlying geology, geography and topography. Thus, high temperature and a large volume of heavy goods results in the deformation of roads.Thus, temperature changes lead to stress and deformation of every component of road infrastructural system because the materials will experience contraction and expansion in response to temperature changes. Structural temperature fluctuations are often separated into two major components: a uniform change and a gradient change which generates strains on structural materials. In the long-term, ambient temperature changes will have adverse effects on the materials used for infrastructure design. Transportation structures are constructed from materials chosen for their performance under design loads and environmental conditions.

Thus, the performance of pavements can change dramatically given changing conditions such as increasing temperature and changing sub-grade soil dynamics due to saturation and erosion. Higher temperatures can cause pavement to soften and expand. This can create rutting and potholes, particularly in high-traffic areas and can place stress on bridge joints. Heat waves can also limit construction activities, particularly in areas with high humidity. With these changes, it could become more costly to build and maintain roads and highways. On the other hand, certain areas may experience cost savings.

In fact, studies have been conducted to understand the relationship between temperature and road accidents. In some studies, higher temperatures appear to have a decreasing effect on accident frequencies and severity both at daily, weekly and monthly bases (Scott, 1986; Brijs, Karlis and

Wets, 2008). However, Malyshkina, Mannering and Tarko (2008) found that extreme temperatures (both low during winter and high during summer) are positively correlated with road accidents. On the other hand, when the monthly number of days with temperature below zero increases, road accidents are reduced possibly due to reduced exposure (Hermans, Brijs, Stiers and Offermans, 2006; Stipdonk 2008).However, the occurrence of road accidents in hazardous weather conditions be it rainfall, temperature, fog, snowfall and wind broadly follows the regional weather patterns for those conditions (Edwards, 1996; Khan, Qin and Noyce, 2008). Hence, the climate of any study area must be well understood in order to have a clearer understanding of the inter-relationship between weather and the occurrence of road traffic accidents as the relationship seem to be multidimensional.

2.2.9.5 Climatic Elements, Climate Change and Road Traffic Accidents

At saturation, a dynamic equilibrium exists between the rate of condensation and the rate of evaporation. For a liquid to evaporate, its molecules must vibrate with enough force to break the bonds holding them together. These vibrations can't happen without energy, so a liquid provided with more energy (in the form of heat) evaporates more quickly.Rate of evaporation depends on both the heat available to the liquid and the strength of the intermolecular forces between the molecules. Evaporation can be faster on sunny days not just because of the extra heat, but also because sunny days are often drier and so have lower relative humidity (Umoh, Akpan and Jacob, 2013).

Evaporation is the amount of water that is converted to vapor, which then rises into the atmosphere. When RH is low, evaporation will increase because the air can hold more water vapor. Cooler air will decrease the rate of evaporation since it reaches its dew or saturation point quicker. Conversely, warming the air will lower RH and diverge it from its dew point. This is why a furnace in a home during the winter will dramatically lower RH in a house since inside air is warmed many degrees higher than the cold air outside.

Relative humidity is a ratio of actual amount of water vapour (content) in the air compared to the maximum water vapour the air is able to hold (capacity) at that temperature. It is expressed as percentage. Relative humidity does not tell how much water vapour is actually in the air. But, it tells how close the air is to being saturated. So, air is said to be saturated or full if relative humidity is 100%. Relative humidity (Rh) is inversely related to the air temperature that is if temperature is increases, the Rh decreases and vice versa. That's why the Rh is higher at higher surfaces (temperature decreases with height), sun rising (minimum temperature) and lower at ground (temperature is greater than the higher surfaces), late afternoon(Maximum temperature).(Umoh, Akpan and Jacob, 2013).Similarly, there is a significant negative association between temperature and wind speed (Wooden, 2011).

Rain drastically modifies the visual environment of road users, particularly at night. It changes visibility through its effects on headlights, windshield, pavement and markings. Rain lessens the performance of headlamps and other light sources by filtering part of their luminous power, thus reducing the luminance on the roadway ahead of the vehicle. Rain affects the capacity of the driver to see through the windshield. Rain also affects visibility by changing the amount of headlight retro-reflected by the road surface toward the driver. The film of water on the pavement makes delineation and pedestrian crossing markings almost invisible by cancelling the retro reflective properties of the beads in the painting materials. The same physical phenomenon makes the pavement appear darker than in dry conditions (Umoh, Akpan and Jacob, 2013).

Weather conditions have an effect on road safety. Several weather variables appear to be important. Stern and Zehavi (1990) investigate the relationship between hot weather and traffic accidents. They conclude that the risk of an accident increases with increasing heat-stress conditions. The largest increase was found to be in the category of single-vehicle accidents (Maycock, 1995).Visibility and wind may have an increasing effect on the number of accidents (Hermans *et al.*, 2006). However, the most important variable is precipitation. Empirical evidence on the impact of rain and snow on the frequency and severity of road accidents is abundant.

Although, studies employ a wide variety of methods (least squares, Poisson and negative binomial regressions, matched-pair approach, mean differences, wet pavement indices) and display a fairly wide variety of outcomes in a quantitative sense, most of them indicate a positive relationship between precipitation and frequency of road accidents (Chung *et al.*, 2005; Eisenberg, 2004; Shankar *et al.*, 2004). Rather extreme increases in road accidents and injuries due to precipitation are found by Andrey *et al.* (2003) using data from mid-sized Canadian cities. On average, precipitation increases the number of accidents by 75% and the number of related injuries by 45%, with snowfall having a more substantial effect than rainfall.

An issue that appears to mediate the impact of rain and snow on road accidents is lagged precipitation. Eisenberg (2004) shows that lagged precipitationthat is rainfall the day or days before substantially increases the impact of precipitation on road safety, implying that rainfall leads to a stronger increase in the number of fatal accidents after a dry spell. This is most likely caused by the fact that precipitation clears the oil that accumulates on roads during dry periods, thereby making roads slippery. It is also possible that people adjust their driving behavior slowly, implying relatively risky driving behavior in rainy conditions after a dry spell. A similar lagged precipitation effect is found by Levine *et al.* (1995) and Brodsky and Hakkert (1988).

Although, precipitation increases accident frequency, it appears to decrease accident severity. For instance, using negative binomial regressions, Eisenberg and Warner (2005) estimate the effects of snowfall on US traffic crash rates between 1975 and 2000. They find that snow days had more nonfatal-injury crashes and property-damage-only crashes, but fewer fatal crashes than dry days. Andrey *et al.* (2003) also find that the increase in the probability of an injury due to rain and snow is lower than the increase in the probability of an accident. For rainfall both the number of accidents and the number of fatalities decrease. Finally, Khattak, Kantor and Council, (1998)use an extensive dataset with single-vehicle and two-vehicle traffic accidents in North Carolina in the period 1990–1995. They estimate an ordered probit model in which they distinguish between four levels of severity, i.e. fatality, severe injury, moderate injury, no injury. The dummy variable on adverse weather (rain, snow, sleet, fog) has a statistically significant but small negative impact on accident severity, i.e. accidents are less severe in adverse weather. The mediating effect in the observed pattern is likely that precipitation, and adverse weather in general, reduces traffic speed, thereby reducing the severity of an accident when it occurs.

Most studies show a substantial reduction in traffic speed due to adverse weather and especially precipitation. For example, results from a study by Martin *et al.* (2000) range from 10% speed reduction in wet conditions to 25% speed reduction in wet and slushy conditions. Hranac *et al.* (2006) use detailed traffic and weather data from 2002 to 2004 for the Baltimore, Seattle and Minneapolis-St. Paul metropolitan areas. Light rain causes reductions in free-flow speed and speed-at capacity around 3% and 9%, respectively. Reductions generally increase with rain intensity, with maximum reductions around 6–9% and 8–14%, respectively. For snow the effects are larger; light snow causes reductions in free-flow speed and speed-at-capacity of 5– 6%. Finally, Maze *et al.* (2006) use a dataset including four years of traffic data from the freeway system in the Minneapolis/St. Paul metropolitan area and weather data from three weather stations nearby the freeway network. They show that rain, snow and reduced visibility lead to a clear reduction in traffic speed; up to 6% for rain, up to 13% for snow, and up to 12% for reduced visibility.

There are some studies, however, that report slightly different results. For example, Lamm, Choueiri and Mailaender (1990)found out that there is no effect of wet pavements on traffic speed on rural highways in the New York state area. An important reason for this result is probably that only the speed of cars with a minimum time gap of 6 s were used, the focus of the study being to assess the purely behavioral response of drivers to wet pavements. This result seems to be more general applicable.

Furthermore, Unrau and Andrey (2006) find small rain effects at low volumes and large effects at high volumes. Furthermore, based on data from a national transport survey and local weather conditions in the Netherlands,Sabir, Van Ommeren, Koetseand Rietveld (2008a)employ panel data techniques to estimate the effect of adverse weather conditions on traffic speed. They discovered that temperature and wind have small or no effect (see also Maze *et al.*, 2006). Again, the effects of rain are small, except for trips made during rush hours in congested areas, where speed reductions are around 10–15%. The associated welfare loss is estimated at 88 eurocent per commuting trip.

In conclusion, these studies showed that the effects of temperature and wind on traffic speed appear to be small or not existent. Also the effect of rain on free-flow speed appears to be small, suggesting that the purely behavioral response of drivers to rain is limited. Likely the behavioral response is larger for heavy rain and snow. Furthermore, although the estimates from different studies are difficult to compare in magnitude, the impact of rain and especially snow on traffic speed at already congested routes and during peak hours appear to be substantial.Next to having an impact on mean travel time, adverse weather conditions may influence travel time reliability as well. This is an issue that has become increasingly important in transportation planning and research during the last two decades. In the literature travel time reliability may be measured in several ways, e.g. by statistical range methods, tardy-trip measures and probabilistic measures.

Thus, studies that analyze the impact of weather on reliability are scarce, however. An exception is a study by Tu,Van Lintand Van Zuylen(2007)for the Netherlands who analyzed the impact of rain, snow, ice, fog and storm on travel time variability which is measured as the difference between the 90th and 10th percentile of travel times on a specific route. They found out that on average, rain, snow, ice, fog and storm increase travel time variance. It is questionable, however, whether travel time differences at the route level are a good measure of travel time reliability, which is preferably measured at the trip level. It is likely that this study simply picks up that part of the car users drive slower under certain circumstances, which would reflect an individual specific change in travel time rather than a change in travel time reliability. Clearly, additional research is needed.

Therefore, the Stern (2007) and Intergovernmental Panel on Climate Change (IPCC) (2007a) reports analyze damages for, among others, the water, agricultural, health and insurance sectors.

A sector that receives fairly little (explicit) attention, however, is the transport sector. This is notentirely surprising, since to date the consequences of climate change and changing weatherconditions for the transport sector have not received much attention in the literature. Still, it iswidely known that transport systems on the whole perform worse under adverse and extremeweather conditions. This is especially true in densely populated regions, where one single eventmay lead to a chain of reactions that influence large parts of the transport system.

Until recently, the overwhelming majority of research outputs in the field was on mitigation, the central issue being the effectiveness and efficiency of measures to reduce the environmental burden of transport (Intergovernmental Panel on Climate Change, 2007b). More recently, policy makers have more or less accepted that certain climate changes cannot be prevented, and have therefore started to explore potential adaptation strategies. Of course, adaptation and mitigation strategies are interrelated, i.e. increasing adaptation opportunities imply decreasing urgency to implement mitigation measures, and vice versa.

There are several ways to examine the influence of climate change on transport. One possibleroute would be to comparetransport systems between regions with very different climateconditions, for example by comparing transport in Spain withtransport in Norway. Differencesin performance of road, rail and waterway transport systems give an indication of the potentialimpacts of climate change. One of the difficulties of this approach is that differences betweencountries are the resultof a whole range of factors, where in addition to climate also other factorsplay a role, such as the level of economic developmentand physical conditions. Anotherapproach to analyze the influence of climate would be to consider seasonal variationsin transportand travel behavior.

Thus, variations in travel behavior and performance of transport systems betweenseasonscan be partly explained by weather variations. For freight transport, variations in demandwill be related to seasonal cycles insome sectors, such as the agricultural sector. For passengertransport one also has to take into account non-weather seasonaleffects, such as Christmasholidays and the holiday calendar of schools, which may be partly correlated with weather. Athirdway to address climate issues would be to consider the instantaneous relationship betweenweather and travel behavior.This may be expected to lead to clearly visible adjustments, but oneshould be aware that these are typically short-termadjustments.

2.2.9.6 Accident Models

Mustakim, Yusof, Onn, Rahman and Samad (2008) proposed an accident prediction model based on the dataset of Federal Route 50 in Malaysia. In this study, they considered number of access point per kilometer of the roadway, hourly traffic volume, time gap between vehicle and 85th percentile speed. Multiple linear regression models resulted in good accuracy level. Similarly, Hong, Kim, Kim, Lee and Yang (2005) also used multiple regression methods in order to develop a crash prediction model but they focused more on road geometry compared to traffic conditions in choosing the independent variables. Road geometry was also considered as predictors in accident prediction model by Kalokota and Seneviratne (1994) but the selected geometry variables are different. Hong *et al.* (2005) chose number of intersections, connecting roads, pedestrian traffic signals, existence of median barrier and lanes, whereas Kalokota and Seneviratne (1994) selected degree of curvature, section length, vertical grade, number of lane, right shoulder width and traffic volume as predictors. This may be due to different site locations (urban and rural highways).

Eisenberg (2004) has developed a crash risk prediction model based on weather variables such as precipitation and snowfall. Negative binomial regression method was used in this study and accident frequencies were predicted in terms of fatality, injury and property damage only. Similarly, Shankar, Fred and Woodrow (1995) made accident frequency prediction model using negative binomial regression. They considered both the road geometry and weather factors to develop the model. Greibe (2003) developed prediction model based on traffic and geometric variables for urban area. Poisson regression model was used in this study. Pham, Bhaskar, Chung and Dumont (2010) developed a model using random forest method by disaggregated traffic data in order to identify the rear end crash on motorway. This study is able to differentiate non-crash and pre-crash situations by using this methodology. They concluded that speed within a lane need to be regulated in order to reduce rear end crash.

Rujun and Xiuqing (2010) proposed a neural network model for forecasting the road accidents based on eight years' accident data of China. The predictor variables used in this model were population, number of automobiles, road mileage and GDP per capita, and it is found that the rapid growths of these variables influence the rapid growth of accidents. In order to predict the accident risk related to environmental weather conditions, Durduran (2010) formulated decision making system (DMS) with the aid of geographical information systems (GIS). The analysis result has shown that DMS can predict accident with more significant accuracy than that of support vector machine (SVM) and artificial neural network (ANN). Gang and Zhuping (2011) developed a traffic safety model based on the combination of particle swarm optimization and support vector machine (PSO-SVM) by using the dataset of 36 years, from 1970 to 2006. The predictor variables used in the model were railway track in use, mobile car retention quantity, population size, passenger turnover volume and turnover volume of freight. It was found that the formulated model has more accuracy than that by BP neural network.

2.2.9.7 Quantifying Safety Benefits of Road Maintenance under Various Weather Conditions

Limited efforts have been devoted to the problem of quantifying the safety benefits of winter road maintenance under various weather conditions. Most of the past research is directed towards establishment of a link between weather and safety (Stern, Garder, Rubin and Olaf Johnson, 2011). Hanbali (1992) was among the first who studied effectiveness of winter road maintenance (salting) on safety. A before-after analysis was conducted on undivided and divided highways randomly selected in New York, Minnesota, and Wisconsin, U.S.A.

Therefore, accidents rates were compared over varied number of hours before and after salting and it was found that for divided highways there was a significant difference in accident rate two hours before and after salting while for undivided highways the difference was significant over four hours. It was found that on average, the accident rate was reduced by 87% and 78% for divided and undivided highways respectively. This study assumes that reductions in accident rates are only due to maintenance, ignoring the fact that other important factors such as storm characteristics and traffic volume could be different over the periods before and after salting.

Norrman *et al.* (2000) was among the first to attempt to quantify the relationship between road safety and road surface conditions. They classified road surface conditions into ten different types based on slipperiness, and then compared the crash rates associated with the different road types. The accident risk for a specific road surface condition type was defined as the ratio of the accident rate under the specific road surface conditions to the expected number of accidents for each month. These rates were then compared with percent of time maintenance was done when an accident occurred under some specific road surface conditions. This comparison showed that the frequency of maintenance operations associated with high accident risks is low. From this, they concluded that in general, increasing maintenance operation frequency could reduce the number of accidents.

However, the approach taken in that study has several limitations. Firstly therefore, it is an aggregate analysis, considering roads of all classes and locations together. This approach may mask some important factors that affect road safety. Secondly, the simple categorical method of determining crash rates may introduce significant biases if confounding factors exist, which is likely to be the case for a system as complex as highway traffic. Thirdly, the study uses the frequency of maintenance operations only, disregarding differences between various types of maintenance operations. The procedure cannot be used to compare the effect of different maintenance operations.

Fu, Perchanok, Miranda-Moreno and Shah (2006) investigated the relationship between road safety and various weather and maintenance factors, including air temperature, total precipitation, and type and amount of maintenance operations. They concluded that anti-icing, pre-wet salting with ploughing, and sanding have statistically significant effects on reducing the number of accidents. Both temperature and precipitation were found to have a significant effect on the number of crashes. Their study also presents several limitations. First, the data used was aggregated on a daily basis, assuming uniform road weather conditions over the entire day for each day of record. Second, their study did not account for some important factors due to data problems, such as traffic exposure and road surface conditions. One of the implications of these limitations is that their results are not directly applicable for quantifying the safety benefit of winter road maintenance of other highways or maintenance routes.

Usman, Fu and Miranda-Moreno (2011) attempted to establish a link between winter maintenance and winter road safety using data over three winter seasons from four maintenance routes in the province of Ontario, Canada. A generalized linear model was developed for collision frequency over individual snow storms and it was found that, in addition to some weather and traffic related factors, road surface conditions is a significant factor, suggesting that the model could potentially be applied for evaluating the effect of alternative maintenance standards.

Nordic countries have conducted extensive research on issues related to winter road safety and road maintenance. Wallman, Wretling and Oberg (1997) provided a comprehensive review on this body of work. In terms of research methodology, most of these studies relied on simple comparative analyses instead of rigorous statistical modeling. Nevertheless, the findings were in general consistent, showing that winter weather increases the risk of accidents by virtue of poor road surface conditions and that maintenance lowers the crash risk by improving road surface conditions.

In terms of safety modeling methodology, the most commonly employed approach for modeling accident occurrence is the generalized linear mixed (Poisson) regression. In particular, the standard Negative Binomial (NB) model with fixed dispersion parameter and its extension, the generalized Negative Binomial (GNB) model, have been found to be suitable in many road safety studies (Shankar, Mannering and Barfield, 1995; Hauer, 2001; Miaou and Lord, 2003; Miranda-Moreno, 2006; Sayed and El-Basyouny, 2006). Both models help dealing with over-dispersion, a common issue in crash frequency data (Maher and Summersgill, 1996; Miranda-Moreno, 2006, Lord and Mannering, 2010). In several applications, the GNB model seems to perform better than the NB in terms of goodness-of-fit. Other model settings have been also used such as the Poisson Lognormal (PLN) and Zero-inflated Negative Binomial (ZINB) models. The latter can deal with the over-dispersion problem due to excess of zero crash counts. However, ZINB has been criticized because of the assumption of a permanent safe state, which is against the logic of accident occurrence (Hauer, 1999; Lord, Washington and Ivan 2004; 2007).

The NB and PLN models have been also extended within a Bayesian framework, to deal with the spatial correction among locations as well as the correlation among crash outcomes, e.g., correlation of accident frequency outcomes classified by injury severity types (Miranda-Moreno, 2006). Some recent empirical studies have applied other model settings, to deal with some particular issues such as presence of subgroups (clusters) and under-dispersion of the data (Geedipally, Lord and Dhavala, 2012).

One of the main issues with most existing approaches to collision frequency analyses is that collision data are commonly aggregated at large spatial and/or temporal levels, which means that the resulting models cannot be applied for evaluating the safety effect of operational treatments such as winter road maintenance. While simpler in terms of modeling effort, such an aggregated approach could cause some serious problems, such as biased parameter estimates and reduced significance of some factors, due to loss of information (reduction in sample size) and averaging (Hutchings, Knight and Reading, 2003; Usman *et al.*, 2011). On the other hand, collision data at a disaggregate level may be correlated, which could result in biased models if used directly in model calibration. This issue can be partially addressed by using a model structure that is capable of accounting for this correlation, such as multilevel models (Goldstein, 1986; Goldstein and

Rasbash 1996; Caldas and Bankston, 1999; Ronald, Thomas and Loring, 2000; Steenbergen and Jones, 2002; Jones and Jørgensen, 2003; Schreiber and Griffin, 2004; Lenguerrand, Martin and Laumon, 2006; Gelman and Hill, 2006). The degree of correlation among observations within the same group (i.e., storm event in this research) is measured using intra-class correlation coefficient (ICC), denoted by ρ (Newsom and Nishishiba, 2002):

$$\rho = \frac{\sigma^2 wg}{\sigma^2 w + \sigma^2 wg} \quad 2.1$$

where$\sigma^2 wg$ is within group (storm) variance and $\sigma^2 g$ is between-group variance. Some studies (Goldstein, 1986; Usman *et al.*, 2011) have shown that in the absence of strong correlation within the groups, single level models could adequately capture the effects of the major factors. Thus, since road traffic accident under hazardous weather conditions is closely related to weather which vary from one region to another (Edwards, 1996; Khan, Qin and Noyce, 2008), this research seeks to understand the impact that weather has on the occurrence of RTA in Zaria. These studies helped the researcher achieve objectives four, five and six of this research.

Mondal *et al.* (2011c) in their work on weather and wet road related crashes presented a critical analysis on wet road driving conditions due to rainfall. RTA data was provided by Delhi Traffic police. A range of statistical techniques were used which include Rain Crash Index (RCI), Wet Crash Rate (WCRi),DryCrash Rate (DCRi), Rain Crash Effect (RCEi) and Rain Class Crash Rate (RCCRi). The results showed that about 19% of RTAs took place in wet days. This could be due to physical or psychological factors like the build-up of oil and dirt on the road surface or the slow mental realignment to wet conditions.

Enete and Igu (2011) examined interactions between rainfall characteristics and roadcrashes inEnugu, Nigeria using indices such as Rain Crash Index (RCI), Wet Crash Rate

(WCRi),DryCrash Rate (DCRi), Rain Crash Effect (RCEi) and Rain Class Crash Rate (RCCRi). The studyestablished that 29.8% of road crashes in Enugu occurred during wet months of 2009, with thehighest wet crash occurred in the month of June (28 crashes). It was also found that the effect ofrainfall on road accident count depends on the length of time since the last rainfall. Large dryspelldays recorded more accident counts. Higher temperatures increase accident frequencies(Scott,1986). Extreme temperatures (low in winter and high in summer) are positively correlatedwithroad accidents. Also, the number of hours of sunlight appears to increase road accidents(Fridstom*et al.*, 1995; Hermans *et al.*, 2006), while deviations from mean daily or monthlytemperatureshave also been found to increase road accidents (Brijs *et al.*, 2008; Stipdonk, 2008).On the otherhand, increases in sub-zero temperatures days, lower exposure thus reducing thenumber of roadaccidents (Hermans *et al.*, 2006; Stipdonk, 2008).

The aforementioned studies helped the researcher achieve objectives five and six of this research.

CHAPTER THREE
STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1 Location and Size

Zaria Unit Command is located between Latitudes 10^{0}49'19" and 11^{0}28'12" North and Longitudes 7^{0}05'41" and 8^{0}08'8"East with Katsina State to its North, Birnin Gwari to its West, Igabi and Soba to its South and to its East is Ikara Local Government Areas respectively. This Unit Command is located in Kaduna state which is located between Latitudes 09° 02'00" to 11^{0}32'0" North and Longitude 06° 15'00" to 08^{0}38'00" East(Kaduna State Government, 2012). See Figure 3.1.

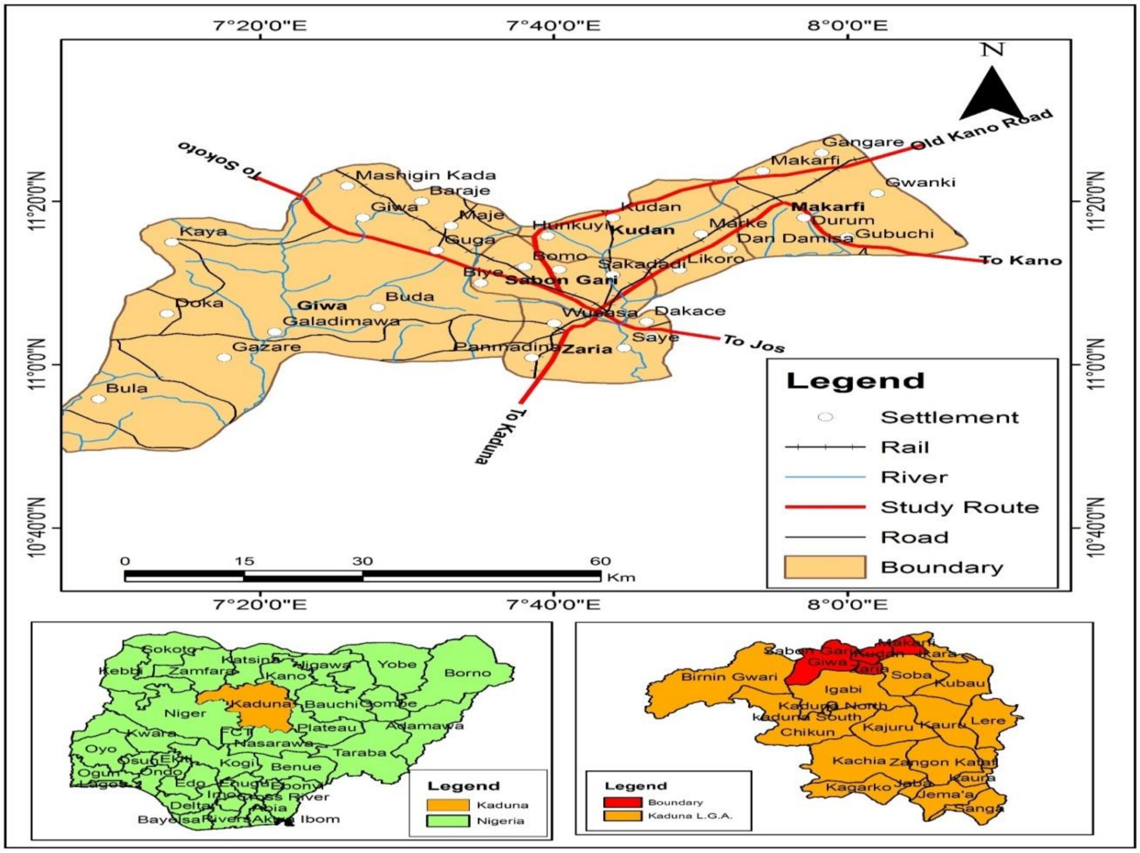


Figure 3.1: Major road network in FRSC Zaria Unit Command

Source: Google Earth Imagery, 2016

3.1.2 Climate

Zaria possesses a tropical continental climate. This is more pronounced during the dry season, especially December and January. The mean maximum daily temperature shows a major peak in April and a minor in October. The mean minimum temperature rises from its lowest in December-January to its highest in July-August(Abaje, Ishaya and Usman, 2010). Temperature encourages RTA due to fatigue on the part of the road users. The wet season here lasts from April through October with the peak in August while the dry season extends from mid-October to April. Rainfall encourages RTA due to skidding due to the slippery nature of roads after rainfall. Thus, since weather parameters have been found to be related to road accidents as reported by Burns (1976), Rohde (1977), Andreescu and Frost (1998), Cho, Lee and Yoo(2006), Yannis and Karlaftis (2007), Mondal, Dalela, Balasubramanian, Sharma and Singh (2008), Mondal, Sharma, Kumar, Vigay, Bhangale, and Tyagi(2011c) and Ayeni and Oni (2012) among others, this study attempted to understand the exact nature of the climate of Zaria particularly the climatic elements of interest to this research..

3.1.2.1 Rainfall

The average annual rainfall recorded in the study area in the past thirty five years is 1015.3mm of rainfall. The highest total annual rainfall recorded within this period was in 2012 when 1333.3mm of rainfall was recorded. The lowest total annual rainfall recorded within this period was in 1983 when 608.2mm of rainfall was recorded. It is on record that rainy season does not begin before March and never exceeds November in the study area. The month that recorded the highest average rainfall for the study area is August with 282.5mm of rainfall annually followed by July with 222.8mm. November has the lowest average rainfall for the study area with an average of 6.2mm annually. The average number of wet days per year in Zaria is 76.4 days. The highest number of wet days per annum was recorded in 1991 with 93 wet days while 1983 had only 62 wet days and the lowest total annual rainfall record within this period. Rainfall encourages RTA due to skidding due to the slippery nature of roads after rainfall.

3.1.2.2 Air Temperature

The mean annual air temperature in Zaria is 25.6^{0}C. The highest mean annual air temperature recorded within this period was 27.4^{0}C in 2012. The lowest mean annual air temperature recorded within this period was 23.6^{0}C in 1989. From the data presented in this study, the mean monthly temperature for the study area is 25.6^{0}C. The month with the highest mean monthly temperature for the study area was April with 29.9^{0}C. The month with lowest mean monthly temperature is January with 22.1^{0}C. Temperature encourages RTA due to fatigue on the part of the road users.

3.1.2.3 Visibility

The mean annual visibility recorded in the study area was 25.9 kilometers. The year with the most severe mean annual visibility was 2010 while the year with the best visibility was 2002. From the data presented in this study, the mean monthly visibility for the study area is 26 kilometers. The month with the best mean monthly visibility for the study area was September with 31.7 kilometers. The month with poorest visibility mean monthly visibility is January with 18 kilometers. Thus, the mean monthly visibility for January, February, March, November and December fell below this average while April, May, June, July, August, September and October are above this average. This implies that months of the year that coincide with the harmattan period have a visibility that is below average. The better the visibility, it is expected that the occurrence of RTA will be lesser than when the visibility is poor.

3.1.2.4 Relative humidity

The mean annual relative humidity for the study area was 45.9 per cent. The highest mean annual relative humidity recorded within this period was 62 per cent in 2002 while the lowest that was recorded within this period was 39.2 per cent in 1983. The mean monthly relative humidity for the study area is 45.7 per cent. The month with the highest mean monthly relative humidity (relative dampness) for the study area was also August with 78.4 per cent while the month with lowest mean monthly relative humidity (relative dampness) is February with 16.1 per cent. This implies that August has the highest mean monthly rainfall as well as relative humidity for the study area. The higher the relative dampness, the poorer is the visibility and hence, the greater the tendency that RTA will occur and vice versa.

3.1.2.5 Wind speed

The mean annual wind speed recorded within this period was 137.9 kilometer per day. The highest average annual wind speed recorded within this period was 161.6 kilometer per day in 1983 while the lowest average annual wind speed recorded within this period was 67.4 kilometer per day in 1999. The mean monthly wind speed for the study area is 139.9 kilometer per day. The month with the highest mean monthly wind speed for the study area was May with 191.2 km/day while the month with lowest mean monthly wind speed is October with 81.6 km/day, a difference of 9.6 km/day. Wind speed is believed to be positively associated with the occurrence of RTA.

3.1.2.6 Evaporation

The mean annual evaporation rate recorded within this period was 8.3 millimeters per day. The highest mean evaporation rate that was recorded within this period was 10.4 mm/day in 1997 and 2004 while the lowest mean evaporation rate that was recorded within this period was 5.7 mm/day in 2012. The mean monthly evaporation rate for the study area is 8.1 mm/day. The month with the highest mean monthly evaporation rate for the study area was March with 12.1 mm/day while the month with lowest mean monthly evaporation rate is September with 5.4 mm/day. Evaporation rate is positively associated with temperature that encourages fatigue leading to loss of concentration on the part of the road users leading to the occurrence of RTA. During rainy season, evaporation rate can reduce RTA due to skidding by evaporation the water on wet roads if the evaporation rate is high.

3.1.3 Transportation and Road Traffic Accidents in Zaria

Zaria is characterized by road networks.These road networks playa very important role in the socio-economic development and activities of its people. It is easily accessible from different parts of the country because the town is almost centrally located in northern Nigeria. It easily links other parts of the country to the Northeastern zone. As a result of the strategic location of Zaria, traffic flow and RTA should be a source of concern to the inhabitants of the area not only its road users. The Major road networks within Zaria unit command include road networks within Zaria Township, Zaria-Kaduna, Zaria-Kano, Zaria-Sokoto, Zaria-Old Kano and Zaria-Jos routes. According to Aminu, Anene and Salisu (2016), Zaria-Kaduna and Zaria-Kano routes have more traffic flow than the other routes. This study confirmed that these routes recorded more RTAs than the other routes.

3.1.4 Vegetation

Zaria lies in the northern guinea savanna zone which is moist woodland under grown with thick bushes and shrubs. A designation which implies a woodland vegetation type characterized by the presence of elephant grass, *Isobalina Doka, Isobalina Tomentosa and Upaca togonensis,* baobab with well-developed grass layer (Jaiyeoba, 1995). The density of trees decreases as one move northwards. Vegetation cover can interfere with the view of the driver like in the case of a bend leading to RTA.

3.1.5 Relief

Zaria belongs to the Precambrian Basement complex of northern Nigeria. It is composed of three rock types; the basement gneiss, porphyritic granite and medium grained granite. The greater part of the area is covered with thick regolith mainly derived from in-situ weathering of the basement complex rocks, which in some areas on the watershed is up to 30 meters thick (Garba, 2000). Relief affects the nature of the road leading to undulating roads or otherwise which affects the view of road users.

3.1.6 Soils

The soils of Zaria are termed “the Zaria Soil group” and usually, the material covering up to 4.27 in depth and consist of deposited silt. Alluvial soils are expansive in Zaria particularly in low land areas.They are easily drained to produce what is known as the hydromorphic soil/Fadama. These are found in the Kubanni and Galma river basins and are mainly for sugarcane cultivation. However, in the state as a whole, ferruginous tropical soil which is related to climate, vegetation, lithology and topography dominate the state (Ishaya and Abaje, 2009). Thus, the soil of an area determines to a large extent the suitability of that area for road construction. If roads are constructed without soil test to determine the suitability of that soil type for road construction, the structure, appearance and serviceability of the road is easily affected leading to poor roads which is one of the primary causes of RTA.

3.1.7Economic Activities

The major activities include agriculture, a little bit of manufacturing, trade/commerce and military activities. The dominant activities in Zaria are military and academic activities, this attracted the present population. This is evident in the presence of primary, secondary, Islamic and higher institutions of learning scattered around the town. The people of Zaria practice wet and dry season farming known as “Fadama farming”. Here farmers are specialized in market gardening for food production. Livestock farming is also practiced in the area, as a result of this meat, milk production and yoghurt processing industries are on the rise.

Manufacturing industries in Zaria started with a very few members of establishment during the colonial era, the Chikaji Industrial Area and Dakace were established during the period. However, during the oil boom era of the 70’s, new industries sprang up producing textiles, electricity meter assemblage. Later on tobacco and beverage processing industrial plots were allocated in phases to entrepreneurs by Kaduna State Ministry of Lands and Survey. Education and military activities in the area are as a result of the presence of different types of institutions, state ministries, judiciaries, schools, military Barracks and Nigerian military school. This employs labour and also provides employment to most of the educated/skillful people in the area. A certain percentage of the people including migrants are engaged in trading activities in the market of Sabon Gari, Tudun Wada and Samaru (Abdulkadir, 2006).

Thus, commercial activities that have to do with retail and distribution of goods and services attract people. Periodic markets are located along major road sides leading to RTA. Therefore, economic activities tend to increase per capita automobile travel which tends to increase traffic crashes and casualties.

3.2 Research Methodology

3.2.1 Reconnaissance Survey

In an attempt to prepare for the collection of data for this study, a reconnaissance survey of Zaria Unit Command of the FRSC was carried out to identify the extent of this unit command. The major routes, FRSC office, Nigeria Meteorological Agency Office were visited and interaction with officers of both organizations undertaken. Thus, the major routes were identified and preparation was made for the collection of data required for the study.

3.2.2 Types of Data

In order to achieve the aim and objectives of this study, data on traffic flow, RTA and weather wereobtained. Data on traffic flow include the following:

a) Date
b) Time
c) Peak periods of motor vehicle movement
d) Number of vehicles plying each route carried out by counting and recording manually

Accident record from Federal Road Safety Commission included the following:

a) Date of accident
b) Time of occurrence of accident
c) Location/route of accident
d) Number of road traffic accident cases
e) Type of accident (fatal, severe or minor)

f) Number of people injured and or killed

g) Probable causes

Data on the selected weather parameters was acquired from the Nigerian Meteorological Agency which includes:

a) Daily rainfall

b) Mean daily air temperature

c) Mean daily visibility

d) Mean daily relative humidity

e) Mean daily wind speed

f) Mean daily evaporation rate

3.2.3 Sources of Data

3.2.3.1 Primary Source

Daily peak periods were established based on the reconnaissance survey conducted. Traffic sensitive points were used which allowed for the counting of moving vehicles. This exercise was carried out for three weeks along each route in the study area.

3.2.3.2 Secondary Sources

Data on RTA was obtained from the Federal Road Safety Commission (FRSC) while data on weather parameters were obtained from Nigerian Meteorological Agency. Other materials for literature review were obtained from books, journals, conference proceedings and archival sources. Some of these materials were used to develop introduction, literature review, improve study areas and to support explanations of data analysis

3.2.4 Method of Data Analysis

Data analysis and presentation used both descriptive and inferential statistics. Data that were collected were analyzed in accordance with the specific objectives of this study.

Objective one: To examine the trends of rainfall, temperature, visibility, relative humidity, wind speed and evaporation rate in Zaria

Time series analysis was used to examine selected weather parameters of Zaria. Here, a graph of the trend for each of the weather parameters was presented; the mean in each case was fitted as a line showing fluctuation of each weather parameter from one year to another and one month to another. A trend in the time series was also identified using a trend line calculated as follow:

$$Y = a + bX \tag{3.1}$$

Y- Weather parameters (rainfall, temperature, visibility, relative humidity, wind speed and evaporation rate**)**
X- Time (months and years)

Objective two: To analyze the spatial variation of RTA in Zaria from 2001 to 2014

Descriptive statistics was used to show the spatial variation of RTA cases and casualties and secondly, to show the spatial variation in the frequency with which RTA case(s) were attributed to different probable causes of RTA along the six routes. In order to determine if there is a significant spatial variation in RTA cases and casualties on one hand and the frequency with which RTA case(s) were attributed to different probable causes of RTA along the different routes, one-way ANOVA was used.

$$SST = \sum_{i=1}^{a}\sum_{j=1}^{b} y_{ij}^2 - \frac{y_{..}^2}{N} \tag{3.2}$$

$$SSA = \sum_{i=1}^{a} \frac{y_{i.}^2}{b} - \frac{y_{..}^2}{N} \tag{3.3}$$

$$SSE = SST - SSA \tag{3.4}$$

Fisher's Least Significance Difference (LSD) was used to generate information for the differences between means in order to specifically test for similarity or significant difference between each route and all the others.

$$\left|\bar{y}_{i.} - \bar{y}_{.j}\right| > t_{\frac{\alpha}{2}}\,(N-k)\sqrt{\frac{MSE}{n}} \qquad 3.5$$

Objective three: To analyze the temporal variation of RTA in Zaria from 2001 to 2014

Tables were used and the total number of cases and casualties recorded within every route or location in the study area was calculated and summarized using frequency distribution and time series graphs to show the temporal variation of accident cases and casualties in Zaria. Bar graphs were used to see the frequency of fatal, serious and minor RTAs cases linked to the causes of RTAs annually while Tables were used to show the results monthly.

Objective four: assess the nature of association between rainfall, temperature, visibility, relative humidity, wind speed and evaporation rate and crash count in the study area

Data transformation was carried using Log base 10 via Minitab software. Pearson's product moment correlation coefficient was used to assess the magnitude and direction of association between weather and RTA cases, casualties and severity of RTA due to different probable causes of RTA in Zaria.

$$r = \frac{{}^{1}\!/_{n}\sum(a-\bar{a})(b-\bar{b})}{\sigma_a.\sigma_b} \qquad 3.6$$

r- Product moment correlation coefficient
a and b are the two sets of observations
σ- standard deviation

In order to test the resulting coefficient for significance, a version of Student's t-test was employed.

$$t = r\sqrt{\frac{n-2}{1-r^2}} \qquad 3.7$$

n- sample size

Regression model was developed using multiple linear regression analysis to make it possible to forecast future occurrences of RTA cases in Zaria.

$$Y = a + bX_1 + bX_2 + bX_3 + bX_4 + bX_5 + bX_6 \qquad 3.8$$

Y- Total cases

X_1- Rainfall
X_2- Air temperature
X_3- Visibility
X_4- Relative Humidity
X_5- Wind speed
X_6- Evaporation rate

Coefficient of determination (R^2) was used to test the strength of the model while the overall F-test was used to know if the regression is highly significant meaning that at least one of the predictor variables is contributing significant information for the prediction of the response variable y.

Objective five: examine the occurrence rate of RTA on wet and dry days and during dry spell in Zaria

A range of statistical methods were adopted from Mondal *et al.* (2011c) who applied it in their study in India to see if wet and dry days have any association with the occurrence of RTA. This objective addressed the same problem in Zaria. Data analysis was preceded with data transformation using Log base 10 via Minitab and R soft wares.First and foremost, rain-crash-index was derived and examined using the following expression:

$$\mathbf{RCI = (C/R)} \qquad 3.9$$

C is the crash count in a particular day and R is the rainfall in mm in that respective day.

Pearson's product moment correlation was used to determine the nature of association between Rainfall, crash count and RCI.

Wet-crash-rate (WCRi) was derived using the following expression:

$$\mathbf{WCRi = (WC/WD)} \qquad 3.10$$

Where WC is the total number of crash that took place in the wet days of a month and WD is the total number of wet days in that respective month. A day which receives any amount of rainfall is termed as a wet day in this study.

Dry-crash-rate (DCRi) for the ith month of a year is defined as:

DCRi = (DC/DD) 3.11

Where DC is the total number of crash took place in dry days of a month and DD is the total number of dry days in a month. A day which receives no rainfall is termed a dry day in this study. Pearson's product moment correlation was used to determine the nature of association between wet days, dry days and RTAs.

Rain-crash-effect (RCEi) was derived using the following expression:

RCEi = ((WCRi-DCRi)/DCRi) x 100 3.12

To look at the RCEi for the ith year, you have to find:

i. $\frac{\text{total crash count for the wet days of a year}}{\text{total number of wet days in the ith year}}$

ii. $\frac{\text{total crash count for dry days of a year}}{\text{total number of dry days in the ith year}}$

RCEi $= \frac{a-b}{b} \times 100\%$ 3.13

Pearson's product moment correlation was used to determine the nature of association between wet days, dry days and RCE.

In order to study the effect of dry spell on RTA, classification of dry spell into three classes was adopted from Mondal *et al.* (2011) namely no (0 day), small (1-5 days) and large (>5ays).

% average crash per no dry spell wet day = $\frac{\text{total number of accidents after NDSWD}}{\text{total number of accidents for the ith yr}} \times 100\%$

$$\text{\% average crash per small dry spell wet day} = \frac{\text{total number of accidents after SDSWD}}{\text{total number of accidents for the ith yr}} \times 100\%$$

$$\text{\% average crash per large dry spell wet day} = \frac{\text{total number of accidents after LDSWD}}{\text{total number of accidents for the ith yr}} \times 100\%$$

Thus, the frequency of RTAs during each of these classifications was examined using frequency distribution and bar graphs and comparism made between them using one-way ANOVA.

Finally, in order to study the impact of rainfall, length of dry spell and evaporation rate on the severity of RTA in Zaria, the amounts of rainfall recorded on all the wet days that RTA cases were reported were identified and their dates recorded. The total amounts of rainfall recorded before and on that date were identified. The length of dry spell, mean monthly evaporation rate, the amounts of rainfall recorded one, two, three, four and five days before that date were also recorded. The degree of association between these variables and RTA cases and casualties were then determined using Pearson's product moment correlation.

Objective six: derive a rain-class-crash-rate (RCCR) for Zaria

Throughout the year rainfall varies in amount and intensity.It is important therefore to know the effect of rainfall class on crash rate. Rain-class-crash-rate (RCCRi) for ith class of rainfall is defined as:

$$\mathbf{RCCRi = (WCi/WDi)} \qquad 3.14$$

Where WCi is the total number of crash that took place in wet days for ith class of rainfall in a year and WDi is the total number of wet days for ith class of rainfall in the respective year. Rainfall will be classified into six classes, namely >0 to 1 mm, >1 to 2 mm, >2 to 5 mm, >5 to 15 mm, >15 to 30 mm and >30 mm. All rainfall amounts are for 24h of a day.

$$\text{RCCRi} = \frac{\text{total number of accidents in wet days for ith class of rainfall in a year}}{\text{total number of wet days for ith class of rainfall in the respecti ve yr}}$$

$$\% \text{ RCCRi} = \frac{\text{total number of accidents in wet days for ith class of rainfall in a year}}{\text{total number of wet days for ith class of rainfall in the respective yr}} \times 100\%$$

One-way ANOVA was used to test the variability between these classes while Pearson's product moment correlation was used to determine the nature of association between them.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1Trends of the Major Weather Parameters within the Study Area

4.1.1 Trend in Rainfall

The trend in rainfall in the study area is presented on Figure 4.1 which presents the original trend, average and trend line representing rainfall experienced in the study area.

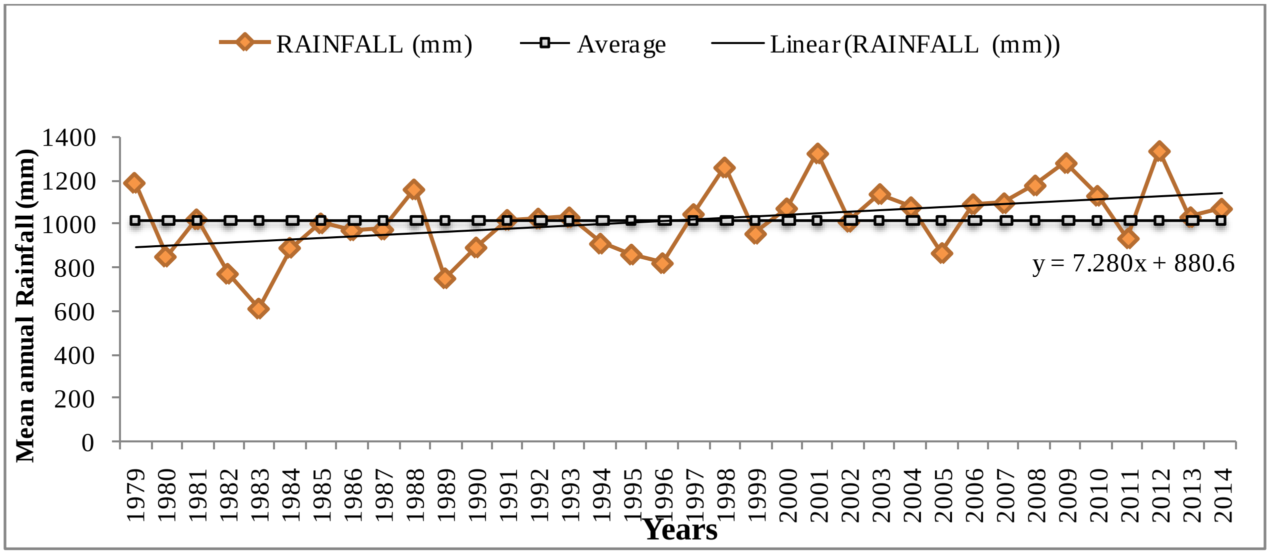


Figure 4.1: Annual Variation of Rainfall Record in Zaria

Source: NIMET, 2016

The average annual rainfall recorded in the study area for this period was 1015.3mm. The trend line revealed a general increase in the annual rainfall of Zaria. Since rainfall encourages RTA due to the slippery nature of roads after rainfall, this could be partly responsible for the general increase in RTA cases and casualties observed in the present study as presented on Figure 4.21. Both rainfall and RTAs were found to temporal variation over time.

4.1.1.1 AnnualVariation in the Number of Wet Days

The annual variation in the number of wet days in the study area is presented on Figure 4.2 which presents the original trend, average and trend line representing the number of wet days in the study area.

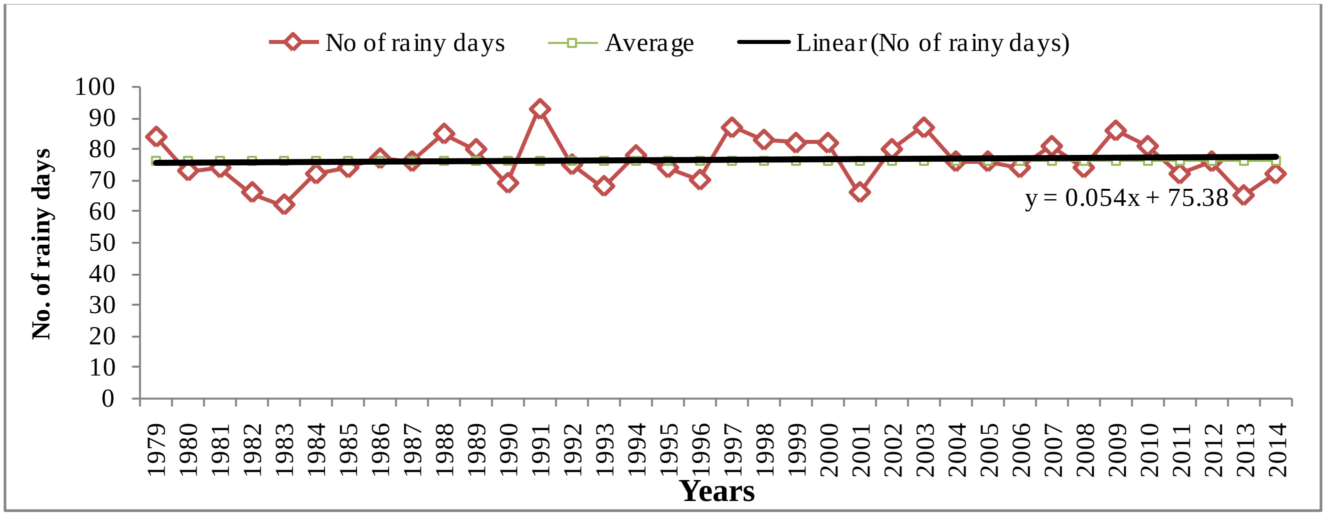


Figure 4.2: Annual Variation of the Number of Wet Days in Zaria
Source: NIMET, 2016

The average number of wet days per year in Zaria is 76.4 days. Since rainfall encourages RTAs due to skidding, temporal variation in the number of RTA cases and casualties was observed over time since the number wet days vary annually. The trend line revealed a slight increase in the number of wet days. This could be partly responsible for the general increase in RTA cases and casualties observed in the present study as presented on Figure 4.21.

4.1.2 Trend in Air Temperature

The trend in air temperature in the study area is presented on Figure 4.3 which presents the original trend, average and trend line representing the air temperature experienced in the study area.

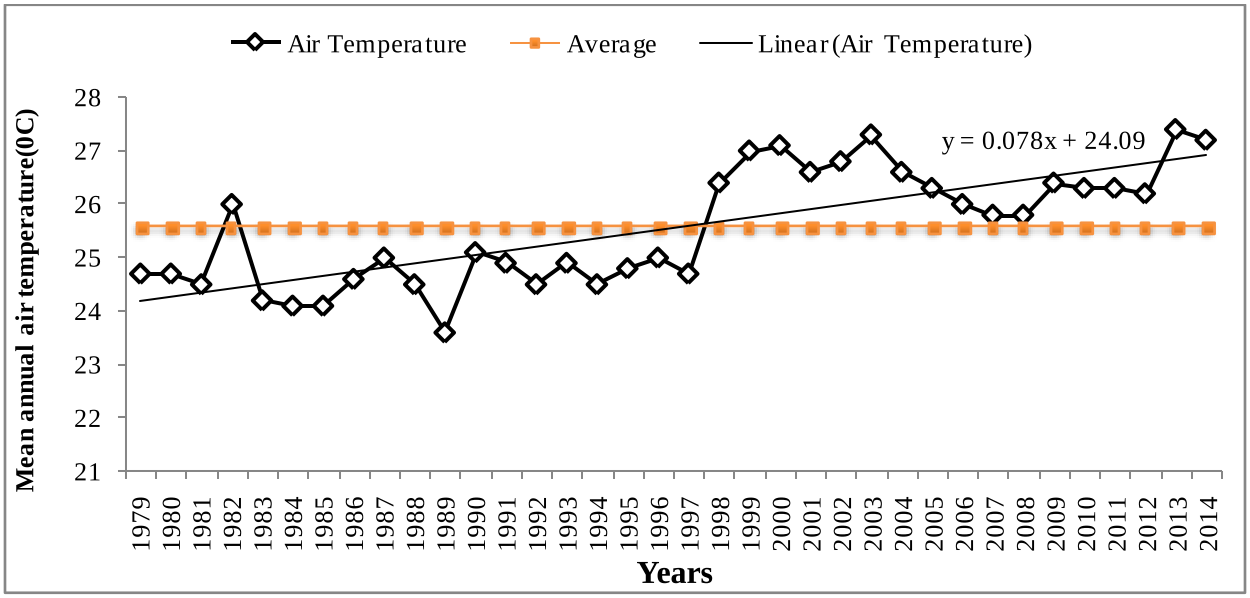


Figure 4.3: Annual Variation of Air Temperature in Zaria
Source: NIMET, 2016

The mean annual air temperature for this period was 25.6^{0}C. High temperature can result into fatigue leading to numerous consequent effects like over speeding in order to get to one's destination faster, tyre burst among others which all lead to RTA. Therefore, more RTA cases and casualties are expected during periods with high temperature. The trend line revealed a general increase in the mean annual air temperature of Zaria. This could be partly responsible for the general increase in RTA cases and casualties observed in the present study as presented on Figure 4.21.

4.1.3 Trend in Visibility

The trend in visibility in the study area is presented on Figure 4.4 which presents the original trend, average and trend line representing the air temperature experienced in the study area.

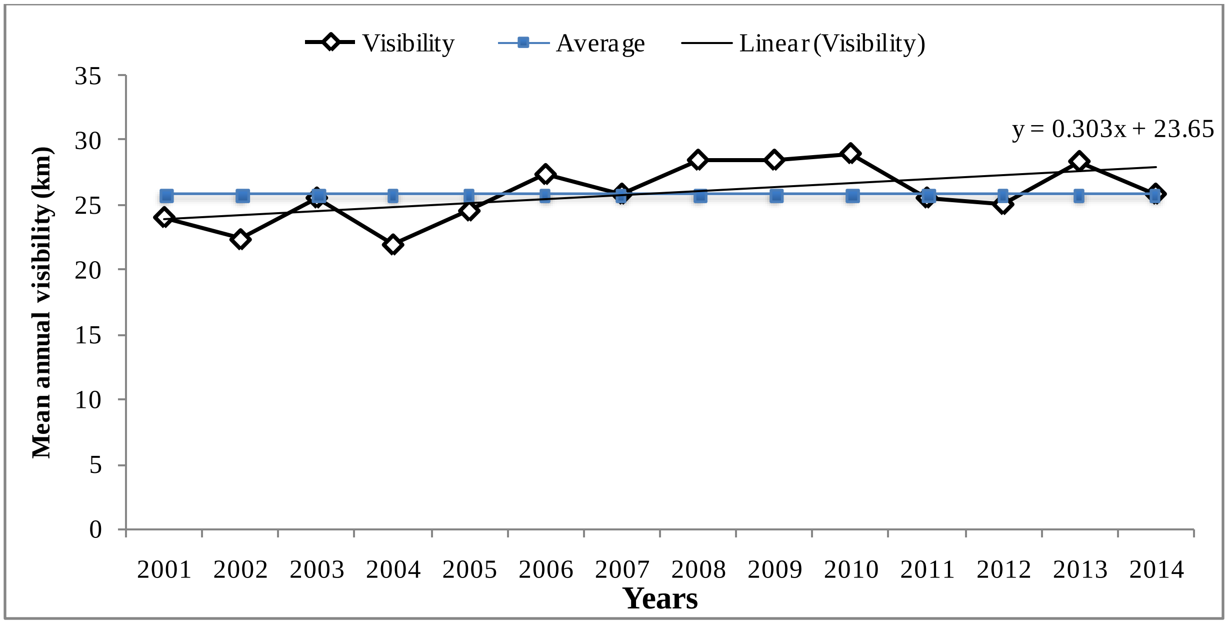


Figure 4.4: Annual variation of the Visibility of Zaria
Source: NIMET, 2016

The mean annual visibility recorded for this period (2001-2014) was 25.9 kilometers. Since better visibility enhances the safety of transportation including road transportation, RTAs are expected to be fewer when visibility is good. However, the present study revealed a positive association between number of RTA cases that occur and better visibility as presented on Table 4.7. Finally, the trend line revealed that there is a general increase in the mean annual visibility of Zaria. This could be partly responsible for the general increase in RTA cases and casualties observed in the present study as presented on Figure 4.21.

4.1.4 Trend in Relative Humidity

The trend in relative humidity in the study area is presented on Figure 4.5 which presents the original trend, average and trend line representing the relative humidity experienced in the study area.

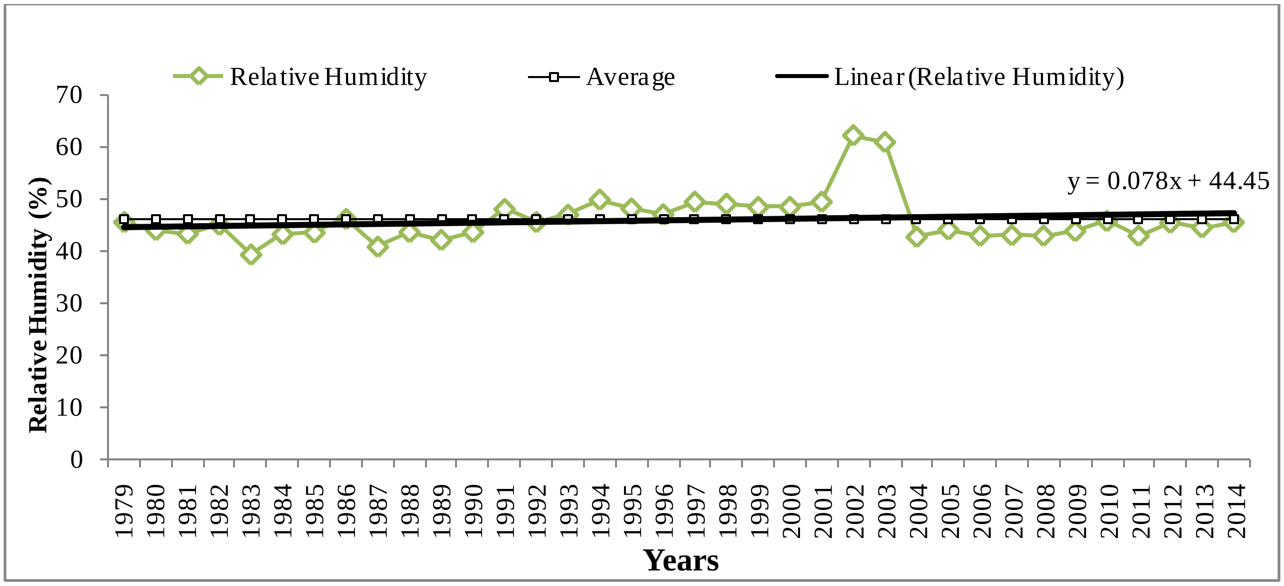


Figure 4.5: Annual Variation of Relative Humidity in Zaria
Source: NIMET, 2016

The mean annual relative humidity for the period (1979-2014) was 45.9 per cent. Since humidity vary over time and can be related with human comfort which can also affect the drivers comfort which can result in RTA, it is expected that the more favourable it is, the lesser will be the occurrence of RTA and vice versa and this vary temporarily over time. The trend line revealed a slight increase in the mean annual relative humidity of Zaria. This could be partly responsible for the general increase in RTA cases and casualties observed in the present study as presented on Figure 4.21.

4.1.5 Trends in Wind Speed

The trend in wind speed in the study area is presented on Figure 4.6 which presents the original trend, average and trend line representing the wind speed experienced in the study area.

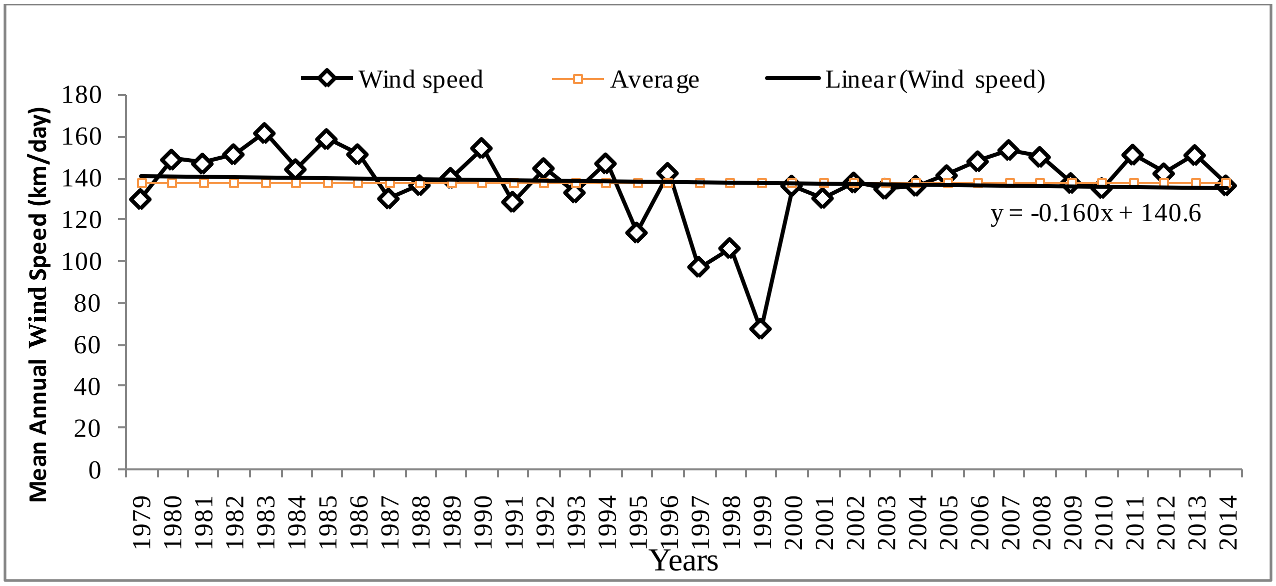


Figure 4.6: Annual Variation of Wind Speed in Zaria

Source: NIMET, 2016

The mean annual wind speed recorded within this period was 137.9 kilometer per day. Since wind speed can influence the controllability of vehicles, it can influence the occurrence of RTA. In fact, there is a positive association between wind speed and the number of casualties as a result of RTAs as presented on Table 4.7. Finally, the trend line revealed that there is generally a slight decrease in the wind speed of Zaria.

4.1.6 Trend in Evaporation Rate

The trend in evaporation rate in the study area is presented on Figure 4.7 which presents the original trend, average and trend line representing the evaporation rate experienced in the study area.

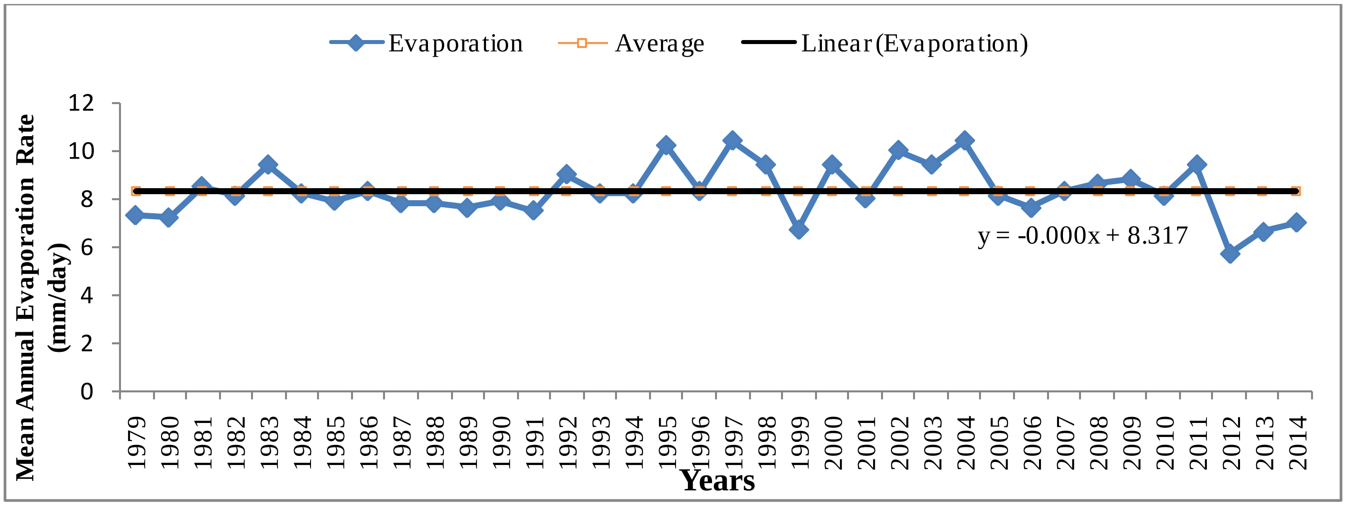


Figure 4.7: Annual Variation of Evaporation Rate in Zaria

Source: NIMET, 2016

The mean annual evaporation rate recorded within this period was 8.3 millimeters per day. High evaporation rate can affect human comfort (driver) which can influence the occurrence of RTA and vice versa and this will vary temporarily over time. The trend line revealed that the mean evaporation rate of Zaria is uniform.

4.1.7 Trend in Mean Monthly Rainfall of Zaria

The trend in mean monthly rainfall of the study area is presented on Figure 4.8 which presents the original trend, average and trend line representing the mean monthly rainfall experienced in the study area.

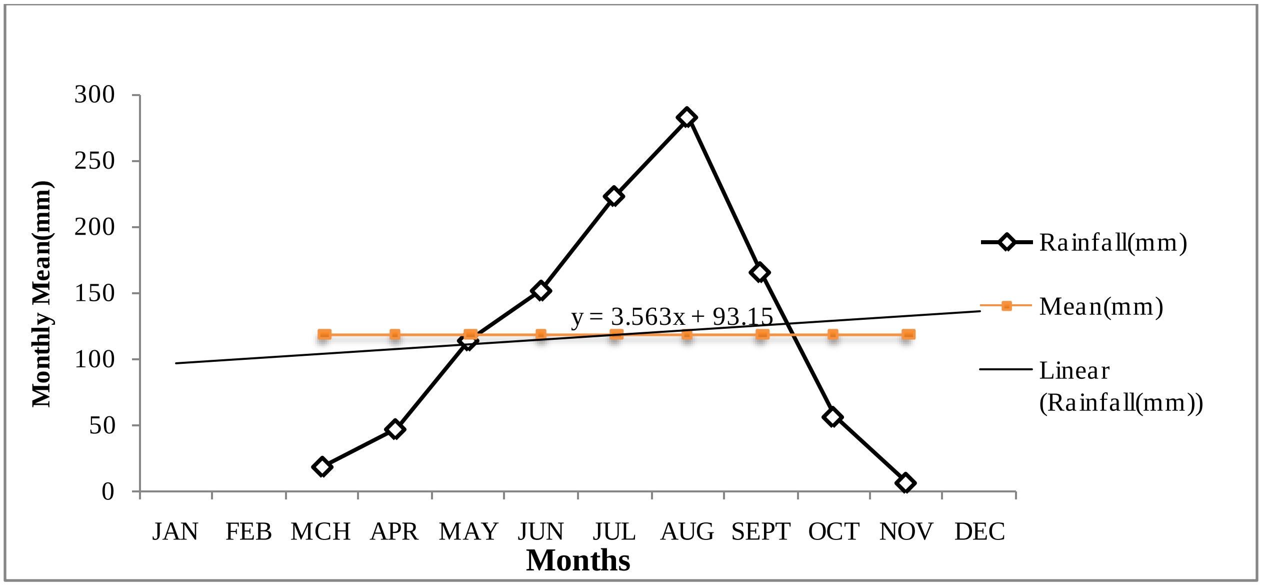


Figure 4.8: Monthly Variation of Rainfall Recorded in Zaria
Source: NIMET, 2016

From the data presented in this study, it is on record that rainy season does not begin before March and never exceeds November in the study area. The month that recorded the highest average rainfall is August with 282.5mm of rainfall then July with 222.8mm. Thus, the occurrence of RTA cases and casualties vary temporarily during the rainy season as presented on Figure 4.28. Finally,the trend line revealed that there is a general increase in the mean monthly rainfall of Zaria.

4.1.8 Mean Monthly Temperature of Zaria

The trend in mean monthly temperature of the study area is presented on Figure 4.9 which presents the original trend, average and trend line representing the mean monthly temperature experienced in the study area.

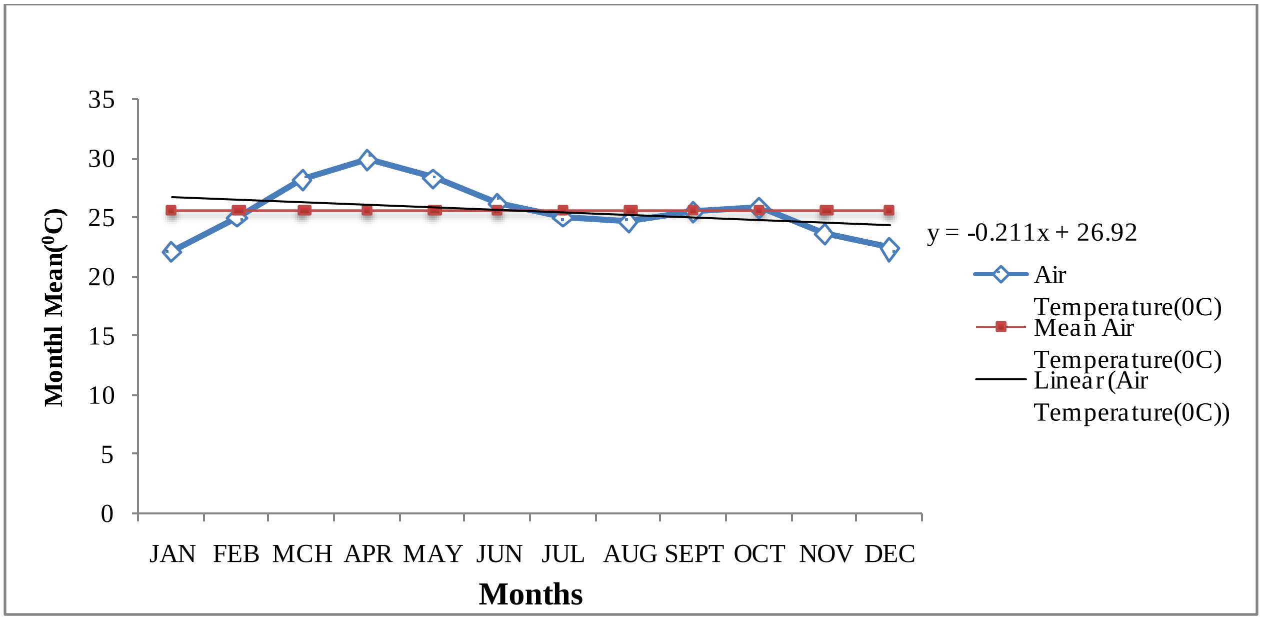


Figure 4.9: Monthly Variation of Air Temperature in Zaria
Source: NIMET, 2016

From the data presented in this study, the mean monthly temperature for the study area is 25.6^{0}C. The month with the highest mean monthly temperature was April with 29.9^{0}C. Months that are very hot cannot be confortable for especially long distance journeys. As such, both drivers and passengers find it very difficult which can easily result into cases of RTA. Thus, the occurrence of RTA cases and casualties vary temporarily as presented on Figure 4.28. The trend line revealed a general decrease in the mean monthly air temperature of Zaria.

4.1.9 Mean Monthly Visibility of Zaria

The trend in mean monthly visibility of the study area is presented on Figure 4.10 which presents the original trend, average and trend line representing the mean monthly temperature experienced in the study area.

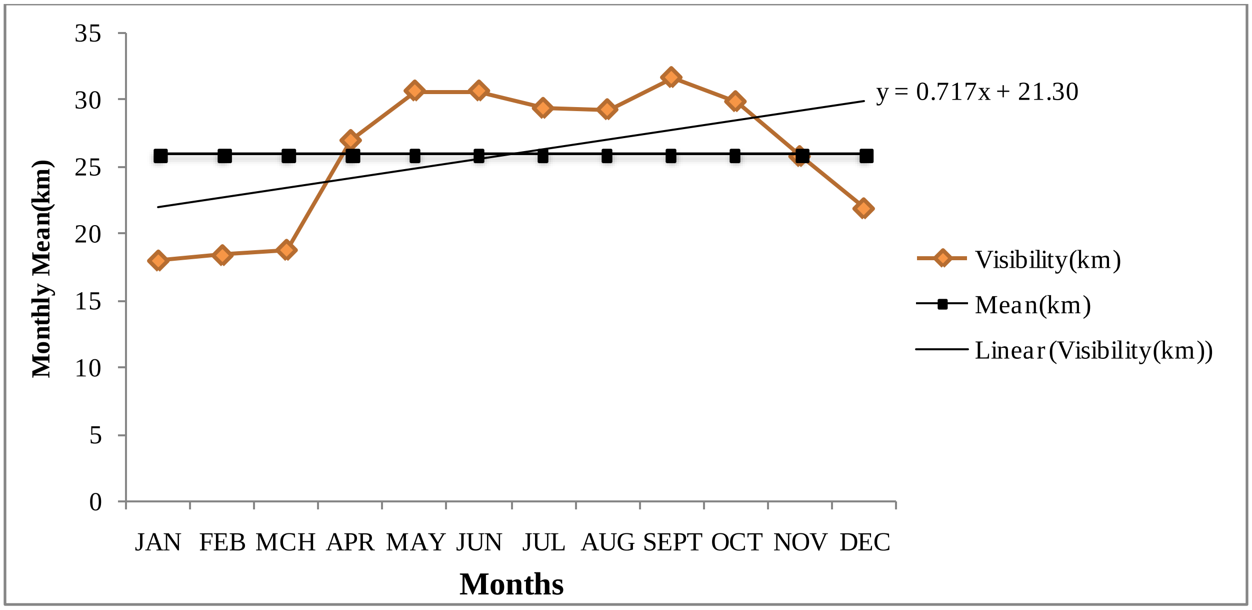


Figure 4.10: Monthly Variation of the visibility of Zaria
Source: NIMET, 2016

From the data presented in this study, the mean monthly visibility for the study area is 26 kilometers. The month with the best visibility was September with 31.7 kilometers while the poorest was January with 18 kilometers. The highest number of casualties was actually recorded in January as presented on Table 4.8. The trend line revealed that there is a general increase in the mean monthly visibility of Zaria.

4.1.10 Mean Monthly Relative Humidity of Zaria

The trend in mean monthly relative humidity of the study area is presented on Figure 4.11 which presents the original trend, average and trend line representing the mean monthly relative humidity experienced in the study area.

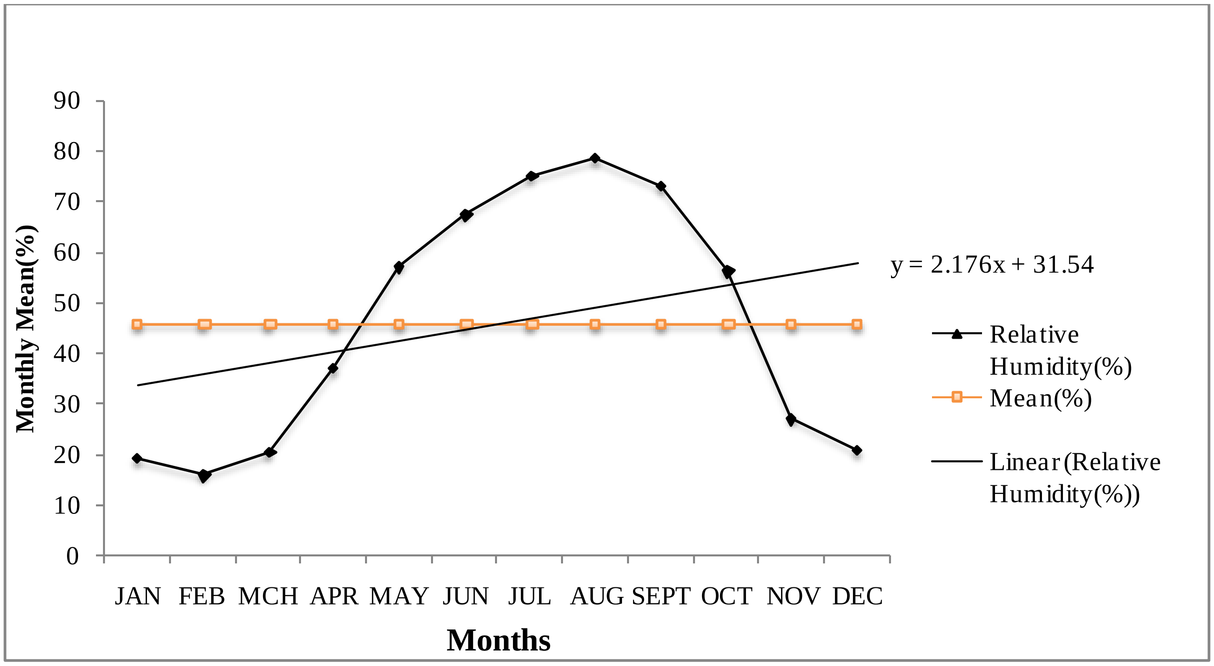


Figure 4.11: Monthly Variation of the Relative Humidity of Zaria
Source: NIMET, 2016

From the data presented in this study, the average monthly relative humidity for the study area is 45.7 per cent. The month with the highest mean monthly relative humidity (relative dampness) was August with 78.4 per cent while February with 16.1 per cent is the lowest. Since humidity varies over time and can be related with human comfort thus affecting the comfort of drivers, it is expected that the more favourable it is, the fewer should be the number of RTAs and vice versa and this will vary temporarily over time. Thus, a positive association was observed between relative humidity and RTA cases as presented on Table 4.8. Trend line revealed steady increase in the mean monthly relative humidity of Zaria.

4.1.11 Mean Monthly Wind Speed of Zaria

The trend in mean monthly wind speed of the study area is presented on Figure 4.12 which presents the original trend, average and trend line representing the mean monthly wind speed experienced in the study area.

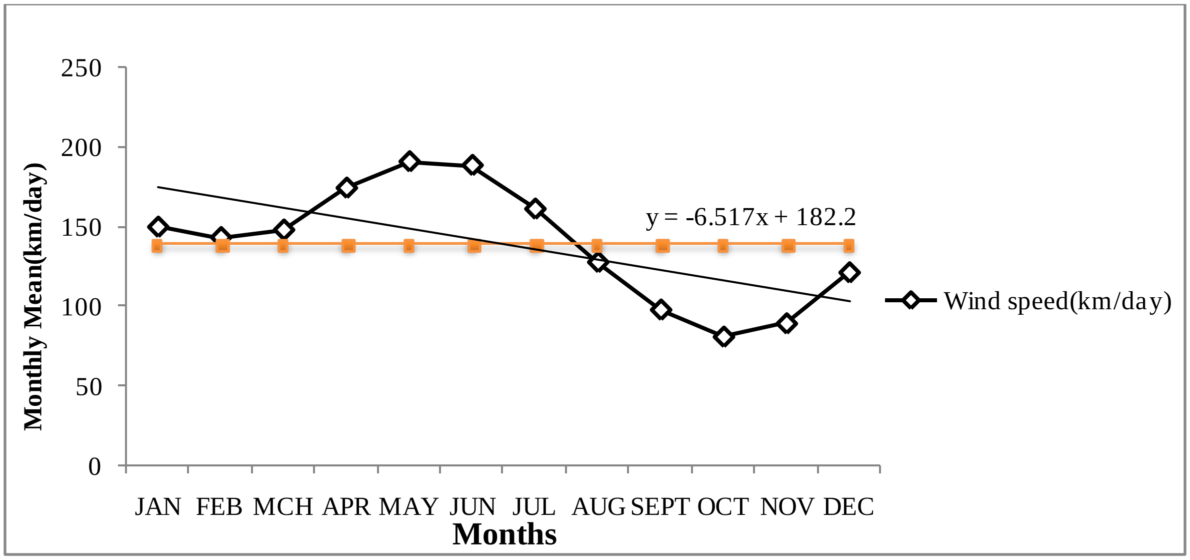


Figure 4.12: Monthly Variation of Wind Speed in Zaria
Source: NIMET, 2016

From the data presented in this study, the mean monthly wind speed for the study area is 139.9 kilometer per day. The month with the highest mean monthly wind speed was May with 191.2 km/day while the lowest is October with 81.6 km/day. It therefore means that the tendency that wind speed will influence the occurrence of RTA is highest in May and lowest in October. However, the trend line revealed that there is a steady decrease in the mean monthly wind speed of Zaria. This could be partly responsible for the general decrease in the number of casualties observed in the present study as presented on Figure 4.29.

4.1.12 Mean Monthly Evaporation Rate of Zaria

The trend in mean monthly evaporation rate of the study area is presented on Figure 4.13which presents the original trend, average and trend line representing the mean monthly evaporation rate experienced in the study area.

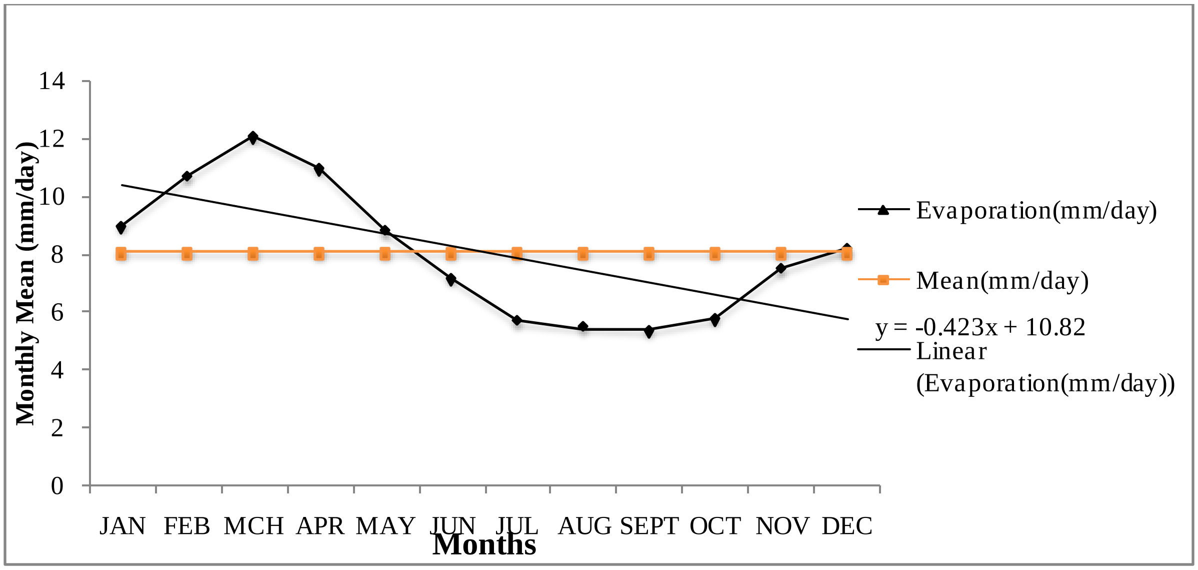


Figure 4.13: Monthly Variation of the Evaporation Rate of Zaria
Source: NIMET, 2016

From the data presented in this study, the mean monthly evaporation rate for the study area is 8.1 mm/day. The highest mean monthly evaporation rate for the study area is March with 12.1 mm/day while the month with lowest is September with 5.4 mm/day, a difference of 6.7 mm/day. It therefore means that the tendency that evaporation rate will influence the occurrence of RTA is highest in March and lowest in September because months with the highest evaporation rate will affect human comfort more than other months due to dehydration and fatigue. As such, the chance for RTAs to occur is very high. However, the trend line revealed that there is a steady decrease in the mean monthly evaporation rate of Zaria. This could be partly responsible for the general decrease in the number of casualties observed in the present study as presented on Figure 4.29.

Thus, the main consequences of climate change as predicted by most of the existing climate models are an increase in global temperatures, changes in precipitation patterns, and sea level rise. In general, climate models predict that increases in temperature will be higher over land areas than over oceans and seas, higher in interiors of continents than in coastal areas, and higher when going from the tropics to the polar region in the Northern Hemisphere. The potential consequences of climate change for precipitation patterns are more complex, and depend largely on continental geometry (vicinity of water) but also on the vicinity and shape of mountains and on wind flow direction. In general the existing climate models predict that precipitation will increase in areas adjacent to the Polar Regions, and will decrease in areas adjacent to the tropics. Furthermore, tropical precipitation is expected to increase especially during the rainy seasons. Global sea level rise in 2100 for the six SRES (Special Report on Emissions Scenarios) marker scenarios ranges between 0.18 and 0.59 m above 1990 levels (Intergovernmental Panel on Climate Change, 2007c). Thus, the trends of rainfall and temperature in Zaria are in agreement with IPCC (2007). Similarly, it was observed also that there is a general increase in the number of RTA cases and casualties in Zaria which may not be unconnected with the increase in rainfall and temperature in Zaria.

The trend of wind speed revealed that it is actually decreasing in Zaria and this is in agreement with IPCC (2007) and Wooden (2011) because Wooden (2011) stated that as temperature is increasing wind speed will be decreasing and vice versa. However, even as rainfall trend showed an increase in rainfall in Zaria, visibility was getting better which is in disagreement with Garg and Nayar (2007) who showed that there is a negative relation between rainfall and visibility. This shows that when the association between weather parameters are derived by considering the general trends for these weather parameters over a long period of time, a different result may be produced compared to an association between these parameters for a short period of time. Furthermore, as rainfall trend showed an increase in rainfall in Zaria, relative humidity was also increasing in Zaria. This agrees with Umoh, Akpan and Jacob (2013) who stated that there is a highly significant positive association between rainfall and relative humidity. They also stated that as relative humidity increases evaporation rate will decrease. Thus, this study is in agreement with Umoh, Akpan and Jacob (2013) as evaporation rate was found to be decreasing in Zaria as revealed by the trend line using analysis of time series. Thus, the trends of each of these weather parameters may encourage or discourage the occurrence of RTAs over time.

4.2 Spatial Variation of Road Traffic Accidents (RTAs) in Zaria

This section attempts to present the result of the spatial variation of RTA cases, casualties and its probable causes on roads within the Zaria unit command of the FRSC for thirteen years from 2001 to 2014.

4.2.1 Spatial Variation of RTA Cases and Casualties

First and foremost, the number of fatal, serious and total number of RTA cases on one hand, the number of passengers injured or killed and the total number of casualties due to RTAs is presented on Table 4.1.

From Table 4.1, Zaria-Kano route had the highest number of fatal cases with 115 cases, which represents 35.7% of all fatal cases recorded. However, considering serious cases, it was observed that Zaria-Kaduna route was more prone to the occurrence of serious RTA cases than the other routes.This is because 286 serious cases representing 32.8% of all the serious RTA were recorded on this route. Furthermore, while considering the total RTA cases that were recorded in the study area, Zaria-Kaduna route recorded 419 RTA cases representing 32.7% which is the highest per route in the study area.

Table 4.1: Summary of RTA Cases and Casualties in the study Area from 2001-2014

Route	Fatal	%	Serious	%	Total cases	%	Number injured	%	Number Killed	%	Number of casualties	%
Township	32	9.9	99	11.3	155	12.1	323	7.1	66	8.3	389	7.3
Zaria-Kaduna	109	33.9	286	32.8	419	32.7	1722	38	221	27.8	1943	36.4
Zaria-Kano	115	35.7	270	30.9	408	31.9	1448	31.9	323	40.7	1771	33.2
Zaria-Sokoto	34	10.6	150	17.2	196	15.3	651	14.3	107	13.5	758	14.2
Zaria-Old Kano	12	3.7	11	1.3	23	1.8	101	2.2	34	4.3	135	2.5
Zaria-Jos	20	6.2	57	6.5	79	6.2	297	6.5	41	5.2	338	6.3

Source: FRSC, 2016

A total of 1722 persons were injured along Zaria-Kaduna route which is equivalent to 38% of the total number of persons injured in the study area which is the highest per route. On the other hand, 323 persons were killed along Zaria-Kano route which is equivalent to 40.7% of the total number of persons killed and the highest per route within the study area. Thus, 5340 casualties were reported by the FRSC in the study area with the highest number of RTA casualties reported along the Zaria-Kaduna route where 1943 casualties representing 36.4% were reported.

In order to determine if there is a significant spatial variation in the number of RTA cases and casualties along the different routes, one-way ANOVA test was used and the result is presented on Table 4.2.

Table 4.2: Variability in RTA Severity Along six Routes in Zaria

Source	DF	SS	MS	F	P
Factor	5	2935246	587049	2.70	0.040
Error	30	6526281	217543		
Total	35	9461527			

Source: Author's Analysis, 2016

The result presented on Table 4.2 showed that the calculated F is greater than the critical value of F at 0.005 and *p*-value ($P = 0.040$) is less than 0.05 meaning that the number of RTA cases and casualties differ significantly along the different routes.

Furthermore, since analysis of variance showed that the effect of the treatment means are not the same, one of the methods of multiple comparison tests called Fisher's Least Significance Difference (LSD) was used in this study to know the treatment means that are different from the others as presented on Table 4.3.

Table 4.3: Grouping Information Using Fisher's LSD

Route	N	Mean	Grouping

Zaria-Kaduna	6	783.3	A
Zaria-Kano	6	722.5	A B
Zaria-Sokoto	6	316.0	A B C
Township	6	177.3	B C
Zaria-Jos	6	138.7	C
Old Zaria-Kano	6	52.7	C

Source: Author’s Analysis, 2016

Note: Means that do not share a letter are significantly different.

Table 4.3 showed that the number of cases and casualties recorded along Zaria-Kaduna route differ significantly from Zaria Township, Zaria-Jos and Zaria Old Kano routes but was not significant different from Zaria-Kano and Zaria-Sokoto routes. The result confirmed that Zaria-Kaduna route had the highest number of RTA cases and casualties followed by Zaria-Kano route and the least being Old Zaria-Kano route.

This study revealed that Zaria-Kaduna and Zaria-Kano routes within the Zaria unit command recorded very high RTA cases and casualties, which is in agreement with the findings of Godwin (2012), who stated that most accidents in Nigeria today occur on federal roads and the roads topping the list include Benin-Ore, Lagos-Ibadan Expressway, Abuja-Lokoja-Okene, Kaduna-Zaria-Kano, Okigwe-Umuahia, Kaduna-Abuja, Enugu-Awka-Onitsha and Otukpo-Otukpa. This is also in agreement with FRSC (2014) which listed Zaria-Kaduna and Zaria-Kano routes among the top twenty routes with the highest number of occurrence of RTA in Nigeria in 2014. FRSC again listed Zaria-Kano route among the top twenty routes with the highest number of persons killed and persons injured in 2014.

According to Aminu, Anene and Salisu (2016), the Zaria-Kaduna and Zaria-Kano routes have the highest traffic flow within the Zaria Unit command of FRSC. Thus, the findings on Zaria-Kaduna and Zaria-Kano routes in the present study have confirmed the work of Dickerson, Peirson and Vickerman (1998), Lord, Manar and Vizioli (2005), Hasan Bajwa, Horan and Chung

(2011) and Bala (2014) who reported that the high probability of occurrence of road accident on the freeway depends significantly on the traffic flow.

4.2.2 Spatial Variation in Occurrence of RTAs due to Identified Causes

Figure 4.14 presents all the nineteen causes of RTAs identified by FRSC and the frequency with which each of the causes was linked with the occurrence of RTAs along the selected routes. These include speed violation (SPV), loss of control (LOC), dangerous driving (DGD), Tire burst (TBT), break failure (BFL), wrongful overtaking (WOT), route violation (RTV), mechanically deficient vehicle (MDV), bad road (BRD), road obstruction violation (OBS), dangerous overtaking (DOT), overloading (OVL), sleeping on steering (SOS), driving under alcohol/ drug influence (DAD), use of phone while driving (UPWD), fatigue (FTQ), poor weather (PWR), sign light violation (SLV) and others (OTH). Every RTA case was attributed to one or more of these causes. Thus, the four most frequently reported causes of RTAs in the study area and least reported causes of RTAs were discussed.

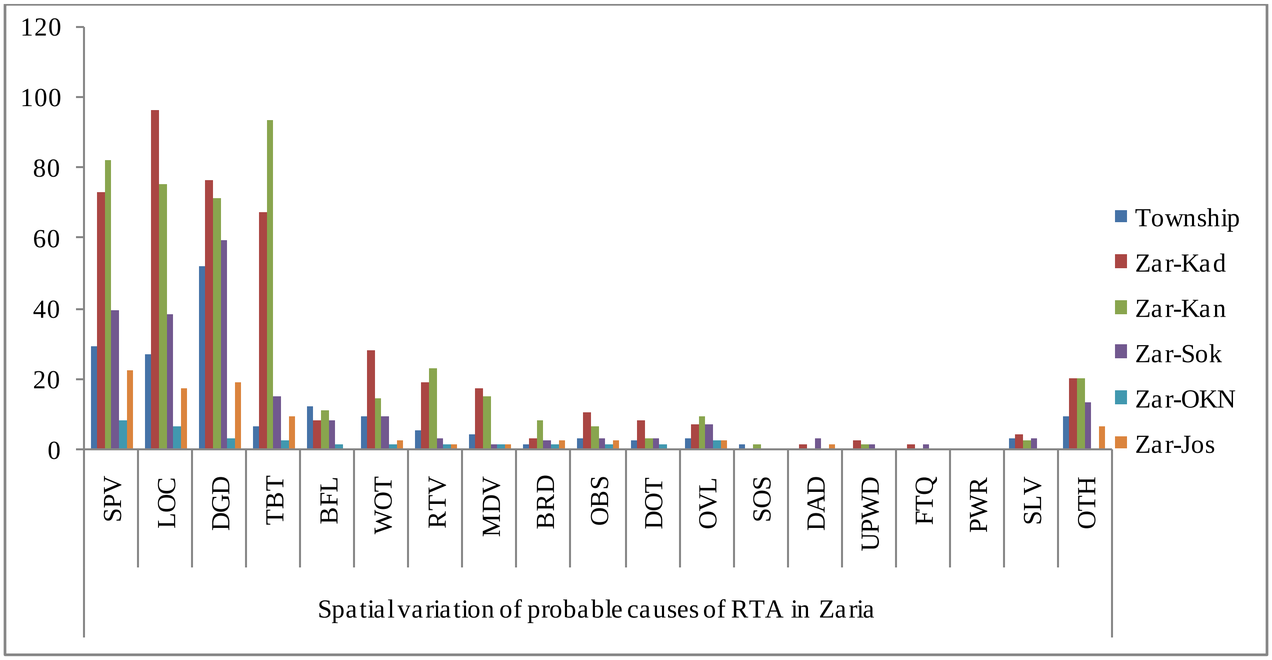


Figure 4.14: Spatial Variation in the Occurrence of Causes of RTAs in Zaria

Source: FRSC, 2016

4.2.2.1 Dangerous Driving (DGD)

This is the most frequently reported cause of RTAs within the study area which is more strongly associated with specific weather elements that include wind speed, relative humidity and poor visibility (see appendix III). It caused 280 RTAs of which 27% of these RTA cases attributed to it were experienced along Zaria-Kaduna route while 25% of RTA cases attributed to it were experienced along Zaria- Kano route. Thus, 52% of RTAs attributed to DGD were recorded along these routes. Only 1% of RTA cases attributed to DGD were reported along Old Zaria-Kano route. See Figure 4.15.

4.2.2.2 Loss of Control (LOC)

This is the second most frequently reported cause of RTAs within the study area which is more strongly associated with specific weather elements that include evaporation rate, air temperature (fatigue), relative humidity and poor visibility (see appendix III). It caused 259 RTAs of which 37% of these RTAs attributed to it occurred along Zaria-Kaduna route and another 29% along Zaria- Kano route. Thus, 66% of RTAs attributed to LOC were recorded along these routes. Only 3% of RTA cases attributed to it were reported along Old Zaria-Kano route. See Figure 4.15.

4.2.2.3 Speed Violation (SPV)

This is the third most frequently reported cause of RTAs within the study area which is more strongly associated with specific weather elements that include air temperature, wind speed and evaporation rate (see appendix III). It caused two hundred and fifty three (253) RTAs of which 32% of these RTAs attributed to it occurred along Zaria-Kano route while 29% of these occurred along Zaria-Kaduna route.Thus, 61% of RTAs attributed to SPV were recorded along these routes. However, only 3% of RTA cases attributed to it were reported along Old Zaria-Kano route. See Figure 4.15.

4.2.2.4 Tyre Burst (TBT)

This is the fourth most frequently reported probable cause of RTA within the study area which is more strongly associated with specific weather elements that include wind speed, air temperature (fatigue), relative humidity and poor visibility (see appendix III). It caused 192 RTAs of which 48% of these occurrences are along Zaria-Kano route with another 35% recorded along Zaria-Kaduna route. Thus, 83% of RTAs attributed to TBT were recorded along these routes. However, only 1% of RTA cases attributed to it were reported along Old Zaria-Kano route. See Figure 4.15.

4.2.2.5 Sleeping on Steering (SOS) and Fatigue (FTG)

This the sixteenth most frequently reported probable cause of RTA within the study area which is more strongly associated with specific weather elements that include rainfall, temperature (low temperature heat exhaustion), visibility, relative humidity (heat exhaustion leading to impatience) and wind speed (leading to poor controllability of vehicles). Only on 2 occasions was RTA attributed to SOS, one along Zaria-Kano route and the other within the township of Zaria. Thus, Zaria-Kaduna, Zaria-Sokoto, Zaria-Jos and Old Zaria-Kano routes did not experience any RTA case(s) linked to it. Fatigue (FTG) like SOS is the least reported cause of RTA within the study area as only on 2 occasions did record show that RTA case(s) were linked to it; once along Zaria-Kaduna route and the other along Zaria-Sokoto route. Thus, there were no recorded case(s) of RTA linked to it along Zaria-Kano, Zaria Township, Zaria-Jos and Old Zaria-Kano routes. It was found to be strongly associated with wind speed and relative humidity.

This study identified dangerous driving, speed violation and loss of control as the leading causes of RTA in Zaria. This agrees with Usman *et al.* (2015) who identified same as the leading causes of RTA along Zaria-Sokoto route. However, the present study ranked dangerous driving as the leading probable causes of RTA in Zaria followed by speed violation and loss of control respectively. On the contrary, Usman *et al.* (2015) identified speed violation as the leading probable causes of RTA followed by loss of control and dangerous driving respectively. Like Usman *et al.* (2015), Jobin (2015) identified speed violation as the leading causes of RTA along Zaria-Kaduna route followed by tyre burst, loss of control and dangerous driving respectively.

In order to determine if there is a significant spatial variation in RTA cases and casualties along the different routes, one-way ANOVA test was used and the result is presented on Table 4.4.

Table 4.4: Variability in RTA Severity along Six Routes in Zaria

Source	DF	SS	MS	F	P
Factor	5	8394	1679	4.02	0.002
Error	101	42148	417		
Total	106	50542			

Source: Author's Analysis, 2016

The result showed that the calculated F is greater than the critical value of F at 0.05 and *p*-value (*P* = 0.017) is less than 0.05 meaning and confirming that the frequency with which the occurrence of RTA is linked to these probable causes differ significantly along the different routes in Zaria.

Furthermore, since analysis of variance showed that the effect of the treatment means are not the same, one of the methods of multiple comparison tests called Fisher's Least Significance Difference (LSD) was used in this study to know the treatment means that are different from the others as presented on Table 4.5.

Table 4.5: Grouping Information Using Fisher's LSD

Route	N	Mean	Grouping
Zaria-Kaduna	18	24.44	A
Zaria-Kano	18	24.11	A
Zaria-Sokoto	18	11.56	A B
Township	18	9.76	B
Zaria-Jos	18	4.67	B
Old Zaria-Kano	18	1.56	B

Source: Author's Analysis, 2016

Note: Means that do not share a letter are significantly different.

Table 4.5 showed that the number of cases and casualties recorded along Zaria-Kaduna, Zaria-Kano and Zaria-Sokoto routes are statistically similar to one another even though Zaria-Kaduna and Zaria-Kano are more similar to one another but they differ significantly from the other routes. Zaria Township, Zaria-Jos and Zaria Old Kano routes but was not significant different from Zaria-Kano and Zaria-Sokoto routes. The result confirmed that Zaria-Kaduna route had the highest number of RTA cases and casualties followed by Zaria-Kano route and the least being Old Zaria-Kano route.

4.3 Temporal Variation of RTAs in Zaria

4.3.1 Annual Variation of RTAs along Different Routes in the Study Area

4.3.1.1 Annual Variation of RTAs within Zaria Township

Figure 4.15 presents the original trends and trend lines representing RTA cases and casualties within Zaria Township.

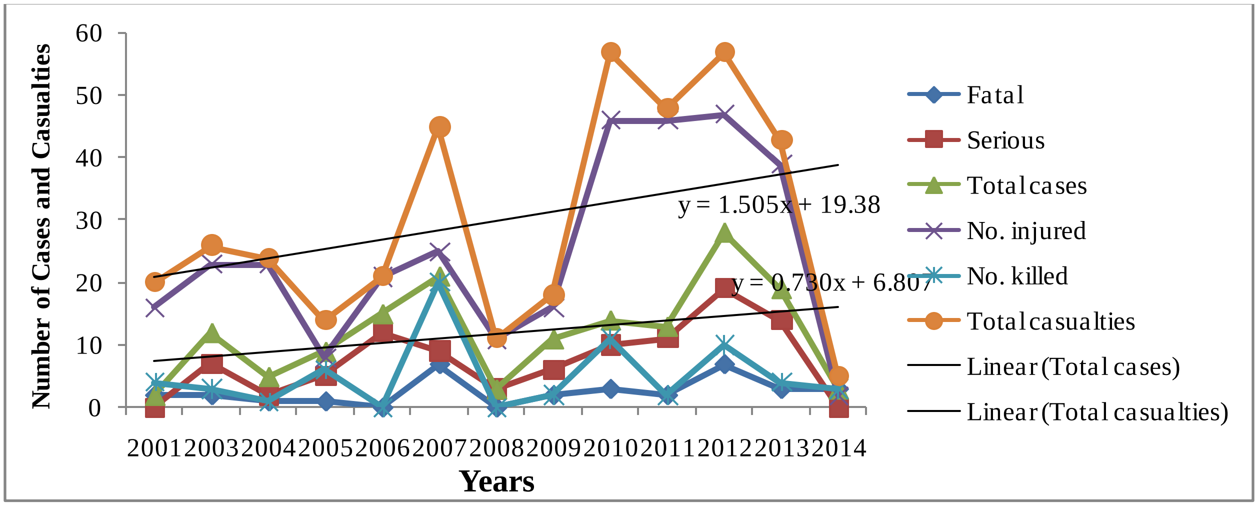


Figure 4.15: Temporal Variation of RTA cases and casualties in Zaria Township
Source: FRSC, 2016

The highest number of fatal cases that was recorded in Zaria Township was in 2007 and 2012. For serious cases, total cases and number of injured persons was in 2012. However, the highest number of persons killed as a result of RTAs was in 2007 while the highest number of casualties from RTA was recorded in 2010 and 2012. The trend line revealed that there is an increase in the number of cases and casualties in Zaria Township. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees in Zaria Township. This is because weather parameters affect how well a driver will see the road, respond to stimulus, skidding, lead to heat exhaustion, impatience and poor controllability of vehicles among others. This applies to all the routes.

4.3.1.2 Annual Variation of RTAs along Zaria-Kaduna Route

Furthermore, Figure 4.16 presents the original trends and trend lines representing RTA cases and casualties along Zaria-Kaduna route.

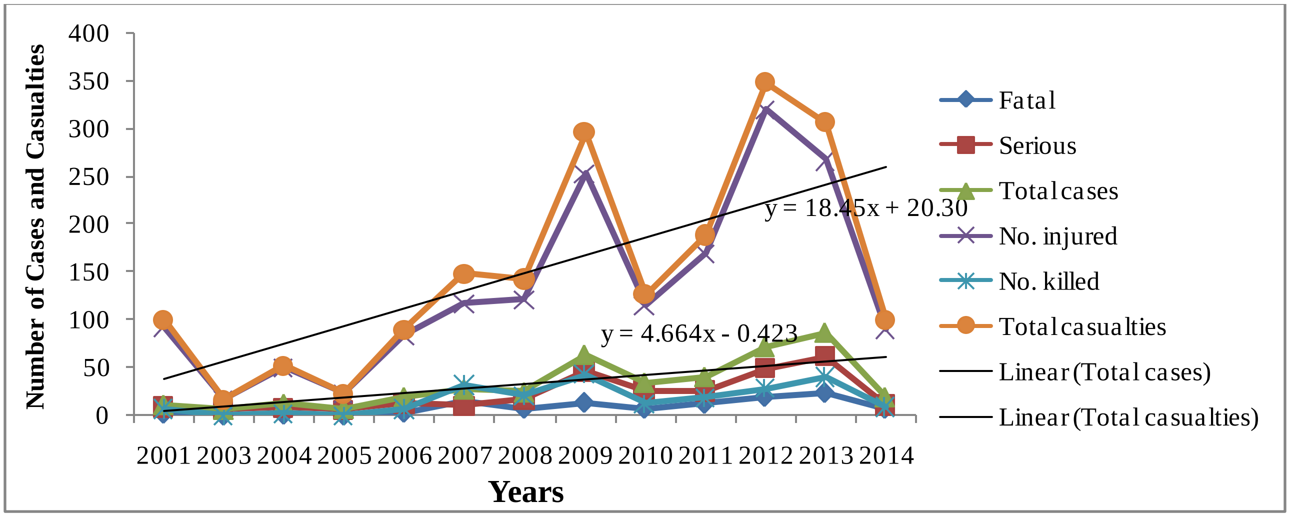


Figure 4.16: RTA Cases and Casualties along Zaria-Kaduna Route

Source: FRSC, 2016

The highest number of fatal, serious and total cases of RTA that was recorded along Zaria-Kaduna route was in 2013. The highest number of injured persons on one hand and total number of casualties on the other as a result of RTA was in 2012 while the highest number of persons killed was in 2009. The trend line revealed that there is a general increase in the number of cases and casualties. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-Kaduna route.

4.3.1.3 Annual Variation of RTAs along Zaria-Kano Route

Figure 4.17 presents the original trends and trend lines representing RTA cases and casualties within Zaria-Kano route.

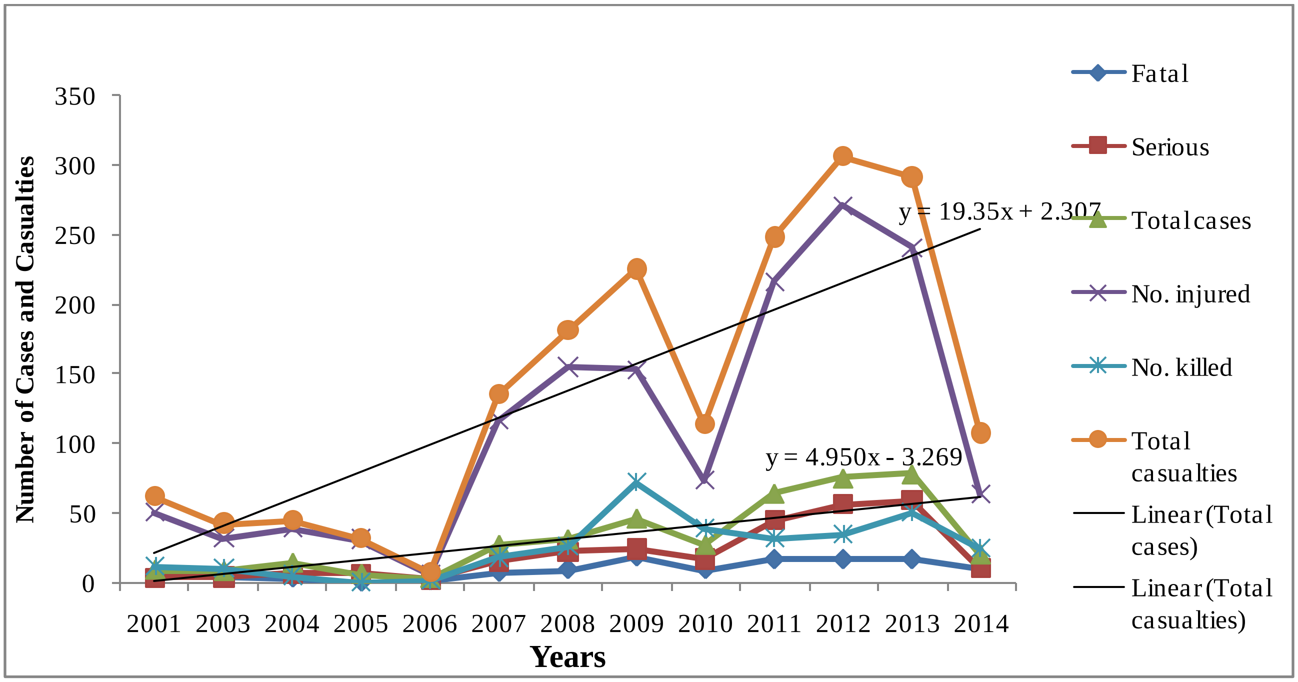


Figure 4.17: Temporal Variation of RTA Cases and Casualties along Zaria-Kano Route
Source: FRSC, 2016

Figure 4.17 revealed that the highest number of fatal cases that was recorded along Zaria-Kano route was in 2009 while serious RTA cases and total RTA cases were recorded in 2013. The highest number of injured persons on one hand and total number of casualties on the other as a result of RTA was in 2012 while the highest number of persons killed was in 2009. The trend line revealed that there is a general increase in the number of cases and casualties.However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-Kano route.

4.3.1.4 Annual Variation of RTAs along Zaria-Sokoto Route

Figure 4.18 presents the original trends and trend lines representing RTA cases and casualties along Zaria-Sokoto route.

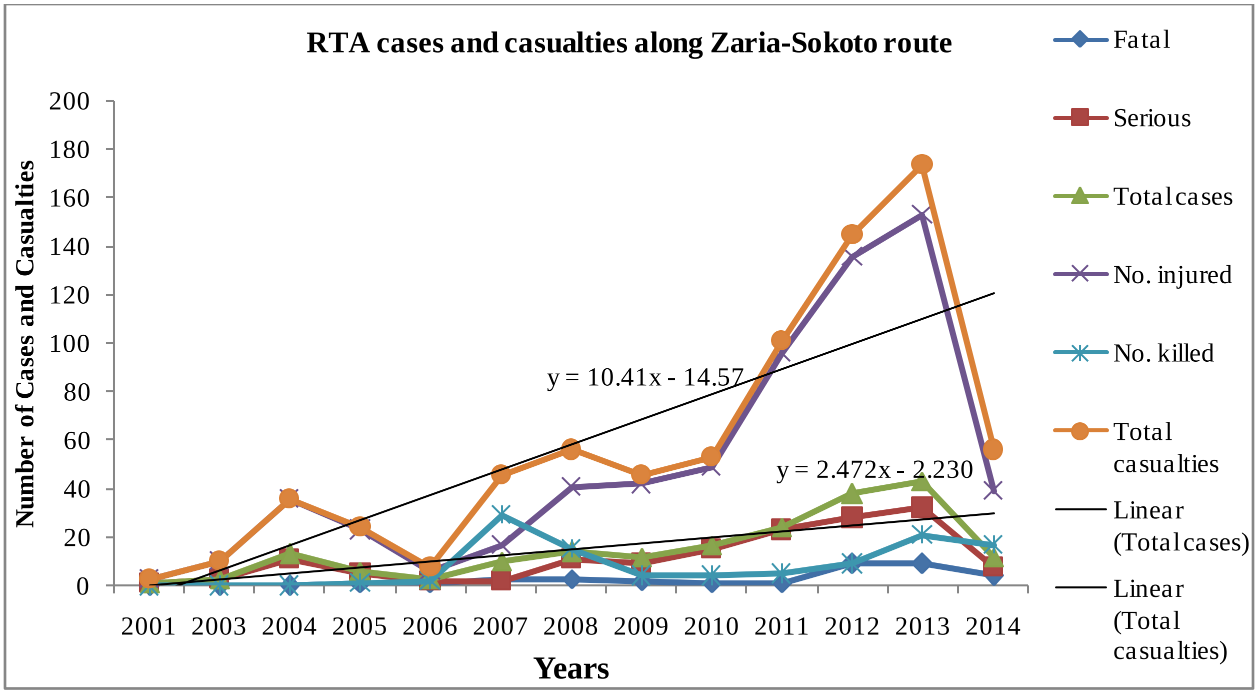


Figure 4.18: Temporal Variation of RTA Cases and Casualties along Zaria-Sokoto Route
Source: FRSC, 2016

The highest number of fatal RTA cases that was recorded along Zaria-Sokoto route was in 2012 and 2013 while the highest number of serious, total cases, number of injured persons and number of casualties was recorded in 2013. The highest number of persons killed as a result of RTA was in 2007. The trend line revealed that there is a general increase in the number of cases and casualties. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-Sokoto route.

4.3.1.5 Annual Variation of RTAs along Zaria-Old Kano Route

Figure 4.19 presents the original trends and trend lines representing RTA cases and casualties along Zaria-Old Kano route.

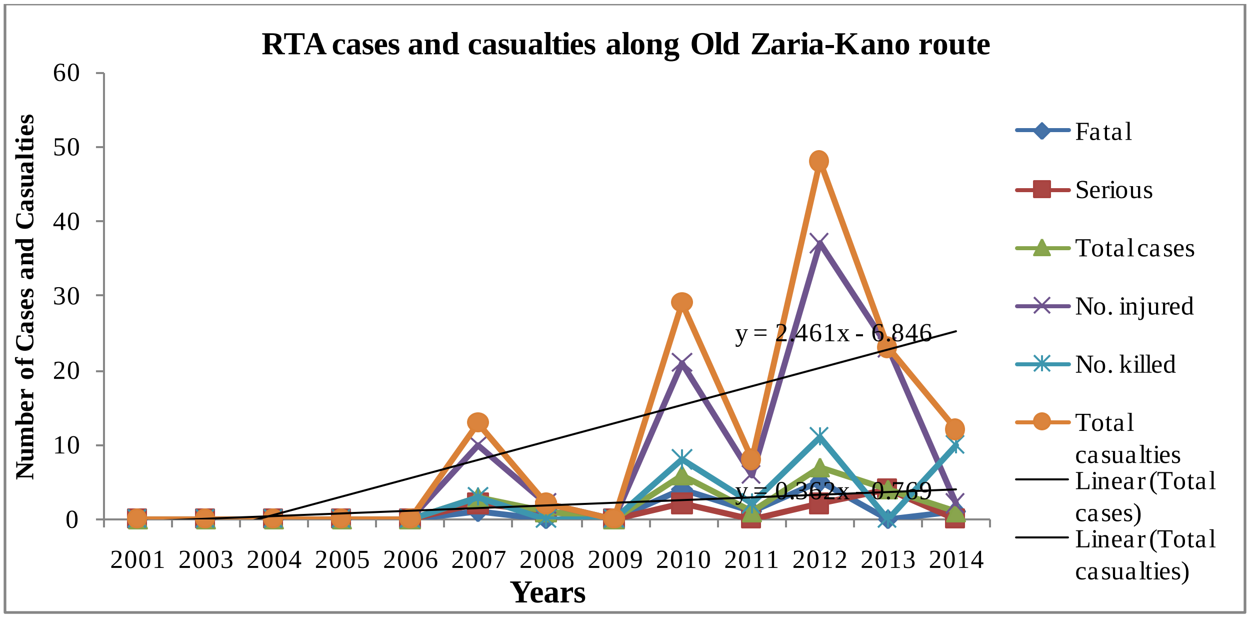


Figure 4.19: Temporal Variation of RTAs along Old Zaria-Kano Route
Source: FRSC, 2016

The highest number of fatal RTA cases, total RTA cases, number of persons injured and persons killed and number of casualties as a result of RTA recorded along Old Zaria-Kano route was in 2012. However, the highest number of serious RTA cases was recorded in 2013. The trend line revealed that there is a general increase in the number of cases and casualties from 2001 to 2014. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-old Kano route.

4.3.1.6 Annual Variation of RTAs along Zaria-Jos Route

Figure 4.20 presents the original trends and trend lines representing RTA cases and casualties along Zaria-Jos route.

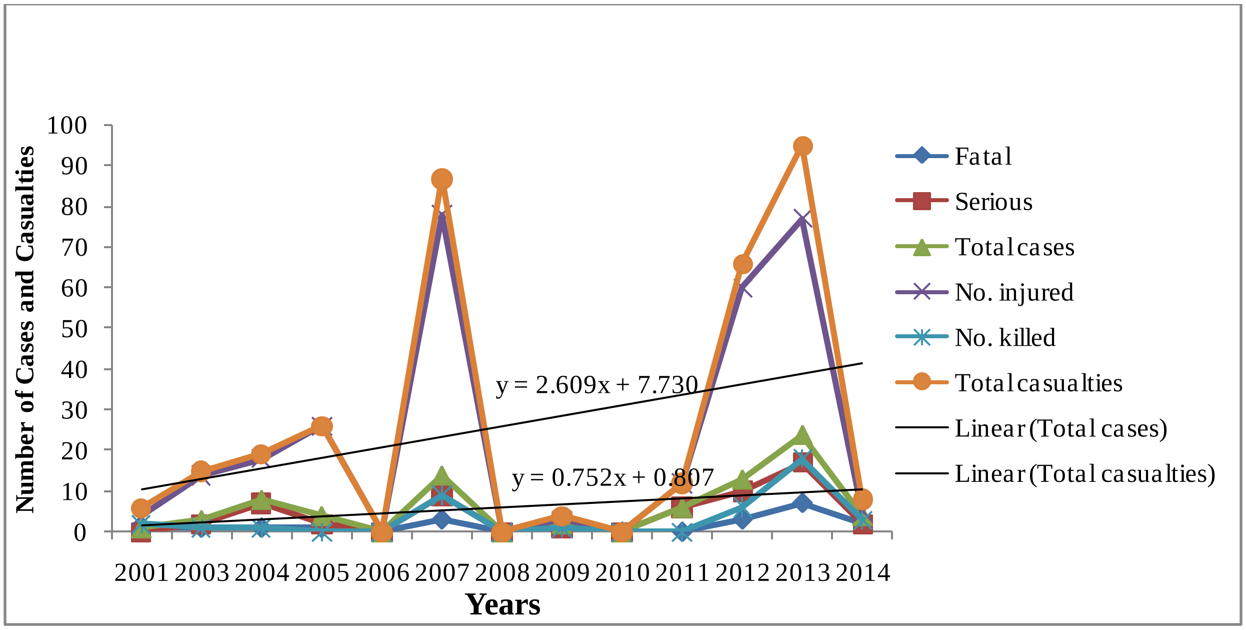


Figure 4.20: Temporal Variation of RTA Cases and Casualties along Zaria-Jos Route
Source: FRSC, 2016

The highest number of fatal RTA cases, serious RTA cases, number of RTA cases, number of persons killed and the number of casualties as a result of RTA were in 2013. The highest number of injured persons as a result of RTA was in 2007. The trend line revealed that there is a general increase in the number of cases and casualties. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-Jos route.

4.3.1.6 Annual Variation of RTAs in Zaria

Figure 4.21 presents the original trends and trend lines representing RTA cases and casualties in Zaria.

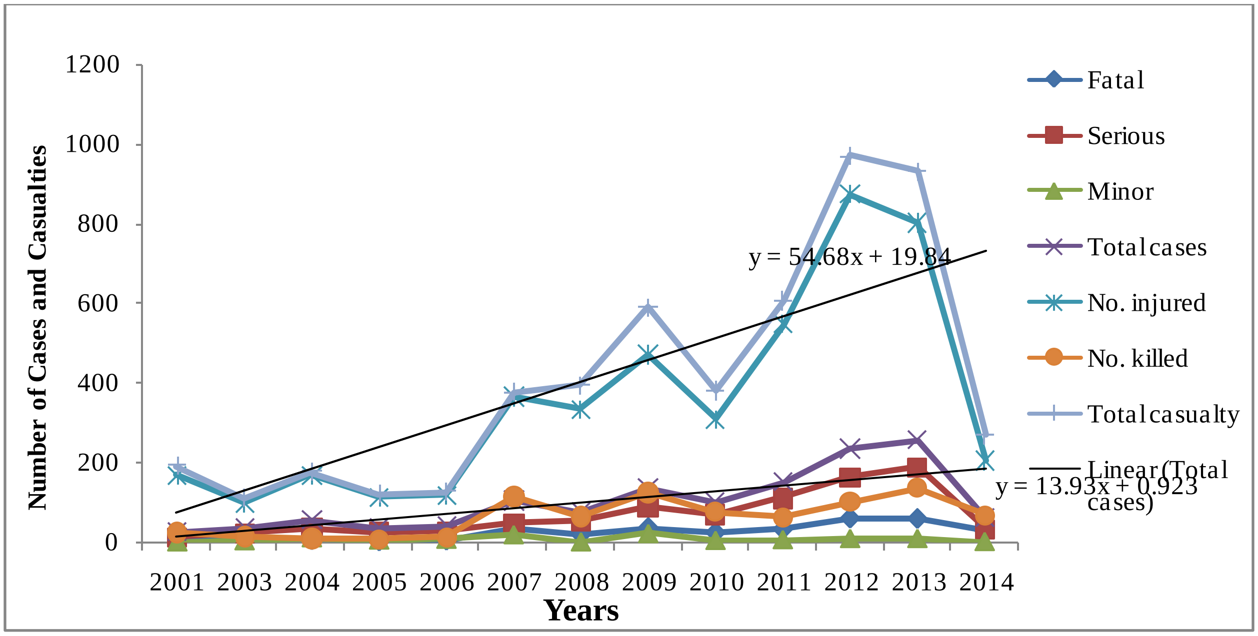


Figure 4.21: Temporal Variation of RTA Cases and Casualties in Zaria
Source: FRSC, 2016

The highest number of fatal cases was recorded in Zaria was in 2012, serious cases in 2013, minor cases in 2009 while the highest number of cases was recorded in 2013. The highest number of injured persons as a result of RTA was in 2012, the highest number of persons killed as a result of RTA was in 2013 while the highest number of casualties from RTAs was recorded in 2012. The trend line revealed that there is a general increase in the number of cases and casualty, there was more increase in the number of casualties than cases. However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of RTAs at different degrees along Zaria-Jos route.

This study is in agreement with Central Bank of Nigeria (1994, 1997), Obinna (2007), Atubi (2009b, 2009c) who stated that RTA cases and casualties has remained at an increase at certain periods example 1991-1992 according to CBN (1994), 1995-1996 according to CBN(1997), 1991-2001 according to Obinna (2007) and 1990-2005 according to Atubi (2009b, 2009c). It is also in agreement with Ovuwori and Asalor (2010) who stated that there is a general increase in incidences of morbidity and mortality rates due to RTA with people getting injured everyday especially in developing countries like Nigeria. It is also in agreement with Atubi (2013) who stated that the trend of fatality from road traffic accidents reveals that the phenomenon is on the increase, in other words, the trend of fatalities from road traffic accidents is on the increase in Lagos State between 1970 and 2001 as revealed by the trend analysis. Accidents were high during the years because of the fact that the federal road safety commission was not in existence then.

4.3.2 Monthly Variation of RTAs along Different Routes in the Study Area

4.3.2.1Monthly Variation of RTAs within Zaria Township

Figure 4.22 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties within Zaria Township.

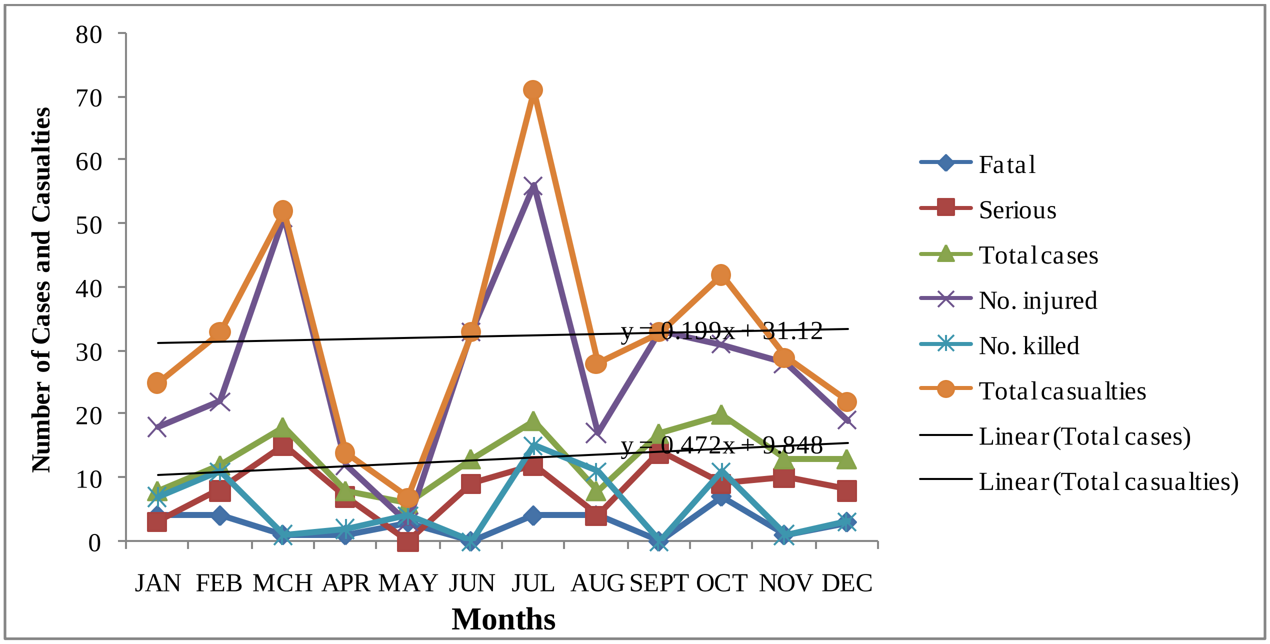


Figure 4.22: Monthly Variation of RTA Cases and Casualties in Zaria Township
Source: FRSC, 2016

The highest number of fatal cases and number of RTA cases that was recorded in Zaria Township was in October; serious cases in September, number of injured persons, number of persons killed and the number of casualties from RTA were all recorded in the month of

July.The highest number of RTA cases occurred in the month of October and this could be due to high temperature leading to heat exhaustion, impatience, tyre burst, overheating of vehicles, drying up of fluid in batteries, failing of fuel pumps while the highest number of RTA casualties occurred in the month of July and this could be due to skidding, high wind speed and poor visibility. The trend line revealed that there was generally a gradual increase in the number of cases and even a more gradual increase in casualties due to RTA from January to December.

4.3.2.2Monthly Variation of RTAs along Zaria-Kaduna Route

Figure 4.23 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties along Zaria-Kaduna route.

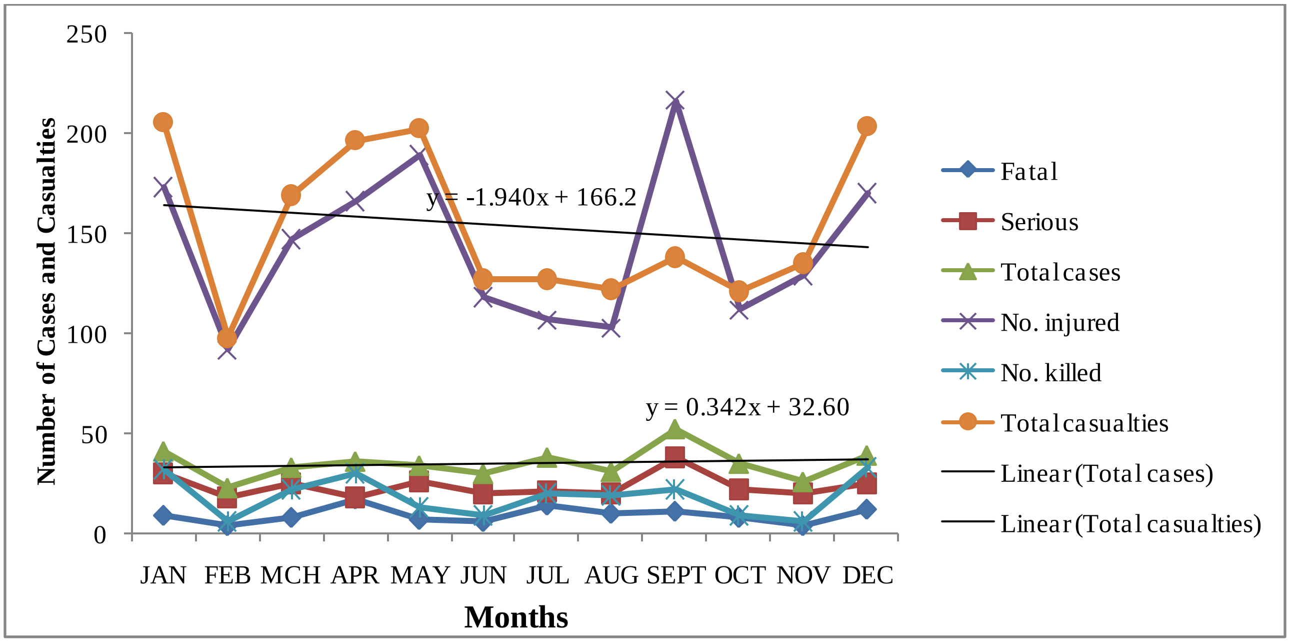


Figure 4.23: Monthly RTA Cases and Casualties along Zaria-Kaduna Route
Source: FRSC, 2016

The highest number of fatal cases that was recorded along Zaria-Kaduna route was in April; serious cases, number of cases and the number of injured persons as a result of RTA were all September. The highest number of persons killed as a result of RTA was in December while the highest number of casualties as a result of RTA was recorded in the month of January. The highest number of RTA cases occurred in the month of September and this could be due to skidding, high wind speed and poor visibility during rainfall, heat stress due to high relative humidity while the highest number of RTA casualties occurred in the month of January and this could be due to high wind speed and poor visibility. The trend line revealed that there was generally a very gradual increase in the number of cases and decrease in casualties due to RTA from January to December.

4.3.2.3Monthly Variation of RTAs along Zaria-Kano Route

Figure 4.24 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties along Zaria-Kano route.

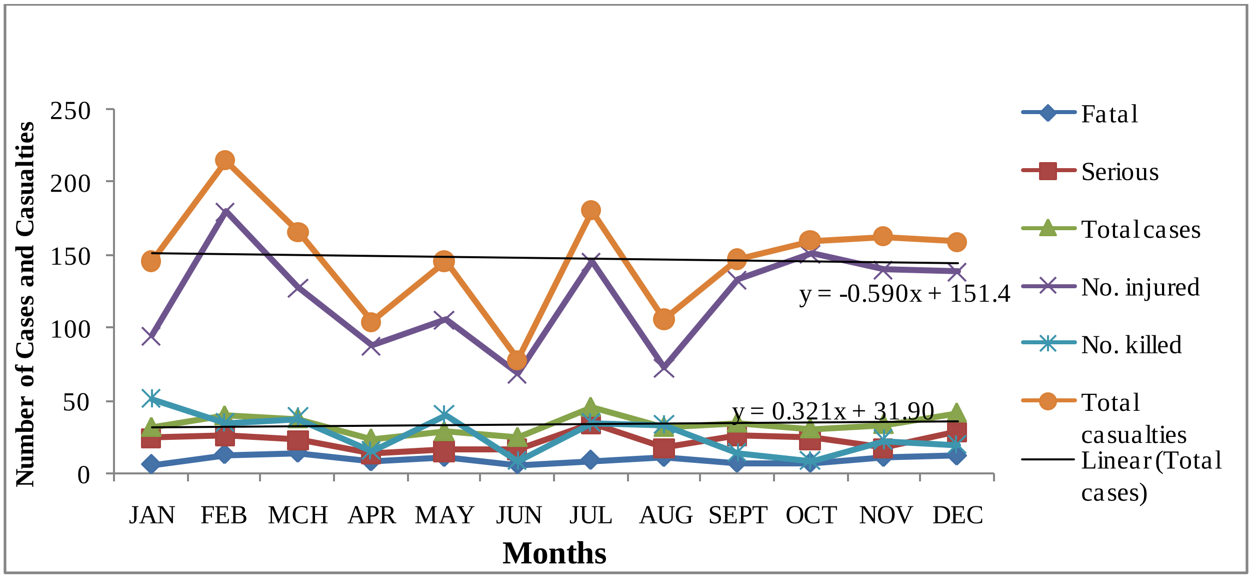


Figure 4.24: Monthly Variation of RTA Cases and Casualties along Zaria-Kano Route
Source: FRSC, 2016

The highest number of fatal cases that was recorded along Zaria-Kano route was in March; serious cases and number of cases were recorded in July. The highest number of injured persons as a result of RTA and the number of casualties were all recorded in February while the highest number of persons killed as a result of RTA was in January. The highest number of RTA cases occurred in the month of July and this could be due to skidding, high wind speed and poor visibility during rainfall while the highest number of RTA casualties occurred in the month of February and this could be due to poor visibility and high wind speed. However, like Zaria-Kaduna route, the trend line revealed that there was generally a very gradual increase in the number of cases and decrease in casualties due to RTA from January to December.

4.3.2.4Monthly Variation of RTAs along Zaria-Sokoto Route

Figure 4.25 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties along Zaria-Sokoto route.

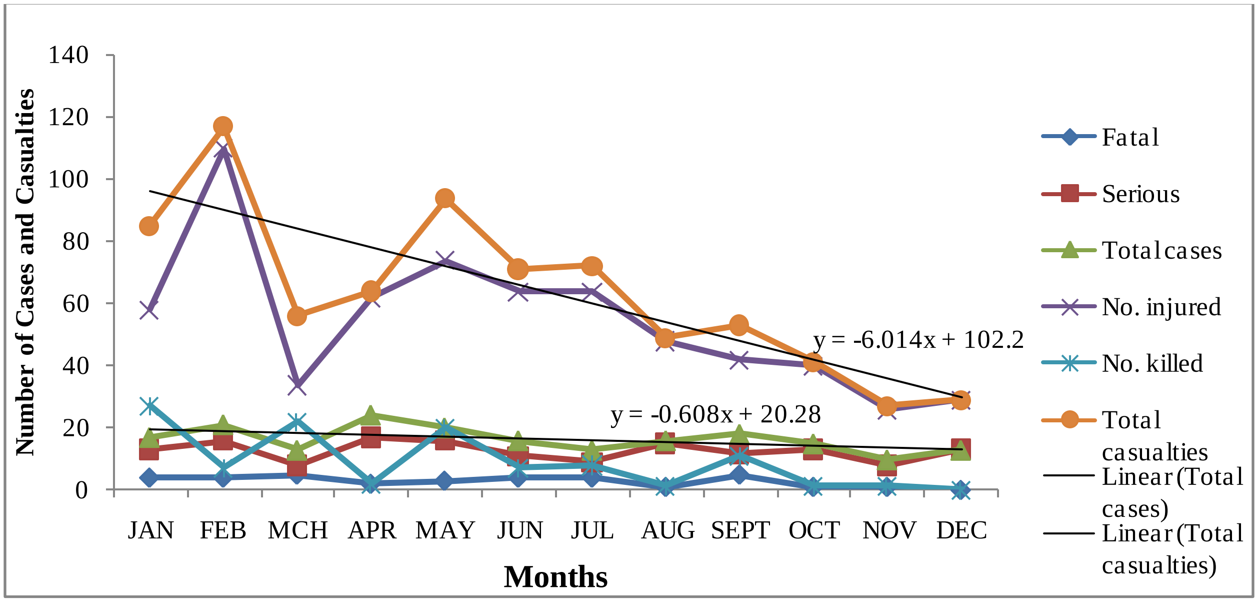


Figure 4.25: Monthly Variation of RTA Cases and Casualties along Zaria-Sokoto Route
Source: FRSC, 2016

The highest number of fatal cases that was recorded along Zaria-Sokoto route was in March and September; serious cases and also number of RTA cases were all recorded in April. The highest number of injured persons and number of casualties as a result of RTAs were all recorded February while the highest number of persons killed was in January. The highest number of RTA cases occurred in the month of April and this could be due to heat exhaustion leading to fatigue, impatience among others because April is the hottest month in the study area while the highest number of RTA casualties occurred in the month of February and this could be due to poor visibility and high wind speed. However, the trend line revealed that there was generally a very gradual decrease in the number of cases and a sharp decrease in casualties due to RTA from January to December.

4.3.2.5Monthly Variation of RTAs along Zaria-Old Kano Route

Figure 4.26 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties along Zaria-Old Kano route.

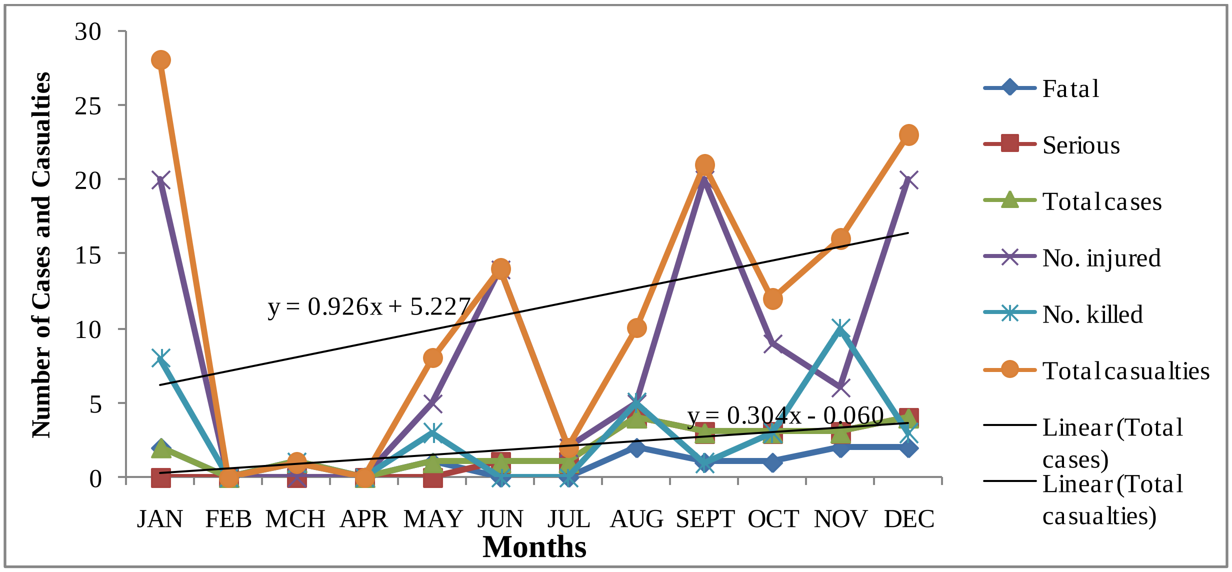


Figure 4.26: Monthly variation of RTA cases and casualties along Zaria-Old Kano route

Source: FRSC, 2016

The highest number of fatal cases that was recorded along Old Zaria-Kano route was in January, August, November and December, serious RTA cases and the number of RTA cases was all recorded in August and December. The highest number of injured persons as a result of RTA was in January, September and December; the highest number of persons killed as a result of RTA was in November while the highest number of casualties from RTA was recorded in the month of January. The highest number of RTA cases occurred in the month of August and this could be due to skidding, high wind speed and poor visibility during rainfall because August is the peak of rainfall in the study area while the highest number of RTA casualties occurred in the month of December and this could be due to poor visibility and high wind speed. However, the trend line revealed that there was generally an increase in the number of cases and casualties due to RTA from January to December.

4.3.2.6Monthly Variation of RTAs along Zaria-Jos Route

Figure 4.27 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties along Zaria-Jos route.

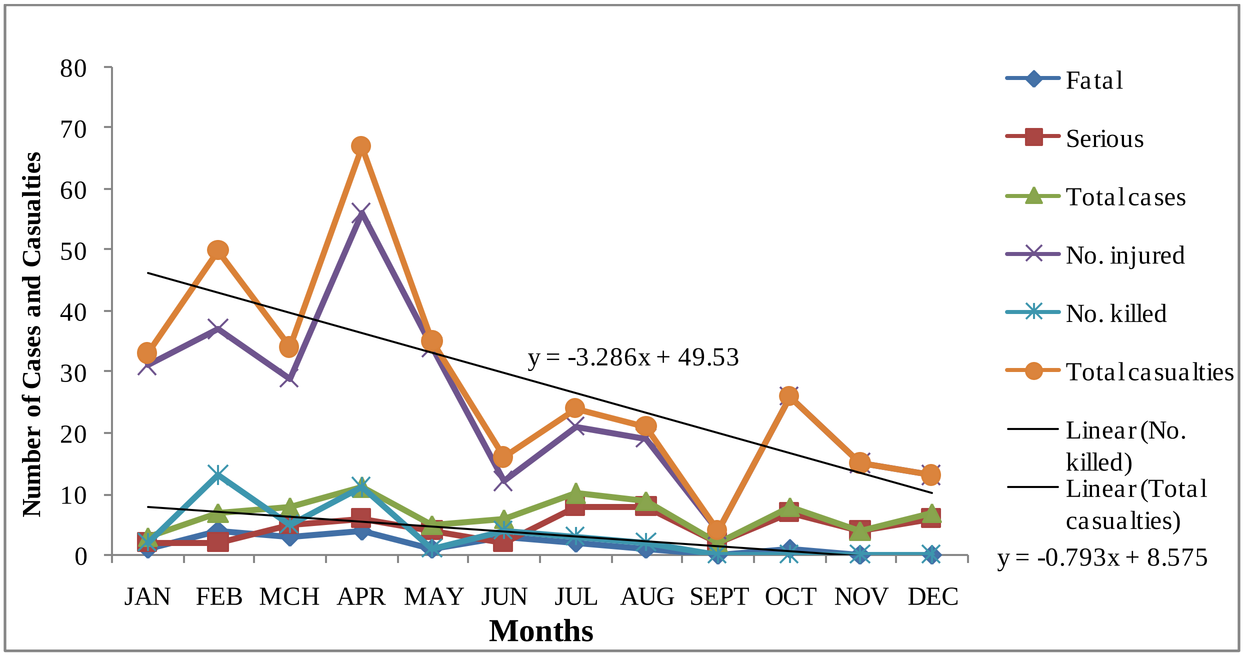


Figure 4.27: Monthly Variation of RTA Cases and Casualties along Zaria-Jos Route

Source: FRSC, 2016

The highest number of fatal cases that was recorded along Zaria-Jos route was in February and April, serious cases in July, August and December while the highest number of RTA cases, number of injured persons and the number of casualties as a result of RTA were all recorded in April. The highest number of persons killed as a result of RTA was in February. The highest number of RTA cases as well as the highest number of casualties due to RTAs occurred in the month of April and this could be due to heat exhaustion leading to fatigue, impatience among others because April is the hottest month in the study area. However, the trend line revealed that there was generally a gradual decrease in the number of cases and a sharp decrease in the number of casualties due to RTA.

4.3.2.7Monthly Variation of RTAs in Zaria

Figure 4.28 presents the original trends and trend lines representing the monthly variation of RTA cases and casualties in Zaria.

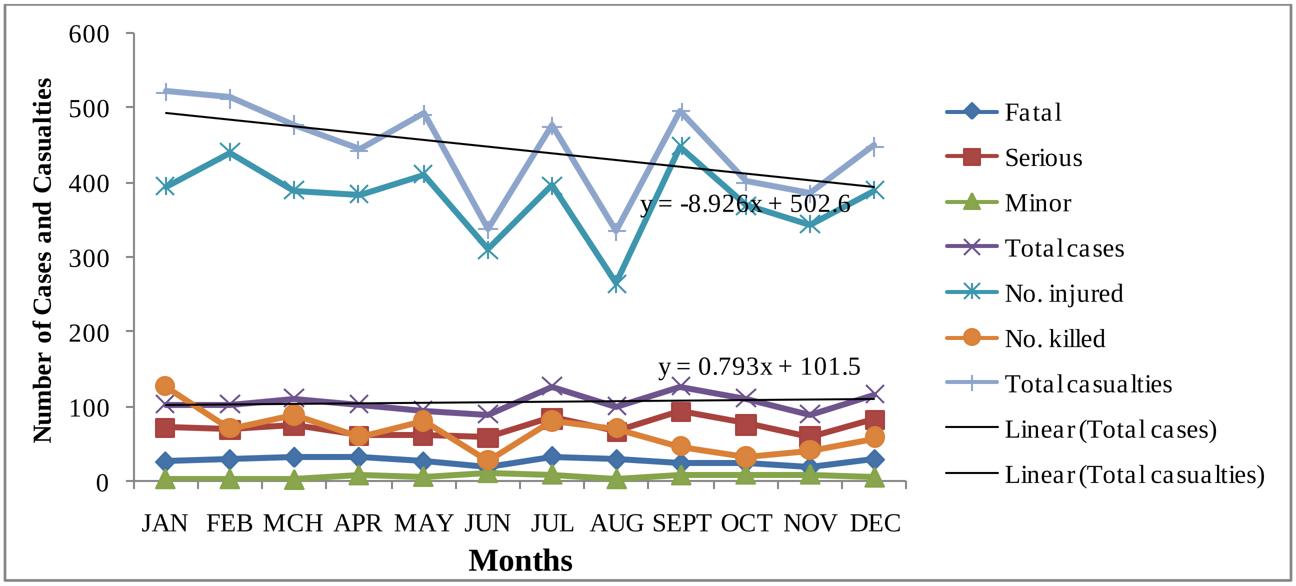


Figure 4.28: Monthly Variation of RTA Cases and Casualties in Zaria

Source: FRSC, 2016

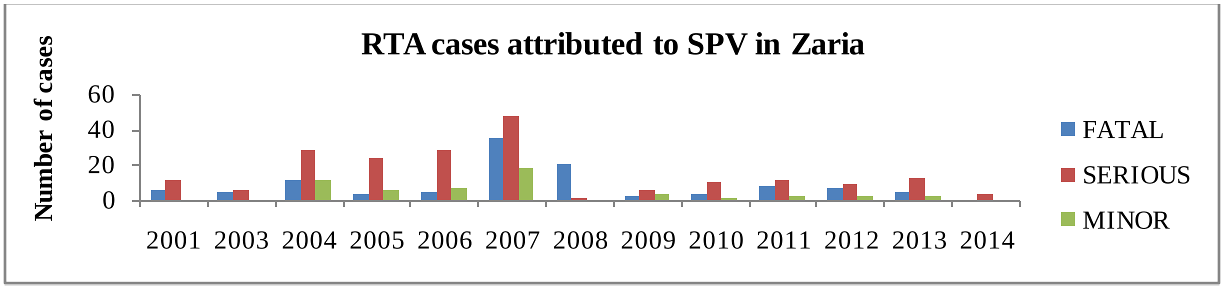
The highest number of fatal cases and number of RTA cases recorded in Zaria was in July; serious cases and number of injured persons in September and minor cases in June. The highest number of persons killed and number of casualties were recorded in the month of January. The highest number of RTA cases occurred in the month of July and this could be due to skidding, high wind speed and poor visibility during rainfall while the highest number of RTA casualties occurred in the month of January and this could be due to poor visibility and high wind speed. However, the trend line revealed that there was generally a very gradual increase in the number of RTA cases and decrease in number of casualties due to RTAs.

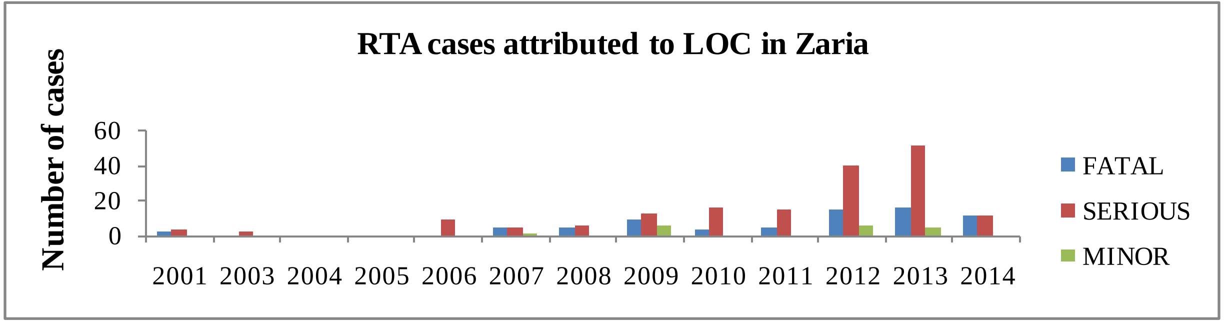
This study is in agreement with Atubi (2012a, 2012b, 2012c, 2013) who stated that proper traffic patrol at the times of very high accident occurrence will go a long way towards reducing traffic accidents and the associated injuries and fatalities in Nigeria. Consistent road safety efforts should be intensified during the months of June, July, September, October, November and December as these are periods when the highest number of road accidents cases involving death and injuries are recorded. This study revealed that more RTA cases were recorded in July than the other months like Atubi (2012a, 2012b, 2012c, 2013) while more casualties were recorded in January unlike July as reported by Atubi in Lagos State, Nigeria (2012a, 2012b, 2012c, 2013). On the other hand, Usman *et al.* (2015) reported that more RTA cases and casualties were recorded in October along Zaria-Sokoto within the Zaria Unit command.

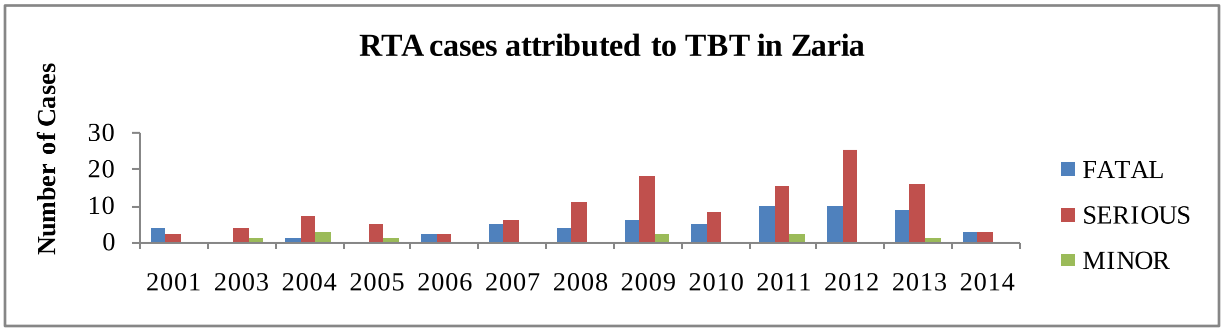
4.3.3 RTA Cases attributed to Identified Causes in Zaria

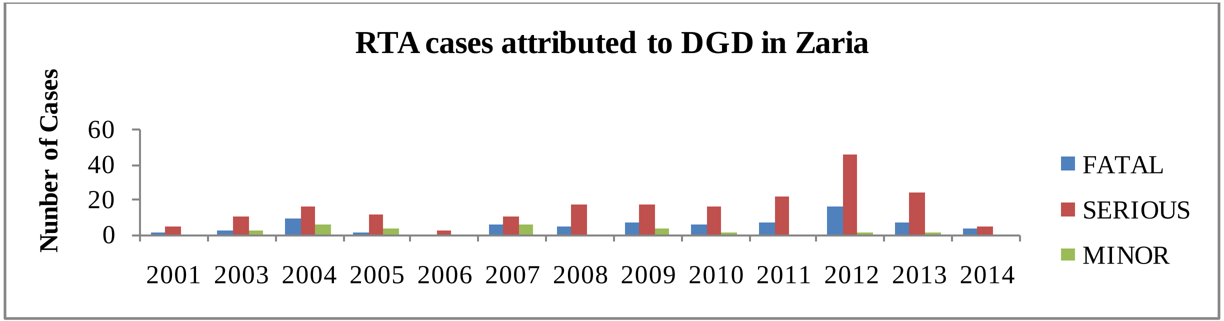
4.3.3.1 Annual RTA cases Attributed to Causes of RTAs in Zaria

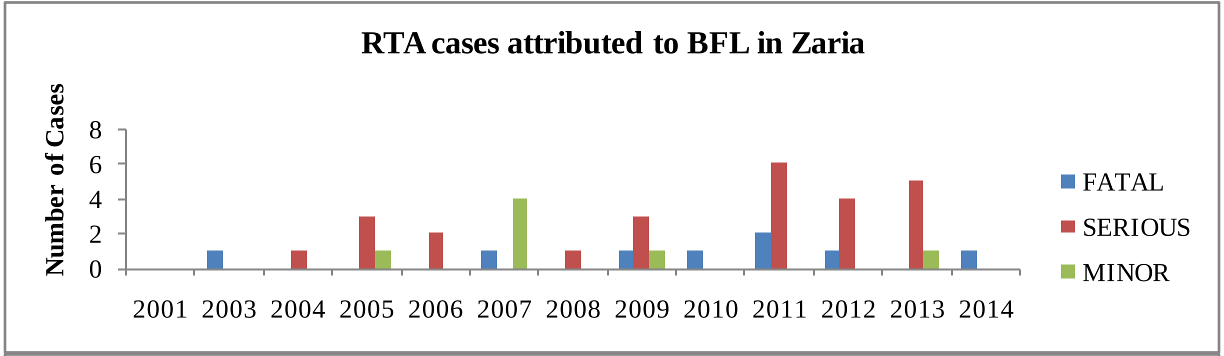
Figure 4.29 presents all the nineteen causes of RTAs identified by FRSC and the frequency with which each of these causes was linked with the occurrence of fatal, serious and minor RTAs in Zaria for the entire study period.

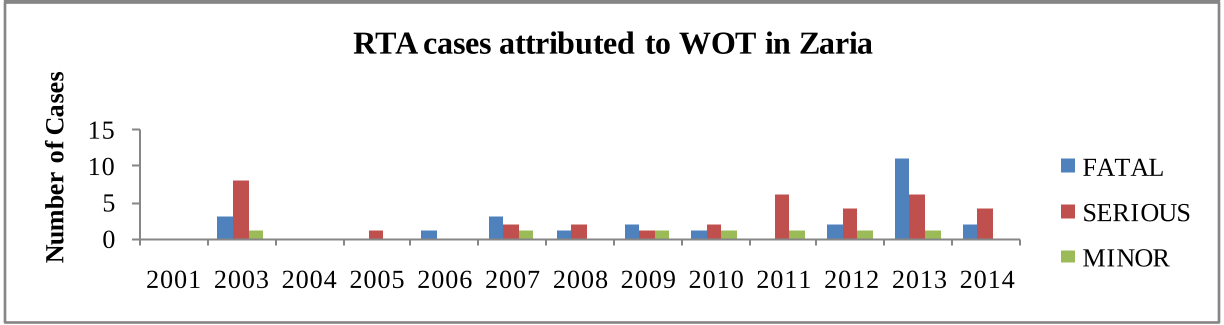


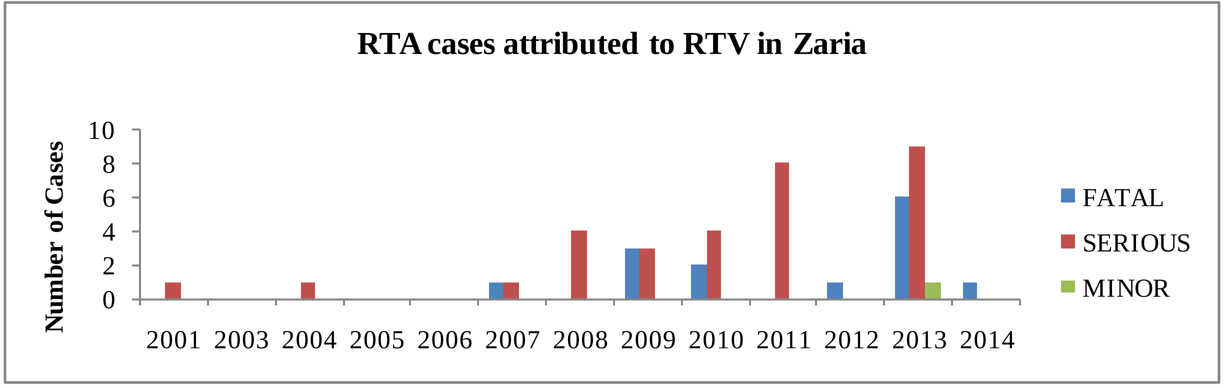


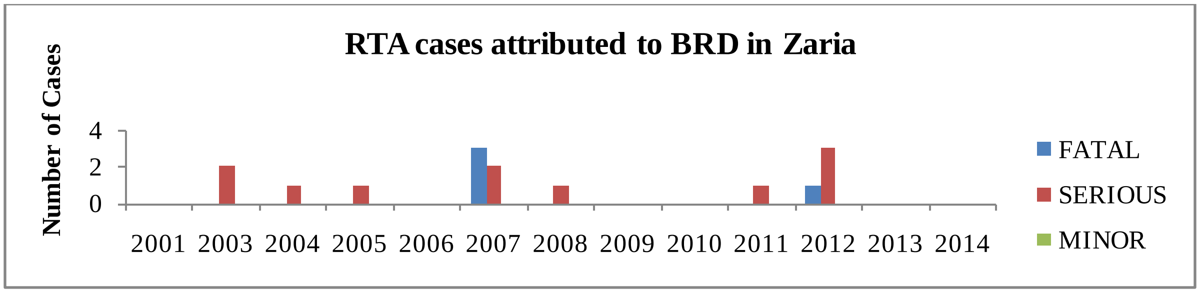

RTA cases attributed to TBT in Zaria

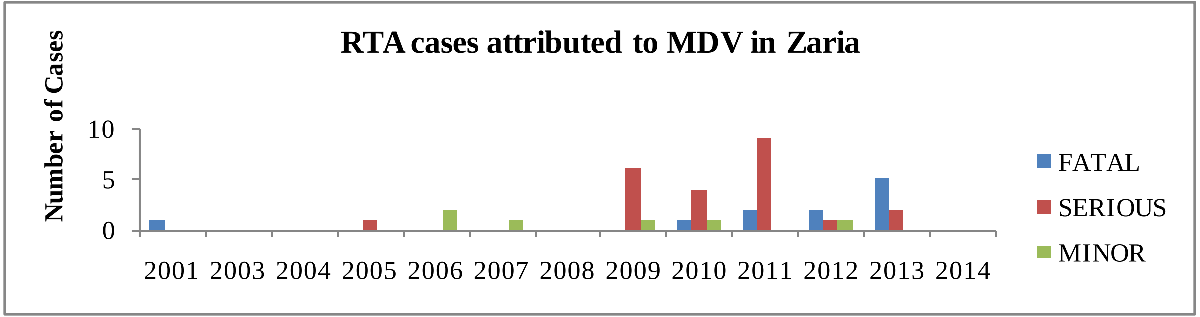

RTA cases attributed to DGD in Zaria

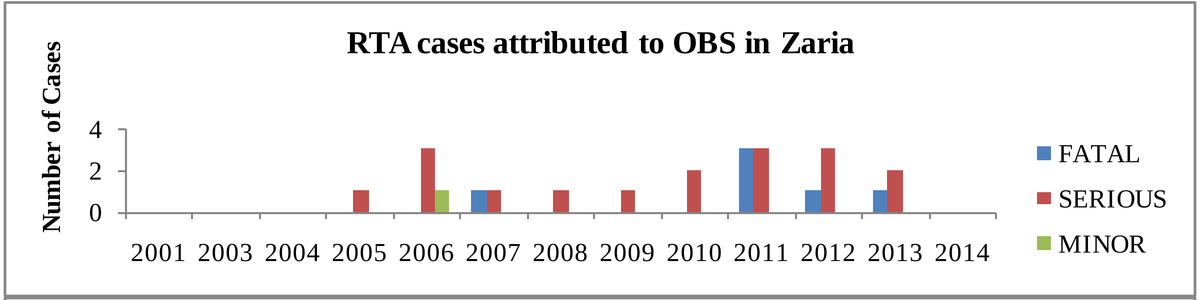

RTA cases attributed to BFL in Zaria

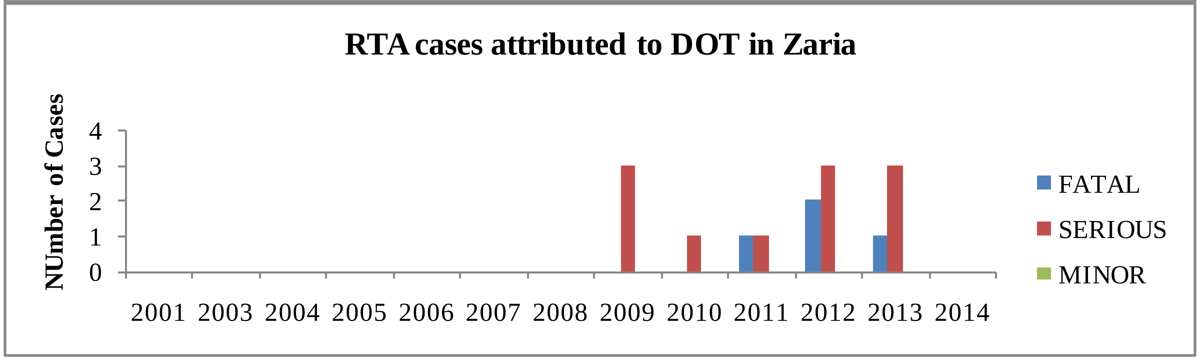

RTA cases attributed to WOT in Zaria

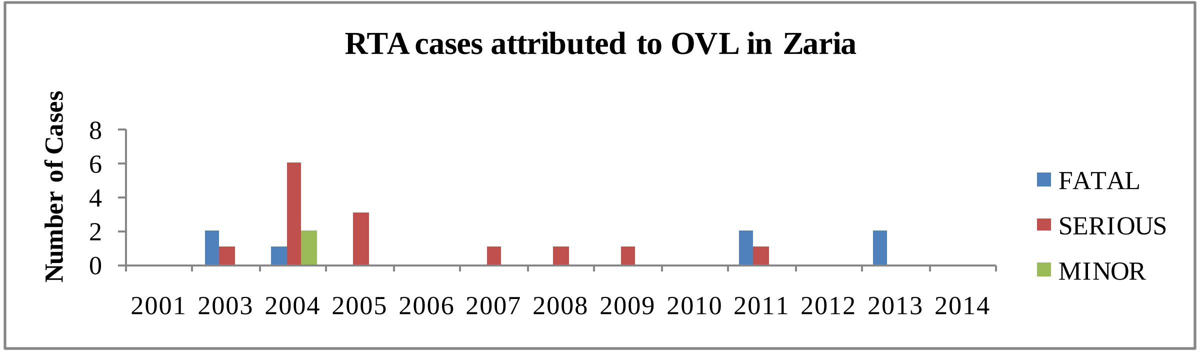

RTA cases attributed to RTV in Zaria

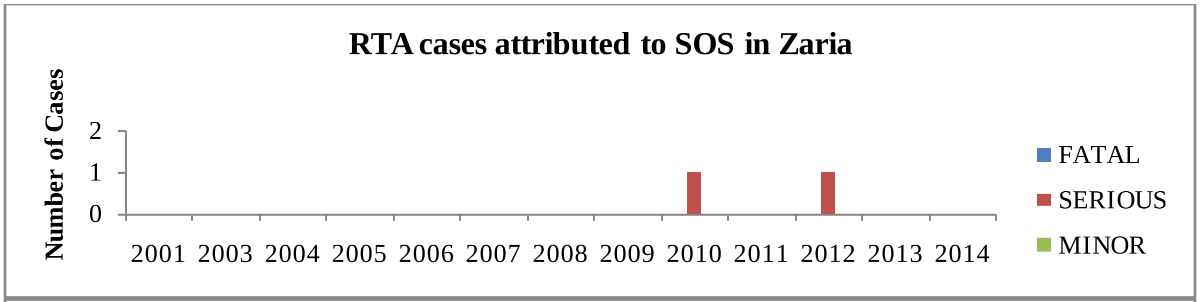

RTA cases attributed to BRD in Zaria
Number of Cases
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

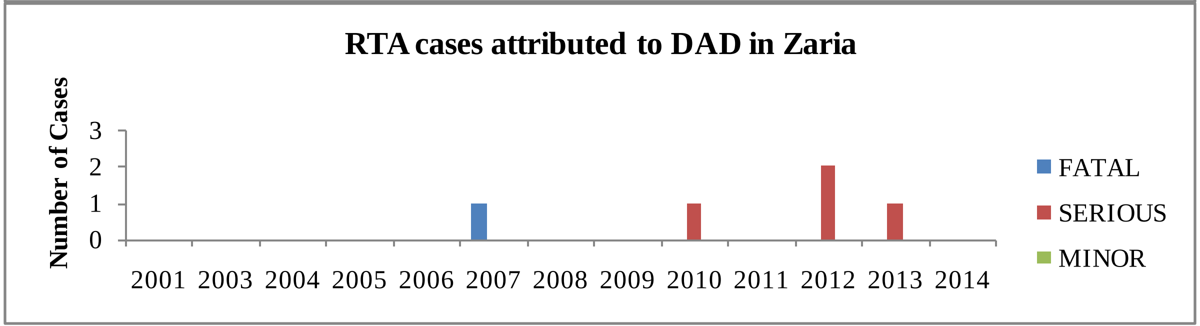

RTA cases attributed to MDV in Zaria
Number of Cases
10
5
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

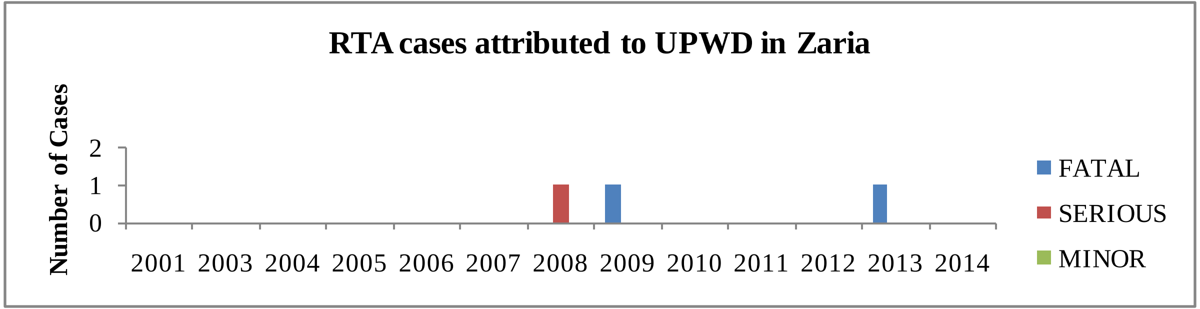

RTA cases attributed to OBS in Zaria
Number of Cases
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

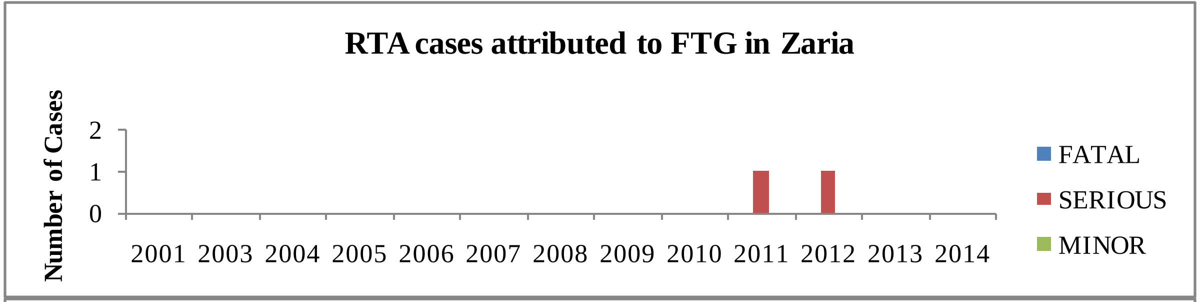

RTA cases attributed to DOT in Zaria
NUmber of Cases
4
3
2
1
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

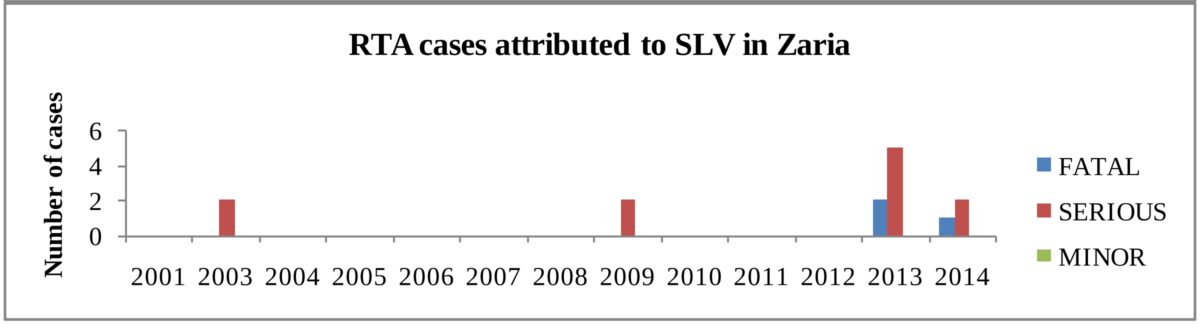

RTA cases attributed to OVL in Zaria
Number of Cases
8
6
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to SOS in Zaria
Number of Cases
0
1
2
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to DAD in Zaria
Number of Cases
0
1
2
3
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to UPWD in Zaria
Number of Cases
0
1
2
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to FTG in Zaria
Number of Cases
0
1
2
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to SLV in Zaria
Number of cases
0
2
4
6
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

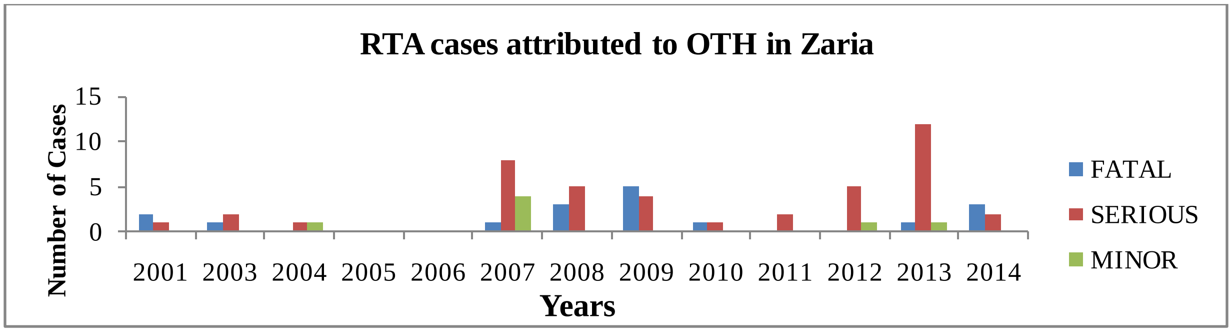


Figure 4.29: RTA Cases Attributed to Identified Causes in Zaria
Source: FRSC, 2016

In Zaria Township, more RTA cases were linked to speed violation (SPV) in 2012 than any other year. That same year, more RTA cases were linked to loss of control (LOC) than any other year. In 2007 and 2003, more RTA cases were linked to dangerous driving (DGD) and tyre burst (TBT) respectively than any other year. Break failure (BFL) was linked to more RTA in 2005, 2006 and 2009. Wrongful overtaking (WOT) and route violation (RTV) were linked to RTA cases in 2003 and 2013 respectively. Mechanically deficient vehicles (MDV) were linked to more RTA cases in 2006, 2007, 2012 and 2013 respectively compared to the other years. Road obstruction violation (OBS), dangerous overtaking (DOT), overloaded vehicle (OVL), sleeping on steering (SOS), sign light violation (SLV) and other probable causes of RTA (OTH) were most frequently linked to the occurrence of RTA in 2006, 2012, 2004, 2012, 2003 and 2007 respectively. Driving under alcohol/ drug influence (DAD), use of phone while driving (UPWD), fatigue (FTG) and poor weather (PWR) were not linked to any reported case(s) of RTA within Zaria Township during this period (see appendix I).

Along Zaria-Kaduna route, SPV, LOC, DGD, TBT, BFL, WOT, RTV and BFL were linked to more RTA cases in 2013, 2013, 2012, 2009, 2013, 2013, 2010 and 2009 respectively than the other years. MDV was reported to be linked to more RTA cases in 2006, 2008 and 2012; OVL was linked to more cases in 2011. OBS was more frequently linked to the occurrence of RTA cases in 2012 and 2013, OVL in 2004, DAD in 2007 while UPWD in 2009 and 2013. FTG, SLV and OTH were more frequently linked to the occurrence of RTA in 2012, 2013 and 2009 respectively (see appendix I).

Along Zaria-Kano route, SPV, LOC, DGD, TBT, BFL, WOT, RTV, BFL, MDV, BRD, OBS and DOT were linked to more RTA cases in 2013, 2013, 2012, 2012, 2011, 2013, 2010, 2011, 2007 and 2011 respectively than the other years. OBS was reported to be linked to more RTA cases in 2009 and 2012; OVL was linked to more cases in 2003 and 2011. SOS was more frequently linked to the occurrence of RTA cases in 2010, UPWD in 2008, SLV in 2013 and 2014 while OTH in 2007 (see appendix I).

Along Zaria-Sokoto route, SPV, LOC, DGD were linked to more RTA cases in 2013, 2013 and 2004 respectively while TBT was linked to more RTA cases in 2004, 2005 and 2013. BFL and WOT were linked to more RTA cases 2011 and 2014, RTV was linked to the occurrence of RTA cases in 2010, 2011 and 2012, BFL and MDV were linked to more RTA cases 2011 and 2004 respectively. OVL was linked to more cases in 2007, 2010 and 2012 while OBS was more frequently linked to the occurrence of RTA cases in 2009, 2010 and 2013. OVL, DAD, UPWD and FTG were more frequently linked to the occurrence of RTA cases in 2005, 2012, 2007 and 2011. SLV was more frequently linked to the occurrence of RTA in 2009, 2013 and 2014 while OTH in 2013 (see appendix I).

Along Old Zaria-Kano route, SPV was linked to more RTA cases in 2010 and 2012, LOC in 2012 and 2013, DGD in 2012 and TBT in 2004, 2005 and 2013 respectively. BFL, WOT, RTV, MDV, BRD and OBS were linked to more RTA cases 2013, 2013, 2010, 2010, 2012 and 2007 respectively. DOT was linked to the occurrence of more RTA cases in 2008 and 2011 (see appendix I).

Along Zaria-Jos route, SPV was linked to more RTA cases in 2007, 2012 and 2013; LOC, DGD and TBT were linked to more RTA cases in 2013, 2007 and 2011. WOT was linked to more RTA cases in 2003 and 2013, RTV, BFL, MDV, OVL, DAD and OTH were linked to more RTA cases in 2004, 2013, 2011, 2004, 2013 and 2013 respectively (see appendix I).

In Zaria, SPV, LOC, DGD, TBT, BFL, WOT, RTV and MDV were linked to more RTA cases in 2007, 2013, 2012, 2012, 2011, 2013, 2013 and 2011 respectively than the other years. Similarly, BRD, OBS, DOT and OVL were more frequently linked to RTA cases in 2007, 2011, 2012 and 2004 respectively. In 2010 and 2012, more SOS induced RTA cases were recorded compared to the other years, for DAD, it was in 2012 while UPWD was most frequently recorded as a probable cause of RTA in Zaria in 2008, 2009 and 2013. FTG was mostly linked to the occurrence of RTA in 2011 and 2012. However, SLV and OTH were both linked to more RTA cases in 2013 than any other year with the period of investigation. See Figure 4.29.

However, rainfall, air temperature, visibility, wind speed, relative humidity and evaporation rate were found to be inducing the occurrence of these probable causes of RTAs and at varying degrees thereby leading to RTAs of varying degrees of severity. (See appendix III).

4.3.3.2 Monthly Analysis of RTA Cases attributed to Causes of RTAs in Zaria

Along all the routes, temporal variation in RTA severity was recorded on monthly basis. In Zaria Township, it was observed that no RTA case(s) was linked to DAD, UPWD and FTG. However, it was observed that the only probable cause of RTA that led to RTA cases in all of the months of the year was DGD. Along Zaria-Kaduna route however, it was observed that all the probable causes of RTA were linked to the occurrence of RTA at one time or the other. It was observed that the only probable causes of RTA that led to RTA cases in all the months of the year were SPV, LOC, DGD, TBT and WOT. Along Zaria-Kano route, it was observed that all the probable causes of RTA were linked to the occurrence of RTA at one time or the other except DAD. It was also observed that the only probable causes of RTA that led to RTA cases in all the months of the year were SPV, LOC, DGD and TBT.

However, along Zaria-Sokoto route, it was observed that all the probable causes of RTA were linked to the occurrence of RTA at one time or the other except SOS. It was observed that along this route, no probable causes of RTA were linked to RTA case(s) in all the months of the year. However, along Old Zaria-Kano route, it was observed that seven probable causes of RTA were not linked to the occurrence of any RTA case(s) throughout the months of the year. They include OVL, SOS, DAD, UPWD, FTG, SLV and OTH. It was observed that along this route also, none of the other probable causes of RTA was linked to RTA case(s) in all the months of the year. Along Zaria-Jos route, it was observed that six probable causes of RTA were not linked to the occurrence of any RTA case(s) throughout the months of the year. They include BFL, RTV, SOS, UPWD, FTG and SLV. It was observed that along this route also, none of the other probable causes of RTA was linked to RTA case(s) in all the months of the year (see appendix II).

Finally, while considering all the routes in the study area, SPV was linked to more RTA cases in July than any other month of the year. This could be due to skidding, high wind speed and poor visibility. It led to more fatal RTA cases in July than the other months, more serious cases in December than the other months and more minor cases in July and October than the other months. LOC was linked to more RTA cases in September than any other month of the year.This could be due to skidding, high wind speed and poor visibility during rainfall. Thus, March had more LOC induced fatal RTA cases, September had more LOC induced serious RTA cases while March and July had more LOC induced minor RTA cases. DGD was linked to more RTA cases in October than any other month of the year. This could be due to high temperature which leads to heat exhaustion and impatience. Thus, July had more DGD induced fatal RTA cases, October again had more DGD induced serious RTA cases while January had more LOC induced minor RTA cases.

Furthermore, TBT was linked to more RTA cases in July than any other month of the year. This could be due to skidding, high wind speed and poor visibility. March had more TBT induced fatal RTA cases, July again had more TBT induced serious RTA cases while November had more TBT induced minor RTA cases. BFL was linked to more RTA cases in August than any other month of the year. This could be due to skidding, high wind speed and poor visibility. August and November had more BFL induced fatal RTA cases, February, August and September had more BFL induced serious RTA cases while June had more BFL induced minor RTA cases. WOT was linked to more RTA cases in June than any other month of the year. This could be due to skidding, high wind speed, poor visibility and high temperature leading to impatience. August had more WOT induced fatal RTA cases; December again had more WOT induced serious RTA cases while May and September had more WOT induced minor RTA cases.

In addition, RTV was linked to more RTA cases in October than any other month of the year. This could be due to high temperature which leads to heat exhaustion and impatience. February, September and October had more RTV induced fatal RTA cases, October had more RTV induced serious RTA cases. MDV was linked to more RTA cases in September than any other month of the year. This could be due to skidding due to the usage of worn out tyres and poor braking performance of these cars, high wind speed which affects the controllability of such vehicles and poor visibility which could partly be due to usage of poor windscreens. This could be due to high temperature which leads to heat exhaustion and impatience. August had more MDV induced fatal RTA cases, September had more MDV induced serious and minor RTA cases than the other months. BRD was linked to more RTA cases in November than any other month of the year. This could be due to poor visibility. February had more BRD induced fatal RTA cases while November had more BRD induced serious and minor RTA cases.

Furthermore, OBS was linked to more RTA cases in May and June than any other month of the year. This could be due to high temperature which leads to heat exhaustion and impatience and high wind speed which affects the controllability of vehicles. January and June had more OBS induced fatal RTA cases; May had more OBS induced serious RTA cases. DOT was linked to more RTA cases in January than any other month of the year. This could be due to poor visibility and wind speed which affects the controllability of vehicles. September, November and December had more DOT induced fatal RTA cases; January had more DOT induced serious RTA cases. OVL was linked to more RTA cases in July than any other month of the year. This could be due to skidding and poor visibility during rainfall, high wind speed which affects the controllability of vehicles and heat stress leading to impatience due to high relative humidity. May and July had more OVL induced fatal RTA cases; July and November had more OVL induced serious RTA cases while July had more WOT induced minor RTA cases. SOS was linked to more RTA cases in January than any other month of the year. This could be due to the cool weather condition. DAD was linked to more RTA cases in June than any other month of the year. This could be due to skidding, poor visibility as it rains high temperature which leads to heat exhaustion and impatience and high wind speed which affects the controllability of vehicles. Use of phone while driving (UPWD) led to more RTA cases in March than any other month of the year. This could be due to poor visibility, high temperature which leads to heat exhaustion and impatience and above all, high wind speed which affects the controllability of vehicles. FTG was linked to only three cases in February, May and December that were all serious cases. This could be due to poor visibility in December and February and high temperature which leads to heat exhaustion and impatience in May. SLV was linked to more RTA cases in December than any other month of the year. This could be due to poor visibility. February and December had more one SLV induced fatal RTA case each; April and December had more SLV induced serious RTA cases. Road users are more prone to the occurrence of RTAs due to other probable causes of RTAs (OTH). This could be due to poor visibility. OTH was linked to more RTA cases in November than any other month of the year. March, April, November and December had more OTH induced fatal RTA cases; November had more OTH induced serious RTA cases while April, August and November recorded more OTH induced minor RTA cases (see appendix III). See Table 4.6.

Table 4.6: Monthly Record of RTA Cases, Severity and their Causes in Zaria

	SPV			LOC			DGD		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	3	10	0	7	19	1	4	16	1
FEB	9	12	0	5	12	0	1	17	2
MCH	6	19	0	9	15	3	6	19	1
APR	9	8	1	7	13	2	6	13	2
MAY	6	12	0	3	19	1	6	9	3
JUN	4	13	0	4	11	0	3	18	6
JUL	11	22	2	6	11	3	11	13	1
AUG	6	10	1	6	17	1	1	19	0
SEPT	2	10	1	6	22	2	7	19	0
OCT	3	16	2	5	15	1	9	20	2
NOV	5	10	0	4	8	1	8	17	5
DEC	5	26	1	7	13	2	5	11	2

	TBT			BFL			WOT		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	4	10	0	1	2	0	1	2	0
FEB	7	13	1	0	4	0	4	2	0
MCH	9	8	0	0	2	0	4	3	0
APR	8	9	1	1	2	0	2	2	1
MAY	4	13	0	1	1	1	4	1	2
JUN	3	9	0	0	0	4	4	5	1

JUL	7	16	1	1	2	0	1	5	1
AUG	3	7	2	2	4	0	6	2	0
SEPT	5	12	1	0	4	0	1	4	2
OCT	4	14	0	0	0	2	1	0	1
NOV	3	8	3	2	2	0	0	1	1
DEC	2	8	0	0	1	0	0	6	1

	RTV			MDV			BRD		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	0	3	0	2	2	0	0	1	0
FEB	2	2	0	0	0	0	2	0	0
MCH	0	1	0	1	1	0	0	0	0
APR	0	3	0	1	2	0	0	2	0
MAY	0	0	0	1	0	1	0	1	0
JUN	0	2	0	0	2	0	0	0	0
JUL	0	4	0	0	1	1	1	0	0
AUG	1	3	0	3	1	0	0	1	0
SEPT	2	9	0	1	8	2	1	1	0
OCT	2	10	0	0	2	1	0	1	0
NOV	0	2	0	1	2	0	0	3	1
DEC	1	5	0	1	1	0	0	2	0

	OBS			DOT			OVL		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	2	1	0	0	5	0	0	1	0
FEB	0	1	0	0	0	0	0	1	0
MCH	0	0	0	0	2	0	0	0	0
APR	0	1	0	0	1	0	0	3	1
MAY	1	4	0	0	0	0	2	2	0
JUN	2	3	0	0	0	0	0	0	0
JUL	0	2	0	0	0	0	2	4	2
AUG	1	1	0	0	2	0	0	2	0
SEPT	1	1	0	1	2	0	0	0	0
OCT	0	1	0	0	2	0	0	2	1
NOV	0	0	0	1	1	0	0	4	0
DEC	0	1	0	1	1	0	0	0	0

	SOS			DAD			UPWD		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1	0	1	0	0	0	0	1	0
FEB	0	0	0	0	0	0	0	0	0
MCH	0	0	0	0	0	0	1	0	1
APR	0	0	0	0	1	0	0	0	0
MAY	0	1	0	0	0	0	0	0	0
JUN	0	0	0	1	1	1	0	0	0
JUL	0	0	0	0	0	0	1	0	0
AUG	0	0	0	0	0	0	0	0	0
SEPT	0	0	0	0	1	0	0	0	0
OCT	0	0	0	0	0	0	0	1	0
NOV	0	0	0	0	1	0	0	0	0
DEC	0	0	0	0	0	0	0	0	0

	FTG			SLV			OTH		
Months	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	0	0	0	0	1	0	0	1	1
FEB	0	1	0	1	1	0	0	4	1
MCH	0	0	0	0	1	0	3	4	0
APR	0	0	0	0	2	0	3	3	2
MAY	0	1	0	0	1	0	1	6	0
JUN	0	0	0	0	1	0	0	5	1

JUL	0	0	0	0	1	0	1	6	0
AUG	0	0	0	0	0	0	2	1	2
SEPT	0	0	0	0	1	0	0	4	0
OCT	0	0	0	0	0	0	0	1	0
NOV	0	0	0	0	0	0	3	5	2
DEC	0	1	0	1	2	0	3	3	0

Source: FRSC, 2016

This study agrees with Usman *et al.* (2015) and Jobin (2015) who in their separate studies reported that along Zaria-Sokoto route and Zaria-Kaduna route respective; the contribution of different causes of RTAs to crash count varies over time as the number of cases attributed to each cause differs with time. This study also agrees with Agbonkhese *et al.* (2013) who opined that every RTA must have a cause which depends on a list of factors. This study also agree with Aljanahi, Rhodes and Metcalf (1999), Navon (2003), Elvik, Christensen and Amundsen (2004), Aarts and Ingrid (2006), Hassan *et al.* (2011) among others who stated that Speed is significantly associated with the occurrence of RTA.

Atubi (2009b) stated that human error is estimated to account for between 64 and 95% of all causes of traffic crashes in developing countries. Thus, high prevalence of old vehicles that are over loaded, lack of safety belts, poor road design and maintenance and the traffic mix on roads are other factors that contribute to the high rate of fatalities in less developed countries. Causes of RTA are multifactorial and involve the interaction of a number of pre-crash factors that include people, vehicles and the road environment (Haddon, 1980; Stanfield et al, 1992; Robertson, 1992). Conclusively, man-environment adjustment and maladjustments (Muhlrad and Lassarre, 2005) the environment, means of transportation (vehicles) and the behavior of man (Krug, Sharma and Lozano, 2000) must be studied to enhance our understanding of the major contributory factors leading to road traffic accidents.

4.4 Association between Weather and RTAs in Zaria

4.4.1 Association between Weather and RTAs from 2001 to 2014 in Zaria

Table 4.7 presents an annual analysis of the strength and direction of association between selected weather parameters and RTA parameters in Zaria.

Table 4.7: Annual Analysis of the Association between Weather and RTAs in Zaria

	Fatal	Serious	Minor	Total cases
Annual Rainfall	0.249	0.091	0.111	0.128
	0.412	0.767	0.718	0.677
Number of wet days	-0.168	-0.244	0.445	-0.200
	0.583	0.422	0.128	0.513
Air temperature	0.090	0.141	-0.234	0.107
	0.771	0.647	0.441	0.727
Visibility	0.353	0.338	0.086	0.427
	0.236	0.259	0.780	0.146
Relative Humidity	-0.261	-0.251	-0.337	0.374
	0.388	0.408	0.260	0.208
Wind speed	0.609	0.617	0.402	0.640
	0.027	0.025	0.173	0.018
Evaporation	-0.605	-0.502	0.111	-0.521
	0.028	0.080	0.719	0.068
	No. injured	No. killed	Total casualty	
Annual Rainfall	0.216	0.258	0.234	
	0.478	0.394	0.442	
Number of Wet days	-0.221	0.020	-0.212	
	0.469	0.948	0.488	
Air temperature	0.026	0.012	0.060	
	0.934	0.969	0.845	
Visibility	0.284	0.551	0.412	
	0.347	0.051	0.162	
Relative Humidity	-0.284	-0.300	-0.279	
	0.347	0.319	0.355	
Wind speed	0.638	0.657	0.635	
	0.019	0.015	0.020	
Evaporation	-0.530	-0.448	-0.536	
	0.062	0.125	0.059	

Source: Author's Analysis, 2016
Cell Contents: Pearson correlation and *P*-Value
Pearson correlation coefficient is significant if *P*-Value < significant level at 0.05

Annual analysis of the association between weather and RTAs from 2001 to 2014 in Zaria revealed the rainfall has a positive association with total cases of RTA (r = 0.13) and total RTA casualties (r = 0.23) due to skidding and poor visibility during rainfall. Number of wet days on the other hand had a negative association with total cases of RTA (r = -0.20) and total RTA casualties (r = -0.21). This could be because the more the number of wet days, the more skilled drivers become on how to drive on wet corridors. Air temperature as a parameter had a positive association with total cases of RTA (r = 0.11) and total RTA casualties (r = 0.06) due to heat exhaustion, fatigue and impatience. Visibility had a positive association with total RTA cases (r = 0.43) and total RTA casualties (r = 0.41). This could be because better visibility encourages drivers to be less cautious. Relative humidity on the other hand also had a positive association with total RTA cases (r= 0.37) due to heat stress resulting to fatigue and impatience and a negative association with total RTA casualties (r = -0.28) which could be as a result of fewer passengers due to the condition of the weather. Wind speed showed that it has a positive association with total RTA cases (r = 0.64) and total RTA casualties (r = 0.64) because it affects the controllability of vehicles. Finally, evaporation rate has a negative association with total RTA cases (r = -0.52) and total RTA casualties (r = -0.54). This could be because lower evaporation rate induces heat stress, fatigue and impatience in humans leading to more RTA cases and casualties.

4.4.2 Monthly Analysis of Association between Weather and RTAs in Zaria

Table 4.8 presents a monthly analysis of the strength and direction of association between selected weather parameters and RTA parameters in Zaria.

Table 4.8: Monthly Analysis of the Association between Weather and RTAs in Zaria

```
                    Fatal             Serious            Minor         Total cases
RAINFALL            0.066              0.125             0.232         0.187
                    0.838              0.700             0.467         0.561
Air Temp            0.273             -0.304             0.158        -0.122
                    0.390              0.336             0.624         0.706
Visibility         -0.313             -0.008             0.723         0.051
                    0.321              0.980             0.008         0.874
Relative Humidity  -0.124              0.148             0.494         0.199
                    0.701              0.647             0.103         0.535
Wind speed          0.254             -0.435            -0.042        -0.288
                    0.426              0.158             0.896         0.363
Evaporation         0.365             -0.342            -0.498        -0.278
                    0.244              0.277             0.099         0.382
                    No. injured        No. killed        Total casualty
RAINFALL           -0.427             -0.137             0.400
                    0.167              0.672             0.198
Air Temp            0.096             -0.154             0.012
                    0.767              0.633             0.971
Visibility         -0.281             -0.593            -0.475
                    0.377              0.042             0.119
Relative Humidity  -0.341             -0.353            -0.422
                    0.278              0.261             0.171
Wind speed         -0.005              0.352             0.145
                    0.988              0.262             0.653
Evaporation        -0.278              0.326             0.432
```

	0.301	0.191	0.161

Source: Author's Analysis, 2016
Cell Contents: Pearson correlation and *P*-Value
Pearson correlation coefficient is significant if *P*-Value < significant level at 0.05

Monthly analysis of the nature of association between weather and RTAs from 2001 to 2014 in Zaria revealed that rainfall has a positive association with total cases of RTA (r = 0.18) and total RTA casualties (r = 0.40) meaning that months that experience more rainfall experience more RTA cases and casualties due to skidding (which affects the frictional force between tyres and the road surface) and poor visibility. Air temperature as a parameter had a positive association with total cases of RTA (r = -0.12) and total RTA casualties (r = 0.01). Visibility had a positive association with total RTA cases (r = 0.05) and total RTA casualties (r = -0.48) which could be due to the fact that better visibility can induce recklessness on the part of road users generally. Relative humidity on the other hand also had a positive association with total RTA cases (r= 0.20) due to heat exhaustion leading to fatigue and impatience and a negative association with total RTA casualties (r = -0.42) which may be attributed to fewer travellers due to the nature of the weather. Wind speed showed that it has a positive association with total RTA cases (r = -0.29) and total RTA casualties (r = 0.15) and this may be because it leads to poor controllability of vehicles. Finally, evaporation rate has a negative association with total RTA cases (r = -0.28) and total RTA casualties (r = 0.43). This could be because lower evaporation rate induces heat stress, fatigue and impatience in humans leading to more RTA cases and casualties.

This study agrees with Stern (2007) and Intergovernmental Panel on Climate Change (IPCC) (2007a) reports confirmed that the transport sector has received fairly little (explicit) attention. This is not entirely surprising because to date, the consequences of the relationship between climate change and changing weather conditions on the transport sector or activities have not received much attention in the literature in the developing countries. However, the occurrence of road accidents in hazardous weather conditions be it rainfall, temperature, fog, snowfall and wind broadly follows the regional weather patterns for those conditions (Edwards, 1996; Khan, Qin and Noyce, 2008).

Weather creates driving hazard but weather hazard is complexly related with road crash and needs more specific and distinguished research (Mondal *et al.,* 2011c). In fact, contrasting reports on the impact of temperature and rainfall on road accident by Atubi (2012a) and Mondal *et al.* (2011c) on one hand and Scott (1986), Brijs, Karlis and Wets (2008) versus Yannis and Karlaftis (2007) have been documented. Atubi (2012a) in his study discovered that the month of July which falls under the long rainy season of southern Nigeria recorded the highest number of accidents. Similarly, in this study, annual rainfall has good fit with RTA occurrence. Very higher temperatures appear to have a decreasing effect on accident frequencies and severity both at daily, weekly and monthly bases according to Scott (1986) and Brijs *et al.* (2008) which is in agreement with the present study that revealed a negative association between mean monthly air temperature and RTA cases. However, mean annual air temperature revealed a positive association between air temperature and RTA cases which is in agreement with a study carried out by Yannis and Karlaftis (2007). The findings of this show that poor visibility and wind speed relate very well with the occurrence of RTA. The same positive association is expressed by Hermans *et al.* (2006) who reported that better visibility and greater wind speed leads to more RTA cases.

Generally, the results of this research show that there is positive relationship between relative humidity and RTA cases ($r = 0.37$) and a negative relationship between evaporation rate and RTA cases ($r = -0.52$). The finding of this research was further strengthened by the findings of Umoh, Akpan and Jacob (2013) who reported a negative relationship between relative humidity and evaporation rate as relative humidity and evaporation rate were discovered to have a positive and negative association with number of RTA cases respectively.

4.4.3 Annual Association between Causes of RTAs and Weather in Zaria

In this section, attention is given to explaining how selected weather parameters (annual records) induce RTA causative factors in Zaria.

The occurrence of fatal, serious and minor RTAs due to speed violation were found to be more closely related to air temperature (r = -0.57, -0.41, -0.43 respectively) than the other selected weather parameters. Thus, variation in the number of occurrence of fatal RTAs is more closely related with the variation in air temperature within the Zaria unit command of FRSC. Thus, there is a general tendency within Zaria unit command for more fatal accidents to occur as air temperature gets cooler. This could be because contrary to high temperature which can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time, a more friendly weather condition can make a road user to comfortable leading to a loss of mental alertness leading to RTAs.

The occurrence of fatal, serious and minor RTAs due to loss of control were found to be more closely related to evaporation rate (r = -0.72, -0.70, -0.53 respectively) than the other selected weather parameters. Thus, variation in the number of occurrence of fatal RTAs is more closely related with the variation in evaporation rate within the Zaria unit command of FRSC. This could be attributed to human comfort as high evaporation rate can affect human comfort (driver) negatively which can influence the occurrence of RTA and vice versa. This is because a more friendly weather condition will make a road user so comfortable and relaxed leading to a loss of mental alertness and then the occurrence of RTAs.

The occurrence of fatal and serious RTAs due to dangerous driving were found to be more closely related to wind speed (r = 0.37 and 0.44 respectively) while minor RTAs were found to be more closely related to the number of wet days (r = 0.46) than the other selected weather parameters. Since wind speed can influence the controllability of vehicles and wet days can encourage skidding, both can influence the occurrence of RTA. Similarly, the occurrence of fatal and serious RTAs due to tyre burst were found to be more closely related to wind speed (r = 0.70 and 0.58 respectively) while minor RTAs were found to be more closely related to evaporation rate (r = 0.67) than the other selected weather parameters. Since wind speed can influence the controllability of vehicles and evaporation rate can affect human comfort negatively, both can influence the occurrence of RTAs.

The occurrence of fatal RTAs due to break failure was found to be more closely related to number of wet days (r = 0.39), serious RTAs was found to be more closely related to wind speed (r = 0.45) while minor RTAs was found to be more closely related to air temperature (r = -0.28) than the other selected weather parameters. Since the number of wet days can encourage skidding, wind speed can influence the controllability of vehicles while high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time, a more friend weather condition can make a road user to comfortable leading to a loss of mental alertness. All these can influence the occurrence of RTAs. Similarly, the occurrence of fatal and serious RTAs due to wrongful overtaking were found to be more closely related to air temperature (r = 0.54 and 0.57 respectively) while minor RTAs were found to be more closely related to wind speed (r = 0.52) than the other selected weather parameters. Since high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time while wind speed can influence the controllability of vehicles, both can influence the occurrence of RTAs.

The occurrence of fatal RTAs due to route violation was found to be more closely related to visibility (r = 0.55), serious RTAs was found to be more closely related to wind speed (r = 0.54) while minor RTAs was found to be more closely related to air temperature (r = 0.52) than the other selected weather parameters. Since better visibility enhances the safety of transportation including road transportation, wind speed influences the controllability of vehicles while high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one's destination in the shortest possible time, all these can influence the occurrence of RTAs. However, the occurrence of fatal RTAs due to the use of mechanically deficient vehicles was found to be more closely related to the number of wet days (r = -0.57) while serious and minor RTAs were found to be more closely related to wind speed (r = 0.52) than the other selected weather parameters. Since number of wet days encourages the skidding of vehicles while wind speed influences the controllability of vehicles, both can influence the occurrence of RTAs.

The occurrence of fatal RTAs due to the poor condition of our roads (bad roads) was found to be more closely related to air temperature (r = -0.42) while serious RTAs was found to be more closely related to visibility (r = 0.37) than the other selected weather parameters. Since high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one's destination in the shortest possible time while it is more friendly when air temperature is cooler making road users so comfortable leading to a loss of mental alertness while visibility enhances the safety of transportation including road transportation, both can influence the occurrence of RTAs.

The occurrence of fatal and serious RTAs due to road obstruction violation were found to be more closely related to wind speed (r = 0.46 and 0.77 respectively) while minor RTAs were found to be more closely related to air temperature (r = -0.27) than the other selected weather parameters. Since wind speed can influence the controllability of vehicles and lower air temperature can make road users so comfortable leading to a loss of mental alertness, both can influence the occurrence of RTAs. On the other hand, the occurrence of fatal RTAs due to dangerous overtaking was found to be more closely related to evaporation rate (r = -0.55) while serious RTAs was found to be more closely related to wind speed (r = 0.52) than the other selected weather parameters. Since evaporation rate can affect human comfort negatively and wind speed can influence the controllability of vehicles, both can influence the occurrence of RTAs.

The occurrence of fatal RTAs as a result of the overloading of vehicles was found to be more closely related to air temperature (r = 0.58), serious RTAs was found to be more closely related to evaporation rate (r = 0.66) while minor RTAs was found to be more closely related to visibility (r = -0.61) than the other selected weather parameters. Since high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time, evaporation rate affects human comfort and visibility enhances the safety of transportation including road transportation, all these can influence the occurrence of RTAs. On the other hand, the occurrence of fatal RTAs as a result of drivers sleeping on steering was found to be more closely related to air temperature (r = 0.58), serious RTAs was found to be more closely related to evaporation rate (r = 0.66) while minor RTAs was found to be more closely related to visibility (r = -0.61) than the other selected weather parameters. Since high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time, evaporation rate affects human comfort and visibility enhances the safety of transportation including road transportation, all these can influence the occurrence of RTAs. The occurrence of fatal RTAs due to drivers driving while they are drunk (drunk and driving) was found to be more closely related to air temperature (r = -0.38) while serious RTAs was found to be more closely related to evaporation rate (r = -0.69) than the other selected weather parameters. Thus, when air temperature is cooler making road users so comfortable leading to a loss of mental alertness and evaporation rate which can affect human comfort negatively can influence the occurrence of RTAs. On the other hand, the occurrence of fatal RTAs as a result of drivers using their phones while driving was found to be more closely related to visibility (r = 0.48) while serious RTAs was found to be more closely related to air temperature (r = -0.38) than the other selected weather parameters. Since visibility can enhance the safety of transportation including road transportation and high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time while it is more friendly when air temperature is cooler making road users so comfortable leading to a loss of mental alertness, both can influence the occurrence of RTAs. The occurrence of serious RTAs due to fatigue was found to be more closely related to wind speed (r = 0.34) while the occurrence of fatal and serious RTAs as a result of sign light violation was found to be more closely related to air temperature (r = 0.67 and r = 0.78 respectively). Since high air temperature can actually result into fatigue leading to numerous consequent effects like over speeding in order to get to one’s destination in the shortest possible time and wind speed can affect the controllability of vehicles, both can influence the occurrence of RTAs.

The occurrence of fatal RTAs due to other probable causes of RTA was found to be more closely related to visibility (r = 0.45) while serious and minor RTAs were found to be more closely related to wind speed (r = 0.52) than the other selected weather parameters. Since visibility enhances the safety of transportation including road transportation while wind speed influences the controllability of vehicles, both can influence the occurrence of RTAs (see appendix III).

4.4.4 Monthly Association between Causes of RTAs and Weather in Zaria

In this section, attention is given to explaining how selected weather parameters (monthly records) induce RTA causative factors in Zaria.

The occurrence of fatal RTAs as a result of speed violation was found to be more closely related to wind speed (r = 0.45), serious RTAs was found to be more closely related to air temperature (r = -0.23) while minor RTAs was found to be more closely related to evaporation rate (r = -0.58) than the other selected weather parameters. Since wind speed, air temperature and evaporation rate affects controllability and human comfort; these can result in the occurrence of RTAs. On the other hand, the occurrence of fatal RTAs as a result of loss of control was found to be more closely related to visibility (r = -0.54), serious RTAs was found to be more closely related to relative humidity (r = 0.25) while minor RTAs was found to be more closely related to air temperature (r = 0.20) than the other selected weather parameters. Since visibility, relative humidity and air temperature affects safety of road transportation and human comfort; these can result in the occurrence of RTAs.

The occurrence of fatal RTAs as a result of dangerous driving was found to be more closely related to visibility (r = 0.35), serious RTAs was found to be more closely related to wind speed (r = 0.52) while minor RTAs was found to be more closely related to rainfall (r = -0.25) than the other selected weather parameters. Since these weather parameters affects safety of road transportation, controllability of vehicles, human comfort and skidding; these can result in the occurrence of RTAs. On the other hand, the occurrence of fatal RTAs as a result of tyre burst was found to be more closely related to air temperature (r = 0.61), serious RTAs was found to be more closely related to relative humidity (r = 0.31) while minor RTAs was found to be more closely related to wind speed (r = -0.39) than the other selected weather parameters. Since these climatic elements can affect drivers, road and vehicles thereby affecting human comfort and the controllability of vehicles thereby resulting in the occurrence of RTAs.

The occurrence of fatal and serious RTAs as a result of brake failure were found to be more closely related to rainfall (r = 0.30 and r = 0.24) while minor RTAs was found to be more closely related to visibility (r = 0.44) than the other selected weather parameters. The occurrence of fatal and serious RTAs as a result of wrongful overtaking were found to be more closely related to wind speed (r = 0.48 and r = 0.24 respectively) while minor RTAs was found to be more closely related to visibility (r = 0.72) than the other selected weather parameters. Since these climatic elements can affect drivers, road and vehicles by making vehicles to skid, affect the vision of road users and affect the controllability of vehicles thereby resulting in the occurrence of RTAs.

The occurrence of fatal and serious RTAs as a result of route violation were found to be more closely related to wind speed (r = -0.62 and r = -0.69 respectively) than the other selected weather parameters. The occurrence of fatal RTAs as a result of usage of mechanically deficient vehicles was found to be more closely related to rainfall (r = 0.23), serious RTAs was found to be more closely related to wind speed (r = -0.43) while minor RTAs was found to be more closely related to visibility (r = 0.61) than the other selected weather parameters. Since these weather parameters make vehicles to skid, affect the vision of road users and affect the controllability of vehicles thereby resulting in the occurrence of RTAs.

The occurrence of fatal RTAs as a result of the condition of our roads (bad roads) was found to be more closely related to visibility (r = -0.16), serious and minor RTAs were found to be more closely related to wind speed (r = -0.43 and r = -0.43) than the other selected weather parameters. The occurrence of fatal and serious RTAs as a result of road obstruction violation were found to be more closely related to wind speed (r = 0.36 and r = 0.67 respectively) than the other selected weather parameters. Since these weather parameters affects safety of road transportation, controllability of vehicles, human comfort; these can result in the occurrence of RTAs.

The occurrence of fatal RTAs as a result of overloading of vehicles was found to be more closely related to wind speed (r = 0.46), serious RTAs was found to be more closely related to visibility (r = 0.28) while minor RTAs was found to be more closely related to relative humidity (r = 0.34) than the other selected weather parameters. The occurrence of fatal RTAs as a result of drivers sleeping on steering was found to be more closely related to visibility (r = -0.48), serious RTAs was found to be more closely related to wind speed (r = 0.44) while minor RTAs was found to be more closely related to visibility (r = -0.48) than the other selected weather parameters. Since these weather parameters affects safety of road transportation, controllability of vehicles, human comfort; these can result in the occurrence of RTAs.

The occurrence of fatal RTAs as a result of drivers driving when they are drunk was found to be more closely related to wind speed (r = 0.42), serious RTAs was found to be more closely related to visibility due to haze or dark cloud during rainy season (r = 0.44) while minor RTAs was found to be more closely related to wind speed (r = 0.42) than the other selected weather parameters. The occurrence of fatal and serious RTAs as a result of drivers using phones while driving sleeping on steering were found to be more closely related to air temperature (r = 0.21 and r = -0.32 respective) while minor RTAs was found to be more closely related to evaporation rate (r = 0.55) than the other selected weather parameters. Since these weather parameters affects safety of road transportation, controllability of vehicles, human comfort and skidding; these can result in the occurrence of RTAs.

The occurrence of serious RTAs as a result of fatigue was found to be more closely related to relative humidity (r = -0.35) than the other selected weather parameters. The occurrence of fatal RTAs as a result of sign light violation was found to be more closely related to wind speed (r = -0.52), serious RTAs was found to be more closely related to wind speed (r = 0.50) than the other selected weather parameters. The occurrence of fatal RTAs as a result of other probable causes of RTA was found to be more closely related to evaporation rate (r = 0.36), serious RTAs was found to be more closely related to wind speed (r = 0.44) while minor RTAs was found to be more closely related to evaporation rate (r = 0.10) than the other selected weather parameters. Since these weather parameters affects safety of road transportation, controllability of vehicles, human comfort and skidding; these can result in the occurrence of RTAs (see appendix III).

This study identified dangerous driving (DGD), speed violation (SPV) and loss of control (LOC) as the leading causes of RTAs in Zaria. This is in agreement with Usman *et al.* (2015) who carried out a study between 2010 and 2013 along Zaria-Sokoto route and identified same as the leading causes of RTAs. However, this study ranked DGD as the leading probable causes of RTA in Zaria followed by SPV and LOC respectively. On the contrary, Usman *et al.* (2015) identified SPV as the leading probable causes of RTA followed by LOC and DGD respectively. Like Usman *et al.* (2015), Jobin (2015) carried out a study between 2010 and 2013 along Zaria-Kaduna route and identified SPV to be the leading probable cause of RTAs followed by tyre burst (TBT), LOC and DGD respectively.

4.4.5 Forecasting Total Cases of RTAs with Weather in Zaria

The fitted regression model on Table 4.9 presents the relationship between total RTA cases and the selected weather parameters showing the predictor variables contributing significantly to the forecasting of the response variable *y* (total cases).

Table 4.9: Forecasting Total Cases of RTAs with Weather Parameters in Zaria

Predictor	Coefficient	Standard Error Coefficient	P
Constant	-2098.5	816.2	0.042
Annual Rainfall	0.04972	0.09609	0.623
Air temp (0c)	103.53	31.1	0.016
Visibility (km)	-18.576	8.484	0.071
Relative Humidity(%)	-2.373	3.356	0.506
Wind speed (km/day)	1.2238	0.2869	0.005
Evaporation(mm/day)	-14.10	10.68	0.235

Source: Author's Analysis, 2016

Note: R-Square = 85.7% R-Square (adjusted) = 71.4%

The regression equation is:

Total cases = - 2099 + 0.0497 Annual Rainfall + 104 Air temp (0c) - 18.6 Visibility (km) - 2.37 Relative Humidity (%) + 1.22 Wind speed (km/day) - 14.1 Evaporation (mm/day)

The fitted regression model shows the relationship between the total cases and the selected weather parameters. The predictor variables contributing significantly to the forecasting of the response variable Y (total cases) are air temperature (P = 0.016) and wind speed (P = 0.005) meaning that these weather parameters make significant contribution to RTAs along the six routes within Zaria unit command. Coefficient of determination (R^2) is used to know how well the model fits that is the strength of the model which is the proportion of the total variation that is explained by the regression of the total cases on the independent variables is as high as 85.7%. This shows that 85.7% of the total variation has been explained by the model. Thus, the model fits very well and can therefore be used for forecasting total cases of RTAs in Zaria.

Furthermore, Table 4.10 presents the result of the overall *F* Test which is used to test the significance of the regression model above.

Table 4.10: Analysis of Variance for Testing the Significance of the Regression Model

Source	DF	SS	MS	F	P

Regression	6	58197	9700	5.99	0.023
Residual Error	6	9718	1620		
Total	12	67915			

Source: Author's Analysis, 2016
Note: *P*-value < significance level, linear relationship is significant

Analysis of variance *F* Test was used to know if the regression is significant or not. Since *p*-value is less than 0.05, it can be declared that the regression is significant meaning that at least one of the predictor variables is contributing significant information for the prediction of the response variable *y*.

4.5. Occurrence Rate of RTAs on Wet and Dry Days and During Dry Spells in Zaria

4.5.1 Deriving Rain-Crash-Index (RCI) for Zaria

Table 4.11 presents the RCI of the study area from 2001 to 2014 which is derived from crash count (C) and amount of rainfall (R) where C is the crash count within a given period and R is rainfall in millimeters (mm) within that period.

Table 4.11: Rain-Crash-Index (RCI) of the Study Area

Year	Crash count	Rainfall(mm)	RCI
2001	24	1322.3	0.02
2003	32	1135.4	0.03
2004	52	1074.9	0.05
2005	32	863.7	0.04
2006	40	1088.5	0.04
2007	102	1093.1	0.09
2008	73	1175.1	0.06
2009	134	1278	0.1

2010	98	1127.3	0.09
2011	148	931.3	0.16
2012	232	1333.3	0.17
2013	254	1028.8	0.25
2014	59	1067.9	0.06

Source: Author's Analysis, 2016

Rain-crash-index is expressed as RCI=C/R. It is derived from crash count (C) and amount of rainfall (R) where C is the crash count within a given period and R is rainfall in millimeters (mm) within that period. Thus, the total number of RTA cases divided by the amount of rainfall recorded in a particular location gives the rain-crash-index of that particular geographical area. From Table 4.11, the highest RCI was recorded in 2013 that recorded an annual rainfall of 1028.8mm, 254 RTA cases and a RCI of 0.25 followed by 2012 that recorded an annual rainfall of 1333.3mm, 232 RTA cases and a RCI of 0.17. The least RCI were recorded in 2003 with an annual rainfall of 1135.4, 32 RTA cases and a RCI of 0.03 followed by 2001 with an annual rainfall of 1322.3mm, 24 RTA cases and the least RCI that was 0.02.

Furthermore, Table 4.12 presents the correlation coefficients between both rainfall and rain-crash-index and rainfall and number of road traffic accidents.

Table 4.12: Correlation Coefficients between RCI, rainfall and RTAs in Zaria

	Rainfall
RCI	-0.78
Number of RTAs	0.78

Source: Author's Analysis, 2016

Thus, rainfall was found to be positively associated with RTAs while it was negatively associated with rain-crash-index. Therefore, there is a general tendency in Zaria that greater amount of annual rainfall will lead to more crash count and vice versa. Similarly, greater amount of annual rainfall will lead to lesser rain-crash-index. This could be because drizzling or light rainfall create 'don't care' attitude among drivers whereas heavy rainfall psychologically threatens drivers extracting more attentive attitude from them. This is in agreement with Mondal *et al.* (2011), Atubi (2013) and Maman and Jediel (2014) who stated that greater amount of annual rainfall will lead to more crash count and vice versa.

4.5.2 Deriving Wet-crash-rate (WCR) and Dry-Crash-Rate (DCR) for Zaria

Wet-crash-rate (WCR) is derived from the total RTA cases recorded on wet days (WC) divided by the total number of wet days within a stipulated period while dry-crash-rate (DCR) is derived from the total RTA cases recorded on dry days (DC) divided by the total number of dry days (DD) within a stipulated period. A wet day in this study refers to any day of the year that recorded any amount of rainfall while a dry day is used to refer to the opposite.

Table 4.13: Wet-Crash-Rate (WCR) and Dry-Crash-Rate (DCR) for the Study Area

Year	Crash count wet days	Total number of wet days	WCR(WC/WD)	Crash count on dry days	Total number of dry days	DCR(DC/DD)
2001	6	66	0.09	18	299	0.06
2003	11	87	0.13	21	278	0.08
2004	10	76	0.13	42	290	0.14
2005	11	76	0.14	21	289	0.07
2006	11	74	0.15	29	291	0.1
2007	18	81	0.22	84	284	0.3
2008	12	74	0.16	61	291	0.21
2009	22	86	0.26	112	280	0.4
2010	27	81	0.33	71	284	0.25
2011	27	72	0.38	121	293	0.41
2012	44	76	0.58	188	289	0.65
2013	29	65	0.45	225	300	0.75
2014	9	72	0.13	50	294	0.1
2001-14	237	986	0.24	1043	3762	0.28

Source: Author’s Analysis, 2016

In 2012, the highest WCR was recorded and it was 0.58 which means that the probability that RTAs will occur on a wet day in 2012 was 0.58 or 58 per cent. The total annual rainfall recorded that year was 1333.3mm, the highest within the period of this research. In 2001, the least WCR for this period was recorded and it was 0.09 which means that the probability that RTAs will occur on a wet day was 0.09 or 9 per cent. The total annual rainfall recorded that year was 1323.3mm which was the next to the highest amount of rainfall recorded within a year from 2001 to 2014. This shows that road users are sometimes careful when exposed to wet road conditions but not always.

The lowest total annual rainfall recorded within this period was in 2005 with 863.7mm and 2011 with 931.3mm. The difference between the total annual rainfalls for these years was only 67.6mm. However, in 2005, the WCR was 0.14 which signifies that the probability that RTA will occur on any wet day in that year was 0.14 or 14 per cent while in 2011, the WCR was 0.38 which indicates that the probability that RTAs will occur on any wet day in that year was 0.38 or 38 per cent. Thus, it was discovered that as against 2005, the probability that RTAs will occur on a wet day was 22 per cent greater in 2011. Thus, it was discovered that when relatively low total annual rainfall were recorded within the period of this research, the behavior of road users was similar to what was obtainable when total annual rainfall was high. This implies that even if a similar amount of rainfall is recorded between two or more years, different crash rate will be observed as drivers tend to be cautious at times and reckless at other times. This could be due to poor understanding of drivers as regards either the effect of weather on the occurrence of RTAs directly or the influence of weather on other causes of RTAs that lead to the occurrence of RTAs or both.

The highest DCR was recorded in 2013 with a total of 225 RTAs cases and 300 dry days and a DCR of 0.75 which shows that the probability that RTA will occur on any dry day is 75 per cent. In fact, 2013 was not only the year with the highest DCR but also the year with the highest number of dry days. The year with the least DCR was 2001 with a total of 18 RTAs cases and 299 dry days and a DCR of 0.06 which shows that the probability that RTAs will occur in any dry day was 6 per cent. Thus, it should be noted that the difference between the numbers of dry days for these years was only a day but it was discovered that as against 2001, the probability that RTAs will occur on any dry day was 69 per cent greater in 2013. The great difference in the probability of occurrence of RTAs between 2001 and 2013 could be due to the fact that drivers do not feel psychologically threatened by dry seasons as they drive making them believe that they can drive recklessly when they feel like doing so and still be safe.

Thus, the probability that a RTA will occur on a wet day in the study area is 0.24 and 0.28 on any dry day while the WCR in the study area is 24% and the DCR is 28%. It was also observed that 18.52% of RTAs that occurred in the study from 2001 to 2014 were recorded on wet days while 81.48% were recorded on dry days which could be due to the attitude of drivers towards driving during the different seasons.

Furthermore, Table 4.14 presents the correlation coefficients between the association of WCR and total number of wet days and crash count on wet days; between number of wet days and crash count on wet days. It also shows the correlation coefficients between the association of DCR and total number of dry days and crash count on dry days; between number of dry days and crash count on dry days.

Table 4.14: Correlation Coefficients for Wet-Crash-Rate and Dry-Crash-Rate in Zaria

	WCR	Total Number of Wet Days	DCR	Total Number of Dry Days
Total Number of wet Days	-0.90			
Crash Count on wet days	0.99	0.52		
Total Number of Dry Days			0.53	
Crash Count on Dry days			0.99	0.63

Source: Author’s Analysis, 2016

Thus, crash count on wet days was found to be positively associated with total number of wet days, crash count on wet days was found to have a strong positive association with wet-crash-rate while total number of wet days was found to be negatively associated with wet-crash-rate. There is a general tendency in Zaria that the more the number of wet days, the greater will be the crash count on wet days and vice versa. Crash count on dry days was found to be positively associated with total number of dry days, crash count on dry days was found to have a strong positive association with dry-crash-rate while total number of dry days was also found to have a positive association with dry-crash-rate. There is a general tendency in Zaria also that the more the number of dry days, the greater will be the crash count on dry days and vice versa. This agrees with Shankar, Mannering and Barfield (1995) who stated that the more the number of wet and dry days, the greater will be the crash count on wet and dry days respectively and vice versa.

4.5.3 Deriving Rain-Crash-Effect (RCE) of Zaria

Table 4.15 presents how the Wet-crash-rate (WCR) and dry-crash-rate (DCR) are used to derive rain-crash-effect (RCE). RCE is used here to know if in any particular year, there are more crash on a unit wet day than a unit dry day or otherwise. Thus, it shows whether the probability of the occurrence of RTAs on a wet day is higher than that of a dry day in any particular year.

Table 4.15: Rain-Crash-Effect (RCE) for the Study Area

Year	WCR	DCR	$\frac{WCR - DCR}{DCR}$	$\frac{WCR - DCR}{DCR} \times 100\%$
2001	0.09	0.06	0.5	50
2003	0.13	0.08	0.63	63
2004	0.13	0.14	-0.07	-7
2005	0.14	0.07	1	100
2006	0.15	0.1	0.5	50
2007	0.22	0.3	-0.27	-27
2008	0.16	0.21	-0.24	-24
2009	0.26	0.4	-0.35	-35
2010	0.33	0.25	0.32	32
2011	0.38	0.41	-0.07	-7
2012	0.58	0.65	-0.11	-11

2013	0.45	0.75	-0.55	-55
2014	0.13	0.17	-0.24	-24
2001-2014	0.24	0.28	-0.14	-14

Source: Author's Analysis, 2016

The value of RCE was positive for five years which include 2001, 2003, 2005, 2006 and 2010 while it was negative in 2004, 2007, 2008, 2009, 2011, 2012, 2013 and 2014. A positive RCEi means more crash per unit wet day than unit dry day in a particular year while negative RCEi means more crash per unit dry day than unit wet day in a particular year. Thus, 2001, 2003, 2005, 2006 and 2010 experienced more crash per unit wet day than unit dry day while 2004, 2007, 2008, 2009, 2011, 2012, 2013 and 2014 experienced more crash per unit dry day than unit wet day.

It was observed that the least total annual rainfall recorded within this period was in 2005. However, 2005 recorded the highest RCEi in the study area which was also a positive RCEi. Year 2013 had the lowest negative RCEi but recorded an annual rainfall that was greater 1000mm. 2012 recorded the highest total annual rainfall within this period but had a negative RCEi. This is in agreement with Mondal *et al* (2011) who observed that the value of rain-crash-effect was positive for seven months and none of them had the highest rainfall. They concluded that negative rain-crash-effect during months with high rainfall in their study area may be due to small dry spell, extra care of drivers during rainy days, low vehicle speed due to traffic congestion and runoff effect. Thus, the average RCE derived from 2001-2014 reveals that Zaria had more crash per unit dry day than unit wet day.

Furthermore, Table 4.16 presents the correlation coefficients between the association of WCR and DCR with RCE. It also shows the association between WCR, DCR, number of wet days, number of dry days, number of RTAs on wet days and number of RTAs on dry days with positive and negative RCE.

Table 4.16: Correlation Coefficients between RTAs and Rain-Crash-Effect in Zaria

	RCE	+RCE	-RCE
WCR	0.65	-0.75	-.073
DCR	0.69	-0.60	-0.67
Total Number of wet Days		0.72	0.79
Crash Count on wet days		-0.64	-0.71
Total Number of Dry Days		-.083	-0.78
Crash Count on Dry days		-.0.60	-0.68

Source: Author's Analysis, 2016

Wet-crash-rate and dry-crash-rate are positively associated with rain-crash-effect; wet-crash-rate and dry-crash-rate are negatively associated with positive and negative RCE respectively. Number of wet days is positively associated with positive and negative RCE while Number of dry days is negatively associated with positive and negative RCE respectively. Crash count on wet days is negatively associated with positive and negative RCE respectively while Crash count on dry days is negatively associated with positive and negative RCE respectively.

The negative association between dry-crash-rate and rain-crash-effect, positive rain-crash-effect and negative rain-crash-effect are all significant. Thus, 54.5% of variations in positive RCE are determined by variations in wet-crash-rate and dry-crash-rate while 53.8% of variations in negative RCE are determined by variations in wet-crash-rate and dry-crash-rate. 68% of variations in RCE are determined by variations in wet-crash-rate and dry-crash-rate.

In a nutshell, annually, if the number of RTA case(s) that are recorded on wet or dry days increase, there is a general tendency also that the number of RTA case(s) that will occur on a unit wet or dry day respectively will decrease and vice versa. This means that RTA cases will not just occur at specific times of the year and will not occur at others. Thus, there is a temporal spread in its occurrence all year round. This is in agreement with Shankar, Mannering and Barfield (1995) who stated that there is a positive association between number of wet and dry days and RTA cases. In addition to that, positive RCE may be due to dry spell effect probably due to increased slipperiness as a result of the buildup of oil on roads when the first rain breaks the spell or as a result of the slow alignment of drivers to wet conditions. Negative RCE on the other hand may be as a result of extra care by drivers or due to low vehicular speed.

4.5.4 Effect of Dry Spell on RTAs in Zaria

Dry spell is defined as the number of dry days between two consecutive wet days. In the present study, small dry spell and large dry spell consisted of continuous dry days of 1 to 5 days and 6 to 40 days respectively. Any immediate wet day after a dry spell is designated by the name of the dry spell which includes no dry spell wet day (NDSWD), small dry spell wet day (SDSWD) and large dry spell wet day (LDSWD). Figure 4.30 presents the number of RTAs on wet days, after NDSWD, SDSWD and LDSWD annually.

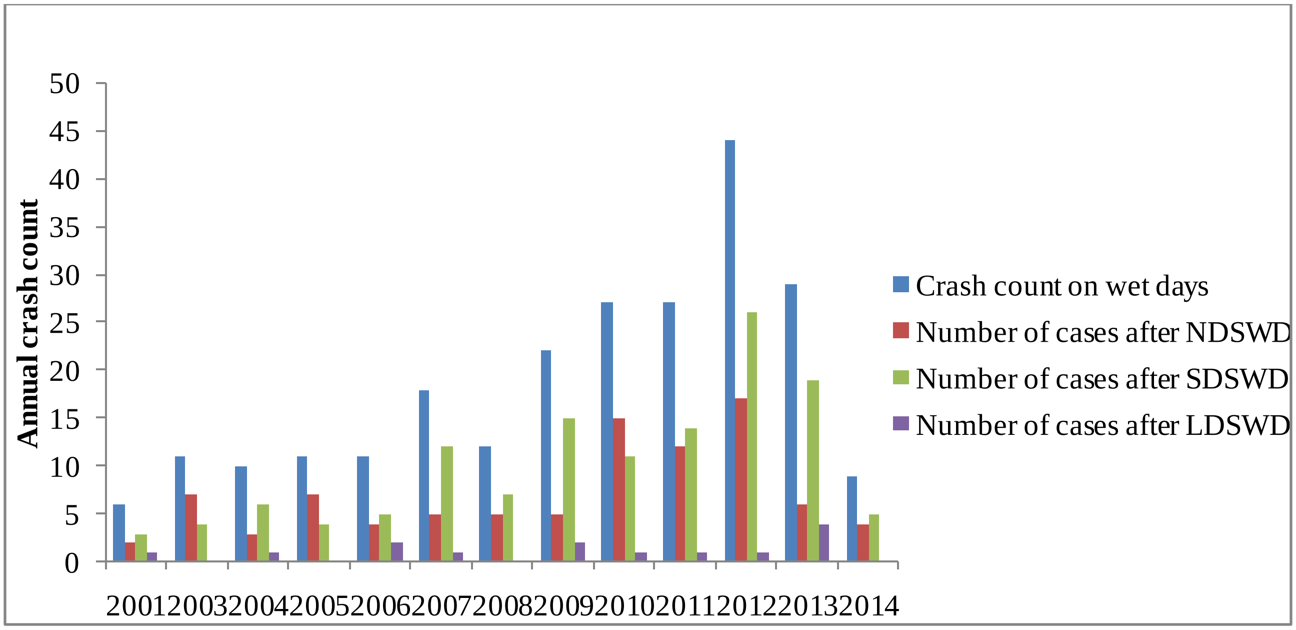


Figure 4.30: Effect of Dry Spell on Annual Crash Count in Zaria
Source: FRSC, 2016

The highest number of RTA cases reported on NDSWD was 17 in 2012 while the highest number of RTA cases reported on SDSWD was 26 in same year. However, the highest number of RTA cases reported on LDSWD was 4 in 2013. The least number of RTA cases reported on NDSWD was 2 in 2001 while the least on SDSWD was 3 in same year. However, no RTA cases were reported on LDSWD in 2003, 2005, 2008 and 2014.

Furthermore, Figure 4.32 presents the total number of RTAs and the number of RTAs that occurred after NSDWD, SDSWD and LDSWD in the study area.

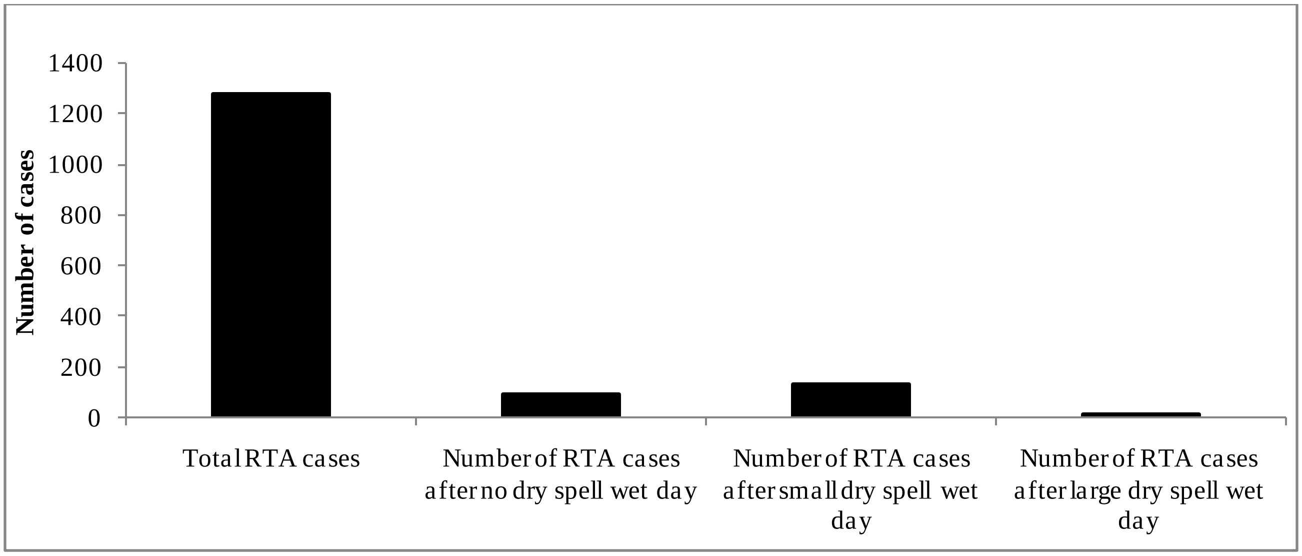


Figure 4.31: Effect of Dry Spell on RTA Cases in Zaria.
Source: FRSC, 2016

It was observed that throughout this period (2001-2014), 237 RTA cases were reported on wet days of which 92 RTA cases were reported on NDSWD, 131 RTA cases were reported on SDSWD and 14 RTA cases were reported on NDSWD. Thus, 38.8 per cent of RTA cases recorded on wet days within the study area occurred on NDSWD. 55.3 per cent of RTA cases recorded on wet days within the study area occurred on SDSWD while 5.9 per cent of RTA cases recorded on wet days within the study area occurred on LDSWD. In Zaria, the probability that a RTA case will occur on a NDSWD is 0.39 (39 per cent) while it is 0.55 (55 per cent) on a SDSWD and 0.06 (6 per cent) on a LDSWD.

Furthermore, Table 4.17 below shows the total annual RTA cases reported within the study area, crash count on wet days, average crash/NDSWD, % average crash/NDSWD, average crash/SDSWD, % average crash/SDSWD, average crash/LDSWD and % average crash/LDSWD.

Table 4.17: Average Crash Count on NDSWD, SDSWD and LDSWD for Zaria

Year	Total Cases	Crash count on wet days	Average crash/	%	Average crash/ SDSWD	%	Ave. crash/ LDSWD	%

2001	24	6	0.083	8.3	0.125	12.5	0.042	4.2
2003	32	11	0.188	18.8	0.125	12.5	0	0
2004	52	10	0.058	5.8	0.115	11.5	0.019	1.9
2005	32	11	0.219	21.9	0.125	12.5	0	0
2006	40	11	0.1	10	0.125	12.5	0.05	5
2007	102	18	0.049	4.9	0.118	11.8	0.001	0.1
2008	73	12	0.068	6.85	0.096	9.59	0	0
2009	134	22	0.037	3.73	0.112	11.2	0.015	1.5
2010	98	27	0.153	15.3	0.112	11.2	0.01	1.02
2011	148	27	0.081	8.11	0.095	9.46	0.007	0.68
2012	232	44	0.073	7.33	0.112	11.2	0.004	0.43
2013	254	29	0.024	2.36	0.075	7.48	0.0157	1.57
2014	59	9	0.068	6.8	0.084	8.47	0	0

Source: FRSC, 2016

The highest crash per NDSWD in a year was in 2005 when 21.9 per cent of RTA cases that were reported occurred on NDSWD while the least was in 2013 when 2.36 per cent of RTA cases that were reported occurred on NDSWD. Secondly, the highest crash per SDSWD in a year was in 2001 when 12.5 per cent of RTA cases that were reported occurred on SDSWD. Similarly, 2003, 2005 and 2006 respectively showed the same result. The least was in 2013 when 7.48 per cent of RTA cases occurred on SDSWD. Finally, the highest crash per LDSWD in a year was in 2001 when 4.2 per cent of RTA cases that were reported occurred on LDSWD. No crash was recorded on LDSWD in 2003, 2005, 2008 and 2014. Thus, 9.2 per cent of RTA cases were reported on NDSWD, 10.9 per cent on SDSWD and 1.3 per cent on LDSWD. Within the study area, the probability that a RTA case will occur on a NDSWD is 0.10, 0.11 on a SDSWD and 0.01 on a LDSWD.

This study agree with Eisenberg (2004) who observed a dry spell effect in an analysis of US daily accident counts. He also cites the buildup of oil on roads during a dry spell as a mechanism for causing increased slipperiness when the first rain breaks the spell. He found that after a spell of 1day there was a 9.7% increase in the non-fatal injury crash rate on the next wet day for 17 states over 1990–1999. This rate rose to 17.9% after 6 dry days and 23.1% after >21 days. This study also agree with Brijs *et al.* (2008) who stated that there is a relationship between the length of dry spell and crash count. Mondal *et al.* (2008) stated that an enhancement of the accident count after a dry spell could be due to physical or psychological factors like the build-up of oil and dirt on the road surface or the slow realignment to wet conditions.

However, in this present study, a different result was obtained compared to these other studies that found a positive relationship between length of dry spell and crash count. This is due to the fact that it is on SDSWDs that more RTA cases were recorded compared to NSDWD and LDSWD. This could be because longer periods of dry spell psychologically threatens drivers extracting more attentive attitude from them compared with SDSWD which they could easily take for granted.

Table 4.18 below presents the result of a one-way ANOVA aimed at checking whether the frequency of occurrence of RTAs after NDSWD, SDSWD and LDSWD differ significantly or otherwise.

Table 4.18: Variability in Dry Spell effect on RTAs in Zaria

Source	DF	SS	MS	F	P
Factor	2	544.1	272.0	11.44	0.000
Error	36	855.8	23.8		
Total	38	1399.9			

Source: Author’s Analysis, 2016
Note: *p*-value < significance level, linear relationship is significant

Since *p*-value is 0.000 and on the other hand, calculated *F* was 11.4 which is greater than the critical value of F at 0.05 (3.26), it shows that the frequency of occurrence of RTA cases after NDSWD, SDSWD and LDSWD differ significantly. Thus, since the probability that a RTA case will occur on a NDSWD is 0.39 (39 per cent) while it is 0.55 (55 per cent) on a SDSWD and

0.06 (6 per cent) on a LDSWD in Zaria. Thus, any day after a short dry spell is more liable to record a significantly greater number of RTA cases compared to NDSWD or LDSWD. Finally, crash count on wet days is positively associated with NDSWD (r = 0.84), SDSWD (r = 0.56) and LDSWD (r = 0.40). Its association with NDSWD and SDSWD are significant.

4.5.5 Effect of Rainfall, Length of Dry Spell and Evaporation Rate on RTAs in Zaria

The amounts of rainfall recorded on all the wet days that RTA cases were reported were identified and their dates recorded. The total amounts of rainfall recorded before and on that date were identified. The length of dry spell, mean monthly evaporation rate, the amounts of rainfall recorded one, two, three, four and five days before that date were also recorded. The degree of association between these variables and RTA cases and casualties were then determined using Pearson's product moment correlation to identify the most significant associations. Hence, only the most significant associations were reported.

Table 4.19 presents the correlation coefficient from the association between total cases of RTAs, number of passengers injured and killed as a result of the occurrence of RTAs within Zaria Township.

4.19: Correlation Coefficients between Weather and RTAs in Zaria Township

	Rainfall (3 days before occurrence of RTA)
Total Cases	-0.94
Number of passengers killed	-0.91
Number of Casualties	0.65

Source: Author's Analysis, 2016

In Zaria Township, a strong negative association between both total cases of RTAs and the numbers of passengers that die in RTAs and the amount of rainfall recorded three days before a RTA was found. Furthermore, a positive association between number of casualties due to RTA case(s) and the amount of rainfall recorded three days before the occurrence of a RTA accident was also found.

Table 4.20 presents the correlation coefficient from the association between fatal RTA cases and the amount of rainfall recorded five days before the occurrence of RTAs, between serious RTA cases and the amount of rainfall recorded both on the day of the accident and three days before the accident, between minor RTA cases and the amount of rainfall recorded both three and four days before the accident and finally, between the number of passengers killed due to RTAs and both the length of dry spell and the amount of rainfall recorded three days before the accident.

Table 4.20: Correlation Coefficients between Weather and RTAsalong Zaria-Kaduna Route

	Rainfall (day of RTA)	Length of Dry spell	Rainfall (3)	Rainfall (4)	Rainfall (5)
Fatal					0.61
Serious	-0.77		-0.80		
Minor			0.71	0.81	
Number of passengers killed		0.82	0.67		

Source: Author’s Analysis, 2016

Along Zaria-Kaduna route, there was a strong negative association between serious cases and the amount of rainfall recorded on the day of the RTA. There is a positive association also between the numbers of passengers that die in an auto crash and the length of dry spell before that RTA accident. There is a negative association between serious cases and the amount of rainfall recorded three days before a RTA. However, the association between minor cases and the amount of rainfall recorded three and four days respectively before a RTA is positive and a positive association also between the numbers of passengers that die in a RTA and the amount of rainfall recorded three days before any RTA. There is a positive association between fatal cases and the amount of rainfall recorded five days before any RTA.

Table 4.21 presents the correlation coefficient from the association between the number of passengers injured due to RTAs and the amount of rainfall recorded five days before the occurrence of RTAs, between the number of passengers killed due to RTAs and the mean evaporation rate of the study area and the number of casualties and the amount of rainfall recorded both on the day of the accident and five days before the accident.

~~Table4.21: Correlation Coefficients between Weather and RTAsalong Zaria-Kano Route~~

	Mean Monthly Evap. Rate	Rainfall (day of RTA)	Rainfall (5)
Number of passengers injured			0.64
Number of passengers killed	0.57		
Number of Casualties		0.61	0.63

~~**Source:** Author's Analysis, 2016~~

Along Zaria-Kano route, there was a positive association between the numbers of passengers killed in RTAs and the mean monthly evaporation rate, a strong positive association between number of passengers injured on one hand or number of casualties and the amount of rainfall recorded five days before any RTA accident. There was a strong positive association between number of RTA casualties and the amount of rainfall recorded on the day of any RTA accident.

Figure 4.22 presents the correlation coefficient of the relationship between minor RTA cases and the amount of rainfall recorded four days before the occurrence of the accident.

~~Table4.22: Correlation Coefficient between Weather and RTAsalong Zaria-Sokoto Route~~

	Rainfall (4 days before)
Minor Cases	0.93

Source: Author's Analysis, 2016

Along Zaria-Sokoto route, there was a strong positive association between the occurrence of minor cases of RTA and the amount of rainfall recorded 4 days before any RTA accident. Thus, the more the amount of rainfall recorded on any particular date, the more the number of minor road traffic accident cases that will be recorded four days later and vice versa. Thus, lagged precipitation has effect on the occurrence of RTAs.

Table 4.23 presents the correlation coefficient from the association between the number of passengers injured due to RTAs and the amount of rainfall recorded four days before the occurrence of RTAs, between the number of passengers killed and the amount of rainfall recorded five days before the occurrence of RTAs and between the number of casualties and the amount of rainfall recorded four days before the RTA.

Table4.23: Correlation Coefficients between Weather and RTAsalong Zaria-Jos Route

	Rainfall (4 days before)	Rainfall (5)
Number of passengers injured	0.93	
Number of passengers killed		0.81
Number of Casualties	0.96	

Source: Author's Analysis, 2016

However, along Zaria-Jos route, there exist a very strong positive association between number of passengers that get injured in an auto crash on one hand or number of casualties due to RTA and the amount of rainfall recorded four days before any RTA accident. There is a positive association also between the numbers of passengers that die in an auto crash and the amount of rainfall recorded five days before any RTA accident along this route.

Table 4.24 presents the correlation coefficient from the association between fatal and serious RTA cases and the amount of rainfall recorded three, four and five days before the occurrence of RTAs, between minor RTA cases and the amount of rainfall recorded four days before the accident and finally, between the number of passengers killed due to RTAs and the amount of rainfall recorded three days before the accident.

Table4.24: Correlation Coefficients between Weather and RTAsin Zaria Unit Command

	Rainfall (3 days before)	Rainfall (4)	Rainfall (5)

Fatal	0.65	-0.75	0.63
Serious	-0.72	-0.60	-0.67
Minor		0.71	
Total cases	-0.64	-0.71	
Number of passengers killed	0.60		

Source: Author's Analysis, 2016

Thus, a negative association was observed between both serious and total RTA cases and the amount of rainfall recorded three days earlier. A positive association was observed between the numbers of passengers killed in RTAs and the amount of rainfall recorded three days earlier. There is a positive association between minor RTA cases and amount of rainfall recorded four days earlier while there was a positive association between fatal RTA cases and the amount of rainfall recorded five days earlier. This revealed that the amount of rainfall recorded three, four and five days earlier has a strong association with RTAs in Zaria. This may be due to dry spell effect as a result of increase in slipperiness due to grime during dry periods. The buildup of oil on roads during dry spells increases slipperiness when the first rain breaks the spell leading to a slow realignment to wet conditions. However, the observed negative association may be due to extra caution by drivers or low vehicular speed and other physical and psychological factors.

Since more RTA cases are recorded on SDSWD, it was observed that as the amount of rainfall recorded three days before a SDSWD increased, both the number of serious and total cases decreased while the number of passengers killed in RTAs increased and vice versa. Likewise, if the amount of rainfall that is recorded three days before a SDSWD increases, the number of fatal cases increased and vice versa. If the amount of rainfall that is recorded four days before a SDSWD increased, the number of minor cases increased and vice versa. Lastly, if the amount of rainfall that is recorded five days before a SDSWD increased, the number of fatal cases increased and vice versa. This is in agreement with the study carried out by Mondal *et al*. (2011) in India which revealed the impact of lagged precipitation on RTA after a dry spell.

Thus, this study also agrees with Eisenberg (2004) who showed that lagged precipitation which is rainfall the day or days before substantially increases the impact of precipitation on road safety as it leads to an increase in the number of fatal accidents after a dry spell. This is most likely caused by the fact that precipitation clears the oil that accumulates on roads during dry periods, thereby making roads slippery. It is also possible that people adjust their driving behavior slowly, implying relatively risky driving behavior in rainy conditions after a dry spell. A similar lagged precipitation effect was found by Brodsky and Hakkert (1988) and Levine *et al*. (1995).

4.6DerivingRain-Class-Clash-Ratefor the Study Area

Throughout the year rainfall varies in amount and intensity.Therefore, it is also very important to knowthe effect of rainfall class on crash rate. Table 4.24 presents the rain-class-crash-rate for class one and class two rainfalls for the study area.

Table 4.25: Rain-Class-Crash-Rate for Class One and Two in Zaria

Class one	Class two

	>0-1mm				>1-2mm			
Year	WCi	WDi	$\frac{WCi}{WDi}$	$\frac{WCi}{WDi} \times 100\%$	WCi	WDi	$\frac{WCi}{WDi}$	$\frac{WCi}{WDi} \times 100\%$
2001	0	5	0	0	0	0	0	0
2003	2	12	0.17	17	0	9	0	0
2004	0	2	0	0	0	4	0	0
2005	1	6	0.17	17	3	8	0.38	38
2006	0	5	0	0	0	7	0	0
2007	1	5	0.2	20	3	8	0.38	38
2008	0	3	0	0	2	8	0.25	25
2009	0	0	0	0	2	5	0.4	40
2010	0	0	0	0	2	3	0.67	67
2011	2	3	0.67	66.7	2	6	0.33	33
2012	1	2	0.5	50	1	7	0.14	14
2013	0	0	0	0	6	5	1.2	120
2014	1	6	0.17	17	0	5	0	0
Average	0.62	3.77	0.14	14	1.62	5.77	0.29	29

Source: Author' Analysis, 2016

First and foremost, careful analysis of class one rainfall (>0 to 1mm) showed that for seven out of the thirteen years under investigation, WCR was zero. These years were 2001, 2004, 2006, 2008, 2009, 2010 and 2013. Throughout the period of this study, the highest WCR recorded under this class was 0.67 in 2011 showing that the probability that RTA will occur on any wet day that falls within this class was 0.67 or 67 per cent. The average crash count for this class was 0.62 RTA case per year while the average number of wet days for this class was 3.77 wet days per year. In conclusion, the probability that a RTA case will occur on a wet day that falls within this class is 0.16 or 16 per cent. Furthermore, careful analysis of class two rainfall (>1 to 2mm) showed that for five out of the thirteen years under investigation, WCR was zero. These years were 2001, 2003, 2004, 2006 and 2014. Throughout the period of this study, the highest WCR recorded under this class was in 2013 when the probability that RTA will occur on any wet day that falls within this class was greater than 100 per cent. The average crash count for this class was 1.62 RTA cases per year while the average number of wet days was 5.77 wet days per year.

In conclusion, the probability that a RTA case will occur on a wet day that falls within this class is 0.28 or 28 per cent.

Table 4.25 below presents the rain-class-crash rate for class three and class four rainfalls in the study area.

Table 4.26: Rain-Class-Crash-Rate for Class Three and Four Rainfall in Zaria

Class three					Class Four			
>2-5mm					>5-15mm			
Year	WCiWDi		$\frac{WCi}{WDi}$	$\frac{WCi}{WDi}$ WCi × 100%	WDi		$\frac{WCi}{WDi}$	$\frac{WCi}{WDi} \times 100\%$
2001	1	8	0.13	13	2	20	0.1	10
2003	1	11	0.09	9	5	29	0.17	17
2004	1	19	0.05	5	4	17	0.24	24
2005	3	18	0.17	17	2	26	0.08	8
2006	2	11	0.18	18	3	24	0.13	13
2007	5	15	0.33	33	5	20	0.25	25
2008	1	12	0.08	8	6	25	0.24	24
2009	5	17	0.29	29	5	27	0.19	19
2010	5	20	0.25	25	12	35	0.34	34
2011	3	17	0.18	18	12	26	0.46	46
2012	6	10	0.6	60	15	20	0.75	75
2013	8	16	0.5	50	9	22	0.41	41
2014	2	15	0.13	13	2	20	0.1	10
Average	3.3	14.54	0.23	23	6.31	23.9	0.27	27

Source: Author's Analysis, 2016

Thirdly, for class three rainfall (>2 to 5mm), no year under investigation had a WCR of zero. However, the highest WCR recorded under this class was in 2012 when the probability that RTA will occur on any wet day that falls within this class was 0.60 or 60 per cent. The average crash count for this class was 3.3 RTA cases per year while the average number of wet days for this class was 14.54 wet days per year. The probability that a RTA case will occur on a wet day that falls within this class is 0.23 or 23 per cent. For four rainfall (>5 to 15mm) also, no year under investigation had a WCR of zero. However, the highest WCR recorded under this class was also in 2012 when the probability that RTA will occur on any wet day that falls within this class was 0.75 or 75 per cent. The average crash count for this class was 6.31 RTA cases per year while the average number of wet days for this class was 23.9 wet days per year. In conclusion, the probability that a RTA case will occur on a wet day that falls within this class is 0.26 or 26 per cent.

Table 4.26 below presents the rain-class-crash rate for class five and class six rainfalls in the study area.

Table 4.27: Rain-Class-Crash-Rate for Class Five and Six Rainfall in Zaria

Class Five					ClassSix			
>15-30mm					>30mm			
Year	WCi	WDi	$\frac{WCi}{WDi}$	$\frac{WCi}{WDi} \times 100\%$	WCi	WDi	$\frac{WCi}{WDi}$	$\frac{WCi}{WDi} \times 100\%$
2001	2	13	0.15	15	1	18	0.06	6
2003	2	18	0.11	11	1	8	0.13	13
2004	3	21	0.14	14	2	10	0.2	20
2005	1	13	0.08	8	1	7	0.14	14
2006	3	15	0.2	20	3	12	0.25	25
2007	1	14	0.07	7	2	11	0.18	18
2008	2	13	0.15	15	1	13	0.08	8
2009	7	12	0.58	58	1	15	0.07	7
2010	5	12	0.42	42	4	11	0.36	36
2011	5	14	0.36	36	3	6	0.5	50
2012	16	24	0.67	67	5	13	0.38	38
2013	4	14	0.29	29	2	9	0.22	22
2014	3	17	0.18	18	1	8	0.13	13
Ave.	4.15	15.4	0.26	26	2.08	10.9	0.21	21

Source: Author's Analysis, 2016

Furthermore, careful analysis of class five (>15 to 30mm) showed that no year under investigation had a WCR of zero. However, the highest WCR recorded under this class was in 2012 also when the probability that RTA will occur on any wet day that falls within this class was 0.67 or 67 per cent. The average crash count or RTA cases that was recorded within this period for this class was 4.15 RTA cases per year while the average number of wet days recorded within this period for this class was 15.4 wet days per year. In conclusion, the probability that a RTA case will occur on a wet day that falls within this class is 0.27 or 27 per cent.

Finally, careful analysis of class six (>30mm) showed that no year under investigation had a WCR of zero. However, the highest WCR recorded under this class was in 2011 when the probability that RTA will occur on any wet day that falls within this class was 0.50 or 50 per cent. The average crash count or RTA cases that was recorded within this period for this class was 2.08 RTA cases per year while the average number of wet days recorded within this period for this class was 10.9 wet days per year. In conclusion, the probability that a RTA case will occur on a wet day that falls within this class is 0.19 or 19 per cent.

Therefore, it was observed that any wet day in Zaria that records between >0 to 1mm of rainfall, the likelihood that any road user that uses the road during or after the rainfall will have an accident is 0.16 or 16 per cent. This implies that for every one hundred road users, sixteen of them will have an accident. Hence, the probability that any road user that uses the road during or after class two, three, four, five or six rainfall will have an accident is 0.28, 0.23, 0.26, 0.27 and 0.19 respectively. In conclusion, 11.5 per cent of RTA cases that were recorded on a wet day in Zaria occurred on a day with class one rainfall. For class two, three, four, five and six rainfall, it was 20.1, 16.5, 18.7, 19.4 and 13.7 per cent respectively. This implies that in Zaria, driving during or after class two rainfalls is the most dangerous while class one is the safest. This may be due to the fact that light rainfall creates more lubrication and slippery condition on the road by mixing dust and oil among others. Secondly, light rainfall may create ‘don’t care’ attitude among drivers. The safety of class one rainfall may be because this amount of rainfall is not significant enough to pose any threat to road users.

The study revealed that class two (>1 to 2 mm) had the highest RCCR in Zaria. Class four (>5 to15 mm), class five (>15 to 30 mm), class three (>2 to 5 mm), class six (>30 mm) and class one (>0 to 1 mm) had the second third, fourth, fifth and least RCCR respectively.

Table 4.27 below presents the result of one-way ANOVA test to see if the RCCR for the six classes of rainfall adopted for study differ significantly or otherwise.

Table 4.28: Variability in RCCR in Zaria

Source	DF	SS	MS	F	P
Factor	5	0.1749	0.0350	0.74	0.597
Error	72	3.4119	0.0474		
Total	77	3.5868			

Source: Author's Analysis, 2016
Note: *P*-value< significance level, linear relationship is significant

The study revealed a *p*-value of 0.597 which is greater than the significance level which is 0.05 which shows that the rain-class-crash-rate for all the classes did not differ significantly. Thus, the probability that road crashes will occur during or after rainfall of all the classes did not differ significantly from one another. This shows that both light showers and heavy rainfall have a statistically similar ability to influence the occurrence of road crashes. Thus, driving during wet conditions generally should be discouraged.

Atubi (2012a) reported that rainfall and road accidents had a positive relationship in his study in Lagos, Nigeria. The result was the opposite in India as reported by Mondal *et al.* (2011c) and this is in agreement with the result from this study as class one rainfall which had the highest RCCR in India had the least in Zaria, Nigeria. Thus, this study agrees with Edwards (1996) and Khan, Qin and Noyce (2008) who reported that the occurrence of road accidents in hazardous weather conditions be it rainfall, temperature, fog, snowfall and wind broadly follows the regional weather patterns for those conditions.Hence, the climate of any study area must be well understood in order to have a clearer understanding of the inter-relationship between weather and the occurrence of road traffic accidents. However, both studies agreed that class four and six rainfall had the second and fifth RCCR respectively in the study areas.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Major Findings

In Zaria, climate trend revealed that there is a general increase in the amount of rainfall, number of wet days, air temperature, visibility and relative humidity and a decrease in wind speed and evaporation rate. Furthermore, Zaria-Kaduna and Zaria-Kano routes recorded more RTA cases and casualties than the others.Zaria-Kaduna route recorded 419 cases and 1722 casualties while Zaria-Kano route recorded 408 cases and 1448 casualties. This study found out that dangerous driving, speed violation and loss of control are the leading causes of RTAs with dangerous driving being the number one cause of RTAs in Zaria.Current trend analysis revealed that there is a general increase in the number of RTA cases and casualties in Zaria.

In Zaria Township, only dangerous driving was responsible for RTAs in all the months of the year. Along Zaria-Kaduna route however, it was dangerous driving, speed violation, loss of control, tyre burst and wrongful overtaking. Along Zaria-Kano route, it was dangerous driving, speed violation, loss of control and tyre burst. No particular cause of RTAs was responsible for RTAs in all the months of the year along Zaria-Sokoto, Old Zaria-Kano and Zaria-Jos routes.

The highest number of fatal RTA cases was recorded in 2012, serious cases in 2013, minor cases in 2009, number of passengers injured in 2007 while the number of passengers that were killed per year was in 2013. The highest number of RTA cases recorded per year was in 2013 while casualties were in 2010 and 2012. Similarly, the highest number of fatal RTA cases was recorded in July, serious cases in September, minor cases in June, number of passengers injured in September while the number of passengers that were killed was in January. The highest number of RTA cases and casualties however were recorded in July and January.

The result of the correlation analysis between RTA parameters and weather parameters on annual basis revealed that rainfall, visibility and wind speed had a positive association with all the RTA parameters, number of wet days had a negative association with all of them except minor cases and the number of passengers killed during RTAs, air temperature positive association with all of them except minor cases, relative humidity has a negative association with all of them except total cases while evaporation rate had a negative association with all the RTA parameters except with minor cases.

In addition to that, the result from monthly analysis between RTA parameters and weather parameters revealed that rainfallhad a positive association with all the RTA parameters except the number of passengers either injured or killed, air temperature had a positive association with all of them except with serious cases, total number of cases and the number of passengers killed, visibility had a negative association all of them except with minor and total cases, relative humidity had a negative association with all of them except serious, minor and total cases, while wind speed and evaporation rate had a negative association with all the RTA parameters except with fatal cases, number of passengers killed and total casualty.

Annual analysis of the nature of association between probable causes of RTA and weather for the most significant probable causes of RTA revealed that the more the amount of rainfall, number of wet days, wind speed and evaporation rate on one hand and the more friendly the temperature is and the poorer the visibility becomes annually, the more the number of fatal cases of RTA as a result of speed violation. Loss of control was positively associated with rainfall, air temperature, visibility and wind speed and negatively associated with relative humidity and evaporation rate with respect to the frequency with which fatal, serious and minor cases were linked to it. Dangerous driving on the other hand was positively associated with rainfall, number of wet days and wind speed and negatively associated with air temperature, visibility, relative humidity and evaporation rate with respect to the frequency with which fatal cases were linked to it.

Monthly analysis was carried out and speed violation revealed a negative association with rainfall and relative humidity with respect to the frequency with which fatal cases were linked to it while it showed a negative association with all these climatic elements with respect to the frequency with which serious cases were linked to it. A positive association was discovered between loss of control, air temperature and evaporation rate on one hand and a negative association between it, wind speed and evaporation rate on the other with respect to the frequency with which fatal and serious cases were linked to it. A negative association was discovered between dangerous driving, wind speed and evaporation rate on one hand and a positive association between it, rainfall and relative humidity on the other with respect to the frequency with which fatal and serious cases were linked to it.

Furthermore, there is a general tendency in Zaria that greater amount of rainfall will lead to more RTAs and lesser rain-crash-index. Secondly, the probability that a RTA will occur on any wet day is 0.24 while it is 0.28 on any dry day while the probability that a RTA will occur on a no dry spell wet day is 0.39, 0.55 on a small dry spell wet day and 0.06 on a large dry spell wet day. Zaria also revealed a negative rain-crash-effect showing that more RTA cases occur per unit dry day than unit wet day.

The amount of rainfall recorded three, four or five days before any day have a significant positive relationship with the number of passengers killed, minor and fatal cases of RTA respectively that will occur on that day while the amount of rainfall recorded three days before any day has a significant negative association with the number of serious and total cases that occurred on that day. Finally, class two rainfall (>1 to 2mm) has the highest rain-class-crash-rate followed by class four rainfall (>5 to 15mm), class five (>15 to 30mm), class three (>2 to 5mm), class six (>30mm) and finally, (>0 to 1mm).

5.2 Conclusion

In Zaria, climate trend revealed that there is a general increase in the amount of rainfall, number of wet days, air temperature, visibility and relative humidity and a decrease in wind speed and evaporation rate. Furthermore, Zaria-Kaduna and Zaria-Kano routes recorded more RTA cases and casualties than the others.Zaria-Kaduna route recorded 419 cases and 1722 casualties while Zaria-Kano route recorded 408 cases and 1448 casualties. The number of RTA cases and casualties are at an increase in Zaria and the primary causes are dangerous driving, speed violation and loss of control respectively. The nature of association between these weather parameters and RTA parameters be it fatal, serious, minor or the totality of RTA cases on one hand or the number of passengers injured or killed or the totality of casualties from RTAs on the other vary from one weather element to another or from one month to another or one year to another.

Furthermore, there is a general tendency in Zaria that greater amount of rainfall will lead to more RTAs and lesser rain-crash-index. Secondly, the probability that a RTA will occur on any wet day is 0.24 while it is 0.28 on any dry day while the probability that a RTA will occur on a no dry spell wet day is 0.39, 0.55 on a small dry spell wet day and 0.06 on a large dry spell wet day. Zaria experienced more RTA cases per unit dry day than unit wet day. The amount of rainfall recorded three, four or five days before any day have a significant positive relationship with the number of passengers that will be killed, minor and fatal cases of RTAs respectively as a result of the occurrence of RTAs on that specified day.The amount of rainfall recorded three days before any day has a significant negative association with the number of serious and total cases that occurred on that day. Finally, class two rainfall (>1 to 2mm) has the highest rain-class-crash-rate followed by class four rainfall (>5 to 15mm), class five (>15 to 30mm), class three (>2 to 5mm), class six (>30mm) and finally, (>0 to 1mm).

5.3 Recommendation

There exist a certain degree of interaction between weather and RTAs which vary from one weather element to another and from one point in time to another. Thus, since this is one area that has received little attention even in the words of the Intergovernmental Panel on Climate Change, more attention should be given to this idea. Hence, this is a reality in this study area because not a single RTA case was linked to weather to the best of the researcher’s knowledge. Thus, with the level of RTA cases and casualties in Nigeria, the academics, the FRSC, Nigerian Meteorological Agency, Federal Ministry of Transportation and all relevant stockholders like the National Union of Road Transport Workers and Centre for Disaster Risk Management and Development Studies, A.B.U, Zaria should be brought together under the chairmanship of Professor E.O. Iguisi or Professor I.M. Jaro in order to exploit this idea hence, curb this disaster in Nigeria and the world as a whole.

The next step however is that Nigerian Meteorological Agency and FRSC must work under one umbrella in such a way that as soon as Nigerian Meteorological Agency present the regular weather forecast which should be presented not only on the television and radio but via all forms of social media available, the FRSC should be there to immediately explain to the nation the implications of the weather forecast on road users and the occurrence of RTAs. Thus, standard weather stations should be provided by the government and stakeholders along the most RTA prone highways in the country. Training and retraining of officials of these agencies is crucial and not forgetting that a close collaboration with academics and research institutes is inevitable. These will help us go a long way in solving this disaster.

In this order to actualize these recommendations, the present study has conducted an in-depth research on this subject matter so as to serve as a good guide for other researchers and agencies who wish to study this subject matter in the further. In order to achieve the aim of the present study, make the aforementioned point possible and the realization of the first recommendation, the research looked at the driver, vehicle and the environment in addition to a careful examination of all the causes of RTAs as enlisted by FRSC, Nigeria. This is because of the relevance and urgent need to reduce the high rate of RTAs in Nigeria. Secondly, in order have a better understanding of the complex nature of association between weather and the occurrence of RTAs. Thirdly, in order to key into IPCC’s recommendation for studies to be carried out globally in order to understand the consequences of climate change and changing weather conditions on transport sector.

Thus, this is a multi-disciplinary issue that deserves a multi-disciplinary approach. Hence, NIMET, FRSC, Nigerian Police Force (NPF), climate experts, transport experts, medical practitioners, engineers, physicist, mathematicians, statisticians, computer scientists, Standard Organization of Nigeria (SON), the automobile industry among a lot more should all key into this idea. The Nigerian Government, NIMET, FRSC and CDRMDS, ABU, Zaria should champion this course and the Federal Government should be visibly seen to be sponsoring and encouraging researches like this while NIMET and FRSC should utilize the expertise of these of these experts and their findings for the achievement of the second recommendation. Hence, research in this area must be continuous due to the dynamic nature of weather. Finally, the

Federal Government should be responsible for enacting and enforcing laws resulting from these researches and expert opinions.

5.4 Contribution to knowledge

A holistic approach geared towards reducing the rate of RTAs is very necessary in Nigeria that is said to have the highest road traffic accident rates in Africa and the second in the world (Akpogomeh, 1998; Obinna, 2007; Atubi, 2012c). This is the motivational statement for this study because FRSC did not attribute RTAs to weather parameters even though it lists poor weather as one of its probable causes of RTAs. Thus, this study has proven scientificallythat weather be it poor or friendly does contribute to the occurrence of RTAs. It is not a proximate factor but combines with other factors to cause RTAs. Furthermore, the study found out that the highest number of fatal RTA cases was recorded in July, serious cases in September, minor cases in June, number of passengers injured in September while the number of passengers that were killed was in January. The highest number of RTA cases and casualties however were recorded in January and July.

This study also identified the rain-crash-index, wet-crash-rate, dry-crash-rate, rain-crash-effect and the effect of dry spell and lagged precipitation on RTA in the study area. Analyzing the wet-crash-rate(WCR) and dry-crash-rate (DCR) for the study area, the researcher realized that the attitude of drivers towards driving remain the same both in the wet and dry seasons which should be corrected as WCR and DCR vary annually. It also identified lagged effect of rainfall on RTAs in Zaria as rainfall the day or days before the occurrence of any RTA substantially increased the impact of lagged precipitation on road safety implying that rainfall leads to a stronger increase in the number of fatal RTAs after a dry spell. This is supported by Eisenberg (2004) who stated that lagged precipitation substantially increase the impact of precipitation on road safety. This study also found out that the frequency with which RTAs occur on a no dry spell wet day (0 day), small dry spell wet day (1-5 days) and large dry spell wet day (more than 5 days) differ significantly with more RTAs occurring on small dry spell wet days. Furthermore, the amount of rainfall recorded three, four and five days before the occurrence of any RTA was found to have a strong relationship with RTA cases and casualties.

This study was able to derive the rain-class-crash-rate for the study area and identified that class two rainfall induces the occurrence of RTAs the most (>1-2mm of rainfall).Wind speed was found to induce more RTAs compared with the other selected weather parameters. In fact, dangerous driving was responsible for more RTAs than any other cause of RTAs and the occurrence of fatal and serious RTAs that were attributed to it were induced mostly by windspeed. Finally, a model was developed to make an attempt towards forecasting the occurrence of RTAs using selected weather parameters.

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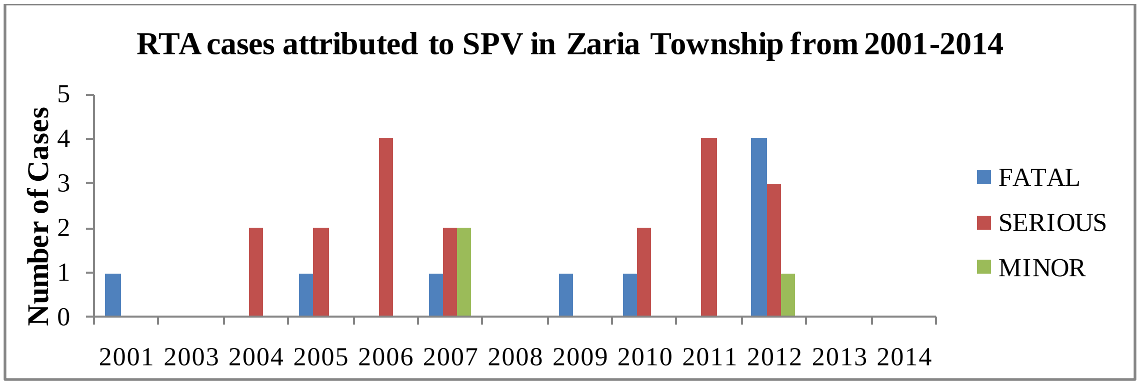
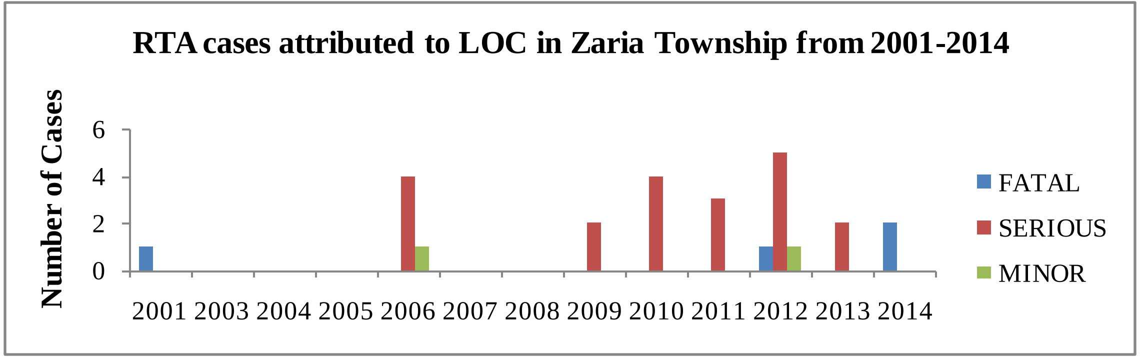
APPENDIX I

Annual record of RTA cases, severity and causes in Zaria


RTA cases attributed to SPV in Zaria Township from 2001-2014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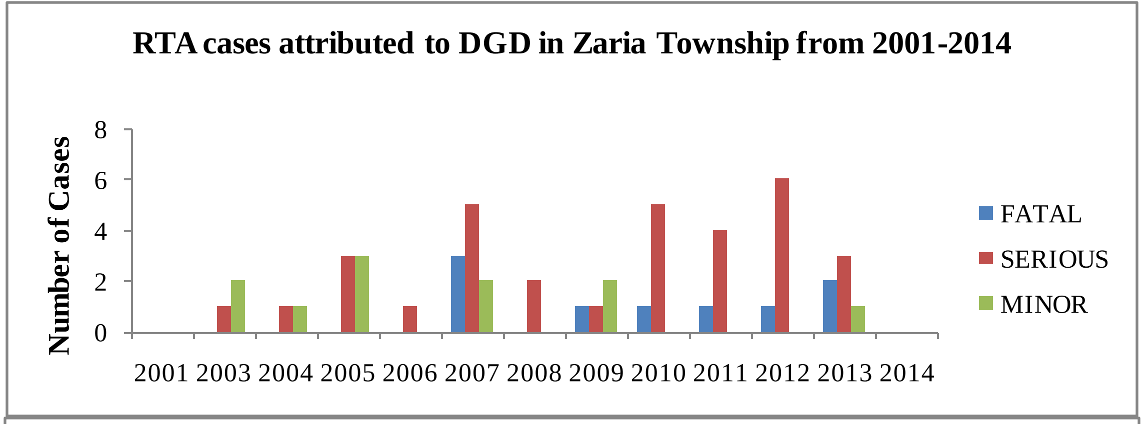
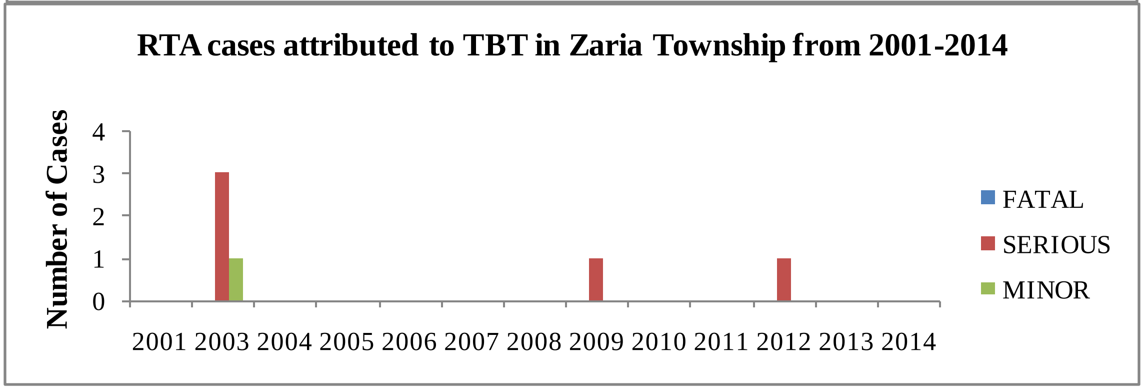
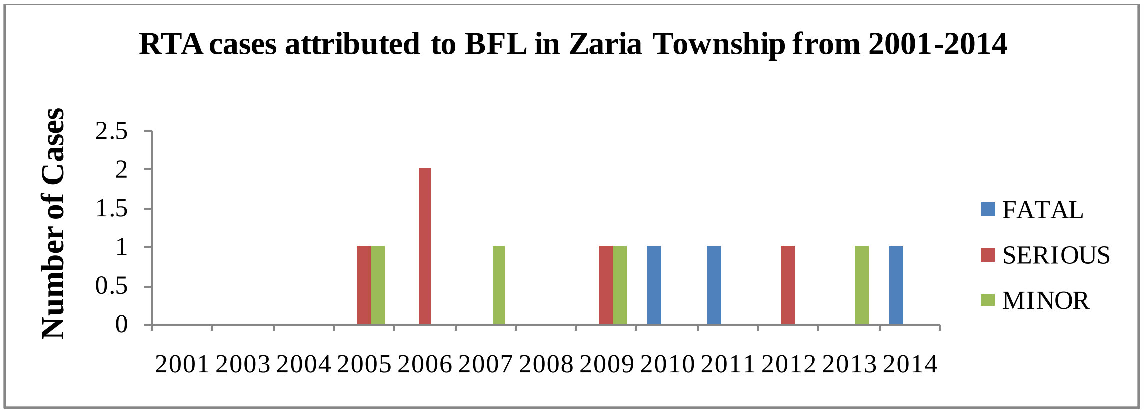

RTA cases attributed to DGD in Zaria Township from 2001-2014


RTA cases attributed to TBT in Zaria Township from 2001-2014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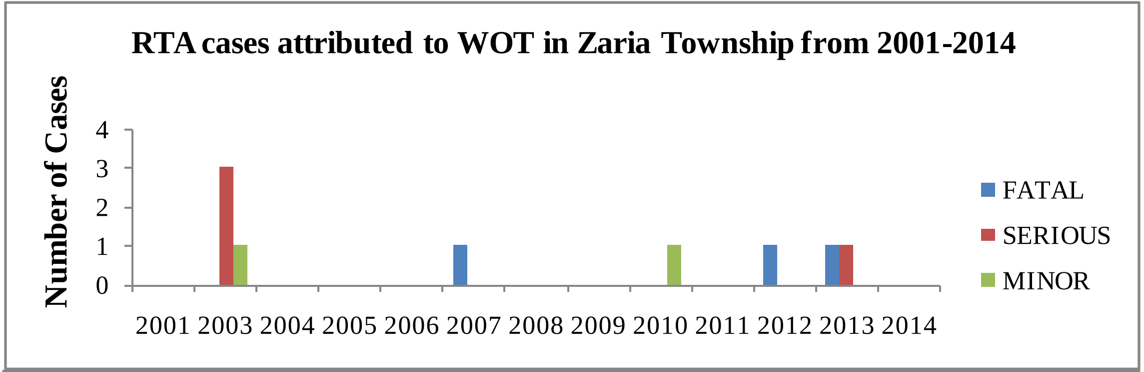
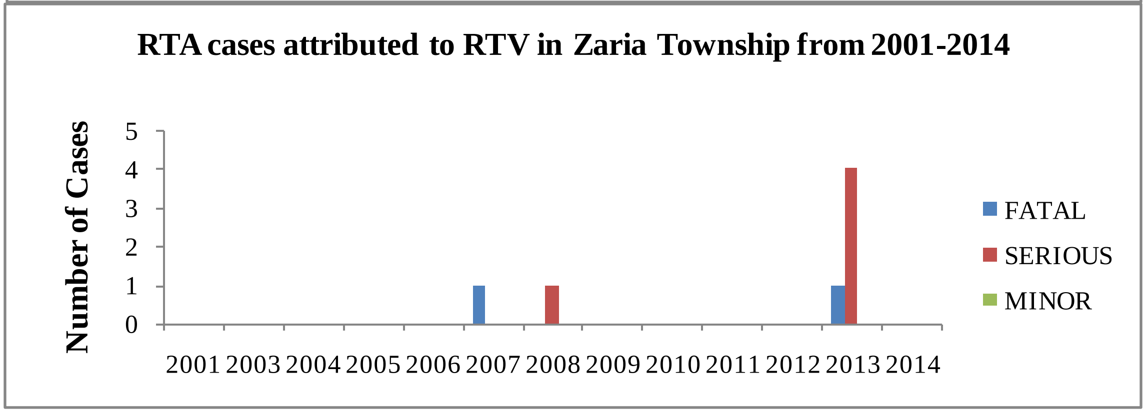
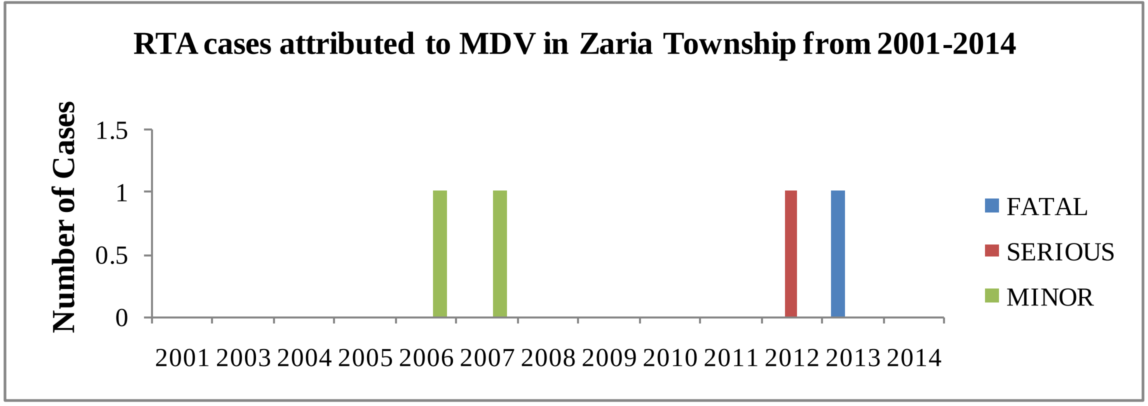
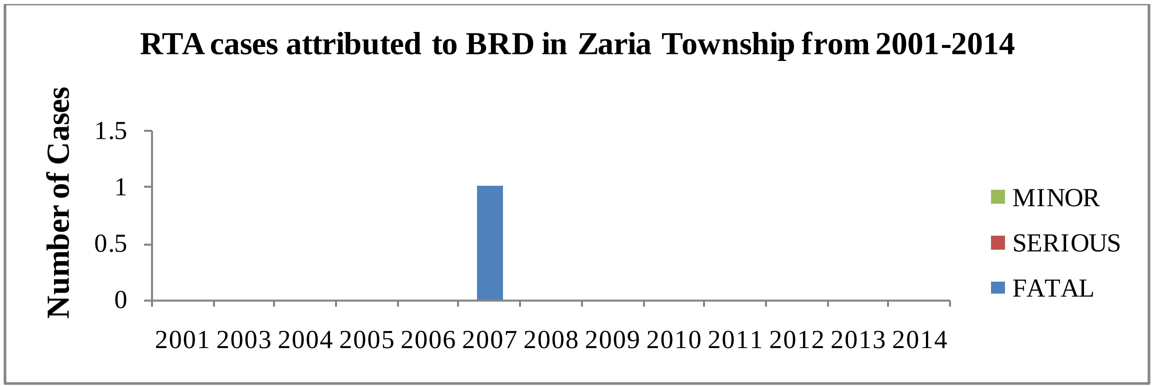
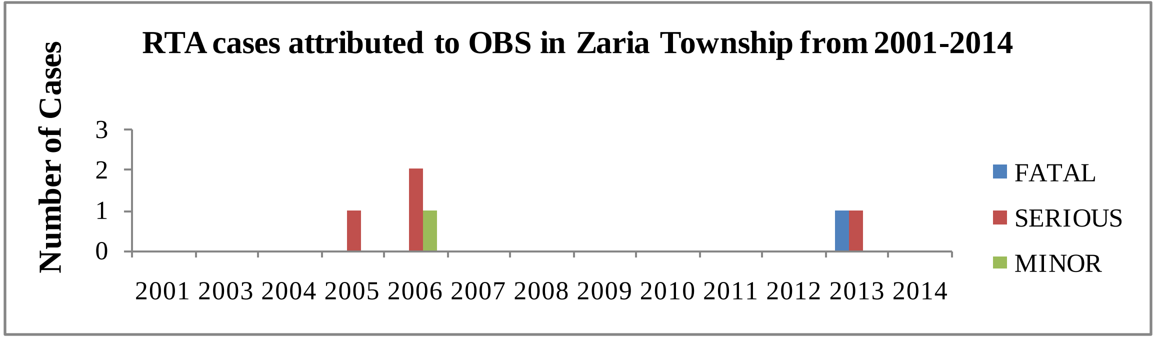
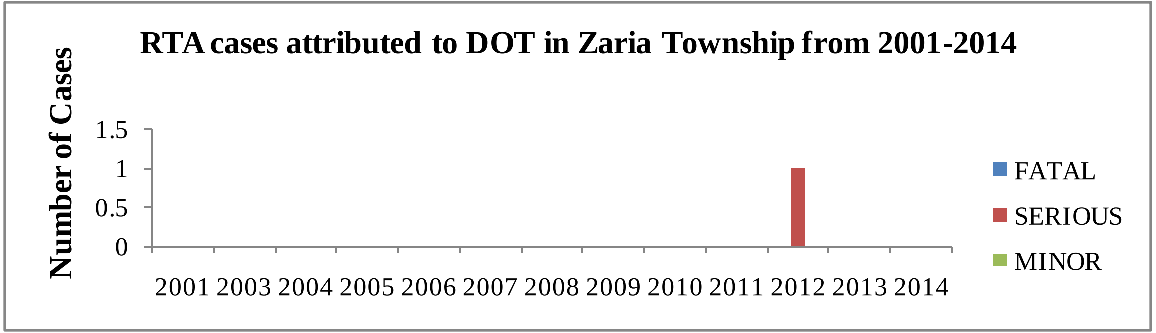

RTA cases attributed to WOT in Zaria Township from 2001-2014


RTA cases attributed to RTV in Zaria Township from 2001-2014


RTA cases attributed to MDV in Zaria Township from 2001-2014


RTA cases attributed to BRD in Zaria Township from 2001-2014


RTA cases attributed to OBS in Zaria Township from 2001-2014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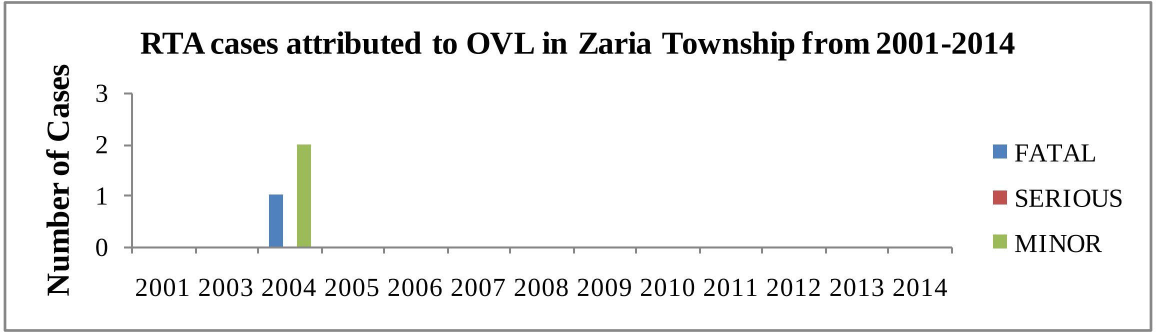
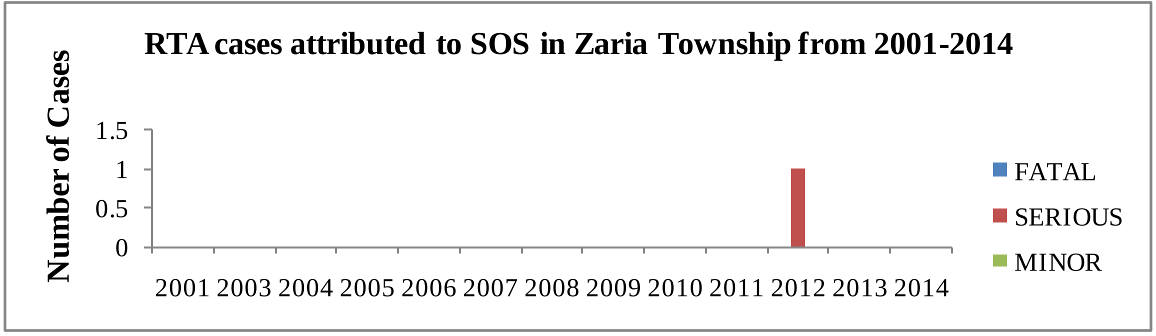

RTA cases attributed to OVL in Zaria Township from 2001-2014


RTA cases attributed to SOS in Zaria Township from 2001-2014

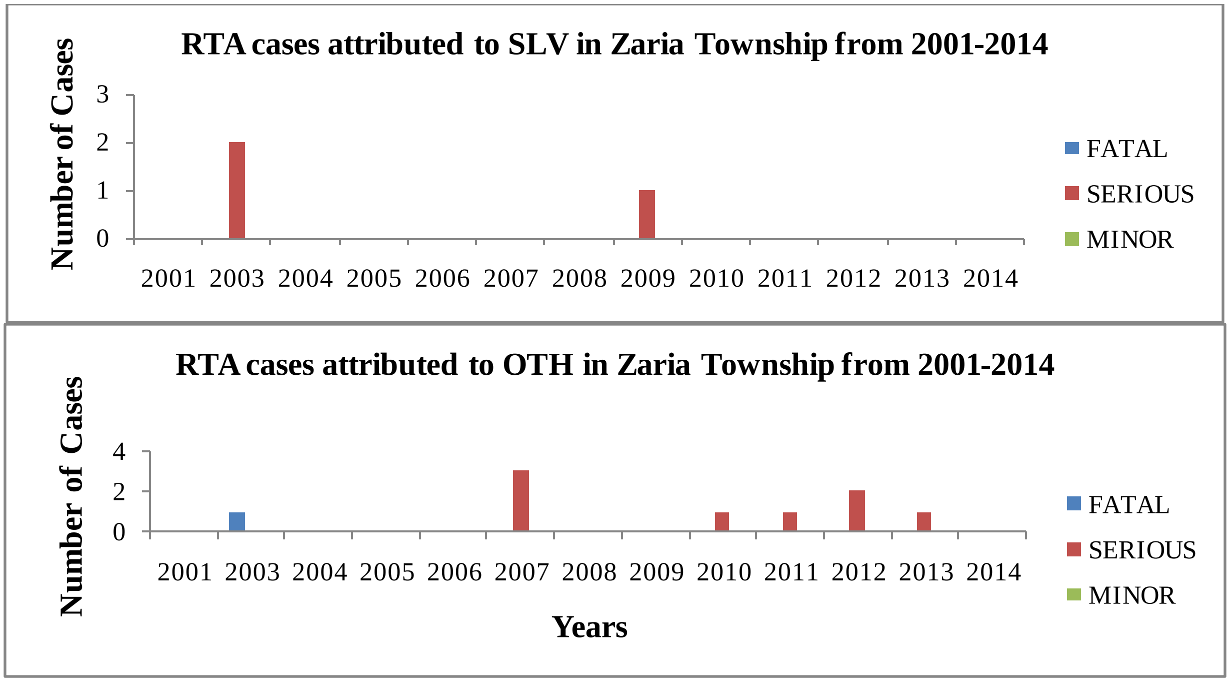
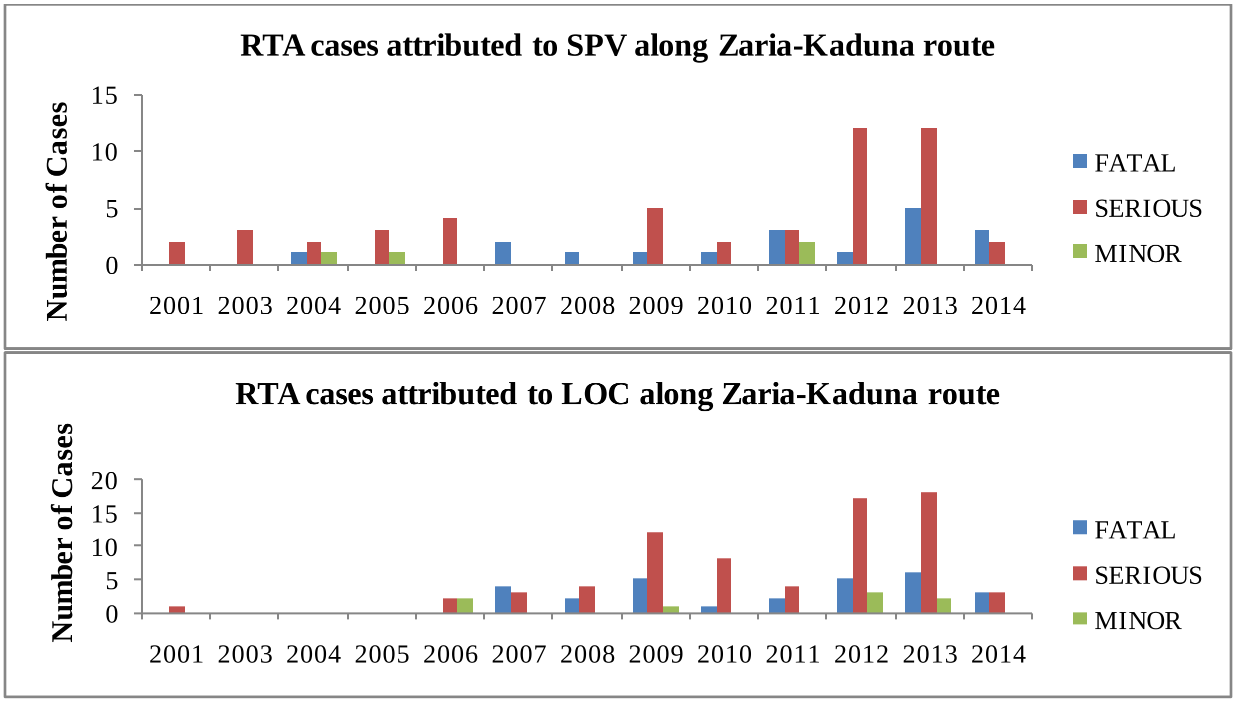
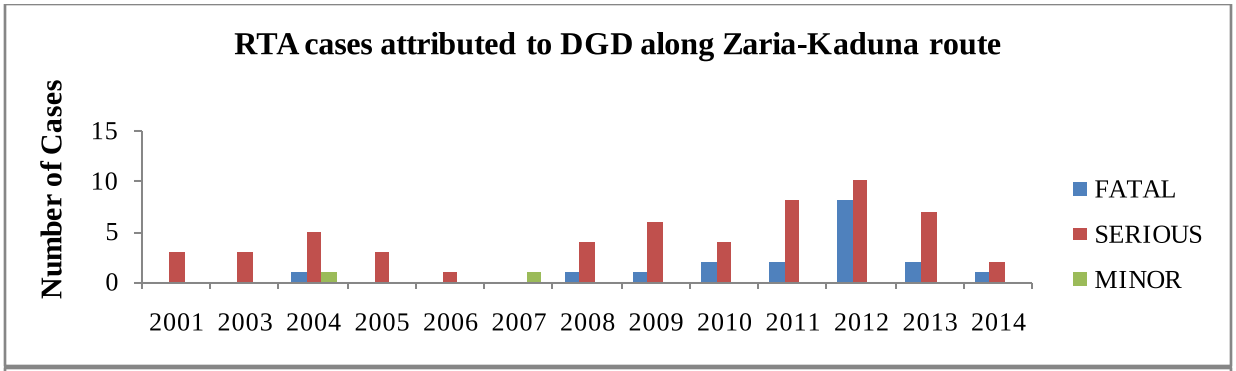
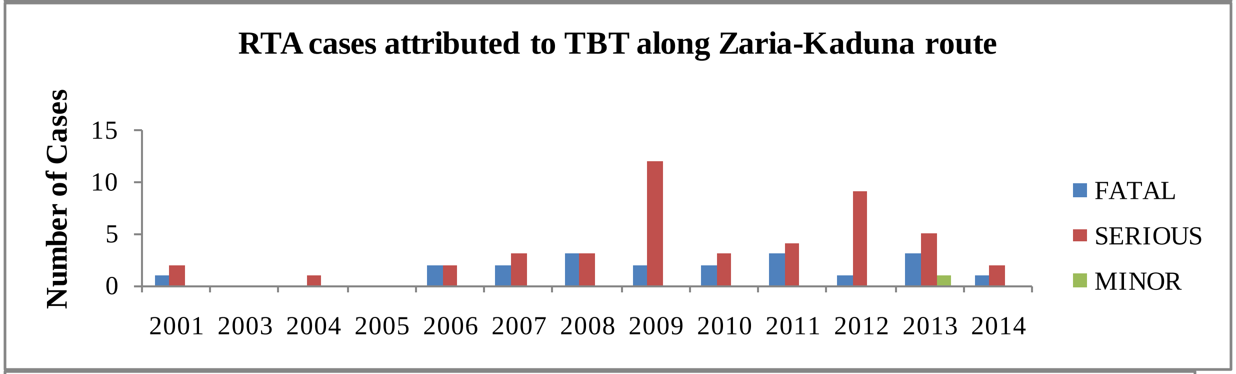
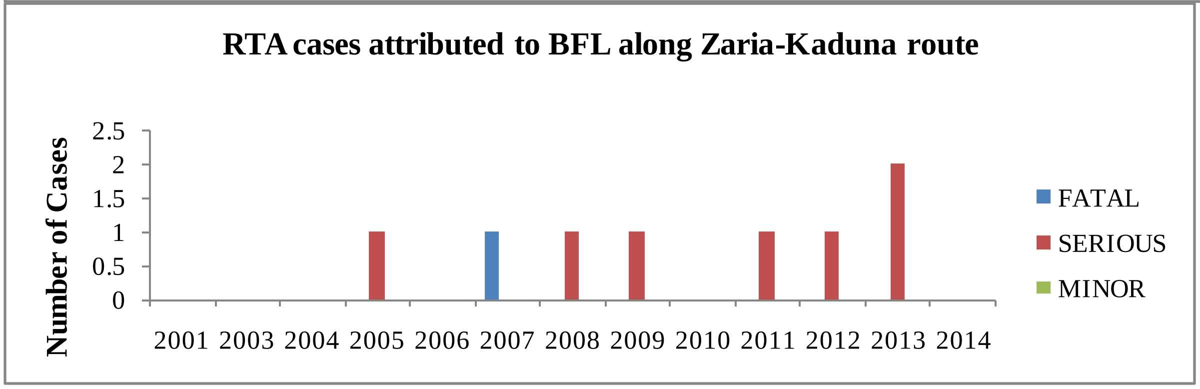


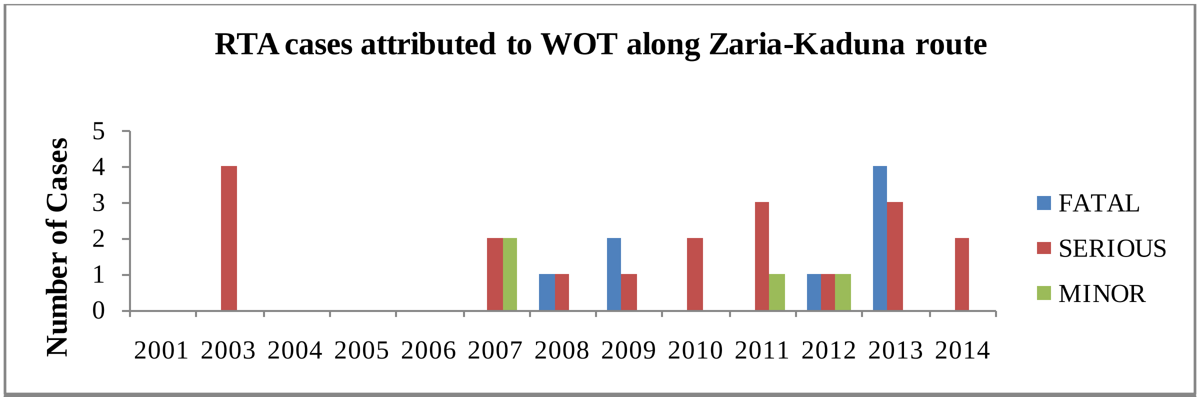
Figure 1: RTA Cases Attributed to Different Causes within Zaria Township
Source: FRSC, 2016



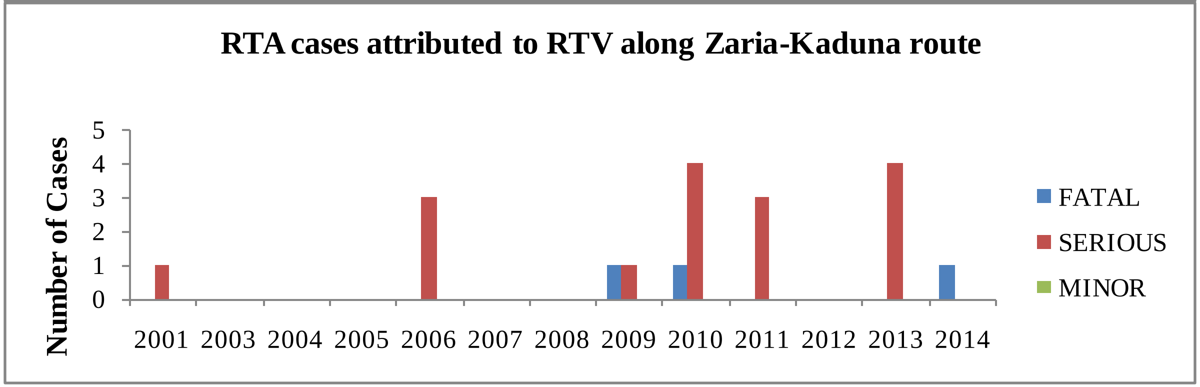

RTA cases attributed to DGD along Zaria-Kaduna route


RTA cases attributed to TBT along Zaria-Kaduna route

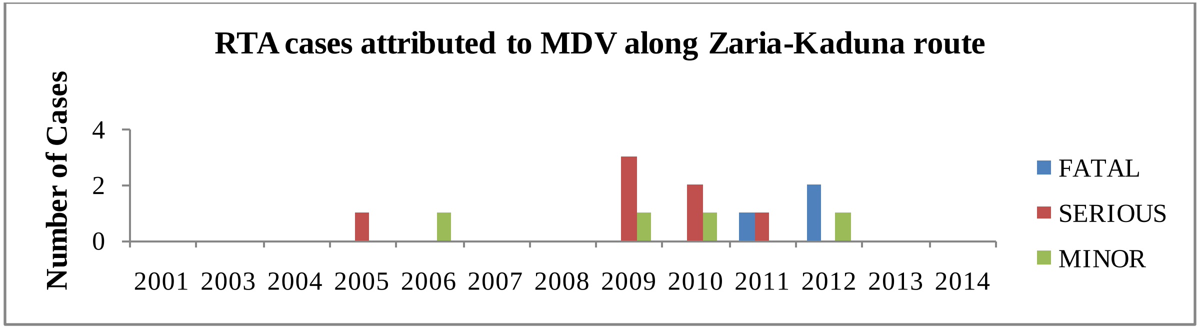

RTA cases attributed to BFL along Zaria-Kaduna route



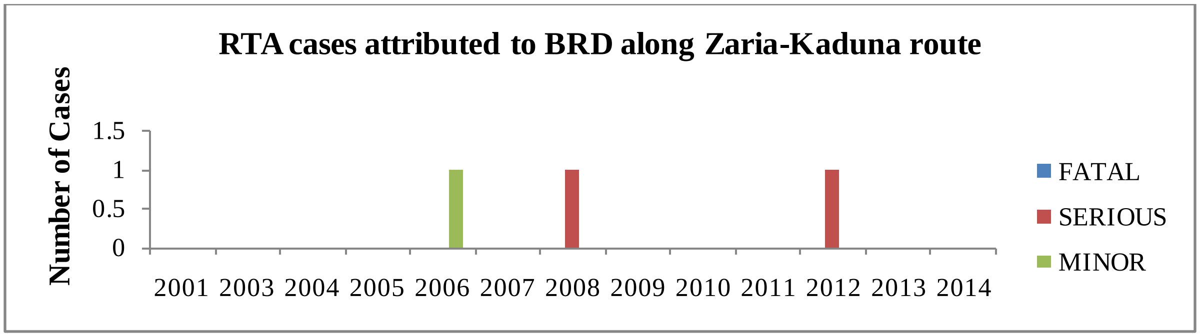
RTA cases attributed to WOT along Zaria-Kaduna route

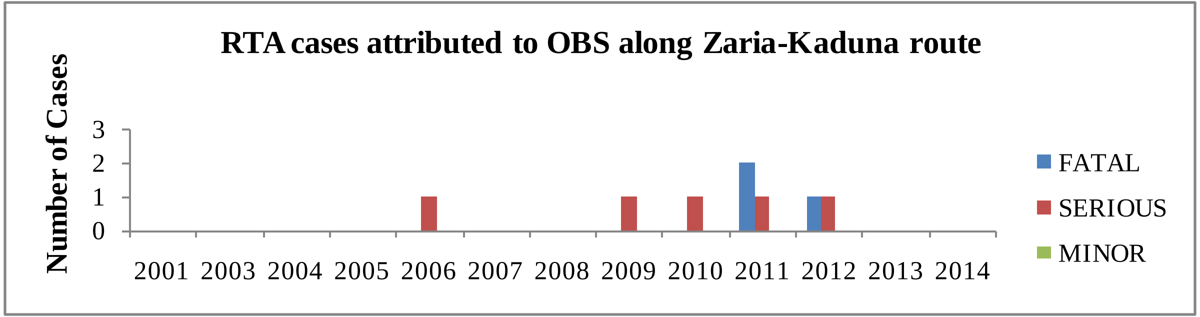


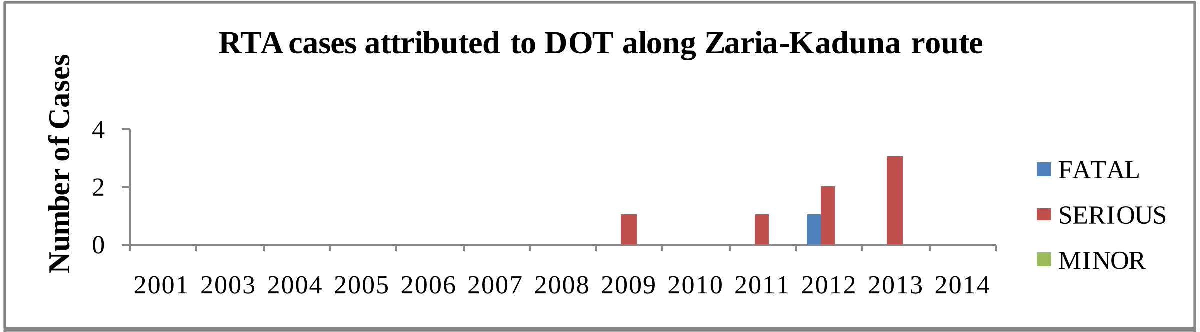
RTA cases attributed to RTV along Zaria-Kaduna route

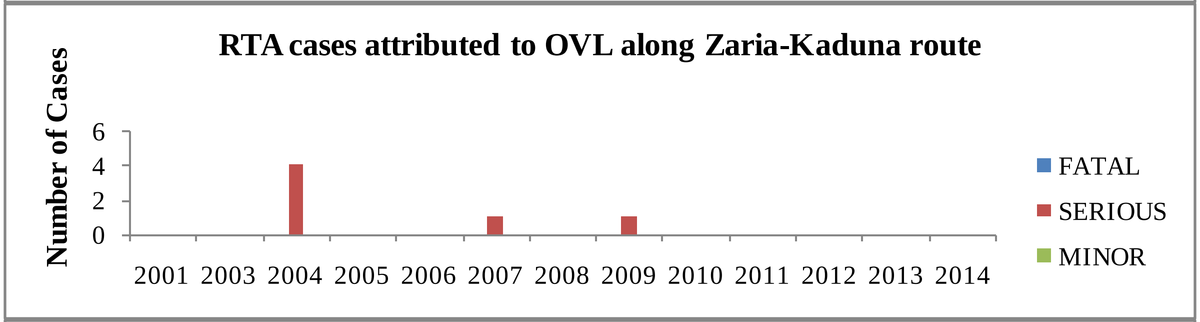


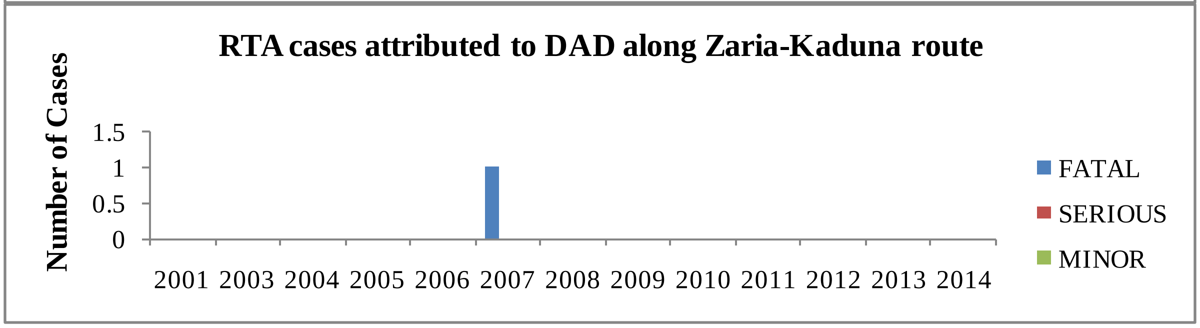
RTA cases attributed to MDV along Zaria-Kaduna route

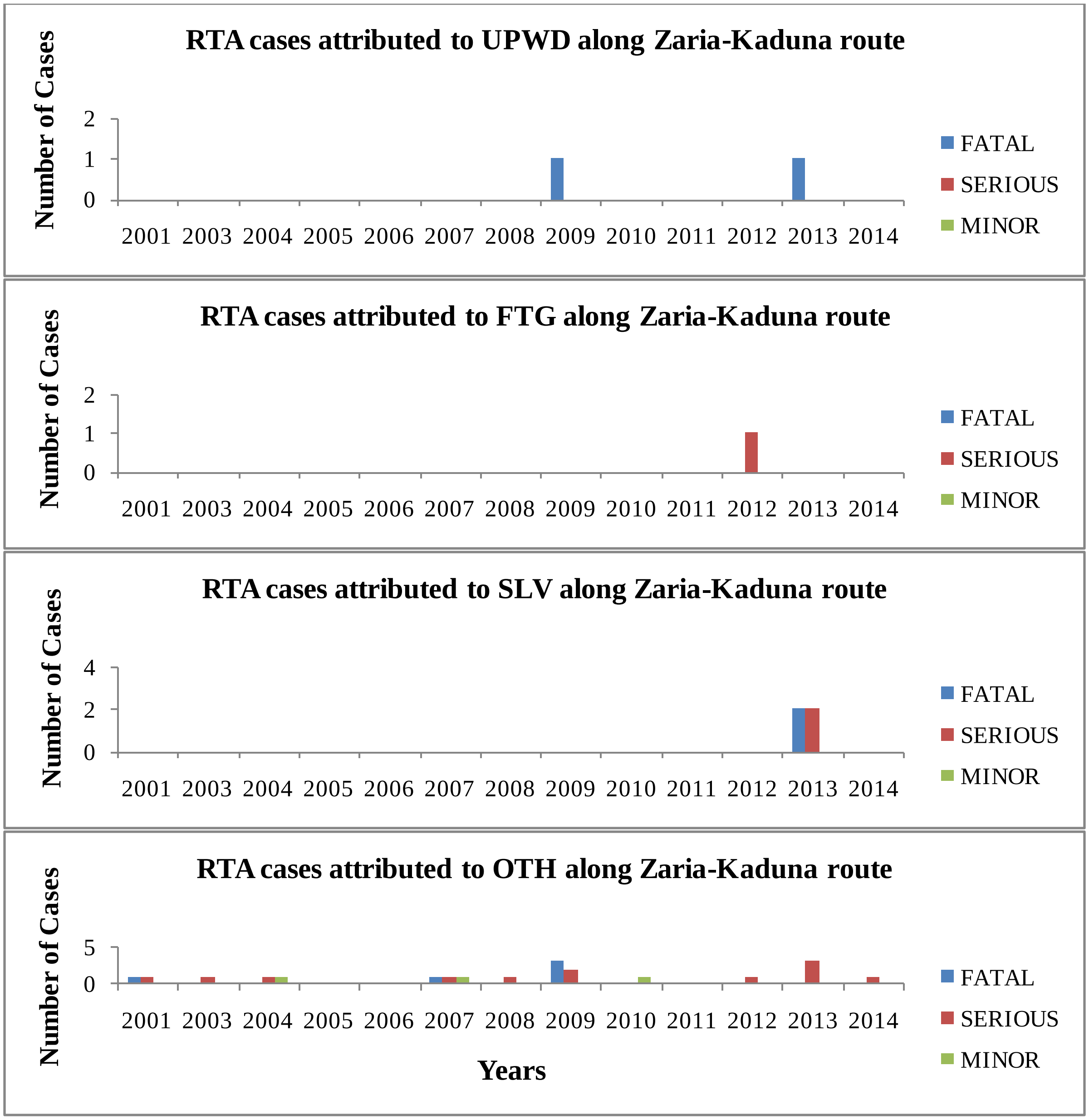

RTA cases attributed to BRD along Zaria-Kaduna route
Number of Cases
1.5
1
0.5
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to OBS along Zaria-Kaduna route
Number of Cases
3
2
1
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to DOT along Zaria-Kaduna route
Number of Cases
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to OVL along Zaria-Kaduna route
Number of Cases
6
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to DAD along Zaria-Kaduna route
Number of Cases
1.5
1
0.5
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

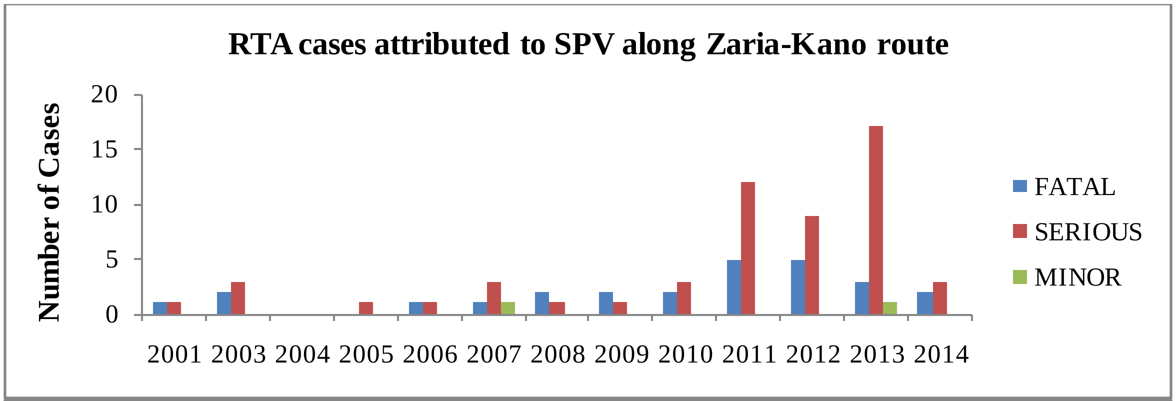

RTA cases attributed to UPWD along Zaria-Kaduna route

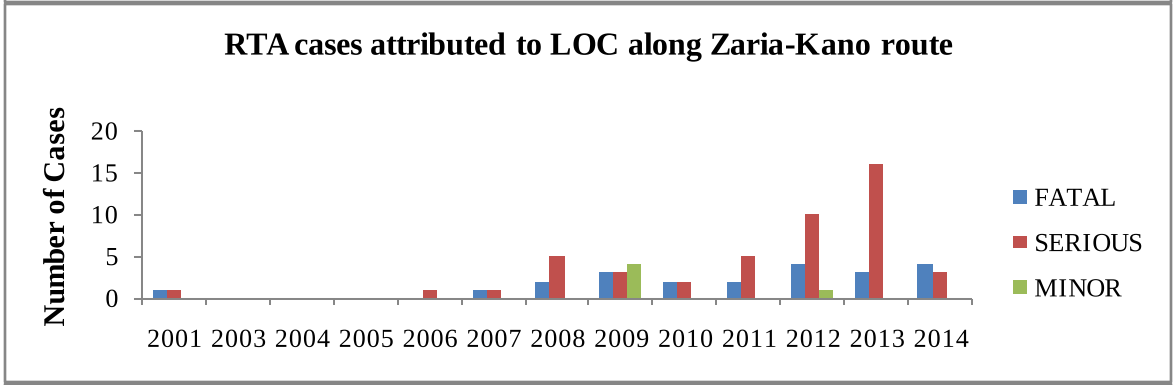
RTA cases attributed to FTG along Zaria-Kaduna route

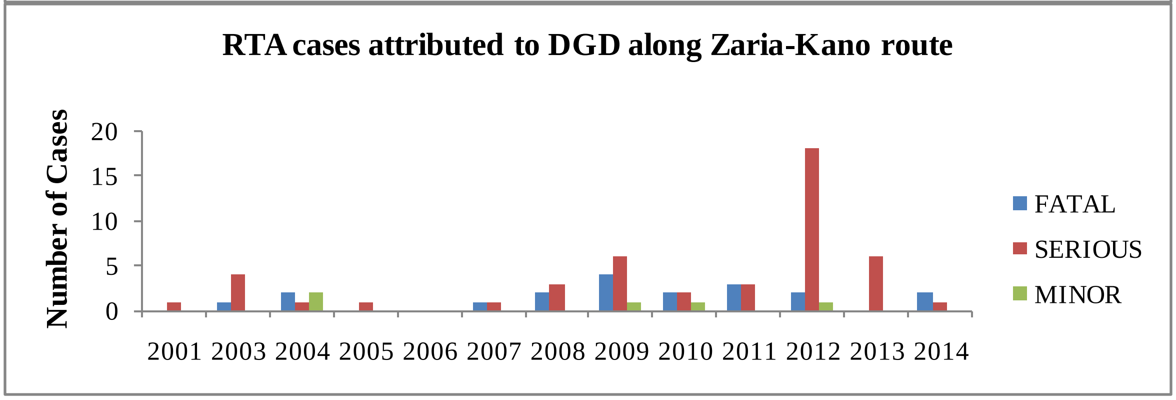
RTA cases attributed to SLV along Zaria-Kaduna route

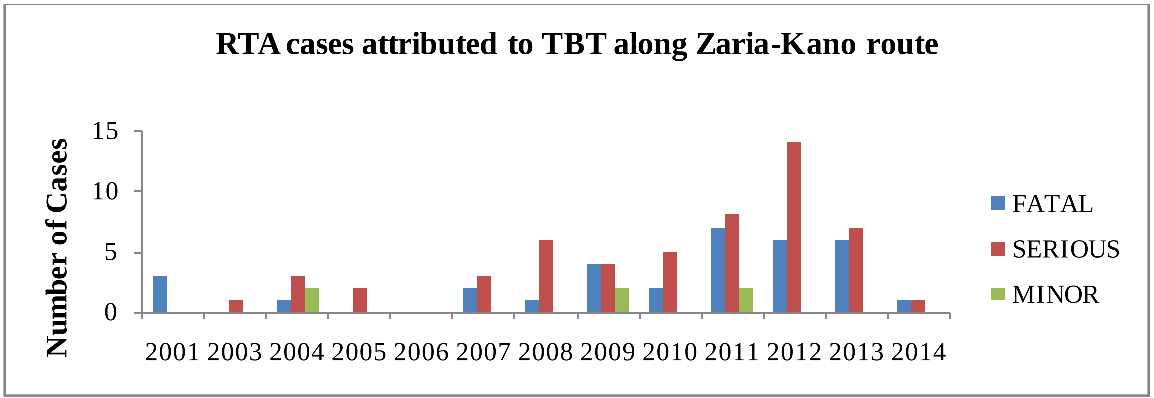
RTA cases attributed to OTH along Zaria-Kaduna route

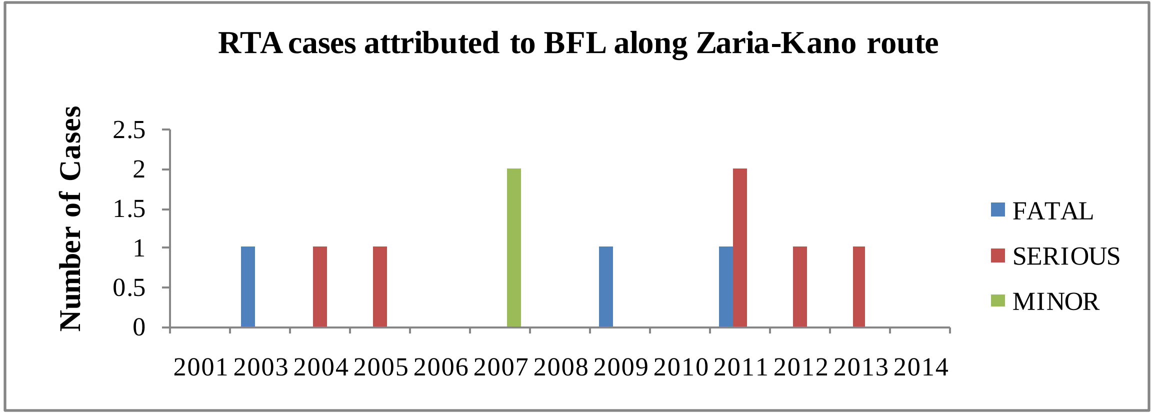
Figure 2: RTA Cases Attributed to Different Causes along Zaria Unit Command
Source: FRSC, 2016

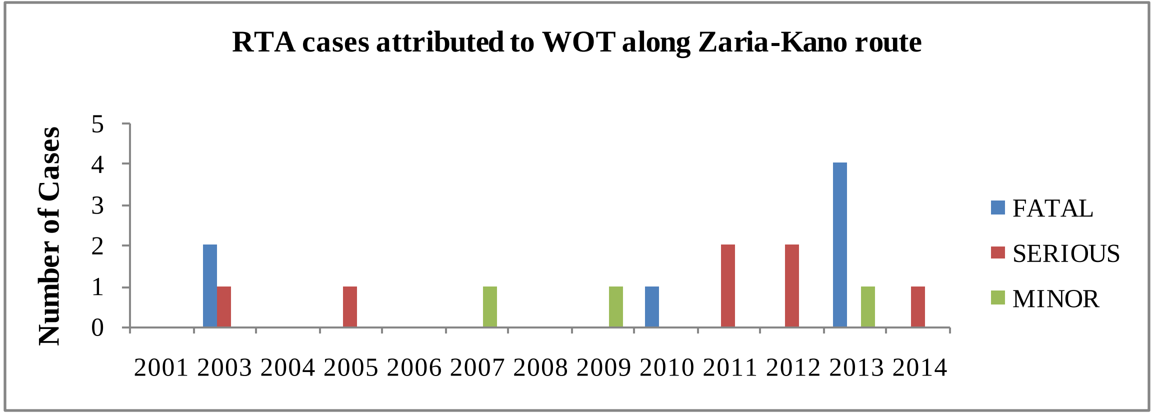

RTA cases attributed to SPV along Zaria-Kano route

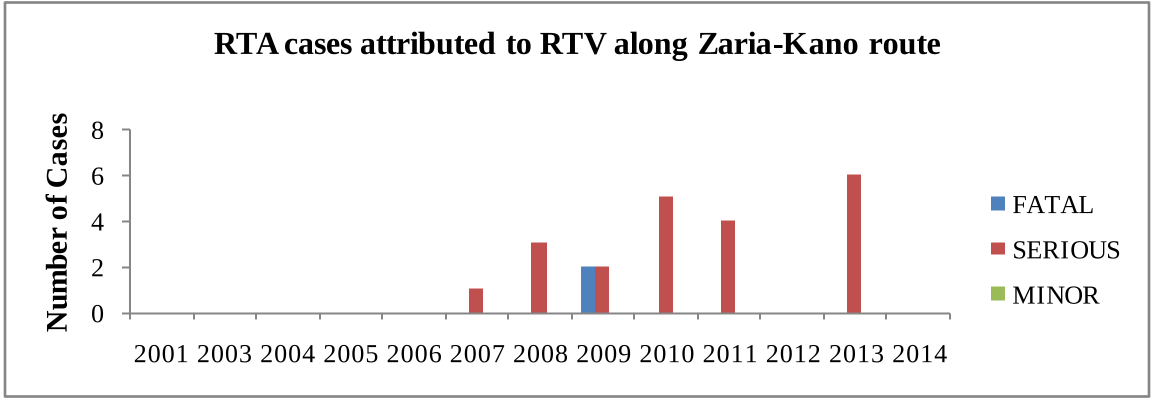

RTA cases attributed to LOC along Zaria-Kano route

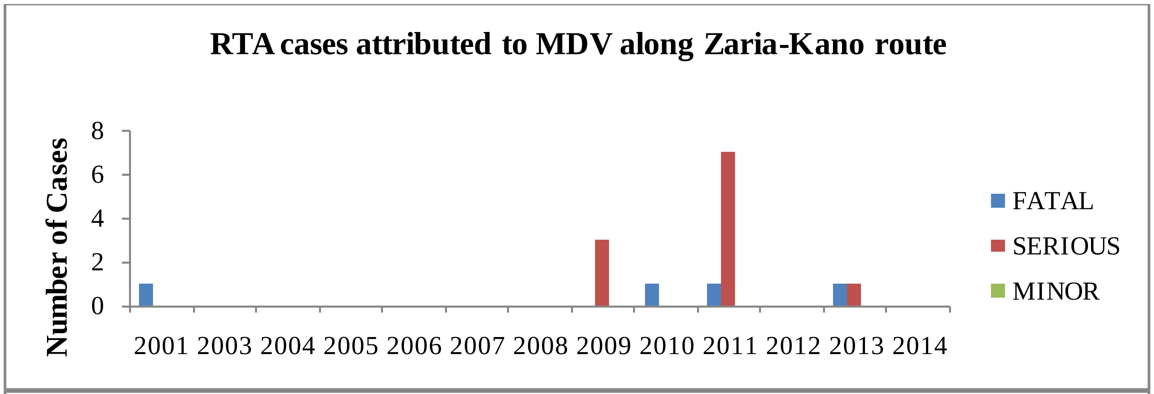

RTA cases attributed to DGD along Zaria-Kano route

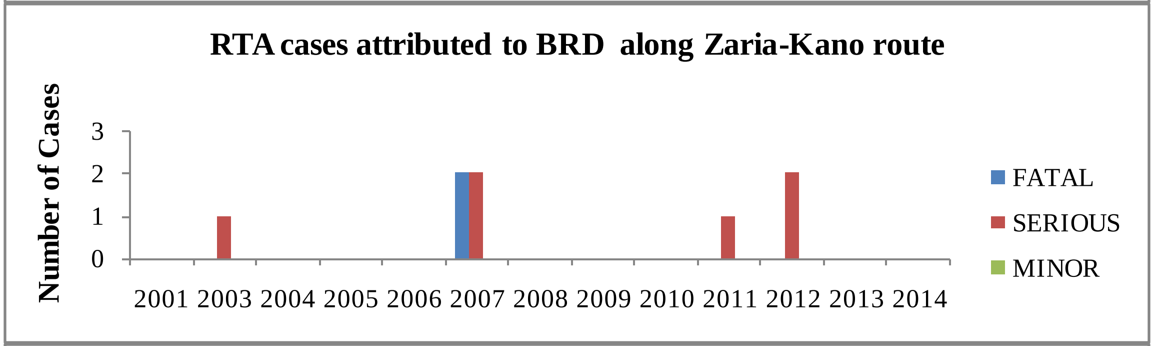

RTA cases attributed to TBT along Zaria-Kano route
Number of Cases
15
10
5
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

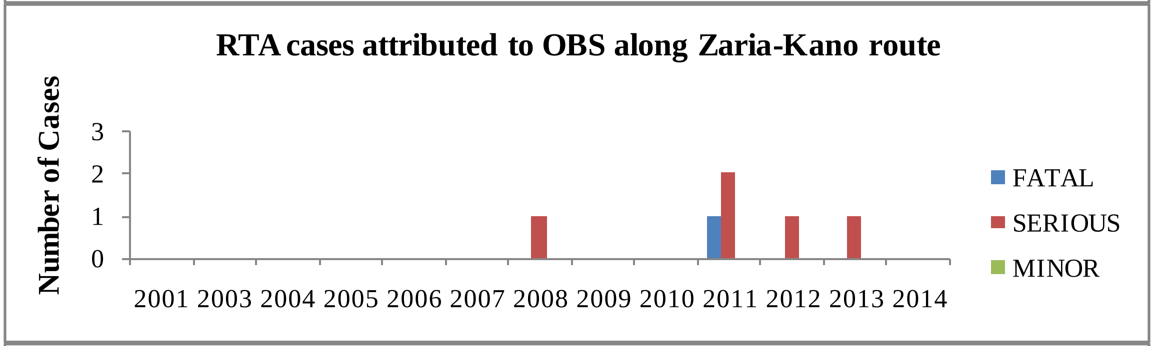

RTA cases attributed to BFL along Zaria-Kano route
Number of Cases
2.5
2
1.5
1
0.5
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR

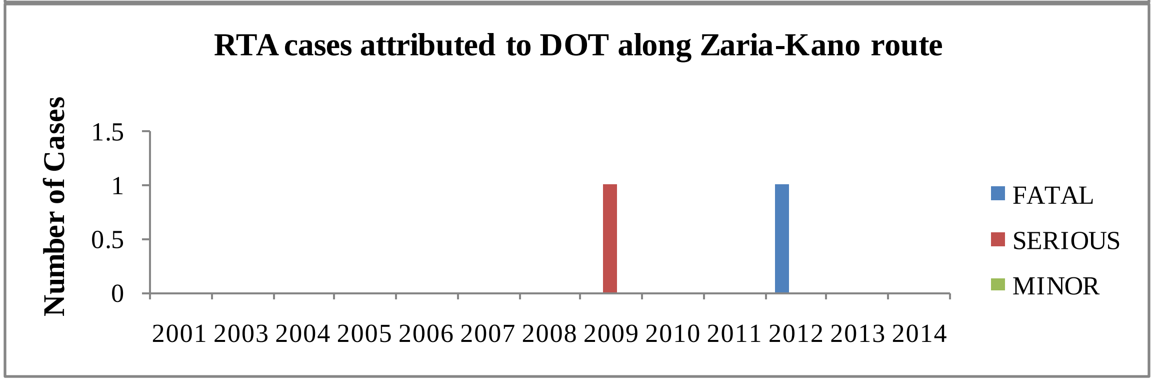

RTA cases attributed to WOT along Zaria-Kano route
Number of Cases
5
4
3
2
1
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to RTV along Zaria-Kano route
Number of Cases
8
6
4
2
0
2001 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
FATAL
SERIOUS
MINOR


RTA cases attributed to MDV along Zaria-Kano route


RTA cases attributed to BRD along Zaria-Kano route


RTA cases attributed to OBS along Zaria-Kano route


RTA cases attributed to DOT along Zaria-Kano route

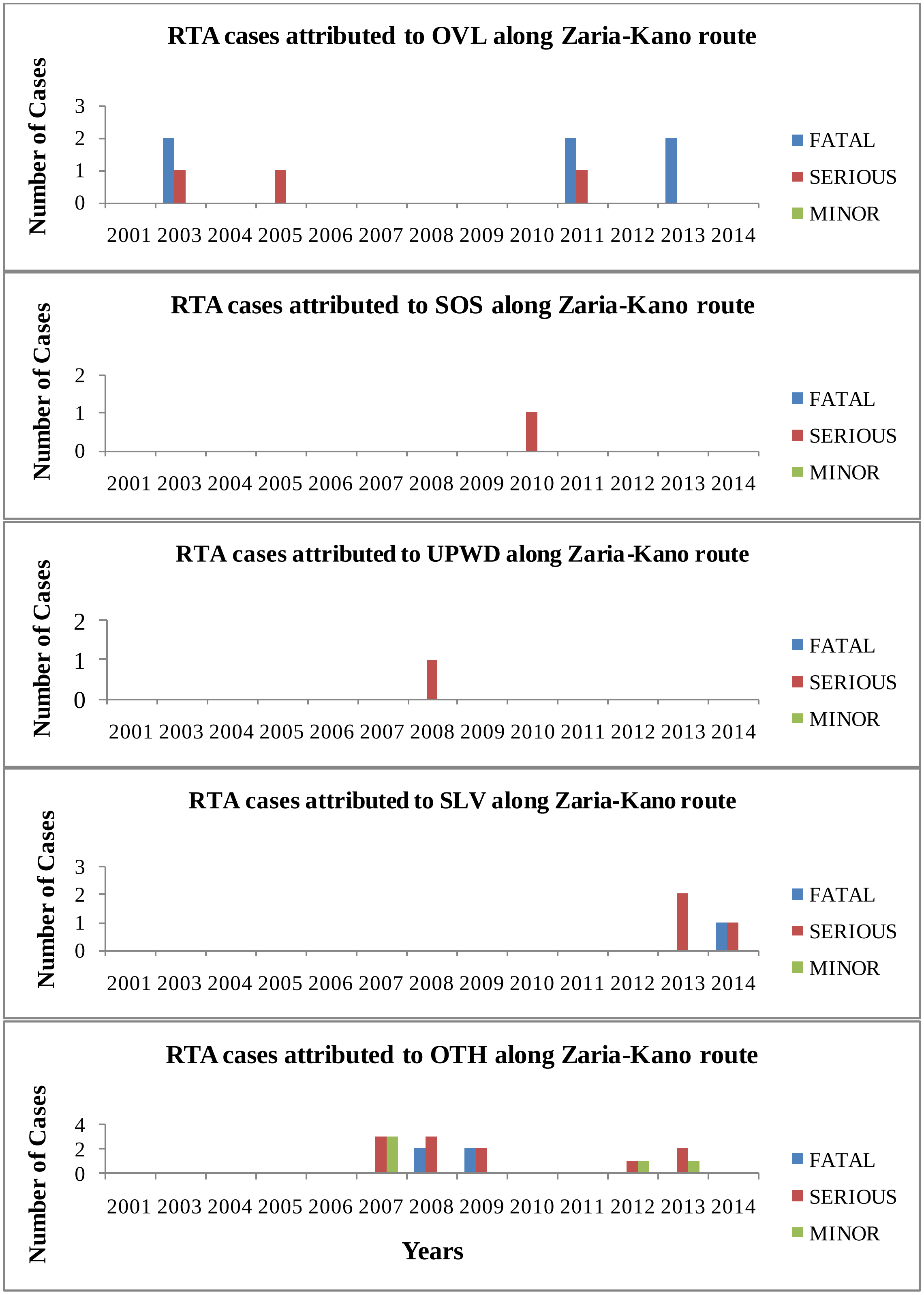
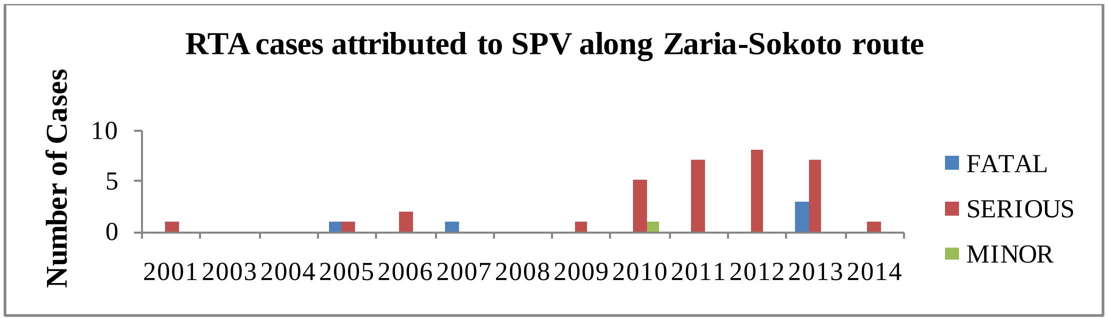
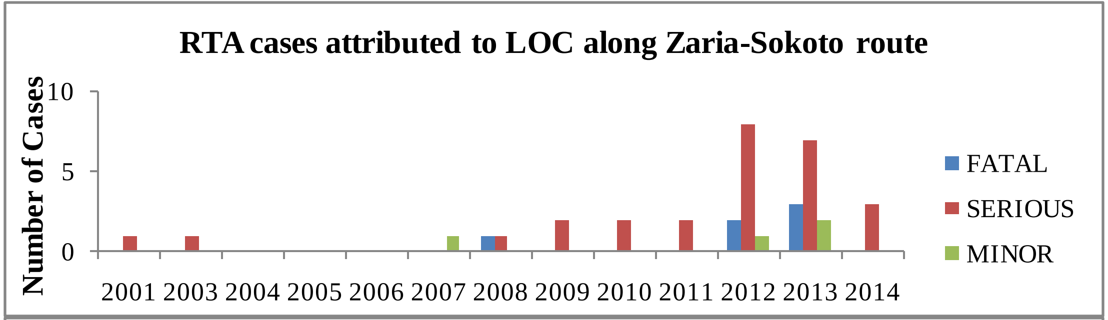
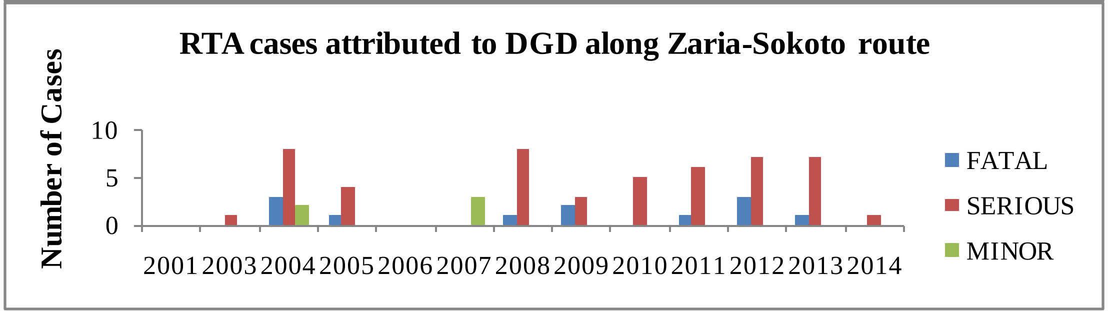
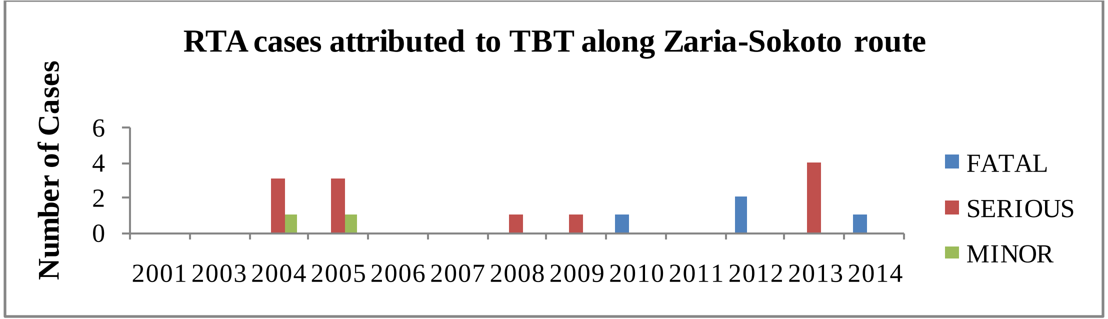


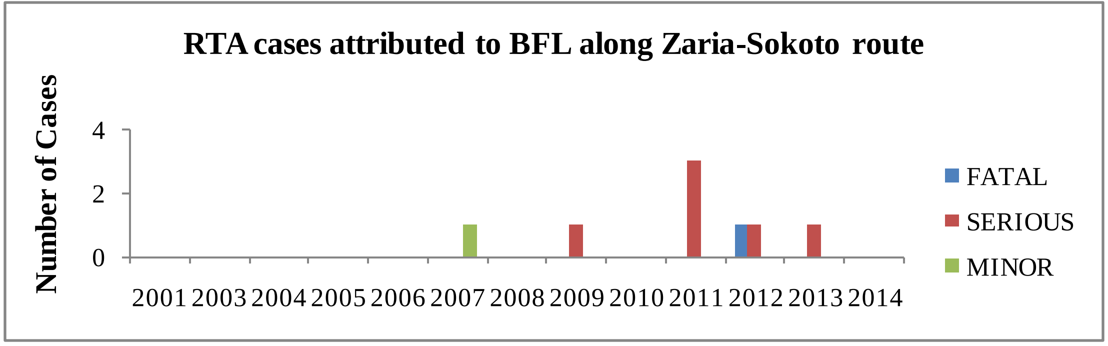
Figure 3: RTA Cases Attributed to Different Causes within Zaria-Kano Route
Source: FRSC, 2016

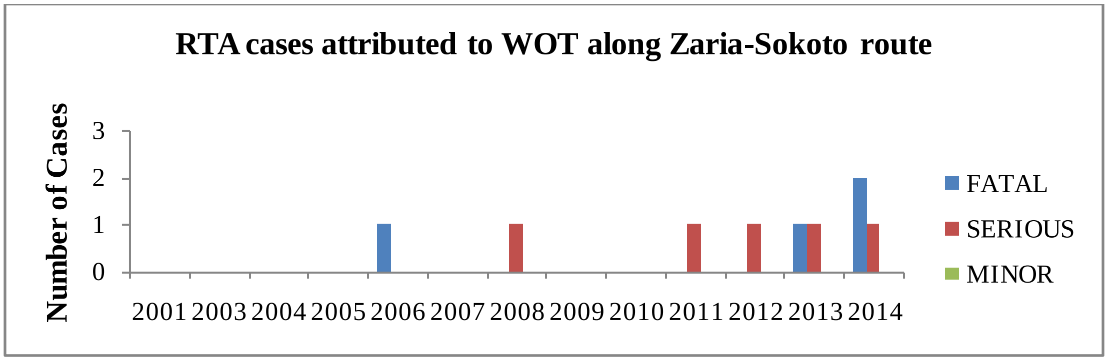

RTA cases attributed to SPV along Zaria-Sokoto route

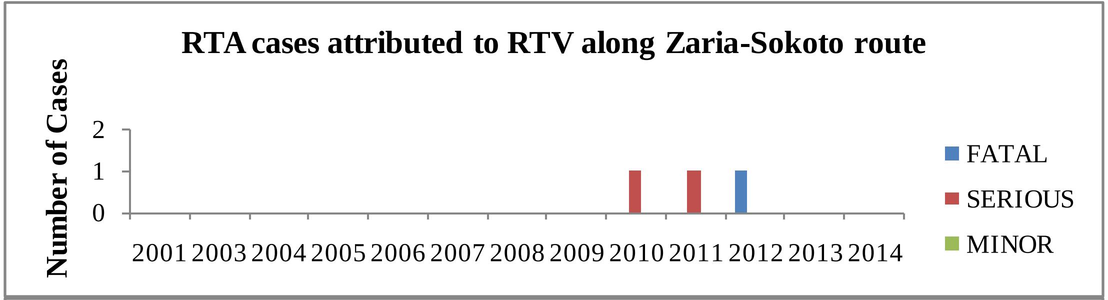

RTA cases attributed to LOC along Zaria-Sokoto route

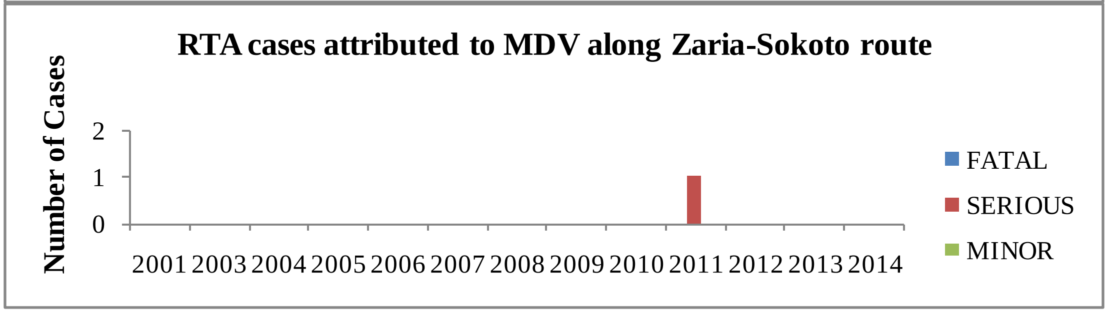

RTA cases attributed to DGD along Zaria-Sokoto route

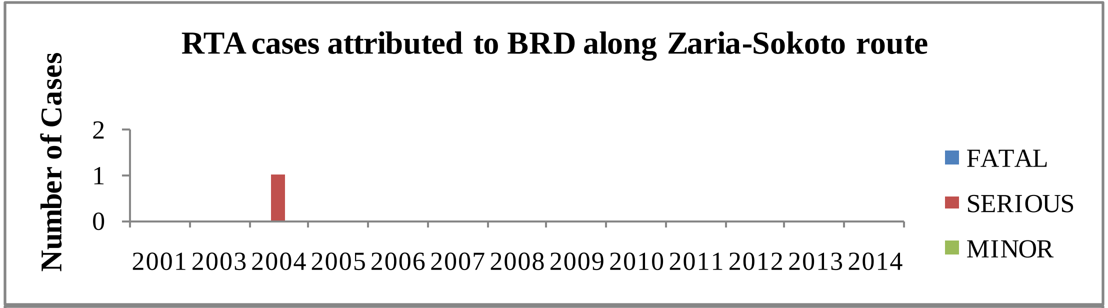

RTA cases attributed to TBT along Zaria-Sokoto route

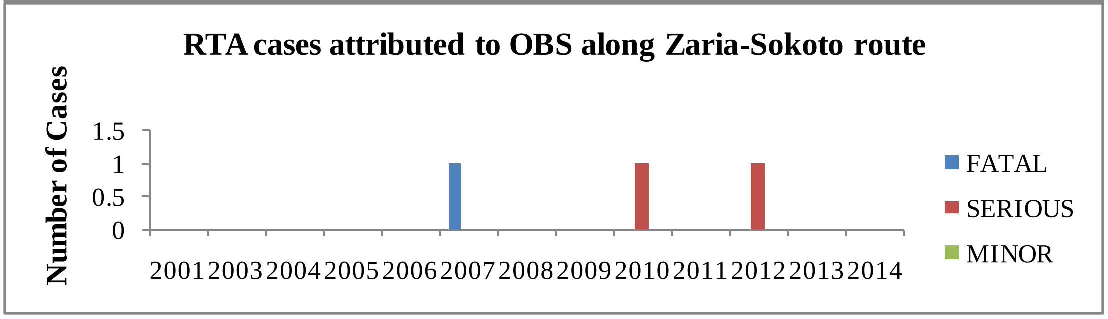

RTA cases attributed to BFL along Zaria-Sokoto route

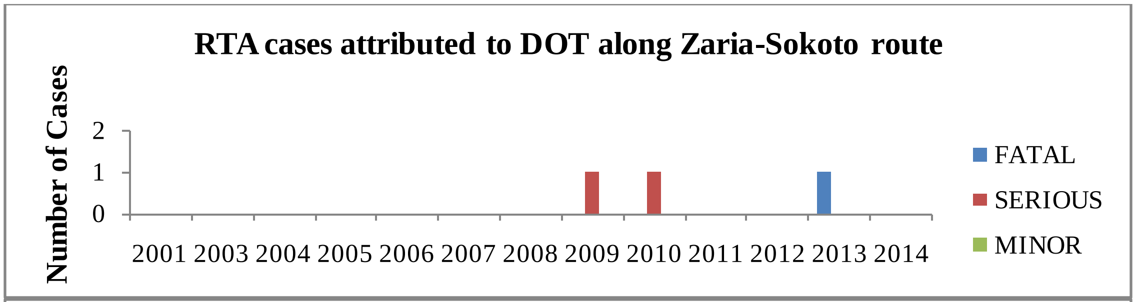

RTA cases attributed to WOT along Zaria-Sokoto route
Number of Cases
0
1
2
3
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR

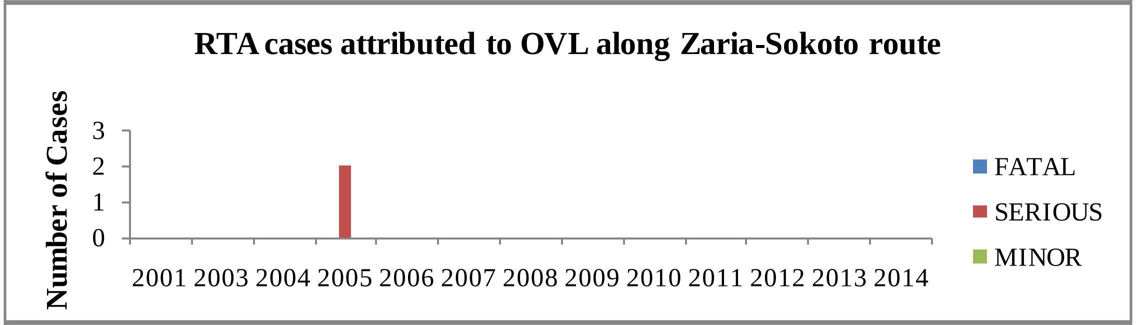

RTA cases attributed to RTV along Zaria-Sokoto route
Number of Cases
0
1
2
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR

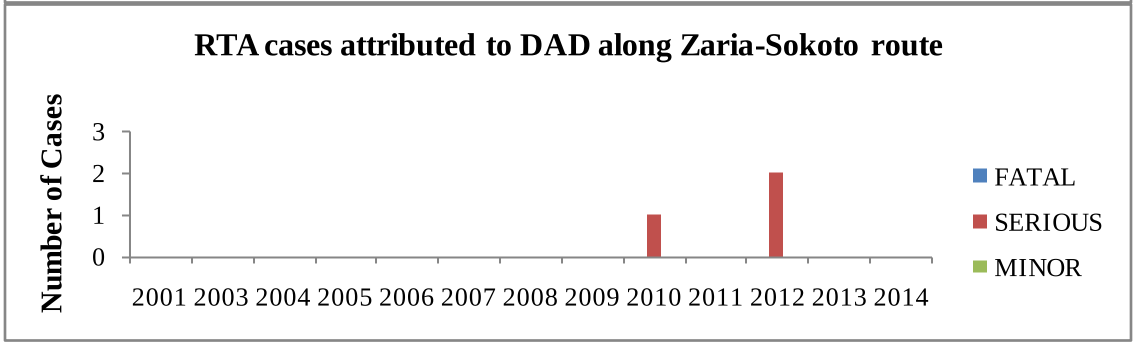

RTA cases attributed to MDV along Zaria-Sokoto route
Number of Cases
0
1
2
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR

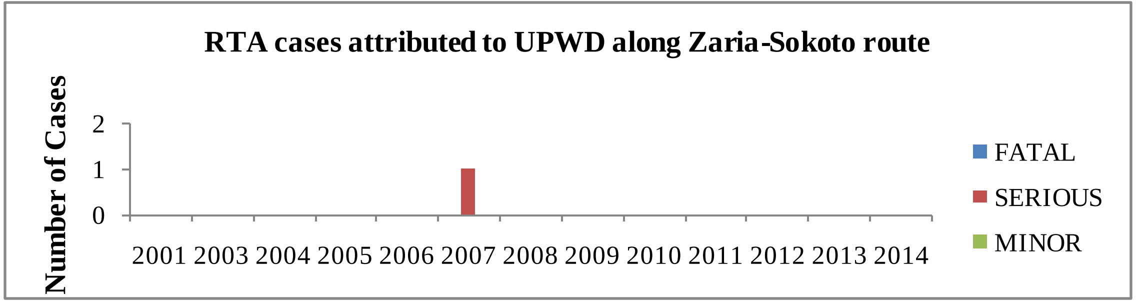

RTA cases attributed to BRD along Zaria-Sokoto route
Number of Cases
0
1
2
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR

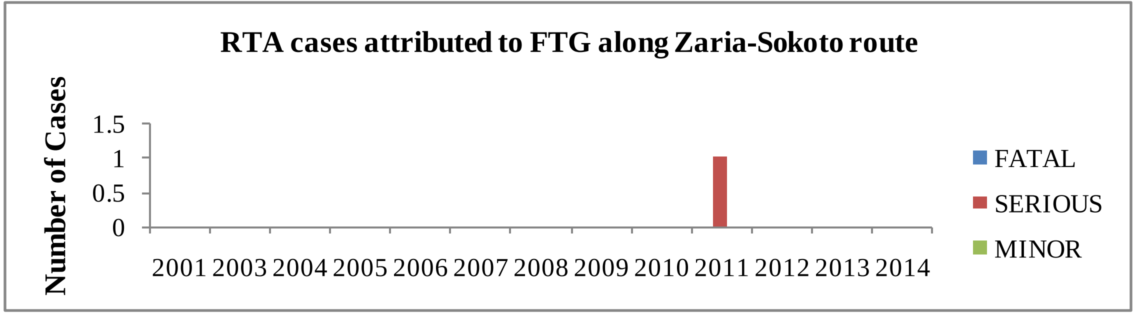

RTA cases attributed to OBS along Zaria-Sokoto route
Number of Cases
0
0.5
1
1.5
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR


RTA cases attributed to DOT along Zaria-Sokoto route


RTA cases attributed to OVL along Zaria-Sokoto route


RTA cases attributed to DAD along Zaria-Sokoto route


RTA cases attributed to UPWD along Zaria-Sokoto route


RTA cases attributed to FTG along Zaria-Sokoto route

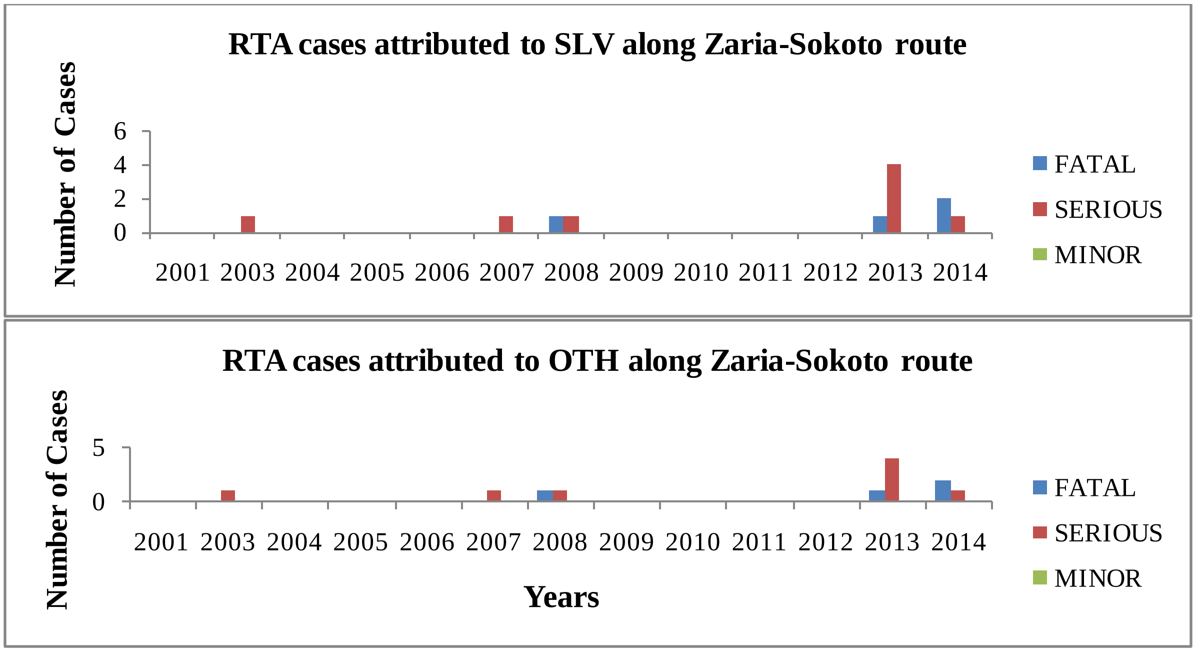
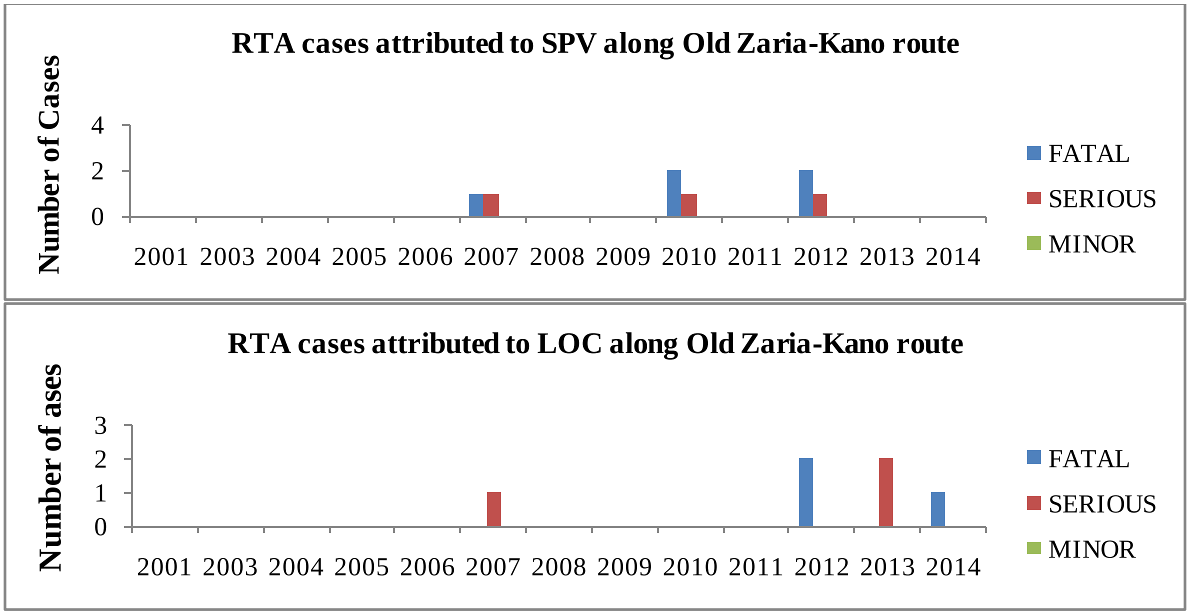
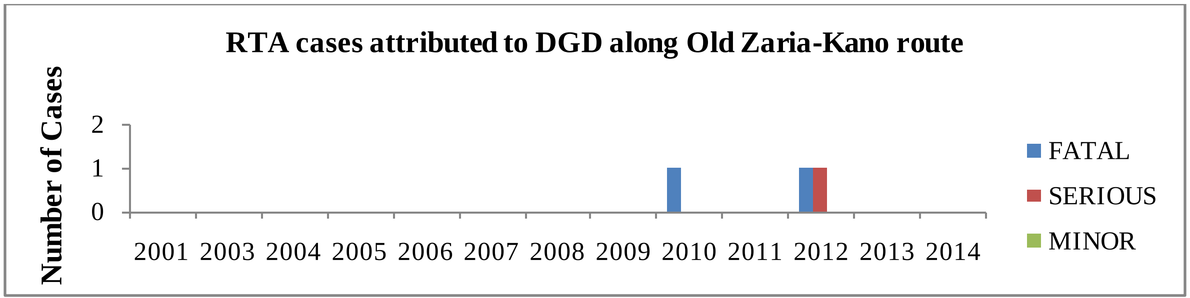
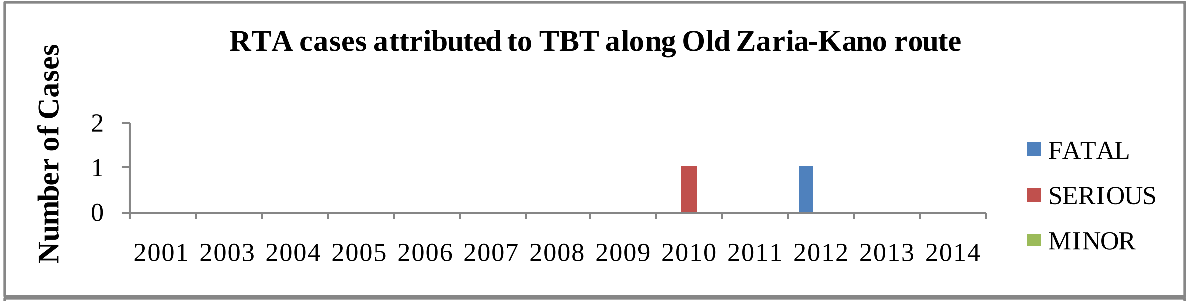


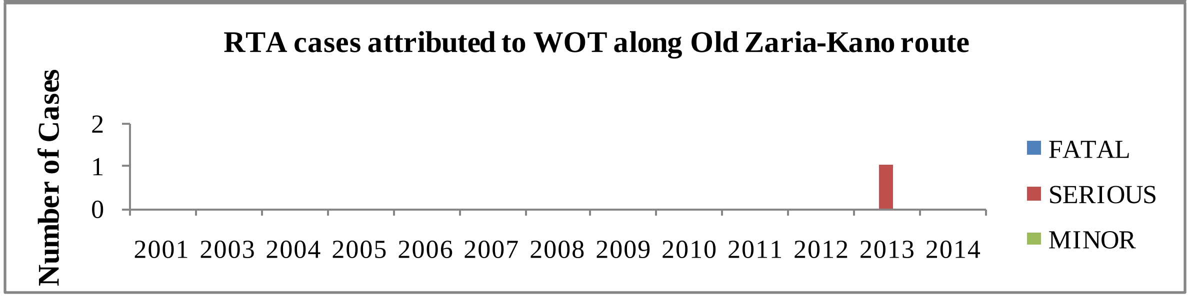
Figure 4: RTA Cases Attributed to Different Causes along Zaria-Sokoto Route
Source: FRSC, 2016




RTA cases attributed to DGD along Old Zaria-Kano route
Number of Cases
2
1
0
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR


RTA cases attributed to TBT along Old Zaria-Kano route
Number of Cases
2
1
0
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR


RTA cases attributed to BFL along Old Zaria-Kano route
Number of Cases
2
1
0
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR


RTA cases attributed to WOT along Old Zaria-Kano route
Number of Cases
2
1
0
2001
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
FATAL
SERIOUS
MINOR

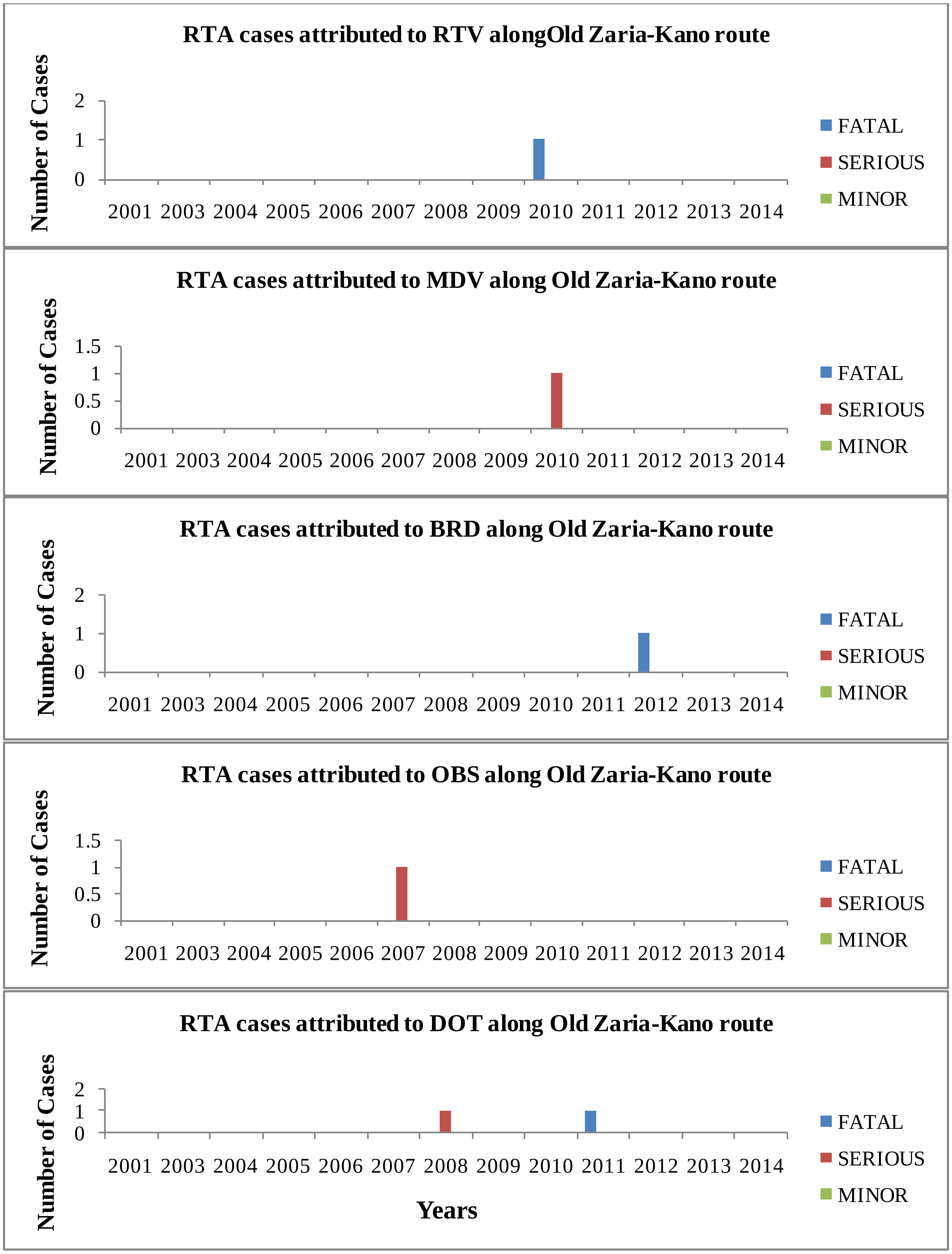
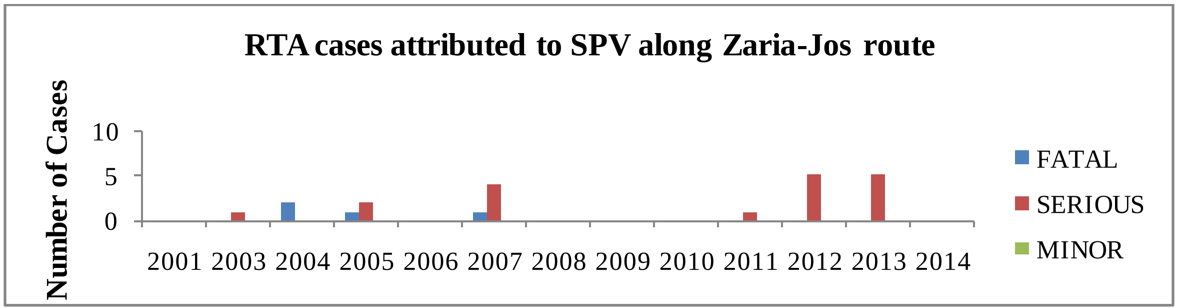
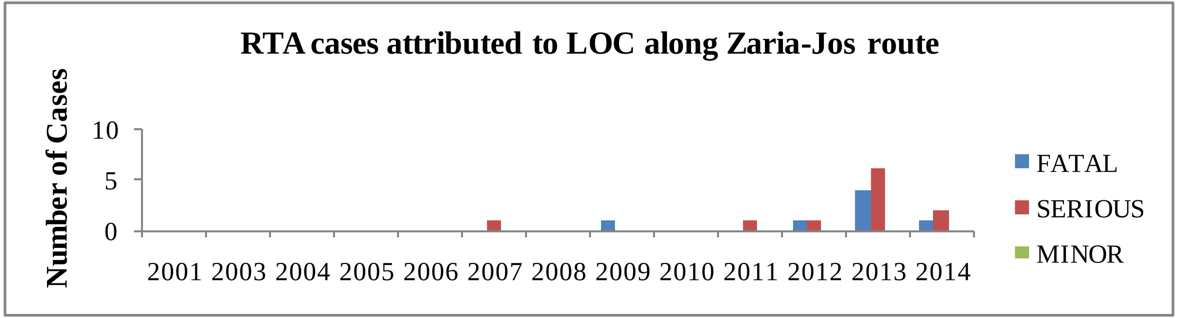
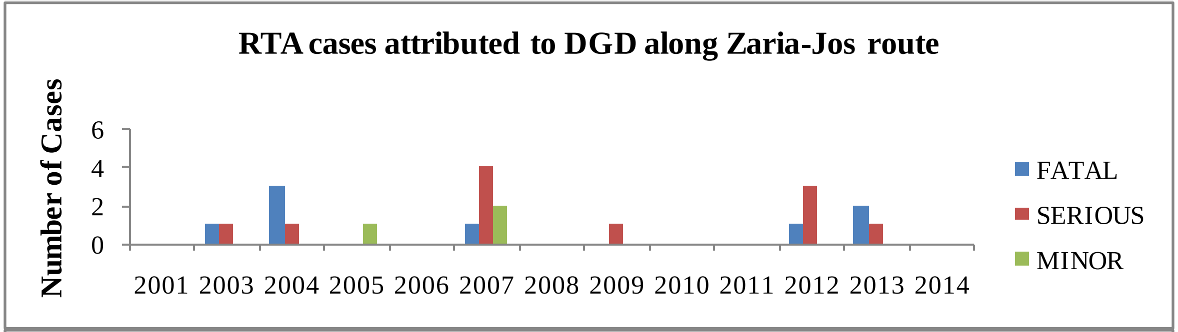
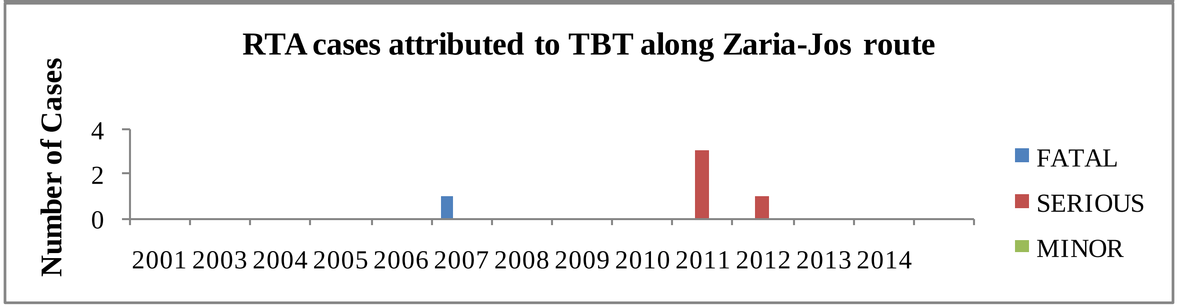


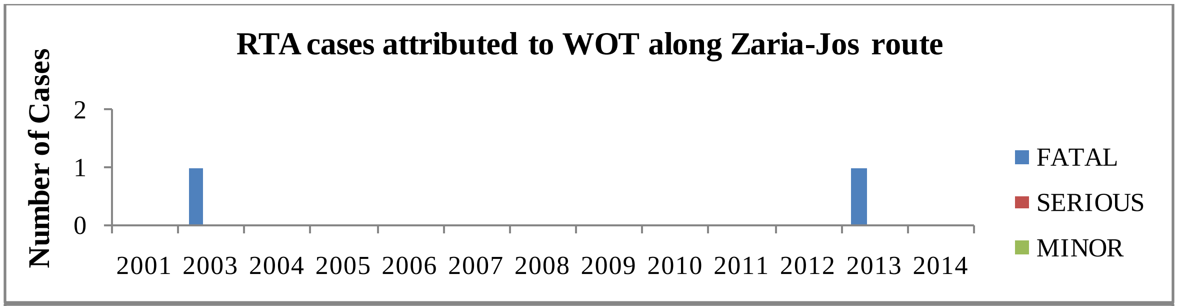
Figure 5: RTA Cases Attributed to Different Causes along Zaria-Old Kano Route
Source: FRSC, 2016

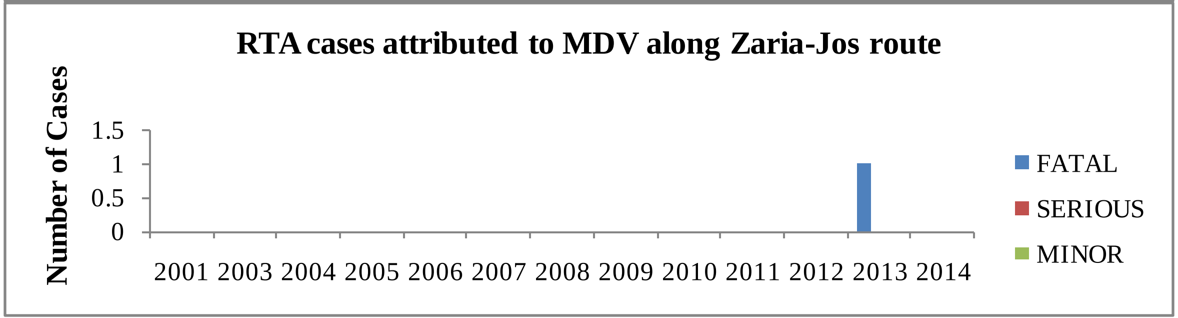

RTA cases attributed to SPV along Zaria-Jos route

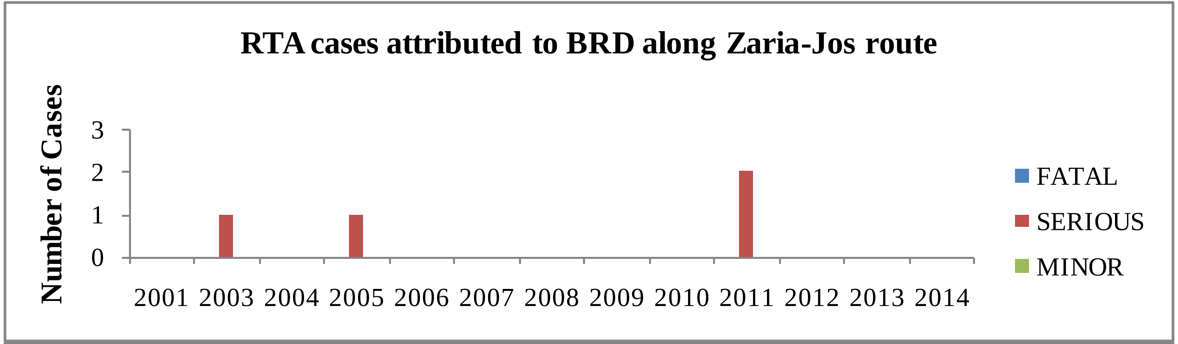

RTA cases attributed to LOC along Zaria-Jos route

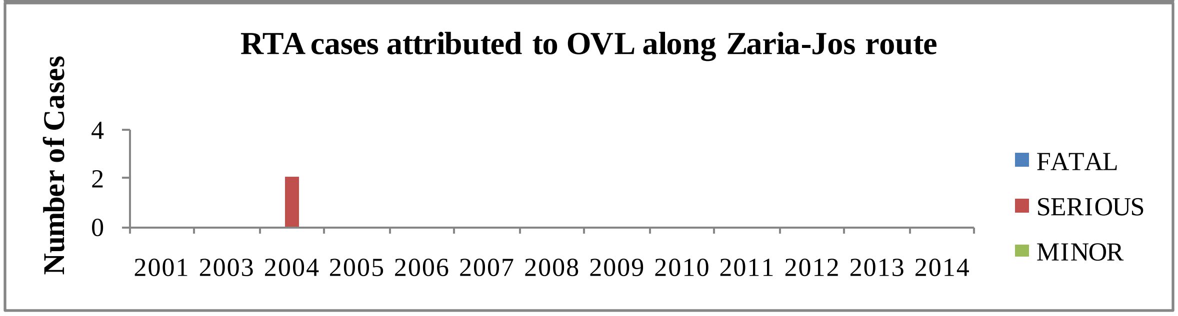

RTA cases attributed to DGD along Zaria-Jos route


RTA cases attributed to TBT along Zaria-Jos route


RTA cases attributed to WOT along Zaria-Jos route


RTA cases attributed to MDV along Zaria-Jos route


RTA cases attributed to BRD along Zaria-Jos route


RTA cases attributed to OVL along Zaria-Jos route

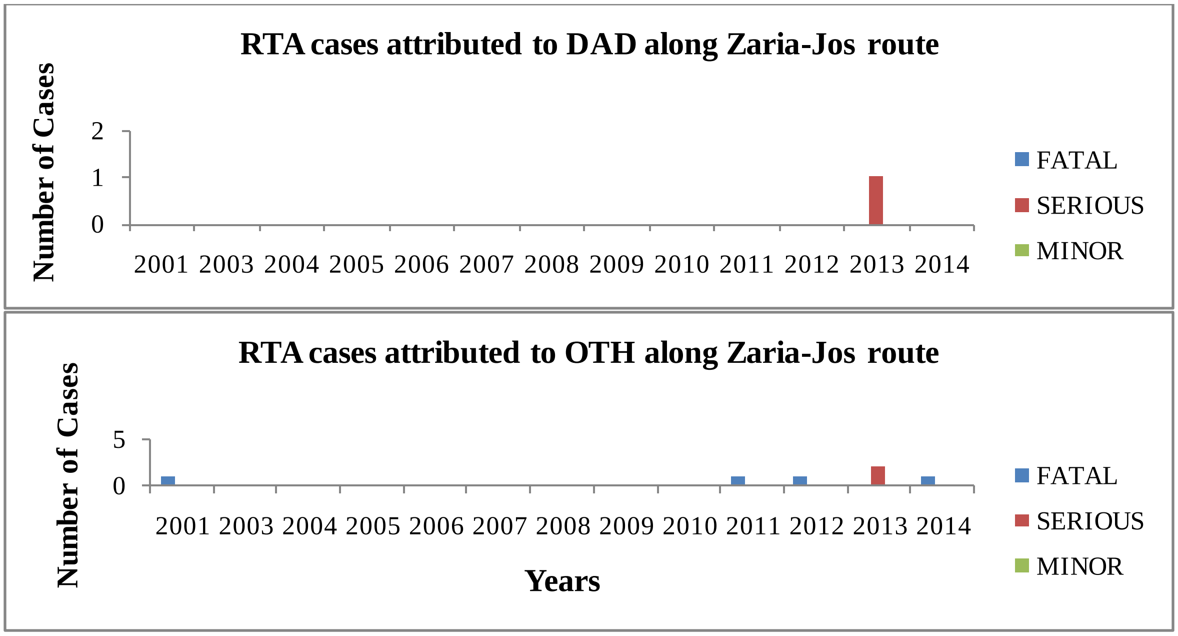


Figure 6: RTA Cases Attributed to Different Causes along Zaria-Jos Route
Source: FRSC, 2016

APPENDIX II

Monthly RTA Severity and Causes within Zaria Unit Command

Table 1: Monthly Record of RTA Severity and their Causes within Zaria Township

	SPV			LOC			DGD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN				1	2	1	1	2	1
FEB	3	2			1		1	1	
MCH		1		1	4	1		4	
APR	1							3	
MAY	2								2
JUN		3			2			3	4
JUL	1	2			1		2	1	1
AUG				1	1			3	
SEPT		1			1		1	3	
OCT	1	1	1		3		4	5	1
NOV	1	1			2			5	2
DEC		3	1	1	1			2	
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN				1			1		
FEB		1			2				
MCH								1	
APR					1				
MAY				1		1			
JUN						1			
JUL		3						2	
AUG				1			1		
SEPT		1			2			1	1
OCT						2	1		
NOV									1
DEC			1						
	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									

MCH		1			1				
APR		1							
MAY									
JUN		1							
JUL							1		
AUG									
SEPT	1	1				1			
OCT	1								
NOV									
DEC		1		1					

	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									2
AUG							1		
SEPT		1	1						
OCT									
NOV									
DEC					1				

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									
AUG									
SEPT									
OCT									
NOV		1							
DEC									

	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB								2	
MCH								1	
APR					1				
MAY									
JUN								1	
JUL					1			2	
AUG									
SEPT					1				
OCT									
NOV								2	
DEC							1		

Source: FRSC, 2016

Table 2: Monthly Record of RTA Severity and their Causes along Zaria-Kaduna

SPV	LOC	DGD

Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1	3		2	7		2	8	
FEB	2	2		2	7			3	
MCH		7		2	8		1	4	
APR	5	2	1	6	5		2	2	
MAY	1	4		1	11			6	
JUN	1	3		2	4			6	1
JUL	3	6	1	3	4	1	3	4	
AUG	1	1	1	2	6			3	
SEPT		4	1	1	11	1	3	7	
OCT		6		4	2	1	3	4	1
NOV	3	3			3	1	4	4	1
DEC	2	8		3	4	1	1	1	
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1	5						2	
FEB		3	1					1	
MCH	4	1					1	1	
APR	3	4					1	1	
MAY	1	4			1		1		
JUN		6					1	2	
JUL	4	2		1				3	
AUG	1	2			3		4	2	
SEPT	3	7			1			2	1
OCT		3							1
NOV		6			1			1	
DEC	1	2						2	1

	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN		2		1					
FEB	1								
MCH									
APR		1		1	2				
MAY				1		1			
JUN									
JUL						1			
AUG		3		1	1				
SEPT	1	4		1	4	1		1	
OCT	1	5				1			
NOV					1			1	1
DEC		2							
	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1	1			3			1	
FEB									
MCH					2				
APR									
MAY	1	2						1	
JUN	1	1							
JUL		1						1	
AUG	1								
SEPT	1			1	1				
OCT					1			1	1
NOV								2	
DEC									

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1								
FEB									
MCH							1		
APR									
MAY									
JUN				1					
JUL							1		
AUG									
SEPT									
OCT									
NOV									
DEC									
	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB								1	
MCH					1		1	2	
APR							2	1	
MAY		1					1	2	
JUN								2	1
JUL								1	
AUG							1		
SEPT									
OCT									
NOV								3	1
DEC				1	1		1		

Source: FRSC, 2016

Table 3: Monthly Record of RTA Severity and their Causes along Zaria-Kano

	SPV			LOC			DGD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	2	2		1	7			4	
FEB	2	5		2	4			6	
MCH	5	6		4	2	2		7	1
APR	2	3		1	4		2		
MAY		3			5		6		1
JUN	3	3			3			3	
JUL	2	8	1	2	3	2	2	5	
AUG	3	2		2	4	1	1	6	
SEPT	1	4		3	5		2	6	
OCT	2	4		1	2		1	5	
NOV	1	4		3	2			5	2
DEC	2	10		3	6	1	4	3	1
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	2	4			2				
FEB	6	6			1		1	1	
MCH	4	7					1	1	
APR	4	2			1				
MAY	3	4					2		1
JUN	2	3				2	1	1	
JUL	3	11	1		2		1		1
AUG	2	4	2	1			1		
SEPT	1	3	1					1	
OCT	3	9							
NOV	2	2	2	2					
DEC	1	4						2	

	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN		1		1	2			1	
FEB	1	1					2		
MCH				1					
APR		1						2	
MAY									
JUN		1			1				
JUL		4			1				
AUG				2					
SEPT		4			4				
OCT		5			2				
NOV		2		1	1			2	
DEC	1	1						1	

	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN					1				
FEB								1	
MCH									
APR									
MAY		2					2		
JUN	1	2							
JUL		1					2	2	
AUG							1		
SEPT									
OCT									
NOV				1	1				
DEC									

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY		1							
JUN									
JUL									
AUG									
SEPT									
OCT								1	
NOV									
DEC									

	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									1
FEB		1		1	1				1
MCH									
APR								2	2
MAY								2	
JUN					1			1	
JUL								1	
AUG							1	1	1
SEPT								2	
OCT									
NOV							2		
DEC					1		1	1	

Source: FRSC, 2016

Table 4: Monthly Record of RTA Severity and their Causes along Zaria-Sokoto Route

	SPV			LOC			DGD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN		3		1	3			2	
FEB	1	3						7	1
MCH		3		2			2	2	
APR		3			3	2	1	5	2
MAY	2	3		1	1	1		3	
JUN		3		1	2		1	6	
JUL	1	2			3		2	2	
AUG	1	5			4			5	
SEPT		1		1	2	1	1	3	
OCT		3	1		5		1	4	
NOV					1		3	2	
DEC		2			1			4	
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1	1							
FEB	1	3			1		2		
MCH					2		1		
APR		2	1	1				1	
MAY		4						1	
JUN	1					1		2	
JUL									
AUG									
SEPT	1	1			1		1		
OCT									
NOV					1				
DEC					1			1	

	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB		1							
MCH									
APR									
MAY								1	
JUN									
JUL									
AUG								1	
SEPT									
OCT									
NOV									
DEC		1			1				
	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN	1				1				
FEB									
MCH									
APR		1			1			3	1
MAY								1	
JUN									
JUL								1	
AUG									
SEPT					1				
OCT		1							

NOV								2	
DEC									

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN								1	
FEB									
MCH									
APR					1				
MAY									
JUN					1				
JUL									
AUG									
SEPT					1				
OCT									
NOV									
DEC									
	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN					1			1	
FEB								1	
MCH							1	1	
APR					1				
MAY					1			2	
JUN									
JUL							1	2	
AUG									
SEPT								1	
OCT									
NOV							1		1
DEC		1						1	

Source: FRSC, 2016

Table 5: Monthly Record of RTA Severity and their Causes along Old Zaria-Kano Route

	SPV			LOC			DGD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN				1			1		
FEB									
MCH	1								
APR									
MAY	1								
JUN									
JUL	1								
AUG	1	1							
SEPT	1			1	2				
OCT					1			1	
NOV				1			1		
DEC	1	1							
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									

AUG					1				
SEPT									
OCT		1							
NOV	1								
DEC								1	

	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN					1				
JUL									
AUG	1								
SEPT							1		
OCT									
NOV									
DEC									

	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									
AUG									
SEPT									
OCT									
NOV									
DEC		1		1					

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									
AUG									
SEPT									
OCT									
NOV									
DEC									

	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									

JUL
AUG
SEPT
OCT
NOV
DEC

Source: FRSC, 2016

Table 6: Monthly Record of RTA Severity and their Causes along Zaria-Jos Route

	SPV			LOC			DGD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN		2		1					
FEB	1			1					1
MCH		2			1		3	2	
APR	1				1		1	3	
MAY		2		1	2				
JUN		1		1			2		1
JUL	3	4		1	1		2	1	
AUG		1		1	2			2	
SEPT					1				
OCT		2			2			1	
NOV		2						1	
DEC		2			1			1	1
	TBT			BFL			WOT		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH	1						1		
APR	1	1							
MAY		1							
JUN							1		
JUL									
AUG		1							
SEPT									
OCT	1	1							
NOV									
DEC		2							

	RTV			MDV			BRD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY				1					
JUN									
JUL									
AUG									
SEPT									
OCT								1	
NOV									
DEC								1	
	OBS			DOT			OVL		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB		1							
MCH									
APR									

MAY									
JUN									
JUL									
AUG		1			2			2	
SEPT									
OCT					1			1	
NOV									
DEC									

	SOS			DAD			UPWD		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH									
APR									
MAY									
JUN									
JUL									
AUG									
SEPT									
OCT									
NOV					1				
DEC									
	FTG			SLV			OTH		
Month	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR	FATAL	SERIOUS	MINOR
JAN									
FEB									
MCH							1		
APR							1		
MAY									
JUN								1	
JUL									
AUG									
SEPT								1	
OCT								1	
NOV									
DEC								1	

Source: FRSC, 2016

Appendix III

Association between Weather and Causes of RTAs from 2001-2014

Speed violation (SPV)

```
                          FATAL         SERIOUS           MINOR
Rainfall (mm)             0.014          -0.316          -0.223
                          0.964           0.293           0.464
Number of wet days        0.098           0.074           0.209
                          0.750           0.809           0.494
Air Temperature          -0.567          -0.414          -0.426
                          0.043           0.159           0.146
Visibility               -0.055          -0.332          -0.306
                          0.857           0.268           0.309
Relative Humidity        -0.269          -0.343          -0.387
                          0.373           0.251           0.191
Wind speed                0.352           0.082           0.137
                          0.239           0.790           0.656
Evaporation rate          0.183           0.154           0.244
                          0.549           0.615           0.422
```

Loss of control (LOC)

```
                             FATAL            SERIOUS              MINOR
Rainfall (mm)                0.273              0.139              0.471
                             0.367              0.651              0.104
Number of wet days          -0.283             -0.368              0.076
                             0.349              0.216              0.804
Air Temperature              0.316              0.287              0.069
                             0.294              0.342              0.823
Visibility                   0.325              0.374              0.245
                             0.279              0.208              0.420
Relative Humidity           -0.197             -0.159             -0.140
                             0.518              0.605              0.648
Wind speed                   0.375              0.515              0.438
                             0.207              0.071              0.134
Evaporation rate            -0.720             -0.702             -0.529
                             0.006              0.007              0.063
```

Dangerous driving (DGD)

```
                             FATAL            SERIOUS              MINOR
Rainfall (mm)                0.325              0.251             -0.137
                             0.279              0.408              0.654
Number of wet days           0.066             -0.002              0.460
                             0.831              0.995              0.114
Air Temperature             -0.074             -0.080             -0.142
                             0.810              0.794              0.643
Visibility                  -0.088              0.046             -0.413
                             0.774              0.882              0.161
Relative Humidity           -0.251             -0.162             -0.118
                             0.407              0.598              0.700
Wind speed                   0.372              0.439             -0.159
                             0.210              0.133              0.604
Evaporation rate            -0.243             -0.361              0.446
                             0.424              0.225              0.126
```

Tyre burst (TBT)

```
                             FATAL            SERIOUS              MINOR
Rainfall (mm)                0.211              0.287             -0.295
                             0.488              0.341              0.327
Number of wet days          -0.302              0.033              0.167
                             0.316              0.915              0.585
Air Temperature             -0.083             -0.096              0.221
                             0.788              0.755              0.468
Visibility                   0.315              0.245             -0.366
                             0.295              0.420              0.219
Relative Humidity           -0.342             -0.267             -0.096
                             0.253              0.377              0.756
Wind speed                   0.696              0.581             -0.189
                             0.008              0.037              0.536
Evaporation rate            -0.437             -0.325              0.666
                             0.136              0.279              0.013
```

Break failure (BFL)

```
                             FATAL            SERIOUS              MINOR
Rainfall (mm)               -0.035             -0.288             -0.147
                             0.910              0.341              0.632
Number of wet days           0.389             -0.305              0.223
                             0.188              0.311              0.464
Air Temperature             -0.004              0.013             -0.283
                             0.990              0.966              0.349
Visibility                   0.099              0.107              0.061
                             0.748              0.727              0.844
Relative Humidity            0.123             -0.363             -0.229
                             0.689              0.223              0.451
Wind speed                   0.262              0.451              0.272
                             0.388              0.122              0.368
Evaporation rate             0.089             -0.213             -0.022
```

```
                                   0.773              0.484              0.943
```

Wrongful overtaking (WOT)

```
                                   FATAL            SERIOUS              MINOR
Rainfall (mm)                     -0.059             -0.190              0.126
                                   0.847              0.535              0.681
Number of wet days                -0.240              0.065              0.412
                                   0.429              0.834              0.162
Air Temperature                    0.537              0.569              0.109
                                   0.059              0.042              0.723
Visibility                         0.409              0.146              0.365
                                   0.166              0.634              0.221
Relative Humidity                  0.085              0.529              0.212
                                   0.782              0.063              0.488
Wind speed                         0.299              0.069              0.522
                                   0.320              0.823              0.067
Evaporation                       -0.433             -0.118             -0.099
                                   0.140              0.702              0.747
```

Route violation (RTV)

```
                                   FATAL            SERIOUS              MINOR
Rainfall (mm)                      0.041             -0.268             -0.191
                                   0.895              0.376              0.532
Number of wet days                -0.163             -0.361             -0.490
                                   0.595              0.226              0.089
Air Temperature                    0.421              0.142              0.521
                                   0.152              0.643              0.068
Visibility                         0.551              0.464              0.319
                                   0.051              0.110              0.288
Relative Humidity                 -0.151             -0.279             -0.071
                                   0.623              0.356              0.817
Wind speed                         0.401              0.540              0.248
                                   0.174              0.057              0.415
Evaporation                       -0.415              0.037             -0.372
                                   0.159              0.904              0.211
```

Mechanically deficient vehicles (MDV)

```
                                   FATAL            SERIOUS              MINOR
Rainfall (mm)                     -0.067             -0.184              0.280
                                   0.828              0.548              0.355
Number of wet days                -0.567              0.112              0.321
                                   0.043              0.716              0.285
Air Temperature                    0.391             -0.075             -0.512
                                   0.187              0.808              0.073
Visibility                         0.228              0.300              0.372
                                   0.453              0.320              0.211
Relative Humidity                 -0.094             -0.237             -0.264
                                   0.761              0.435              0.383
Wind speed                         0.375              0.433              0.553
                                   0.207              0.139              0.050
Evaporation                       -0.472              0.215             -0.284
                                   0.104              0.481              0.347
```

Bad road (BRD)

```
                                   FATAL            SERIOUS              MINOR
Rainfall (mm)                      0.102              0.132                  *
                                   0.740              0.668                  *
Number of wet days                 0.229              0.351                  *
                                   0.452              0.239                  *
Air Temperature                   -0.422             -0.229                  *
                                   0.150              0.451                  *
Visibility                        -0.094             -0.375                  *
                                   0.760              0.206                  *
Relative Humidity                 -0.164              0.243                  *
                                   0.593              0.424                  *
Wind speed                         0.319              0.052                  *
```

	0.288	0.865	*
Evaporation	-0.157	-0.047	*
	0.609	0.880	*

Road obstruction violation (OBS)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.310	-0.105	-0.062
	0.303	0.734	0.842
Number of wet days	-0.244	-0.152	-0.083
	0.422	0.619	0.787
Air Temperature	-0.100	-0.385	-0.269
	0.745	0.194	0.374
Visibility	-0.046	0.381	0.174
	0.882	0.198	0.569
Relative Humidity	-0.239	-0.408	-0.169
	0.431	0.166	0.581
Wind speed	0.462	0.769	0.235
	0.112	0.002	0.439
Evaporation	-0.009	-0.411	-0.133
	0.976	0.163	0.666

Dangerous overtaking (DOT)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.152	0.325	*
	0.621	0.278	*
Number of wet days	-0.286	-0.003	*
	0.344	0.992	*
Air Temperature	0.048	0.165	*
	0.877	0.589	*
Visibility	-0.038	0.390	*
	0.901	0.188	*
Relative Humidity	-0.120	-0.167	*
	0.697	0.586	*
Wind speed	0.405	0.517	*
	0.170	0.070	*
Evaporation	-0.549	-0.461	*
	0.052	0.113	*

Overloaded vehicles (OVL)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.379	-0.346	-0.091
	0.202	0.246	0.767
Number of wet days	-0.099	0.163	0.007
	0.748	0.596	0.982
Air Temperature	0.582	-0.053	0.069
	0.037	0.864	0.822
Visibility	-0.101	-0.635	-0.610
	0.743	0.020	0.027
Relative Humidity	0.377	-0.173	-0.181
	0.204	0.573	0.553
Wind speed	-0.032	-0.439	-0.364
	0.918	0.134	0.221
Evaporation	0.312	0.664	0.538
	0.299	0.013	0.058

Sleeping on steering (SOS)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.379	-0.346	-0.091
	0.202	0.246	0.767
Number of wet days	-0.099	0.163	0.007
	0.748	0.596	0.982

Air Temperature	0.582	-0.053	0.069
	0.037	0.864	0.822
Visibility	-0.101	-0.635	-0.610
	0.743	0.020	0.027
Relative Humidity	0.377	-0.173	-0.181
	0.204	0.573	0.553
Wind speed	-0.032	-0.439	-0.364
	0.918	0.134	0.221
Evaporation	0.312	0.664	0.538
	0.299	0.013	0.058

Driving under alcohol (DAD)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.052	0.339	*
	0.867	0.258	*
Number of wet days	0.233	-0.107	*
	0.444	0.728	*
Air Temperature	-0.382	0.048	*
	0.198	0.877	*
Visibility	-0.044	0.179	*
	0.888	0.559	*
Relative Humidity	-0.163	-0.044	*
	0.595	0.886	*
Wind speed	0.257	0.376	*
	0.396	0.205	*
Evaporation	0.035	-0.686	*
	0.910	0.010	*

Use of phone while driving (UPWD)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.117	0.126	*
	0.704	0.681	*
Number of wet days	-0.023	-0.083	*
	0.940	0.787	*
Air Temperature	0.353	-0.382	*
	0.237	0.198	*
Visibility	0.482	0.334	*
	0.095	0.265	*
Relative Humidity	-0.137	-0.169	*
	0.656	0.581	*
Wind speed	0.325	0.244	*
	0.278	0.422	*
Evaporation	-0.161	0.107	*
	0.600	0.728	*

Fatigue (FTG)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	*	0.049	*
	*	0.873	*
Number of wet days	*	-0.123	*
	*	0.689	*
Air Temperature	*	-0.189	*
	*	0.536	*
Visibility	*	-0.182	*
	*	0.551	*
Relative Humidity	*	-0.137	*
	*	0.656	*
Wind speed	*	0.340	*
	*	0.256	*
Evaporation	*	-0.214	*
	*	0.484	*

Sign light violation (SLV)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.226	-0.071	*
	0.458	0.818	*
Number of wet days	-0.534	-0.159	*

```
                             0.060             0.604                 *
Air Temperature              0.671             0.778                 *
                             0.012             0.002                 *
Visibility                   0.275             0.366                 *
                             0.362             0.219                 *
Relative Humidity           -0.070             0.228                 *
                             0.819             0.453                 *
Wind speed                   0.061             0.031                 *
                             0.844             0.921                 *
Evaporation                 -0.472            -0.275                 *
                             0.103             0.363                 *
```

Others (OTH)

```
                             FATAL           SERIOUS             MINOR
Rainfall (mm)                0.451             0.088            -0.005
                             0.122             0.775             0.988
Number of wet days           0.199            -0.195             0.112
                             0.514             0.524             0.716
Air Temperature              0.090             0.152            -0.269
                             0.770             0.621             0.374
Visibility                   0.452             0.376            -0.154
                             0.121             0.205             0.616
Relative Humidity            0.008            -0.158            -0.226
                             0.979             0.606             0.457
Wind speed                   0.036             0.522             0.277
                             0.908             0.068             0.360
Evaporation                  0.025            -0.384            -0.069
                             0.935             0.195             0.822
```

Association between Causes of RTAs and Selected Weather Parameters in Zaria (monthly analysis from 2001-2014)

Speed violation (SPV)

```
                             FATAL           SERIOUS             MINOR
Rainfall (mm)                0.130            -0.081             0.412
                             0.686             0.801             0.183
Air temperature              0.314            -0.234            -0.020
                             0.321             0.465             0.951
Visibility                  -0.117            -0.179             0.460
                             0.718             0.577             0.132
Relative Humidity           -0.043            -0.109             0.504
                             0.895             0.737             0.095
Wind speed                   0.454            -0.051            -0.347
                             0.138             0.876             0.269
Evaporation                  0.313            -0.040            -0.581
                             0.323             0.902             0.048
```

Loss of control (LOC)

```
         FATAL             SERIOUS            MINOR
Rainfall (mm)               -0.194             0.227             0.094
                             0.545             0.478             0.772
Air Temperature              0.008             0.071             0.203
                             0.980             0.827             0.526
Visibility                  -0.543             0.132            -0.033
                             0.068             0.682             0.918
Relative humidity           -0.356             0.252             0.032
                             0.256             0.429             0.920
Wind speed                  -0.066            -0.027            -0.042
```

```
                         0.838             0.934             0.896
Evaporation rate         0.390            -0.138             0.076
                         0.211             0.669             0.814
```

Dangerous driving (DGD)

```
        FATAL          SERIOUS           MINOR
Rainfall (mm)            0.011             0.108            -0.249
                         0.973             0.737             0.436
Air Temperature          0.123            -0.109             0.060
                         0.704             0.735             0.853
Visibility               0.349            -0.015             0.157
                         0.266             0.964             0.625
Relative humidity        0.202             0.129            -0.106
                         0.530             0.690             0.743
Wind speed              -0.259            -0.518             0.219
                         0.416             0.085             0.495
Evaporation rate        -0.287            -0.218             0.074
                         0.365             0.496             0.820
```

Tyre burst (TBT)

```
                         FATAL            SERIOUS            MINOR
Rainfall (mm)           -0.124             0.166             0.214
                         0.701             0.605             0.504
Air Temperature          0.608             0.092            -0.182
                         0.036             0.776             0.572
Visibility              -0.289             0.275             0.157
                         0.362             0.387             0.626
Relative humidity       -0.198             0.312             0.108
                         0.536             0.324             0.737
Wind speed               0.288             0.042            -0.394
                         0.364             0.897             0.205
Evaporation rate         0.582            -0.272            -0.260
                         0.047             0.392             0.415
```

Break failure (BFL)

```
                         FATAL            SERIOUS           MINOR
Rainfall (mm)            0.302            0.243             0.159
                         0.339            0.448             0.621
Air Temperature         -0.134           -0.123             0.182
                         0.679            0.704             0.571
Visibility               0.168           -0.183             0.438
                         0.603            0.569             0.154
Relative humidity        0.162            0.022             0.361
                         0.615            0.945             0.249
Wind speed              -0.016           -0.196             0.259
                         0.960            0.541             0.416
Evaporation rate        -0.207            0.006            -0.232
                         0.518            0.986             0.467
```

Wrongful overtaking (WOT)

```
                         FATAL            SERIOUS           MINOR
Rainfall (mm)            0.420            0.222             0.202
                         0.174            0.489             0.529
Air Temperature          0.415           -0.229             0.269
                         0.180            0.475             0.399
Visibility               0.054            0.001             0.717
                         0.868            0.998             0.009
Relative humidity        0.252            0.135             0.452
                         0.430            0.677             0.140
Wind speed               0.479            0.238            -0.005
                         0.115            0.455             0.989
Evaporation              0.200           -0.130            -0.381
                         0.534            0.687             0.222
```

Route violation (RTV)

	FATAL	SERIOUS	MINOR
RAINFALL (mm)	0.017	0.112	*
	0.957	0.729	*
Air Temperature	-0.209	-0.218	*
	0.515	0.496	*
Visibility	0.067	0.344	*
	0.835	0.273	*
Relative humidity	0.103	0.318	*
	0.750	0.314	*
Wind speed	-0.615	-0.688	*
	0.033	0.013	*
Evaporation rate	-0.315	-0.592	*
	0.319	0.043	*

Mechanically Deficient vehicles (MDV)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.232	0.188	0.392
	0.469	0.559	0.208
Air Temperature	-0.221	-0.050	0.136
	0.491	0.877	0.674
Visibility	-0.112	0.369	0.608
	0.730	0.238	0.036
Relative humidity	0.026	0.333	0.587
	0.936	0.290	0.045
Wind speed	-0.080	-0.425	-0.251
	0.806	0.168	0.431
Evaporation rate	-0.058	-0.415	-0.546
	0.858	0.180	0.066

Bad road (BRD)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.048	-0.327	-0.267
	0.881	0.300	0.402
Air Temperature	-0.101	-0.198	-0.260
	0.756	0.537	0.414
Visibility	-0.158	0.058	-0.010
	0.624	0.858	0.976
Relative humidity	-0.015	-0.259	-0.235
	0.963	0.417	0.462
Wind speed	-0.045	-0.430	-0.427
	0.889	0.163	0.166
Evaporation rate	0.012	-0.062	-0.078
	0.970	0.848	0.809

Road obstruction violation (OBS)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.288	0.395	*
	0.364	0.204	*
Air Temperature	-0.187	0.277	*
	0.560	0.383	*
Visibility	0.159	0.514	*
	0.621	0.087	*
Relative humidity	0.291	0.486	*
	0.359	0.109	*
Wind speed	0.363	0.672	*
	0.246	0.017	*
Evaporation rate	-0.220	-0.184	*
	0.493	0.567	*

Overloaded vehicles (OVL)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.382	0.172	0.278
	0.220	0.592	0.381
Air Temperature	0.218	0.081	0.207
	0.496	0.803	0.518
Visibility	0.362	0.282	0.313

	0.248	0.374	0.321
Relative humidity	0.388	0.174	0.342
	0.213	0.588	0.276
Wind speed	0.462	-0.053	0.075
	0.131	0.871	0.817
Evaporation rate	-0.167	-0.202	-0.248
	0.604	0.529	0.438

Sleeping on steering (SOS)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.287	0.081	-0.287
	0.366	0.802	0.366
Air Temperature	-0.461	0.367	-0.461
	0.132	0.240	0.132
Visibility	-0.476	0.283	-0.476
	0.118	0.373	0.118
Relative humidity	-0.340	0.150	-0.340
	0.280	0.642	0.280
Wind speed	0.089	0.437	0.089
	0.784	0.155	0.784
Evaporation rate	0.126	0.099	0.126
	0.696	0.760	0.696

Drunk and driving (DAD)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.203	0.029	0.203
	0.526	0.929	0.526
Air Temperature	0.087	0.235	0.087
	0.788	0.462	0.788
Visibility	0.283	0.397	0.283
	0.373	0.201	0.373
Relative humidity	0.281	0.166	0.281
	0.376	0.606	0.376
Wind speed	0.418	-0.039	0.418
	0.176	0.905	0.176
Evaporation rate	-0.119	-0.096	-0.119
	0.712	0.767	0.712

Use of phone while driving (UPWD)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	0.153	-0.291	-0.227
	0.634	0.359	0.477
Air Temperature	0.208	-0.317	0.354
	0.516	0.315	0.259
Visibility	-0.165	-0.179	-0.428
	0.607	0.578	0.165
Relative humidity	0.036	-0.150	-0.325
	0.911	0.643	0.303
Wind speed	0.191	-0.303	0.073
	0.551	0.338	0.821
Evaporation rate	0.167	-0.136	0.549
	0.604	0.672	0.065

Fatigue (FTG)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	*	-0.314	*
	*	0.320	*
Air Temperature	*	-0.081	*
	*	0.802	*
Visibility	*	-0.263	*
	*	0.409	*
Relative humidity	*	-0.350	*
	*	0.265	*
Wind speed	*	0.202	*
	*	0.530	*
Evaporation rate	*	0.302	*
	*	0.340	*

Sign light violation (SLV)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.425	-0.293	*
	0.168	0.356	*
Air Temperature	-0.367	0.222	*
	0.241	0.488	*
Visibility	-0.515	-0.261	*
	0.086	0.412	*
Relative humidity	-0.518	-0.325	*
	0.085	0.302	*
Wind speed	-0.090	0.503	*
	0.780	0.095	*
Evaporation rate	0.278	0.499	*
	0.382	0.099	*

Others (OTH)

	FATAL	SERIOUS	MINOR
Rainfall (mm)	-0.206	0.108	0.027
	0.521	0.739	0.934
Air Temperature	0.169	0.302	-0.020
	0.600	0.340	0.951
Visibility	-0.205	0.245	-0.048
	0.523	0.443	0.883
Relative humidity	-0.340	0.138	-0.099
	0.279	0.669	0.761
Wind speed	-0.044	0.413	0.027
	0.891	0.183	0.934
Evaporation rate	0.364	0.085	0.101
	0.244	0.792	0.755