EXPLORING SPATIAL PATTERNS AND TRENDS OF VEHICULAR ACCIDENTS IN ABUJA, NIGERIA.

FATIMA FIBAYI MAKAMA

SUPERVISORS:
Dr S. Amer
Dr A. B. Grigolon
Chair: Prof. Dr. K. Pfeffer

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ABSTRACT

Increased agglomeration of population and misalignment with infrastructure has led to infrastructural pressure, on roads which is a means of movement of people, goods and services. Vehicular movement on roads have experienced an ugly trend of activity from its inception. Road traffic accidents have resulted to loss of lives, emotional trauma, injury and destruction of properties. There have been efforts put in place to reduce this menace in most developed countries, but the situation persist in developing countries despite counter measures. The research seeks to understand the where, when and how of vehicular accidents in parts of Abuja metropolis, Nigeria. To recognise locational causes of accidents, selected high accidents prone areas in the study area were visited to identify specific causes and proffer recommendations to improve safety on roads.

Exploratory study by the use of quantitative method for data analysis was utilised. Firstly, accident point data were acquired from recorded accidents data of the Federal Road Safety Commission (FRSC). Geo-referencing of the x and y coordinates of each available recorded accident data was carried out for the study area. This was to aid visualisation and evaluation of variables contained in the data set. Findings from the spatial and descriptive analysis on factors causing accidents in the study area showed that speed violation (SPV) had the highest occurrence of accidents as well as fatality. Human factor was also a lead factor amongst the three elements (human, environment and vehicle factor) in the concept of the research. Spatial clusters of accident point locations and factors were found distributed around the study area. The Local Moran's Index was employed to determine significant cluster locations. The significant locations further aided in identifying specific hazardous cluster locations and identification of land-uses related to selected cluster locations.

The explanatory study focused qualitatively on the primary data collection. Here, 15 selected locations were visited; one out of these 15 locations was a street check location while the 14 others were hazardous locations. Individuals (workers and pedestrians) were interviewed along the segments. Although the location specific causes identified were case specific, each location had a major cause which was similar in some instance to other locations. Contributory factors identified were; road designs, absence of signage on major roads, user behaviour, underutilization of safety facilities and absence of safety facilities in some locations. Study examination of existing measures were based on qualitative data from FRSC annual report, interviews and other documents. It was realised that the FRSC have embarked on various counter measures to help reduce accidents and promote safety. These cut across regions in Nigeria, Abuja metropolis inclusive. Although with high initiatives, there were constraints in funding and service delivery (data acquisition and vehicles maintenance).

The study recommends, amongst others, the incorporation of spatial and geographical aspects of accidents data collection in Nigeria to help improve safety on roads.

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DEDICATION

To the Almighty God, You made it all possible, because Your words are unfailing.
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LIST OF ACRONYMS

AGIS	Abuja Geographic Information System
AMAC	Abuja Municipal Area Council
BAC	Breath Alcohol Consumption
BSU	Basic Spatial Unit
CADZONE	Cadastral Zone
DBF	Database File Format
DGD	Dangerous Driving
ESDA	Exploratory spatial data analysis
FCC	Federal Capital City
FCDA	Federal Capital Development Authority
FGD	Focus Group Discussion
FRSC	Federal Road Safety Commission
GIS	Geographic Information Systems
GDP	Gross Domestic Product
GNI	Gross National Income
KMZ	Keyhole Mark-up Language
LISA	Local Indicator of Spatial Analysis
LOC	Loss of Control
NASRDA	National Space Research and Development Agency
NN	Nearest Neighbour
NPF	Nigerian Police Force
PDF	Portable Document Format
QUAL	Qualitative
QUAN	Quantitative
RTAs	Road Traffic Accidents
SLV	Sign Light Violation
SLW	Sliding Window
SPA	Spatial Autocorrelation
SPV	Speed Violation
TIFF	Tagged Image File Format
UTM	Universal Transverse Mercator
VMR	Variance Mean Ratio
VRUs	Vulnerable Road Users
WHO	World Health Organisation
WISLR	Wisconsin Information System for Local Roads
WOT	Wrongful Overtaking

1. INTRODUCTION

Vehicular accidents are generally traumatic experiences that leave the individual involved either emotionally terrified, injured or possibly deceased. This has been of concern over the years and has led to researchers carrying out different studies on spatial and temporal accident hotspots (Harirforoush & Bellalite, 2016; Young & Park, 2014). Most developing countries (including Nigeria) have experienced road traffic accidents since their inception. Studies have been conducted on road traffic accidents in Nigeria (Femi, 2013; Oluwasanmi, 1993; Daniel, Adejumo, Oritogun, Mautin, & Salako, 2017; Jegede, 1988; Asogwa, 1992), but few have based their studies on the spatial and temporal aspects of road traffic accidents. Although there are measures put in place by government and other authorities to curb vehicle accidents, yet high rate of fatality remains. There is need to understand the location, time and reasons for these accidents so as to help in developing strategies in preventing road traffic accidents (Plug, Xia, & Caulfield, 2011). Studies have shown road accidents in Nigeria having significant clusters in two places, Abuja and Nasarawa States (Daniel et al., 2017). But to know the reason that underlie the high level of fatal deaths, where and why in these regions, it is essential that a research be conducted to look into the spatial, temporal and other factors causing the accidents at a city scale to a single crash level.

1.1. Background and Justification

Road Traffic Accidents (RTA) occur when there is an impact between a vehicle and either a pedestrian, an animal, a stationary obstruction (building or utility pole) or another vehicle(Cham et al., 2015). This can lead to injury, death, disability, as well as financial loss to the society and individual (Bun, 2012). A road traffic system is the most complex and dangerous amongst all other systems which people deal with on a daily basis. An estimated figure of 1.2 million people are killed in road accidents every year and 50 million others are injured (Harirforoush & Bellalite, 2016). These statistics corresponds to the World Health Organisation (WHO) report, WHO (2015) of more than 1 million deaths worldwide in 2001 to 2013 figures with the middle and low income countries having percentages of 74 and 16 of road traffic deaths and 53 and 1 percent of registered vehicles. WHO (2004a) report states that; road traffic injuries are a major but neglected public health challenge and concern. The same report also states that, majority of the high-income countries have managed to curtail the relationship between rising motorization and increased road traffic deaths. However in low and middle-income countries road traffic deaths and injuries are estimated to cause economic losses of 5% of the Gross Domestic Product (GDP). The knowledge of where, when and why RTAs occur on a road network is one of the important concerns of transportation authorities (Harirforoush & Bellalite, 2016).

Most RTA deaths involve pedestrians, cyclists and motorcyclists. These are referred to as Vulnerable Road Users (VRUs) (WHO, 2004b). Besides, as the number of death vary by region, the forecast is for an increase in deaths by as much as 80% in low-income and middle income countries if no increased efforts and new initiatives are implemented. WHO (2015) report confirms that low and middle-income countries have the highest fatality rates (90% of global road traffic deaths) with VRUs constituting half of the victims. Pedestrians and motorcyclists has numerous benefits to the individuals and the city, these includes; increase healthy physical activity to the individuals as well as in the liveability of a city, less traffic congestion, less noise and environmental pollution, with less impact on climate change. Regrettably, VRUs are the most susceptible to RTA's in transport system, which can results in fatalities. A fatality have been defined as death occurring within 30 days of a collision event (Jones et al., 2008), however, some countries use 'on the spot', within 24 hours, or 3 days . A wide range of activities in the urban transport system are as a result of complex interactions between various elements of the urban environment and human activities occurring in space and time (Rodrigue, Comtois, & Slack, 2013). These interactions occur mostly between factors which include; environment (road), human and vehicles. These factors constitute of what is now well known as the Haddon Matrix, produced by William Haddon Jr. The Haddon Matrix illustrates the interaction of human, vehicle and environment, during three phases of crash events identified as pre-crash, crash and post-crash (Haddon, 1968). The matrix, models a dynamic system with each cell allowing opportunities for intervention to reduce road crash injury. The research by Haddon, led to significant improvements in the understanding of the behavioural, road-related and vehicle-related factors that affect the number and severity of casualties in road transportation (WHO, 2004a). Building on the insights by Haddon (1968), this research seeks to explore the interaction between the environment (roads), human and vehicle factors causing accidents.

It has been observed, that road accidents in the urban environment are relatively high within certain times (year, months or days) of the year (Singh, 2017). This can be due to extreme conditions, e.g., weather, which can contribute to the occurrence of road accidents. Similarly, road characteristics such as road geometry, quality of infrastructure and other traffic characteristics, such as, traffic flow and speed can cause road accidents (Wang, Quddus, & Ison, 2013). Additionally, human factor, such as lack of safety belt and helmet use, the use of alcohol and other intoxicating drugs, social and behavioural factor, e.g., the use of mobile phones while driving as well as fatigue, are some of the determinant of road traffic accidents (Odero, Garner, & Zwi, 1997). With regards to vehicular conditions, a high prevalence of old vehicles that carry more passengers than are designed to, are mostly involved in accidents. Worn out tires and brake linings (Evans, 1996) are vehicle maintenance problems associated with the occurrence of accidents. The effects of each crash are represented by interlinked factors, with which relationships between factor components are determined. Road features or vehicle characteristics may influence particular aspect of road user behaviour for example, the absence of speed signs can result to over speeding in residential areas or in low speed lanes. Also, vehicle defect may be compounded by a particular road characteristic such as potholes, which can affect vehicle wheels and sometimes cause a tire burst (Mohan, Tiwari, Khayesi, & Nafukho, 2006). The interactions between these elements occur at a particular location and at a certain period.

Spatial pattern and trend analysis of road accidents can reveal patterns and variables influencing changes in vehicular accidents over space and time (Shahid, Minhans, Puan, Hasan, & Ismail, 2015). An understanding of the temporal and spatial characteristics of accidents can contribute to the reduction and prevention of traffic deaths and injuries. Unfortunately, not many studies have examined spatial and temporal road accident analysis in Nigeria (Olajuyigbe, Ogan, Adegboyega, & Fabiyi, 2014; Korter, Olubusoye, & Salisu, 2014; Aderamo, 2012; Ukoji, 2014; Jegede, 1988). The three latter studies looked at variations over regions and examined how accidents in particular Nigerian States as well as the distribution of road vehicle accidents injuries and death. These zones are termed large units of aggregation rather than a single metropolitan area (Levine, Kim, & Nitz, 1995a). Olajuyigbe et al., 2014 examined accidents in the Central Business District (CBD) of Abuja using three years accident record. In the research accident points were acquired using a Global Positioning System (GPS), spatio-temporal and hotspots analysis were performed based on high frequency of road accidents. Only the study by Daniel et al., (2017) examined the spatial autocorrelation of road traffic accidents and mortality at a national level (over the entire country); the emphasis was on variations across the subnational levels and identification of states with significant clustering in Nigeria , rather than city-scale to a single crash level.

Analysis of accident patterns usually involves large volumes of data which mostly exists in the form of linear record file system. This is only helpful in placing the analysed information in tabular forms, missing the spatial aspect which is most important in analysing accident locations. Nigeria is among countries that have based its database of recorded accidents on tabular form. This has led important data to methodological limitations identified as bias, leading to invalid results, compared to exploratory (point data), explanatory variables (factor related to vehicle facilities, road condition, traffic management) and exposure variables (traffic flow, traffic volume). Backalic, (2013) examined accidents from different time aspects, hour, day and month and emphasised on time being the first step in traffic analysis. Accidents, however, are not just spatially random events, there is an overall regional or city scale pattern making their location more than just an irregular spatial distribution (Levine et al., 1995a). This research examined recorded information on accident locations in a spatial database. This is for easier data manipulation and understanding of the relationship between accidents causing factors, and locations in which they occur at a city-scale to a single crash level. The knowledge can optimize resources and guide the efforts of law enforcement and safety officials in reducing road traffic accidents.

1.2. Problem Statement

Adequate road infrastructure is central to the growth of every nation, particularly, it plays a critical role in the growth of other sectors of the economy of a nation (National Planning, 2015). Nigeria's vision to become one of the world's 20 largest economies by 2020 is not well aligned with its transport infrastructure. Nigeria has a national road network of about 200,000km constituting 18% of federal roads of about 35,000km, 15% states roads of about 17,000km and 67% local government roads of about 150,000km. Most of the local government roads are unpaved. In Nigeria, the road sector account for about 90% of all freight and passenger movements (Kolawole, 2015). Nigeria, has been ranked as having the highest incidence of road traffic accidents worldwide, with a death rate of 33.7/100 000 (Peden, Kobusingye, & Monono, 2013).

The Federal Road Safety Commission (FRSC), established in 1988, is responsible for prevention and minimizing road accidents on high-ways, giving prompt attention and care to accident victims, conducting research into causes of vehicle accidents as well as the development and implementation of methods aimed at preventing road accidents (FRSC, 2018). Although there has been a reduction in the rate of road traffic accidents since the establishment of FRSC, the number of accidents in Nigeria is still very high compared to other countries. Some of the causes of traffic accidents are drug use among drivers, young and poorly trained drivers (FRSC, 2014). These accounted for 875 vehicle accidents between January and August 2014 (greater than 100 accidents per month) in Nigeria. In 2014 the FRSC recorded an increase of 39% in the rate of accidents due to speed violation compared to 2013.

In recent studies on road traffic accidents and mortality in Nigeria, Abuja was found to be one of the identified hot spots for mortality (Daniel et al., 2017; Adeleke, Salami, & Oyewo, 2013). These analysis were performed on a national level. Most, studies on accidents follow an epidemiological approach (Loidl, Traun, & Wallentin, 2016), for instance, Daniel et al. (2017) based their studies on spatial distribution of road traffic accidents and mortality in Nigeria. Spatial analysis tools were used to locate significant clusters across the country. A high concentration of accidents and mortality was observed in specified cities in Nigeria with Abuja inclusive. Also, Adeleke et al. (2013) identified states in Nigeria with high accident locations (HAL) based on their accident hazard index (AHI), integrating both population-based accident rate (PAR) and kilo meterage based accident rate (KAR). Few studies investigate multiple temporal intervals and spatial scales, ranging from city-scale to single crash locations, they mostly base their studies on the non-spatial and other statistical representations, leaving out the spatial relationship between accidents locations. The consequences of this is that geographic aspects are not considered in the quest for solution to high accidents.

Spatial pattern and temporal analysis of vehicular accidents in Abuja will quantitatively and qualitatively describe and explain road safety developments, giving understandings to the organisational efforts to reduce the rate of vehicle accident injuries and mortality. The analysis can guide safety officials on the where, when and how of the occurrences while implementing road accidents safety measures. It aim to look into factors associated with accidents, their occurrence over time and spatially identify accident locations. The research will also detect and provide insights to specific location causes of road accidents, in a delineated study area.

1.3. Objectives and Research Questions

1.3.1. Main objective

To identify factors that underlie traffic accidents and explore the spatial and temporal pattern of traffic accidents in Abuja with the aim to improve road safety.

1.3.2. Specific objectives

1. To analyse factors causing traffic accidents in Abuja
   a. What are the factors influencing road traffic accidents in Abuja?

2. To identify the spatial distribution of traffic accidents in Abuja
   a. Which methods are suitable for analysing and visualizing temporal clustering of vehicular accidents?
   b. Which methods are suitable for identifying the spatial distribution of vehicular accidents in Abuja?
   c. What is the spatial distribution of traffic accidents in the study area?
   d. Are there spatial clusters of accidents in Abuja? Are these clusters more or less prominent to specific land-uses?
3. To understand the efforts in improving road safety in Abuja and provide recommendations
   a. What are the existing measures of road safety and what other organisations are involved in collaborative efforts?
   b. What are the attainments, strengths, prospects and limitation of Federal Road Safety Commission?
   c. What are possible recommendations based on findings?

1.4. Significance of Study

As spatial information extraction and spatial discovery are great challenges faced by urban science and technologies, so are road traffic accidents complex and pressing challenges faced by the developing world. This research addresses a real world problem in an urban context, by identifying contributory factors and the recognition of safety deficient locations within the city. It goes further to provide insight into specific location accidents causes in the recognised hazardous locations, and provides measures to help in curbing the menace. Academically, this research have met the challenges of spatial information extraction, specifically, accidents point data extraction and spatial discovery of hazardous accident point location within the study area. It has brought more initiative into methods used to analyse accidents data in particular recorded accidents data. This is by proving the fact that, despite defects in the original accidents location description information, for example; spelling errors, missing prefix, suffix and sometimes incorrect street names and landmark description (Qin, Parker, Liu, Graettinger, & Forde, 2013). The mapped accident locations should be correct, based on the information and methods employed. This research have also ascertained the application of Geo-Information System and Remote Sensing as important technologies and basis for the development of a sustainable smart city, with smart people, smart mobility and a smart environment.

1.5. Thesis Structure

The thesis will consist of 5 chapters. Chapter one, consist of the introduction, background and justification. The problem statement is stated in this chapter, the aim of study, objectives and research questions are stated here and lastly the significance of study. Chapter two consist of literature review. A review is given of basics about the research, concept, and an overview of factors of road traffic accidents and trends in Nigeria. A presentation of approaches is also carried out in this chapter, this are methodological approaches that will aid to reveal trends and patterns related to road accident in the study area. Chapter three is about methods, study area and description of available data and data collection process. Here, an overview of the study area and its geographical feature is given. A detailed description of methods employed in this study is made. Research weakness and lapses are identified and appropriate technique applied are discussed. Chapter four gives results and discussion of adopted and devised methods, descriptively, spatially and qualitatively (street design with respect to fieldwork and physical observation with Focus Group Discussion). In chapter five, summary of work carried out in the research, conclusion and recommendation. Figure 1-Avisualizes the research design structure. The research design include in it, components of each chapter listed.

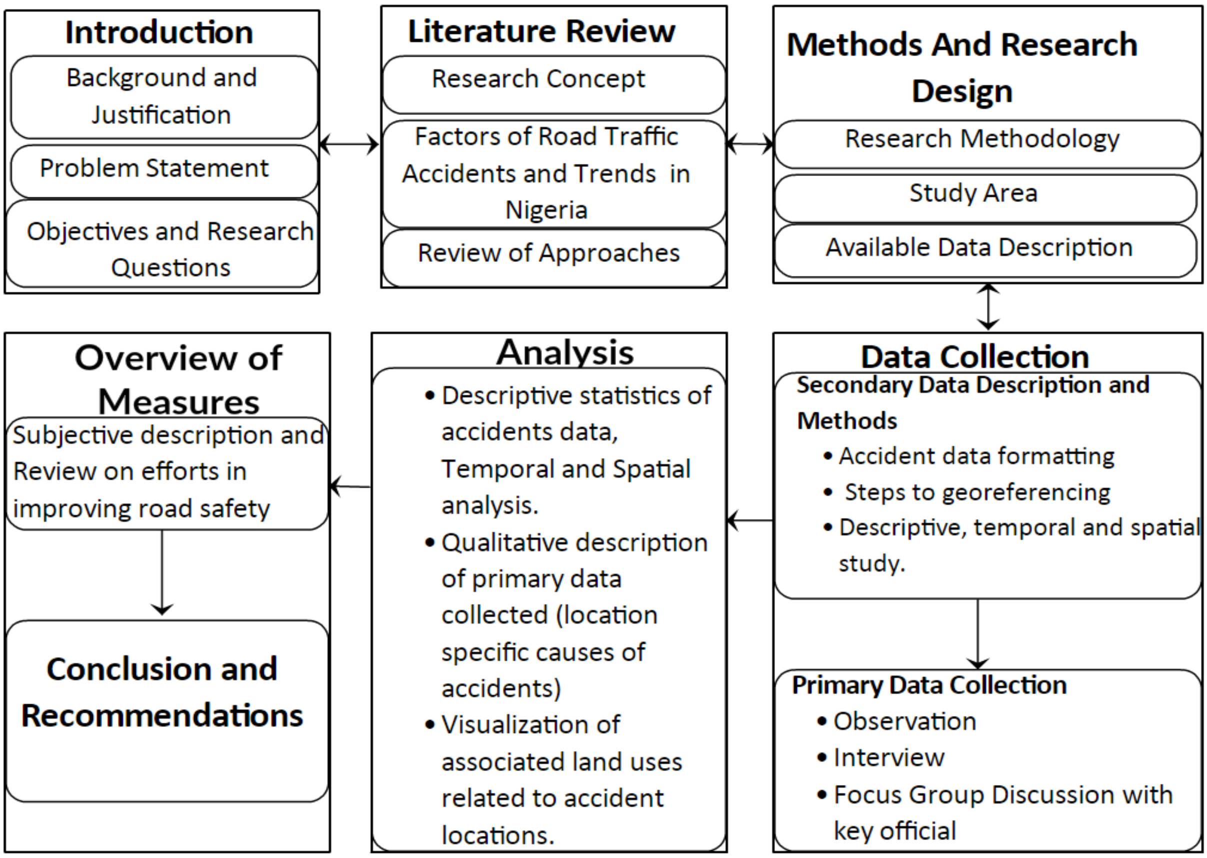

Figure 1-A Research Design

2. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

In this chapter, the concept of the research is discussed and a general outline of contributing factors to road accidents is presented. The relationship of these factors with the geographic location of accidents aided in identifying and proposing measures that will help in reducing vehicular accidents. Methods used by other researchers to analyse the influence of traffic accidents are also reflected on.

2.1. Road Traffic Elements

Transportation safety is a great concern both in the developed and developing countries of the world, however, road traffic related deaths occur disproportionately in developing countries, making this a particularly important concern for affected countries (Rahman, Crawford, & Schmidlin, 2018). Countries that have been most successful with transport safety are those that have good political will and have looked at the transport system as a whole, i.e. the interaction between the environment (road), vehicle and the humans (road user) (Peden, 2005). Various researches have undertaken analysis of accident risk factors, examining the built environment, road user, and vehicle separately (Dai & Jaworski, 2016; Russo & Comi, 2017; Harris et al., 2013 and Nordfjærn, Jørgensen, & Rundmo, 2011). They analysed road accidents critically, based on the independent factors relating them to their variables and investigating their effect to the contribution of accidents.

In the proceedings of the 13th international conference on Man-Machine-Environment system engineering, it was noted that the traffic management objective, is to guarantee traffic safety and organise the traffic transport elements; the driver, vehicle and environment (Zhang & Wang, 2014). The authors mentioned that the traffic manager's knowledge and attention amongst others, concern the transport system problems. Peden (2005) and Zhang & Wang (2014) recognised in their work that humans make mistakes and to have a safe road traffic system, the system have to accommodate their weaknesses. It was examined that causes of accidents can be found through past knowledge, experience and data collection and the interaction between the transport system elements in order to identify where there is potential for intervention. To help the traffic safety managers with practical details and knowledge about specific traffic accident prone areas, the spatial and temporal analysis of accidents data have to be examined. This study will investigate the interaction of these three traffic elements; human, vehicle and environmental (road) factors in a delineated area in the city of Abuja, Nigeria.

The conceptual framework (Figure 2-A) shows the interrelationship between the human, vehicle and environment factors that can result to road accidents. The framework serve as a guide for the research to attain its objectives, and also to help identify and rectify major causes of error or road design weaknesses, which contribute to accidents. The study not only considers underlying factors, but also the role of the responsible agency and actors in prevention efforts. However, the location and time of interaction between the basic elements causing accidents is important in identifying where there are possibilities for intervention. Each accident and its consequences can be represented by its system of interlinked factors. As these components interact, linkages are seen between factors and accidents as shown in Figure 2-A. For instance, a driver or car owner who has not properly maintained a vehicle can cause the vehicle to develop a fault which in turn can lead to an accident. Likewise, the use of worn-out tyres can result to an accident during wet seasons. For safety organisations to effectively plan countermeasures on road traffic collisions, it is important to understand the where and when processes (causation process). This provides vital information and leads to a wide-range of possible preventive interventions. These factors are further discussed in subsequent sections as the interaction between them is being analysed and related to relevant literature in the study region.

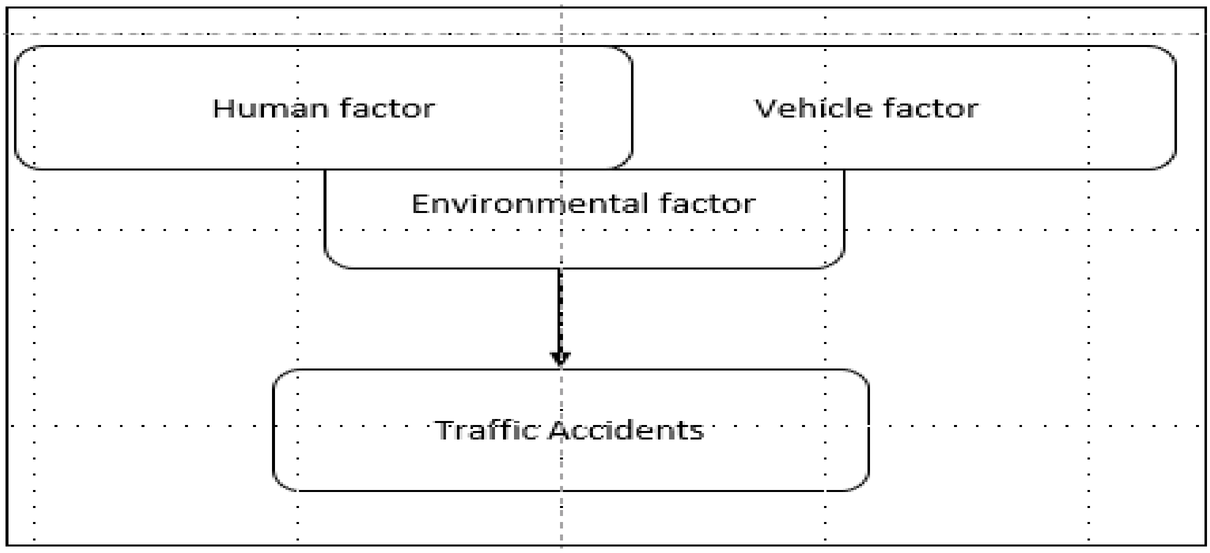

Figure 2-A Conceptual Framework Author (2018)

2.2. Road Traffic Accidents in Nigeria

Road transportation is the most common, accessible and affordable means of mobility in most African countries. Since intercity trains or air transport are not readily available or are very expensive, people are unfortunately exposed daily to unsafe road environment (Adeloye et al., 2016; WHO, 2015; WHO, 2009). In the developing world, road infrastructures are not normally upgraded to accommodate the increased number of commuters and ensure safety (Gorham, 2017). The author stated that, the international standards suggest urbanization to often correlate with rising per capita income and per capita GDP, increased manufacturing and declining poverty rates, in Nigeria irregularities are seen as urbanisation do not conform to the mentioned trend. It was further explained by Gorham (2017) that the Nigerian government have relatively less ability to pay for infrastructure at the same rate of urbanisation. As at 2014, Nigeria was at an urbanisation rate of 47%, the highest in Sub-Saharan African. But competitor developing economies had higher Gross National Income (GNI) per capita at the year they attained 46% urbanisation. This has affected the deteriorating state of road infrastructure in Nigeria.

Various studies on RTAs have been carried out to improve measures of reducing their occurrences. It is noteworthy that despite advancement in technology, RTAs remain a global menace. The risk of dying in a RTA is highest in the African region (24.1 death per 100, 000), and Nigeria has the highest road traffic death rate of 33.7 per 100,000 (Peden et al., 2013). Among 193 countries globally, Nigeria has the second highest rate of road accidents (Agbonkhese et al., 2013). Bhalla et al. (2014) in their report ranked Nigeria to be third in absolute number of world's road traffic fatality after India and China, and ranked fourth in the world traffic fatality rates at 47 deaths per 100,000 vehicle kilometre in 2010 after Gabon, Equatorial Guinea and Congo. However, the non-availability of road traffic data systems and low reported death rate has impacted directly on scientific research results on road accidents and responses by government agencies (Adeloye et al., 2016). It also affected the reliability of official statistics of road traffic accidents in Nigeria (Bhalla et al., 2014). For example, Korter et al. (2014) in their studies gave instances of disproportionate data inconsistency of number of accident deaths in Nigeria in comparison to the worlds average by over 636 percent.

In Nigeria, commercial drivers are organised into associations; the Nigeria Union of Transport Workers (NURTW) and the Road Transport Employers Association of Nigeria (RETEAN). This are the major transport unions in Nigeria that operate at the Local Government, State, and National Level. They are meant to oversee issues related to commercial public transports (of both privately owned and government mass transit system) in Nigeria, although sometimes this organisations have internal crisis (T. Johnson, 2017). FRSC work in conjunction with this unions to elaborate on issues and challenges they have with drivers on transportation. The aim of the study is to examine the causes of road traffic accidents leading to deaths and injury. Factors causing accidents is going to be examined based on researches, available FRSC data, and specific location causes in the study area. Outcomes will help to direct safety policies that are targeted towards reducing the rate of road accidents in the region as well as the entire nation.

2.3. Road Traffic Accidents Factors in Nigeria

The factors contributing to RTA in Nigeria are multi-factorial as well and are divided into three namely; (i) driver factor, (ii) vehicle factor and (iii) environmental factors (Bun, 2012)variables.

Table 1 shows an overview of these main factors and their associated variables.

Table 1 List of factors and possible related sub-factors Author (2018)

Factors	Variables
Human factor	Speed violation, sleeping while driving, and the use of alcohol (impairment and attitude) amid others.
Environmental (Roads, Metrological and Land-use)	Rain, visibility, temperature, road design and road layout, speed limits and pedestrian facilities.
Vehicle factor (vehicle design and vehicle maintenance)	Malfunction of tyres, engine failure, braking systems, light systems, speed management and roadworthiness.

2.3.1. Human factor

Human factors in road traffic accidents can be described as actions influenced by either the driver or road users that could contribute to incidents of road accidents. In Nigeria, records and investigations have shown that the attitudes of road users to driving codes and other road safety features and facilities are important contributory and sometimes the main accidents causing factors (Agbonkhese et al., 2013). It was also noted that the indiscriminate use of sirens on vehicle that are driven at very high speed, belonging to private or political office holders, banks, and government, are a contributory factor to road traffic accidents in Nigeria. Distracted driving particularly the use of phones while driving, inexperienced and unqualified drivers and the non-use of safety device e.g., seatbelts are among the common accident causes. Other contributory factors include the negligence of duty by established agencies as well as crime.

The FRSC (2016) annual report listed causative factors of RTAs in Nigeria that are related to human behavioural factor. These include speed violation (SPV), which is known to have caused the highest number of road traffic accident cases of 3,848 (33.9%) in 2016. Figure 2-B shows a chart of the number of accident that occurred in Nigeria in 2016 and their causative factors. Figure 2-B shows a chart of the number of accidents that occurred in Nigeria in 2016 and their causative factors. It can be seen that SPV has the highest number of cases (3448). This is closely followed by Loss of Control (LOC) in which 1753 were involved.

Dangerous driving (DGD), wrongful overtaking (WOT) and sign/traffic light violation (SLV) involved 969, 832 and 736 people respectively. Others are, route violation, drunk-driving and use of drugs, distracted driving, inexperienced and unqualified drivers and non-use of safety devices (Figure 2-B). These elements are categorised under human related factors that give rise to RTAs.

In Nigeria, crime is another causative factor of RTAs. This occurs on board either public or private vehicle transportation systems (Ayodeji & Ajayi, 2010). The activities of criminals on the federal, state and local roads is among the leading factor that causes RTAs in Nigeria. Criminals engage in hijacking and stealing vehicles and consequently cause road traffic accidents. They hide in nearby bushes close to roads and unleash terror on helpless road users. It is a common sight to see large stones, used car tyres and rims, logs of woods etc. on Nigerian roads. These common obstacles are used on roads by armed bandits/robbers to cause road accidents. Most night time accidents are hardly noted or recorded, this is because emergency service personnel or first responders would be putting their own lives at risk when responding to RTAs at night time. According to Zhang & Wang (2014), behavioural factors account for more than 90% of the traffic accidents causes. Generally, human behavioural factors are a central element in accident occurrences (Marolda, 2011). In a similar study, Evans (1996) gave more significance to the road user factor (human factor) as a sole contributor to RTAs. From all indications, human factor tends to be the leading risk factor for traffic accidents. However, the existing interaction with other factors e.g., visibility, roadway engineering, vehicle maintenance etc., should also be considered.

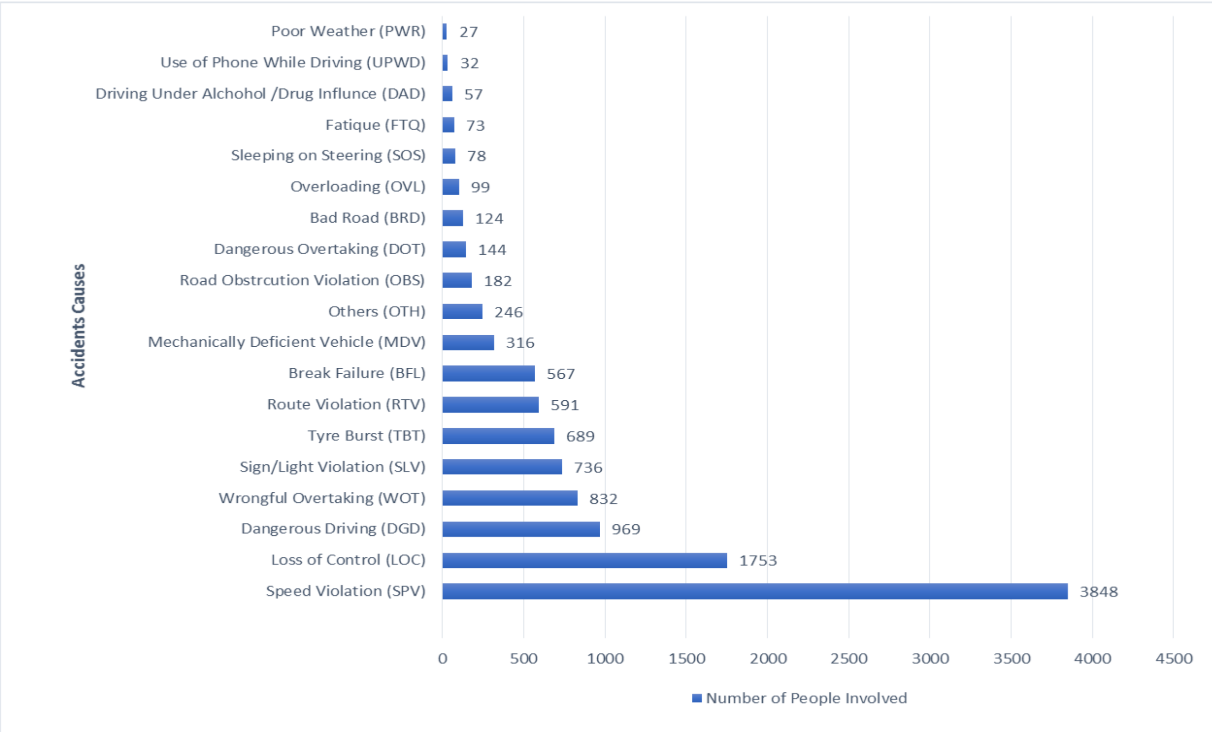

Figure 2-B Factors causing RTAs Adapted from FRSC (2016)

2.3.1.1. Vehicle factors

Vehicle factor has also been recognised as key when analysing road accidents in Nigeria. Vehicle factors can be defined as the malfunction of any of the vehicle parts e.g., tyres, engine, braking systems, light systems etc., which can cause RTAs. Vehicle factors are further be divided into two parts: vehicle design and vehicle maintenance (Evans & Frick, 1992; Evans, 1996). Evans (1996), has also related vehicle factors such as worn out tyres or brake linings to vehicle maintenance. In 2016, the number of accidents caused by Mechanical Deficient Vehicles (MDV) was 316 (Figure 2-B). Social liberalization led to a decline in discipline and respect for applicable laws after 1989, particularly in developing countries. This period was also the beginning of the importation of used cars from developed to developing countries and the onset of increased road traffic. The period also witnessed the decline in the quality of roads, which was a contributory factor to increased RTAs (Masilkova, 2017). In Nigeria, vehicle fleet management has witnessed a lack of concerted policy, although slowly undergoing evolution on import regulations, the existing vehicle fleet is made up of aging vehicles with high environmental pollution tendencies (Kaenzig, 2013). Current regulations in Nigeria only allows the importations of cars not older than 10 years and trucks not more than 15 years. However, whist in Nigeria, vehicles end up being used for several more years and in most cases under poor maintenance and harsh environment conditions. This circumstances worsens their existing deteriorating state, making the vehicles become unsafe and liable to road accidents. To mitigate RTAs due vehicle design and vehicle maintenance the FRSC in recent years has been carrying out on-the-road inspections, to check the quality and road worthiness of vehicles. In case of vehicle design, driver fatality risk is been examined to depend strongly on the weight of a vehicle, for instance in a study by Evans & Frick (1992), it was concluded that between an incidence involving two cars, driver fatality risk would be higher in the lighter car. This was on the bases that when cars of similar weight but of different wheelbase (shorter and longer wheelbase) crash into each other, the driver fatality rate in both cars are similar. But with different mass in two cars, driver fatality rate is lower with the heavier car.

2.3.1.2. Environmental factors

Environmental conditions such as fog, sunrays, mist, haze and rainfall contribute to RTAs in Nigeria. Also, visibility, temperature, wind speed and humidity are important variables that can lead to traffic accidents. These factors also relates to each other, e.g., a poorly maintained vehicle with worn out tyres or without wind shield wipers can be more susceptible to an accident during a rainy day compared to a dry day. Furthermore, the interactions between different factors can determine the occurrence and severity of road accidents (Raicu, Costescu, & Burciu, 2016). Heal Nigeria (2009), argued that the cause of accidents in Nigeria are not just due to human error or driver carelessness but also due to the physical conditions of the road infrastructure which has suffered from decades of neglect. The author rated Nigerian highways as one of the worst and most dangerous in the world. Some of the reasons that have led to deteriorating states of roads in Nigeria are; overwhelming prevalence, inexperienced political leadership and rational self-interest (Gorham, 2017). The overwhelming prevalence is due to shortage of specialist in town planning, economics and urban development compared to the civil engineers working in the state and federal levels of governance. This gives dominance of professional cadre in the transport sector, as a result, there is a natural bias towards decision making as regards physical construction of infrastructure. Similarly, inexperienced political leaders, lack the understanding of urban dynamics especially in the transport system sector which is a complex system. Transportation challenges are enormous and their causes require more than an inadequate supply of infrastructure. The political leaders face constituency pressure and as such they put undue pressure on organizations or companies, mostly privately owned to deliver infrastructure (road). Nigerian political economy of large infrastructure projects has a driving logic, in which all actors pursue rational self-interest. Contracts are sources of both patronage and kickbacks for most of the actors involved at both federal, political and state levels. Also, the myopic focus on the need for building more transport infrastructure (road) alone, excluding other concerns such as transport management (traffic and parking) and maintenance is a shortcoming. A good transport system that can respond to the dynamic and complex movement of people within a city, resulting in a safe and sound environment, has to be critically examined in its spatial and temporal context, including the subjective perception of the environment and the interactions of the transport elements, in addition to local and expert knowledge. However, road traffic accident factors in Nigeria, addressed individually, and reflects the human behavioural elements in both vehicle and environmental factors. It is therefore considered best for accident causing factors to be examined as a whole, understanding the interaction between the elements. And further giving insights to the where, when and why of the incidences.

2.4. Trends of Road Traffic Accidents in Nigeria

The Nigerian road traffic situation during the last half century has been alarming (Mohammed, 2016). There has been a significant increase in the number of accident cases reported from 1960 (14,130 RTA cases and 1,083 deaths) to 1988 (25,799 accident cases and 5,077 deaths). Statistics from the FRSC report (2015), shows that after the agency was established in 1988, RTAs reduced from 25,799 accident cases and 5,077 deaths to 9,734 accident cases and 5,440 deaths by 2015. However, when compared to developed and other developing countries, these figures are still too high. The FRSC (2016) annual report showed the trend of fatality and accidents from 1960 until 2016. From the graph (Figure 2-C) the highest number of car crashes were recorded in 1976, 1978 and 1982, with a rise in fatality rate from 1960 to 1982. Although the number of crashes has generally reduced since 1982, there has been occasional fluctuations. From 1982 to 2016, the trend of fatality and accidents has generally been on a downward trend. Figure 2-C also shows that since the inception of the FRSC in 1988, there has been a decrease in the number of accidents and rates of fatality. However, the graph also shows that the number of crashes and fatalities are still in the thousands yearly, hence additional mitigations measures need to be taken to further decrease the rate of road accidents and fatalities.

In the annual FRSC (2014) report, the 2013 and 2014 RTA cases were compared (Figure 2-D). Out of the 37 states in Nigeria, the state with the highest number of accident cases was Abuja (FCT[1]). This is consistent with the research work by Daniel et al. (2017) which shows a significant cluster of RTA and death in the FCT. To find out when and where these accidents occur and develop into clusters in specified areas, the accident records have to be examined to a single crash level.

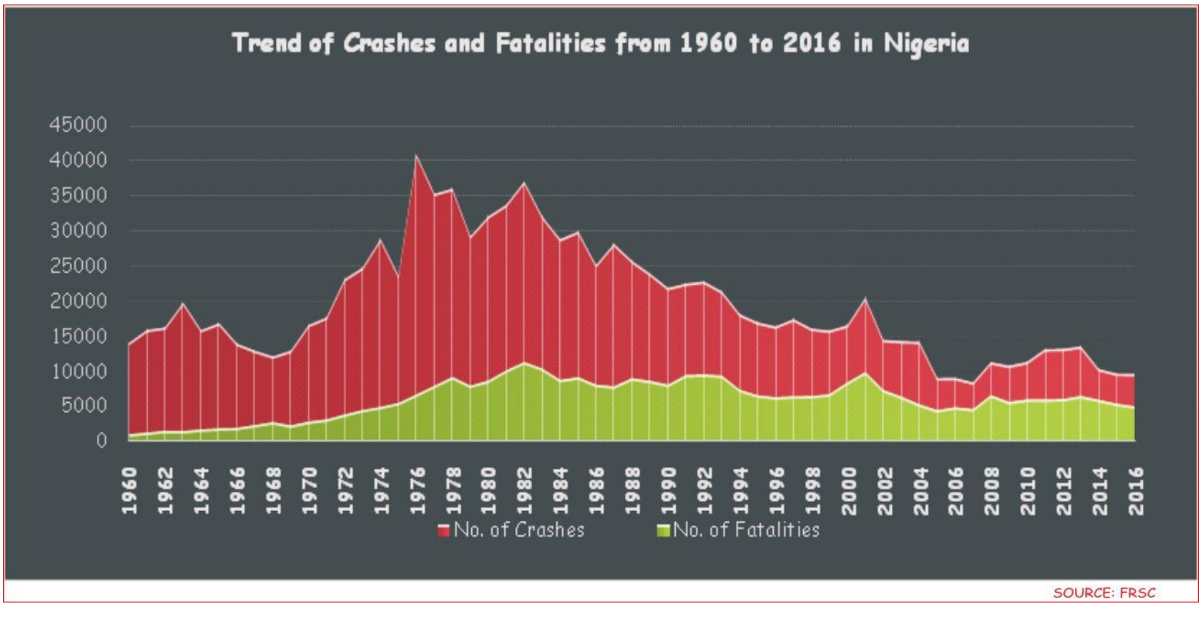

Figure 2-C Accident and fatality rate FRSC (2016)

[1] Federal Capital Territory

The magnitude of RTAs and level of fatality among Nigerian states is visualised in Figure 2-E (Kolawole, 2015). The states were ranked on the basis of their level of fatality per 100,000 population. From the graphs, FCT had a higher magnitude of RTAs and fatality compared to other states in the region. This is because Abuja being the capital city of Nigeria, has witnessed the influx of people from all over the country. This has resulted in an increase in urban population from 250,000 inhabitants in 1990 to a projected population of 2 million inhabitants by 2020. Abuja is among the 25 largest urban centres with the highest annual urban growth rate of 7.2% (Federal Ministry of Transport, 2006). This has also increased the vehicular movement in the city which increases the possibility of RTAs. Additionally, the rapid development of economic activity in the city may have contributed to the higher rates of accidents. With respect to this, this study will have an in depth analysis of the measures the Federal Road Safety of Nigeria have put in place to reduce the high rate of accidents in Abuja city. It is however important to note that these figures are subject to issues of under reporting. These are made up of under recording (follow-up hospital cases involved in accidents) and non-reporting of incidence.

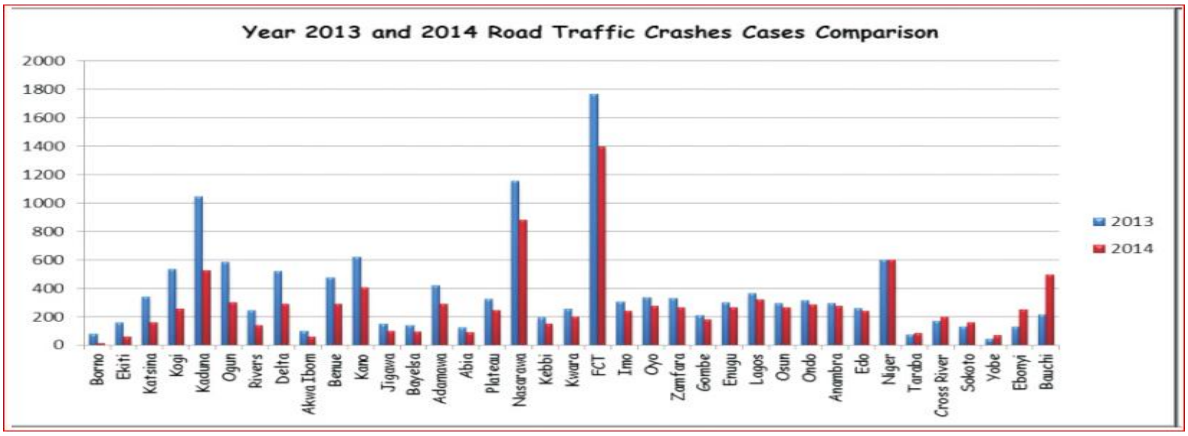

Figure 2-D Traffic Accidents Cases in 37 States in Nigeria 2013 to 2014 FRSC (2014)

In order to help curb the high occurrences of accidents around the FCT, the study will help to critically view spatial and temporal accidents clusters to proffer measures and identify locations that needs urgent interventions.

Accidents Mortality

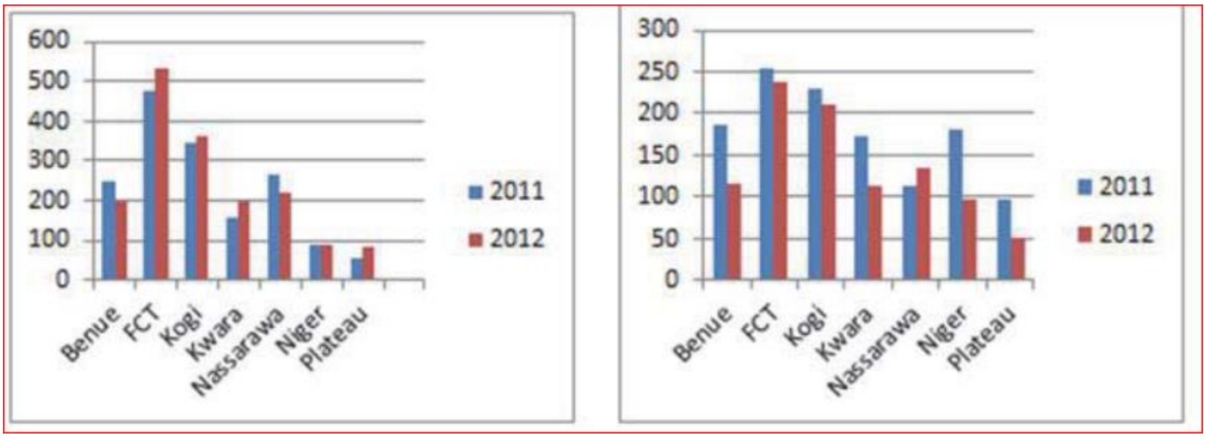

Figure 2-E Vehicle accidents and mortality from 2011-2012 (Central region of Nigeria) Kolawole (2015)

Since human, vehicle, environment and other accident causing factors, are multifaceted variables involved in RTAs. Similarly, RTA mitigation actions such as enforcement, enlightenment (educating the public and individuals), engineering and environment are multifaceted approaches used in reducing accidents (Olajuyigbe et al., 2014). Some methods used in mitigating road traffic problems are: widening of roads, optimization of the existing road network with various traffic management measures, and encouraging the use of public transport. Scientific approaches can be used to describe and examine the accident situation of an area. Accident data, if well explored, can help identify spatial patterns and temporal conditions and provide more insight into incidents.

2.5. Related Literature on Study Area

While searching for relevant literature on related topics with reference to accident data in Abuja, only two related works were discovered. The first, a publication by Olajuyigbe et al. (2014) was an attempt to identify factors responsible for accidents and assess their pattern with the aim of mapping out blackspots in the city of Abuja metropolis. This was carried out using GIS technique to ascertain the spatio-temporal analysis of road accidents around Wuse, Maitama, Asokoro, Garki and Central District Area of Abuja metropolis. Point data were obtained through a primary data collection process using GPS to determine accident prone locations. The research was complemented by the administration of structured questionnaires to produce information on causes of RTA. Hotspots were determined using spatial query operation based on high frequency of accidents and a spatial join was carried for the spatio-temporal trend for the 3 year period data used. To best of my knowledge, this is the only research identified that have used the spatial aspect in accident study within Abuja. The second literature by Mohammed (2016) published by the FRSC, was on the traffic management and frequency of road accident in Abuja. The author aimed to examine the relationship between road traffic management and frequency of RTAs in Abuja. He identified causes of RTAs and frequency relating fatality, and evaluated the institutional capacity of FRSC. Also, issues and extent of cooperation between agencies were determined. Methods employed to describe road traffic situation in Abuja were statistical and non-spatial models. The study found, inadequate manpower, poor funding, inadequate tow trucks, poor road user attitude, and corruption within traffic management personnel. Others were, poor road infrastructure, lack of incentive for performance and lack of inter-agency cooperation between traffic management agencies. Relevant methods that are used in analysing road traffic accidents are discussed in subsequent sections

2.6. Review of Research Methods

An understanding of features exhibited by incidents is necessary prior to the development of expert remedies for reducing traffic accidents. Over the years, various researchers have carried out analyses of RTAs using different methods. Although most methods have positively impacted this field of study, limitations have also been observed. These limitations have led to setbacks in the methodology and usually results in deliberation regarding the appropriate technique required to get meaningful results. For this reason, this section reviews important literature on methods, providing insights into related areas of method application and how the data to be used for this research will be analysed. The research is not focused on improving the appropriate methods for the analysis, but only methods fit for the available data to be used will be applied.

The built environment has been described as street networks and land-use (Granié, Brenac, Montel, Millot, & Coquelet, 2014). Dai & Jaworski (2016) has described the built environment as that which offers opportunities for activities but may become hazard for individuals involved in the traffic. From the traffic system perspective, the built-environment have been referred to road designs, surrounding establishments, infrastructure and land-use type amongst others (Clifton, Burnier, & Akar, 2009; Chen, 2015). Although land-use is not a direct input to accidents prediction models, the association between road traffic accidents and land-use has been studied by researchers on the basis that land-uses generate and attract trips (Priyantha Wedagama, Bird, & Metcalfe, 2006). Flahaut (2004) in his research on the impact of infrastructure and the local environment on road unsafety, the author stated that the built environment played the most significant role in the risk zones. He also found out that the local environment and road infrastructure play a substantial role in the co-occurrence of road accidents. The road infrastructure and land-use will be examined in this research at specific cluster locations. Determining accident causes and hotspots and utilising this with significant location-specific data and interview, gives a better understanding of the process occurring around these hotspots. This is important for allocation of resources for safety improvement (Anderson, 2009).

Spatial point data has been defined as observational data available on some processes operating in space (for example, accident point data occurrences), where methods are required to describe or explain the interaction of the system and its possible relationship to other spatial phenomena (Bailey & Gatrell, 1995). Spatial statistical mapping is key to understanding the spatial and temporal occurrence of accidents. These comprises techniques used in modelling spatial data (Levine et al., 1995a; Prasannakumar, Vijith, Charutha, & Geetha, 2011). Spatial statistical analysis related to road accidents can be performed on a spatial database incorporating all desired information and generating data layers from the available sources and subsequently updated by field verification. Geographically, it is desirable to analyse whether accident events exhibits a spatial pattern so as to better understand the underlying process to generate the events (Delmelle, 2009). Delmelle (2009) further explained that such events are considered discrete because they occur in a specific location. He pointed out that a visual inspection of a map showing locations of events may not always bring a correct interpretation of the true pattern, for example, a distribution map or a scatter plot, especially when the events are recurrent at same locations. Rather, the events should be represented using **bubble plots**, these are generally referred to as **frequency loops** in this research, where the size of a circle is a function of the event frequency (Vandenbulcke-Plasschaert, 2011).

Other methods to explore point data are Kernel Density Estimation, Spatial Autocorrelation, and Wavelet analysis. Similarly, Vandenbulcke-Plasschaert (2011), defined the point pattern method as one used in exploring and comparing spatial patterns of events, where in the case of traffic accidents, collection of accident data, geocoding into GIS, comparative statistics and point pattern exploration techniques are central. From a methodological point of view, he explained most accident researches to be classified into two; exploratory and explanatory models, depending on the purpose of study. The author further advised that exploratory method should be applied first before the explanatory method. This is to help have a first look at the data before exploration. This can be done by the use of basic statistics (descriptive statistic, test statistics, odd ratios etc.) and/or other various spatial methods. Explanatory models are commonly used to estimate the importance several factors may have on the occurrence and severity of accidents. Both approaches are implied in this research, firstly the exploratory followed by the explanatory methods. In order to conduct a reliable analysis of road accident data, it is important to investigate how the accidents point are geographically distributed, find out areas where clusters are observed of more dense concentration and their geo-statistical aspects (Ozkan, Tarhan, Eser, Yakut, & Saygin, 2013). This can be considered in spatial data analysis as, point data visualization (geo-referencing), spatial pattern exploration and point data modelling using geo-statistical techniques. A similar structure is to be observed for this research to attain its anticipated outcome.

2.6.1. Temporal analysis

In an accidents analysis, the time vehicle accidents occur is valuable for understanding factors underlying accidents, thereby improving infrastructure and emergency response (Plug et al., 2011). Statistically, the accident data in this research (2013 to 2017) was decomposed into different temporal intervals, yearly, monthly, weekly and hourly using histograms and spider plots. Spider plots have been used in different analysis to visualize temporal variations (Kuo, Zeng, & Lord, 2011; Plug et al., 2011; Soltani & Askari, 2017; Rahman et al., 2018). Spider plots are used for visualizing accident time series because it is circular and makes examining the complete time distribution quite easier with no interruption. This is unlike a normal frequency graph with x and y axis, the spider plot connects the beginning and end time together, resulting in the time axis being in a circular form (Kuo et al., 2011). In their work, the daily temporal pattern of crime and accidents were determined during the day and night periods and it was discovered that accidents were more frequent during the afternoon rush hour. The time at which vehicle accidents occur is important for understanding the factors underlying accidents and improving infrastructure, emergency response time and counter measures for road safety (Plug et al., 2011). Plug et al. (2011) in their work identified the temporal scale (daily and weekly) with respect to their causes, it was realised that while object crashes occur during the night time, pedestrian crashes were observed at the morning and afternoon periods. It was also observed that there was increase in vehicle accidents during working days (Monday to Friday) with peak on Saturday. Graphs and spider plots are used in this section to describe time series. In the study by Soltani & Askari (2017), similar patterns of distribution were realised for injuries and property damage only with accidents occurrence during the day time. Fatality showed a different pattern with increase in the morning and evening to night times. A similar occurrence noticed with the temporal studies was that the rate of accidents during the night periods tend to be lower.

2.6.2. **Point pattern analysis**

Delmelle (2009) referred to spatial point pattern as data in the form of points, where a point denotes the location of an event. It is desirable to analyse whether particular events (e.g. in crime or accidents) exhibit a spatial pattern. This is to better understand the process that generate the event. The events are considered discrete because they occur at a specific location. Geocoding accidents on a digital road network has a great advantage for safety studies, such as; quick visualization of accidents distribution, fast gathering of relevant information according to specified selection criteria and the evaluation of different variables contained in the database (Vieira Gomes, 2013).

In Loo's (2006) paper on validating accident locations, it is reported that among the 3 alternatives for geocoding road accidents, i.e., address geocoding, approximate geocoding and map grid geocoding proposed by Kam (2003), address geocoding is the most preferable. This is because the second alternative adopts the methodology of randomly selecting a point along a given road when only the road name is known. The third approach resorts to map grid and randomly selects a point within permissible locations, e.g., a road network. Spatial analysis of accident point locations using GIS software requires the establishment coordinates (geocoding) depending on available accident details. The ESRI ArcGIS software provides matching options to assist in geocoding various types of data (Bennett, 2010). Although the first is the most preferable, the second option, which is explained further by Kam (2003) as; when addresses provided are incomplete i.e., not inclusive of either a street number, street name and suburb name or postcode. In these instances a geocoding procedure needs to be devised. This method will be utilized in the analysis of the available data acquired for this research. In the data acquired, street names, intersections and landmarks such as gas stations, places of worship and bus stops are used as references or given addresses. Address data bases area not available hence an exact match to locations cannot be made using an address database or by reference to a landmark database in this case. Though the method is time consuming and less economical in relation to funds, it was a most suitable option for the point data collection.

2.6.3. **Planar and network space**

In a planar space, the study area is characterised as a 2-dimensional homogenous Euclidean space, while the network space characterises point events such as traffic accidents usually in a 1-dimentional linear space (the road network) (Xie & Yan, 2008a). The two dimensional planar world in which events (crime, diseases) can occur anywhere, are analysed using statistical techniques available to ascertain its spatial distribution (Strauss

& Lentz, 2009). The authors stated that accidents are constrained to a linear road network, this affects the assumed expected level of clustering under completely random conditions. Likewise clustering behaviour of motor vehicle accidents is often overstated using standard spatial statistics. It has also been stated that techniques that ignore network constraints can falsely identify accident clustering even with randomly generated accidents distribution (Yamada & Thill, 2004; Loidl, Traun, & Wallentin, 2016). Besides, Braga et al. (2011) stated that there is evidence that the focus on micro-scale in networks reveals hotspots that might not be detectable on the macro-scale or in planar space. This therefore illustrates that network based method is more appropriate for accident analysis. However in this analysis, literature is reviewed as regard to both planar and network-space, this is to help determine the appropriate method that gives adequate understanding of the available data.

2.6.4. Spatial reference unit (aggregate and disaggregate)

Some studies have described aggregated data to hide specific micro-level spatial pattern (Braga, Hureau, & Papachristos, 2011; Lord & Mannering, 2010). Suggesting that analysis at a city level is best understood as larger area units such as neighbourhoods and census tracts might not discover important place-based dynamics that vary within geographical boundaries. While others have based their studies dependent on point data aggregation over definite spatial units and time periods (Levine, Kim, & Nitz, 1995a; Erdogan, 2009; Jones et al., 2008). Vandenbulcke-Plasschaert (2011) explained the individual level, as regard each individual accident as a single point in space (with coordinates x and y). Studies are generally based on discrete dependent variables (for example; vehicle vs pedestrians). This is aimed at predicting mode choice and driver preferences using logistic specifications and methods measuring the global variation in the mean value of the point pattern (Yamada & Thill, 2004; Myint, 2008; Levine et al., 1995a). However, the drawbacks in the aggregated data is that outcomes depend on the spatial unit (Levine, Kim, & Nitz, 1995b). Vandenbulcke-Plasschaert (2011), referred to this as Modifiable Areal Unit Problem (MAUP), which means that the use of different spatial units can lead to different results and conclusions. Regarding the spatial unit to be chosen for an analysis when accidents are aggregated over space, the author listed road nodes (intersections), road junctions (links) and administrative areas (statistical wards, municipalities, counties, regions or countries). Xie & Yan (2008) is one among many who has used the road segment as a unit of analysis and the delineation method such as the quadrat method (Shiode, 2008) or Voronoi diagram (Loidl et al., 2016) has also been used. He further explained that aggregation over space or time serves as an advantage for further statistical analysis and that the choice of an exploratory spatial method depends strongly on the level to which data is available or aggregated. Disaggregated data is best for a spatial and temporal analysis and can later be aggregated to specific segments for use in the analysis, depending on the aim of a research.

Both methods are employed in this research, aggregation is used to determine the significant hotspots using the Spatial Autocorrelation methods. As with most other social science data, accidents are non-experimental data, and the best option for a researcher is to analyse accidents by means of statistical analysis based on observed data (Thomas, 1996). Aggregation is used for the significant hotspot analysis using the road segment as the unit of analysis. This have been used by many studies (Loo & Yao, 2013; Li, Zhu, & Sui, 2007; Thomas, 1996; Satria & Castro, 2016; Lord & Mannering, 2010; Yu, Liu, Chen, & Wang, 2014) as a unit of analysis. Yu et al. (2014) in their study clarified that, hotspot or hazardous road segment identification require road segmentation, where a road is divided into a set of segments with constant length, or homogenous segments with varying lengths. One of the limitations mentioned in this study was that segmenting the road relies on the researcher's subjective judgment to determine the segment length and verifying whether a segment can be considered homogenous. Until recently, the effect of road segmentation on hotspot identification are still not clear. The actual length of road within the study area was used in this analysis. The aggregation of points to segments gave rise to an increase in the number of segments for the analysis. Although this study is not a comparative study of methods for spatial analysis of hotspots identification, the literature review carried out provided a better insight into various approaches that have been used for spatial analysis of road accidents.

2.6.5. Hotspot/black spot and hot zones/black zones

"Spatial autocorrelation is the tendency for the level of a variable at one location to influence the level of that variable at sites in proximity to the first location" (Black, 1991). If positive spatial autocorrelation is present, it results in the clustering of similar variable values. Therefore the analysis of spatial autocorrelation for a linear system such as a highway involves the adaptation of conventional autocorrelation techniques used in point analysis and areal distributions to linear situations. This gives the resulting pattern of either hotspot (black spot) or hot zones (black zones) of clustered patterns of values. The most important question in road traffic accidents analysis is, whether there is significant clusters of accident locations? If yes, where are these clusters located? A Hot spot or Black spot is a location with an observed number of accidents that is higher than expected, in comparison with similar locations as a consequence of local risk factors (Moons, Brijs, & Wets, 2009; Elvik & Sørensen, 2007). Table 9 in the Appendix shows different definition and identification methods of black spots in selected European countries (Elvik & Sørensen, 2007). This also clarifies that there is no specific definition of what a hotspot or black spot entails. Hotspot or black spot definition is dependent on the region or country. However, Brimicombe (2005) have described clustered patterns as one with a significant proportion of its data having a tendency towards exact spatial repetitiveness although with a temporal separation between events. He gave typical examples with crimes recorded against a property address (e.g. residential), traffic accidents recorded against the section of road or intersection, utility failure recorded against a node or discrete section of a network etc. The author further suggested defining the focus of an analysis where spatial clustering exist, either for hotspots or black spots.

In similar studies, Hot zones or Black zones have been defined, as a set of contiguous spatial units taken together and characterised by a high number of accidents (Flahaut, 2004). Hot zones or black zones have been identified with two distinct characteristics; first, most include more than one segment (distinction must not lie on the length of the segment), and secondly, the segments with high crash number must be contiguous (Loo, 2009; Moons, Brijs, & Wets, 2009a). Loo & Yao (2013) gave insights into the portrayal between the two definitions as a junction or an individual road segment with a large number of crashes to refer to hotspot. While with the hot zones, more than one individual road segment is taken together to become a single hot zone, that is, a single spatial cluster of traffic crashes. In other words network contiguity of more than one road segment is an essential criterion for identifying hot zones. However, the procedures and related methodological issues (such as the rules and threshold of hot zone identification) have never been systematically examined. Also, some of the geostatistical techniques for detecting clusters do not consider the specific nature of the network involved, this often leads to biased conclusion (Loo & Anderson, 2016a). The latter two statements are limitations found with the hot zone identification technique.

Loo & Anderson (2016b) described two techniques that are found to discover positive spatial autocorrelation. These are; the local spatial autocorrelation method following the link-attribute approach and the kernel method following the event-based approach. It was also noted in the study that both methods are easily applicable and give comparable results for simplified road segments (for example, exclusive highways or hypothetical linear roads) as independent spatial units with no intersections or analysis of road networks. Though this was said not to be a straight forward techniques because of the special nature of road networks (connectivity) which has to be considered. For the link attributes method, positive spatial autocorrelation is said to be defined by mapping and building statistical models to analyse the attribute values (e.g. collision counts and collision density) of the road segments or Basic Spatial Units (BSUs). The fundamental spatial unit (BSU) of analysis is represented by a geographic features on the road network. Asides the accidents, geometric (road width and gradient) and non-geometric features (traffic volume, and presence of road markings) of the BSUs can be stored in the relational database of the road network.

Additional information are also gotten by assigning traffic accidents to a road network such as, collision type, number of injuries, degree of injuries and number of fatality can be visualised and analysed spatially by BSUs. It is further known that various methodologies of analysing traffic collisions by considering them as attributes of the road features are generally called to be following the link-attribute approach. An advantage of the link attribute is its ability to integrate various key databases such as accidents, hospital, transportation and land-use database in an appropriate network settings. While with the event-based approach, collision are presented as points. This method is further classified into the distant based methods e.g. Nearest Neighbour Distant analysis, K-function etc. and density-based measures such as the Quadrat Count and Density Estimation (KDE). These methods are briefly discussed in subsequent paragraphs.

The main reason the identification of clusters is carried out is to help decision makers in carrying out appropriate measures. Some of these methods are the Sliding Window (SLW) screening methods, the Spatial Auto Correlation (SPA) method & Empirical Bayesian (EB) method (Ghadi & Török, 2017), EB & Kernel Density Estimation (KDE) (Yu et al., 2014), local spatial autocorrelation indices (Moral Index statistics) and Getis-Ord method (Soltani & Askari, 2017), KDE & Wavelet analysis (de Andrade et al., 2014), Nearest Neighbour Distance analysis, K-function analysis, and KDE, (Shafabakhsh, Famili, & Bahadori, 2017) amongst others. Subsequent paragraphs briefly discuss this techniques, looking into their advantages and limitations.

Network Kernel Density Estimation (NKDE) was used to determine traffic accident hotspots (Benedek, Ciobanu, & Man, 2016), it was implemented by the means of the KDE tool in the SANET toolbox. NKDE calculates the density of point type events along a network. However, a limitation for NKDE and KDE is that no formal statistical inference is employed in the process. There is also no indication of a density threshold above which a hotspot can be confidently declared (Xie & Yan, 2013; Xie, Zhixiao, 2008).

Quadrat Analysis is a spatial statistical method used to measure clustering among events. It is made-up of overlaying a uniform grid made out of equal sized quadrats onto a map containing point incidents (Delmelle, 2009). The number of points within each quadrat is determined, importantly, it compares the actual count of events within each quadrat with the expected frequency of occurrence. The degree of clustering in a study area is determined using the variance mean ratio (VMR). Besides its simplicity to implement, some drawbacks are mostly related to cell size and ability of the method to differentiate different spatial patterns of points.

K-function analysis has been used for determining of spatial clustering of unexpected fatalities in traffic accident analysis (Jones, Langford, & Bentham, 1996). It was found that calculation of K-function in the manner described in the study exhibits a number of advantages, one of which is its convenience in avoiding problems associated with integration of scale into the analysis. Yamada & Thill (2004) compared the network and planar K-function methods in a traffic accident analysis. It was found that, the planar K-function analysis mistakenly detects clustered pattern though the observed pattern was actually random. The results indicated that planar K-function analysis was problematic since it has a significant chance of over-detecting clustered patterns.

The Sliding Window (SLW) screening method defines the identification of black spots mostly based on a countries location (Elvik, 2007). The SLW identifies the appropriate start and endpoint blackspot locations along the road segments containing homogenous traffic and similar built-in environment attributes. It requires the input of the window length and a critical number of accidents per spot (Ghadi & Török, 2017). The authors compared methods to identify blackspots. It was realised that longer length had some deviation, i.e. the length of a critical window may not cover any collision and result in partial false positive. This can lead to another drawback on the same window in the same road section revealing that the moving window failed to detect some real black spots identified by other spatial method. The SLW can be more efficient where it can identify less accidents clustering locations based on certain threshold value that represent the average number of observed accidents in similar sections with the same length especially in speed.

Nearest Neighbour analysis (NN) was used to investigate the distribution of urban accidents. This was to determine whether accident points were clustered based on the nearest distance between two neighbouring accident points (Shafabakhsh et al., 2017). It measures cumulatively, the number of points against the nearest neighbour distance. When the average distance is smaller than expected random point pattern, the null hypothesis is rejected in favour of clustering. However, the NN analysis did not prove hotspots in the research but only points out the higher concentration of accidents. The shape of the study area decreases the NN statistic, especially if narrow, because events are next to each other (Delmelle, 2009). Clustering may only be detected on a small scale, in that case, it is possible to extend the statistics to a higher order (second or third nearest neighbour).

Autocorrelation literally means that if pairs of objects are close to each other, they are more likely to have similar values. Identifying a hotspot in Spatial Autocorrelation (SPA) is based on the spatial aggregation of contiguous spatial units that are geographically approximate (Ghadi & Török, 2017). Its assessment is based on measuring the degree of co-variance between spatial units. Positive resulted I index indicate a positive association between variables and a higher covariation. While a negative index I means a negative association between variables, and (0) indicates no correlation between the variables. Statistically, spatial autocorrelation takes into account simultaneously discrete events locations and values into one index I. The statistical significance of Global Moran's I is calculated using a Z-score method. However, when sometimes the Global Index do not dictate the presence of clusters, like the case when equal amount of positive and negative clustering exist, then a local index is also important to detect these locations. Local indices are useful to point at the contribution of smaller parts of the investigated area (Local Indicators of Spatial Association) LISA (Moons et al., 2009b). That is if they meet two conditions: (i) they need to measure the extent of spatial auto correlation around a particular observation and this for each observation in the data set and (ii) the sum of local indices needs to be proportional to the global measure of spatial association. The most commonly used spatial autocorrelation index is the Moran's I, proposed in 1948 by Moran (Moons et al., 2009a). Spatial autocorrelation (Moran's I method) works not only on feature locations or attribute values alone, but on both feature locations and feature values simultaneously. It has been known that, the assumption of structural stability over space may be highly unrealistic, especially when a large number of spatial observation are used (Anselin, 1995). The Exploratory Spatial Data Analysis (ESDA) still ignores this instability e.g. global statistics as Moran's I or Geary's c (as Griffith 1993). The focus on local patterns of association (hot-spots) and allowance for overall spatial association has recently been suggested as more appropriate. For example, Cluster and Outlier Analysis (Anselin in Local Moran's I), Grouping analysis, Hot Spot Analysis (Getis-Ord Gi*), Optimized Hot Spot Analysis and others, are tool for cluster analysis. One that gives more clear insight into clustering is the Local Indicator for Spatial Analysis (LISA), that is, the Anselin in Local Moran's I.

Before any analysis is initiated using LISA, there is need to consider 1) the number of neighbours 2) the value of weights (Moons et al., 2009b). All the same, the indicators are very useful in the toolbox of ESDA techniques as two important interpretations are combined: the assessment of significance local spatial clustering around an individual location, which is similar to statistics of Getis and Ord (1992) and the indication of pockets of spatial non- stationarity, or the suggestion of outliers, similar to the use of the Moran scatterplot of Anselin (1993a). Though the LISA is chosen to be used for cluster analysis for this research, its limitation is that this measure is not uniquely defined, that is, there is no optimal specification of weights this is one of most controversial and difficult in spatial econometrics (Anselin & Florax, 1995).

The work of Flahaut (2004) was the first paper that documented methods for identifying local traffic hot zones (with a binary variable 0 and 1) for individual road segments using the link attribute approach. LISA was introduced to examine the accidents patterns of the crashes on the road segments within the study area in one of the provinces in Belgium. The research also explained advantages of hot zones and logistic regression models which were developed to explain traffic accidents hot zones with road characteristics and local environmental conditions. Loo (2009) also proposed a three stage hot zone methodology and presented the first large scale empirical study of hot zones by comparing the hot zone results with the official "black-site" methodology in Hong Kong. Although hot zones are hazardous to road users in contrast to hot spot analysis, there is no systematic methodology of hot zone identification on road networks (Moons et al., 2009a). Loo & Yao (2013) in their studies have considered the link attribute approach performance to be better and more stable in detecting hot zone to a 93.3 % in terms of identified number. Overall, the two methods (link-attributes and event-based) are said to correctly identify hidden hot zones. Although this varies according to road structure, the link-attribute approach is said to be computationally more efficient. It is a more cost effective solution to coordinate safety improvements along a corridor with multiple intersections (a group of neighbouring hotspots) (Young & Park, 2014) than a single road segment of hot spots, distributed on a network system. The cluster of contiguous hot spots is then treated as hot zone. This method will be adopted in this research.

In summary, factors causing road accidents in Abuja were reviewed and analysed descriptively in this study, LISA is used to identify significant clusters. Division of the road network into BSUs introduces an error term. As such, the actual network length of the road dataset was used. For the identification of hot zones, the global Moran I was first used to check the overall tendency of the study area, to determine whether there is a possibility of significant clustering in the study area or not. Furthermore, the LISA was applied to find significant local clusters in the study region. The **hot zones** are defined in this study as high-high adjacent cluster locations with accidents within the 5 year period and fatal accidents in at least 3 year period located on the highways. This definition is best for this case because if all the high-high clusters are considered, a very high percentage of the road network will be considered as hot zones. It is more economically reasonable to present hot zones of a study area that needs immediate attention. The definition helped in this study to know and critically examine this hot zones locations based on accidents counts and fatality. Temporally, the data was decomposed into different temporal intervals and identification of spatial clusters was carried out to observe the change in spatial pattern over time. Software to be used are ArcGIS and Excel.

2.7. Interview

An interview is a conversation between the interviewer and respondent for the purpose of information gathering from the respondent (Groenendijk & Dopheide, 2003). It is a tool for primary data collection used in surveys. Types of interviews range from structured to unstructured. With unstructured interview, the interviewer does not use an interview guide to ask a pre-defined set of questions nor are the questions asked in a specific order, key points are explored during the interview. Unstructured interviews are said to be the most flexible type of interviews and are recommended when complex problems need to be involved. Because of the person to person interaction, interviews are an important tool in planning and management. They are often used in combination with other data collection methods such as secondary data analysis, observation, and measurement. In this research, unstructured interview was used for primary data collection to aid in supplementing the secondary data, and to give more understanding to the findings of the secondary data analysis. Opinions of interviewees on causes of accidents, the influence of road infrastructure and land-use, as well as possible intervention measures that could help reduce accidents in the study area were acquired.

2.8. Observation

Observation is a method of data collection suitable for investigating phenomena that can be directly observed or measured (Groenendijk & Dopheide, 2003). This can be done either through photographs and/or a filming technique (Híjar, Vazquez-Vela, & Arreola-Risa, 2003). Observations can be carried out systematically during an interviewing process. There is little, if any, of systematic interviewing that excludes observation (Glaser & Strauss, 1967). It can be used in understanding the substantive area the researcher has decided to study and the qualitative sources can be used for descriptive analysis. Observation was carried out in this research to help in assessing junction designs, road signs, road curvature, speed limits, road surfaces, road separations(count method) and land-uses (recreation, commercial, offices, suburbs etc.) using the count method and photographs. This was to aid in knowing the influence of these infrastructure on road accidents. Land-uses that are 1km buffer from the highways and accidents locations were identified using Google Earth Map (Goel, Jain, & Tiwari, 2018). This distance have been used by researchers (Moudon, Lin, Jiao, Hurvitz, & Reeves, 2011; Kam, 2003) from each accident point and confined route to capture physical environmental variables and the buffer zone serving as an exposure corridor. In this research, prominent land-uses associated with each hot zone location were identified by this method. These land-uses are characteristics of the environment created or modified by human interaction and might affect human health (Lopez, Campbell, & Jennings, 2008). This assessment, aided in answering the last part of sub-objective 2 d and enable the proposal of solutions and improvements.

In conclusion, geocoding of accident points was carried out in this research to enable the spatial distribution and analysis of traffic accidents data of the study area. Both planar and net-work base approaches were used in this study. These approaches gave a better understanding of the temporal and spatial pattern of accidents in the study area. Temporally, the accident data was decomposed to visualise and have an in-depth understanding of when accidents occur and their possible causes at specific times of the hour, day, week and month (how pattern changes over time). Aggregated and disaggregated methods were used for the analysis. This aided in the determination of cluster locations depending on the nature and purpose of data. Factors causing accident were aggregated into 3 categories (human, environment and vehicle factors), this gave a better understanding of each factor as it relates to accident causes. Frequency maps gave more insights into cluster locations in the study area. Using the road network as a unit of analysis for aggregation, the Moran I and subsequently LISA were administered for the cluster analysis. Significant cluster locations with accidents occurrence within the 5 year period and 3 to 5 year fatality were considered as hot zones. Interview and observation gave more weight to the study because perceived view of individuals were acquired in relation to the cluster location and accident causes. Observation of the locations, carried out provided additional facts about the surrounding areas as well as the influence of infrastructure in road accidents. This gave more understanding to the spatial pattern of accidents occurrence and insights into the major causes of accidents in specific locations. Tools used for the analysis were ArcGIS and Excel.

3. DATA DESCRIPTION, STUDY AREA AND METHODS

3.1. Secondary Data Description

Traffic accident data obtained for the research was acquired from the FRSC and contained the following variables: location (time, day, month, year, number of vehicles involved, vehicle categories, possible causes of accidents, and number of people killed, injured and involved). The recorded road traffic accident data, from the year 2013-2017 shows a total of 7,016 occurrences in Abuja.

Although the FRSC is the lead organisation responsible for ensuring safety on the roads, data on reported accident cases in Abuja metropolis was also acquired from the Nigerian Police Force (NPF). This was done to verify the robustness of the data from FRSC and to make a data **comparison** of **attributes** of the occurrences, and the number of **reported cases**. The NPF had a yearly summary of accident data extracted from a record book containing details of each reported accident case. This data was available in hard copy (paper) format only. Using the yearly summary data was the most practicable option available, because of the volume of data involved and the limited time and resources available to convert the data from hard copy format into an excel file. The data from the NPF had a total of 7,041 reported accidents cases in Abuja between 2013 -2017. This figure was observed to be quite comparable to the one obtained from FRSC (7,016 accidents) for the same period. The variables in the NPF accident data acquired were: number of vehicles involved and vehicle categories, types of accident (fatal, serious and minor), number of persons killed, number of persons prosecuted, cases under investigation, cases closed, number of people affected, accident causes e.g., excessive speed, driver carelessness at road junction, improper over taking, inexperienced drivers, intoxication, recklessness and negligence of driver, overloading, mechanical defects, obstruction and stray animals. Although the main variables were slightly different from those used by FRSC, the data appears to give a good understanding to the various causes of accident and the cluster locations. Thorough data scrutiny and investigation is essential to get this information into a workable database. The accident data for the analysis was acquired for a period of 5 years (2013 to 2017). This research focuses on the first eight variables as shown in Table 2.

Table 2 Accident variables in excel sheet (FRSC) Author (2018)

Variables	Types of indicators
Date	Day, month and year.
Time	Accident time, report time, arrival time and response time.
Locations	Streets, landmarks and accident point description.
Routes	Route name of accidents
Causes	Speed violation, dangerous driving, sign light violation, wrongful overtaking etc.
Injured	Number of people injured.
Killed	Number of people Killed
Involved	Number of People involved

Road network data with district boundaries of the city and land-use map were obtained from the Development Control Unit (DCU), of the Federal Capital Development Authority (FCDA) in Abuja. The data was obtained in an AutoCAD format. Road networks are very important in traffic accident study, because accidents occur on road network systems. However, in other to get a detailed understanding of the road categories, an extracted road network from Open Street Map (2018) was obtained. The data to be used for the study is shown in Table 3. Recorded accident cases from FRSC, literature from online sources and organisations, as well as cadastral maps from Abuja Geographic Information System (AGIS).

Table 3 Data description Author (2018)

Data	Availability/ Format	Year	Description
Accidents data (tabular form)	Federal Road Safety (FRSC)/ Excel data Nigerian Police Force (NPF)/Paper document.	2013-2017	Statistical data (no. of deaths, defects in vehicles checked, injured, causes of RTCs, accidents cases by sex)
Literature	Online/Organisations e.g. FRSC	--	Literature related to research study
Network of roads in Abuja	Online/Open Street Map/ Shapefile	2018	Tertiary, Primary and secondary roads of Abuja
Satellite Image/Cadastral Zone Maps	AGIS/PDF	2010	Geographic district boundaries of Abuja
Map of Abuja	FCDA/AutoCAD/TIFF	2015	Map with, road network, municipalities and districts in Abuja.

3.1.1. Data Formatting

After the secondary data of reported accident cases was collected from the FRSC, there was a need for appropriate data cleaning (formatting of date and time, vehicle category, possible causes etc.). This was carried out before the data was put to use. Three technical staff helped with data cleaning and selection, while two skilled personnel (5 research assistants) were employed to help with the accident point data extraction. The process for the secondary data cleaning and processing lasted for about 4 weeks (from March 23 to April 25, 2018). This data contained selected variables e.g., the location description, route names and dates of accident. Formatting of address description and route locations was carried out manually using Microsoft Excel, for accident occurrence in Abuja Municipal Area Council (AMAC) district. AMAC is one of the six municipal councils in Abuja, Nigeria (shown in Figure 7-A) in which the study area is located. This district was chosen because it is located in the Central Business District (CBD) area of Abuja and contains the major routes in the city. Data cleaning of the entire accident data was followed by thorough checking of the spreadsheet containing the original accident point locations from the FRSC to ensure accuracy of address locations, route names and dates of accidents. All discrepancies in some text codes in the recorded accident data was clarified by the responsible government authorities who provided the data. The checked data from 2013 to 2017 was hand-inspected, colour coded and assigned on the specific selection format styles using excel sheet. 'Good' was assigned if the selection was for the AMAC (colour code green), 'check cell' or 'neutral' (colours codes grey or yellow) if the selection was to be verified, and 'bad' (colour code red) was assigned if the selection was a left out location.

3.1.2. Steps to Georeferencing

The unavailability of digital geocoded point data in the accident data collected from the FRSC and NPF, was a major limitation, the second objective of this research would not have been achieved with this data limitation. To identify the spatial distribution of vehicular accidents in AMAC, georeferencing of recorded accident data had to be carried out. Geocoding is a basic requirement in point pattern analysis (Delmelle, 2009). The FRSC accident recorded data of 2013 to 2017, was used for this purpose since it was more detailed and contained in a database spreadsheet. Although spatial information has been traditionally acquired through field surveys, this is time consuming (Niebergall, Loew, & Mauser, 2008). Therefore, prior to data georeferencing, the different road networks of AMAC were assessed by inspection and interpretation of the satellite image. This was carried out to get familiar with road networks and locational routes, by considering locational routes with high rate of accident occurrences, AMAC had a total record of 3,297 accident data, and this is almost 47% of the entire recorded accident data of Abuja.

In this study, accident locations were geocoded based on random geocoding procedure devised, explained in section 2.6.2. Using this method, points could be selected randomly along the street as earlier stated. But for this research purpose, a method was devised and the accidents points were manually extracted via, Google Earth. This was a preferred option because, Google Earth gives access to street names, routes and landmarks available in the address location and route descriptions of the accident data. Qin, Parker, Liu, Graettinger, & Forde (2013) in a study on intelligent geocoding, verified the consistency between intersection locations on the Wisconsin Information System for Local Roads (WISLR) map and Google Source maps. This was carried out by importing intersection names in WISLR into Google Source maps to obtain the Universal Transverse Mercator (UTM) coordinates for each intersection. On comparing, it gave a 90% high agreement between Google Source maps and WISLR map. This gave a confirmed assurance of Google Earth Map as a referencing tool. Various authors have also used Google Earth maps in network analysis (Goel, Jain, & Tiwari, 2018; Delmelle, 2009; Vandenbulcke-Plasschaert, 2011; (Kuo, Lord, & Walden, 2013).

Extracting the corresponding accident records, (i.e., road accidents falling within the boundary of defined study area) was introduced. This was to enable matching of accidents records to the road network, as map layer of accident locations have to be created with precise geographic references to accident sites (Kam, 2003). Information contained on location of accident mentioned in the FRSC data consisted of the description of accident points along with landmarks, distance away from accident location in meters, road junctions, bridges, names of suburbs and U-turns. Some location description used in the data includes:

- 50 m from zone 4 overhead bridge
- Head of service junction by federal secretariat
- Phase 3 junction
- Dei-dei (name of suburb)
- NNPC by 2nd gate (that is, Nigerian National Petroleum Company by second gate). A gas station.
- Cross junction before Kagini (name of suburb)
- NNPC U-turn

Information on routes includes, name of roads where each accident occurred. Examples include:

- Gwarinpa express way
- S/Shagari way (meaning Shehu Shagari way)
- KUB-ZUB (names of suburbs meaning Kubwa to Zuba on the express road).
- KUB-ABJ (names of suburbs, meaning Kubwa to Abuja on the same express road but signifying a different direction).

For dates, information consisted of day, month and year of accident occurrence.

These details found in the record database were used in point extraction using Google Earth. The Open Street Map was also used for some locations and street address verification. The following were steps undertaken:

- Using Google Earth, routes and dates, as well as accident points from the acquired data were individually searched by their locational addresses, according to the year of occurrence (2013-2017).
- To extract the accurate distances (meters) specified by the addresses of the location for a specific accident incidence, the ruler tool on the menu bar on Google Earth was used. The ruler gives options of different scales (meters, kilometres, centimetres, inches, yards, miles, degrees etc.). In this case, all measurements were recorded in meters (m). After activating the ruler tool, the mouse navigator was then used to click on the landmark location described by the address and the distance between the location (e.g. 10, 50 or 60 meters after or before a landmark as specified) and the actual point of the accident was measured. This distance location is taken as a point where the incidence had occurred.
- The route description provided, showed the direction of a moving vehicle by the indication on the route name along a specified direction for example; KUBWA-ZUBA indicates a vehicle moving along the Murtala Mohammed Express (Figure 3-A) from the East to the West of the highway. When the route description reads ZUBA-KUBWA, it indicates a vehicle moving from West direction of the same highway to the East but on the opposite lane.
- In cases where addresses were not shown on Google Earth, the OpenStreetMap, a free open licensee software of the map of the world, was used to search for the address location of the specified incidence. After these locations were identified, the actual accident points were then traced on Google Earth.
- A drop pin (a point location identifier feature on Google Earth) was used to mark the identified accident locations and then labelled in Google Earth. This was carried out for the entire data for each year.
- After identification and extraction, the points were exported from Google Earth. The extracted accident points were then saved as Keyhole Markup Language (KMZ), imported into ArcGIS and then converted into a shapefile. The attribute table of the shapefile which is now a point data was opened and the x and y coordinates generated.
- The updated attributes with the x and y coordinates was then exported as a Comma-Separated Value (CSV) file and further imported into Microsoft Excel environment. This was then updated with the serial number and date of the original data. Errors were checked in extracted point data as stated in section 3.1.1.
- Finally, the updated CSV file was imported into ArcMap and exported as a Database File Format (DBF) to enable easy data manipulation for further analysis. It is believed that sufficiently, accurate approximation of accidents locations for this study has been achieved. Geo-validation of the point data (2013-2017) is recommended for future studies.

After georeferencing, the 3,297 accident point locations (with x, y coordinates), a total of 237accidents were considered as not having 'specific location description'. These are locations that had no clear or specific location depiction, or no longer existed (due to use of temporal land marks) and locations not found (probably due to development purposes). These were not included in the data for this study. For the research purpose, further exploration of the accident point locations was carried out, areas seen with high accidents occurrences mostly situated around the city core and high concentration of accidents on routes were selected. As a result, the point data was reduced to 1713 accident points (number of accident points to be used for analysis). The map in Figure 3-A shows the road networks within the study area with major routes namely; Murtala Muhammed expressway situated on the North-Eastern region of the study area, Nnamdi Azikiwe expressway, this is seen running centrally from the North to the South-East of the study area, and the Umaru Musa Yar'Adua expressway which runs from the central area to the South-West of the study area.

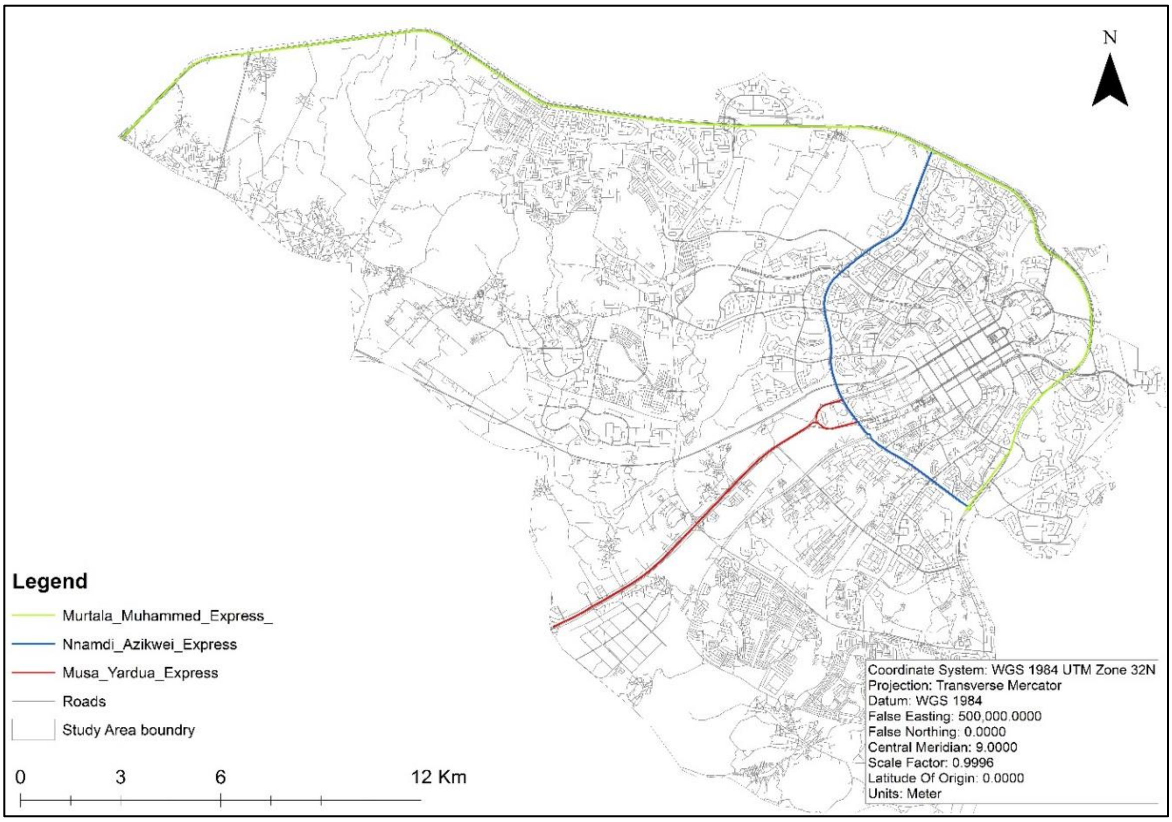

Figure 3-A Road Network with Major routes Author (2018)

3.2. Study Area

Abuja is the Federal Capital Territory (FCT) of Nigeria. Abuja is located in the central region of Nigeria, North of the confluence of two rivers, River Niger and River Benue. It has a land area of about 8000km2 which makes it almost two and half time the size of the former capital of Nigeria (Lagos). The city has an estimated population of 3 million people, but its day time population grows to 7 million (Abubakar, 2014), making the city the fourth largest urban city in Nigeria after Lagos, Kano and Ibadan. Abuja has experienced a very high growth in population over the years and its urbanisation rate of 8.2% per annum makes it the fastest growing city in Africa (Myers, 2011).

Abuja is also geographically located at the intersection of two highways connecting the Northern and Southern parts of the country. These highways make the city more accessible from different parts of the country. The city has witnessed an increase in industrialization, and most companies desire a main or branch office, or a company outlet in the Federal Capital City (FCC). In terms of commerce, activities in Abuja have expanded, corner shops have grown into big shopping malls, shopping stalls and mini-markets. The city now enjoys the presence of an international modern market which is fast expanding (under construction). The residential property market in the FCC has since taken a different phase. Most old buildings have been replaced by modern ones in other to adhere to the new Abuja master plan design for the city. All these and other infrastructure changes makes Abuja one of the fastest growing cities in Nigeria. This has contributed to increase in motorization and in the rate of accidents in the city

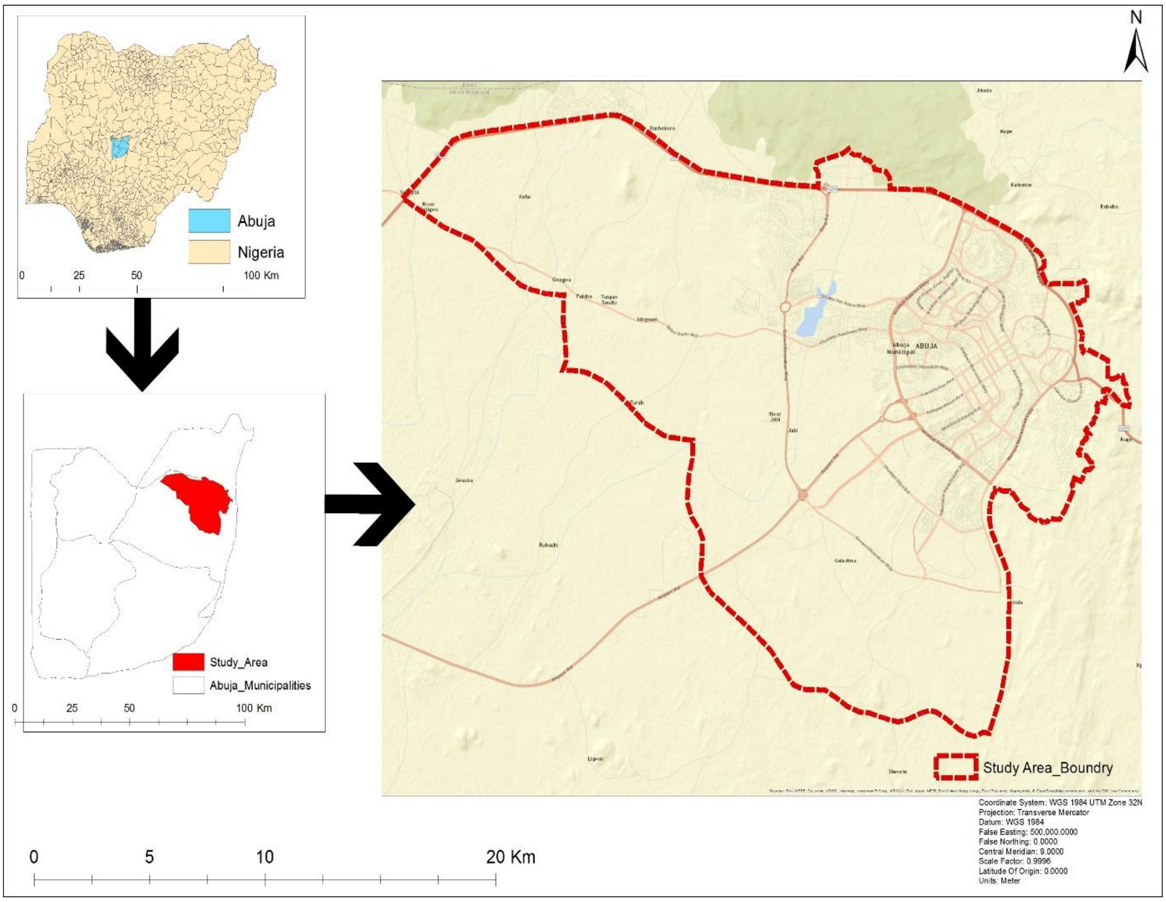

Figure 3-B Study Area Author (2018)

The total length of federal roads in Abuja was 244.60km as at 2014. With a total of 227km for asphaltic concrete and 17km for gravel earth. The trunk routes total 146km and secondary routes are in total 98.6km. (Nigeria, 2015). The geographic extent of the study area was narrowed down into district levels by selection of a number of routes with high accident rates. This was decided after getting an insight into available recorded accident data from the FRSC. The study area consists of a major part of the Cadastral Zone where most activities of the city dwellers is concentrated, this is shown in Figure 3-B. It visualizes the map of Abuja showing the cities six municipal areas. Abuja municipal area council (AMAC), the study area is shown in red and further has the red boundary line, it is known as Federal Capital City (FCC).

3.3. Research Methodology

A mixed method approach is implemented in this research. The mixed method is used to explain research that integrates both quantitative and qualitative study within a single project (Bryman, 2012). In a mixed method study, the quantitative and qualitative arms often run either sequentially or concurrently (Griensven, Moore, & Hall, 2014). In the secondary data collection process, quantitative methods were used which involve the georeferencing of recorded vehicular accidents acquired in tabular form from the FRSC. This is the main data used for the research. Quantitative techniques are used to descriptively and spatially analyse results. The primary data collection entail the qualitative aspect aimed at reviewing literature, Focus Group Discussion (FGD) and fieldwork observations. The mixed method approach is further illustrated on the method workflow on Figure 3-C. It shows in summary, methods used in the research work, the colours in the methodology chart gives a better explanation of what methods are for the specified objectives numbered 1 to 3.

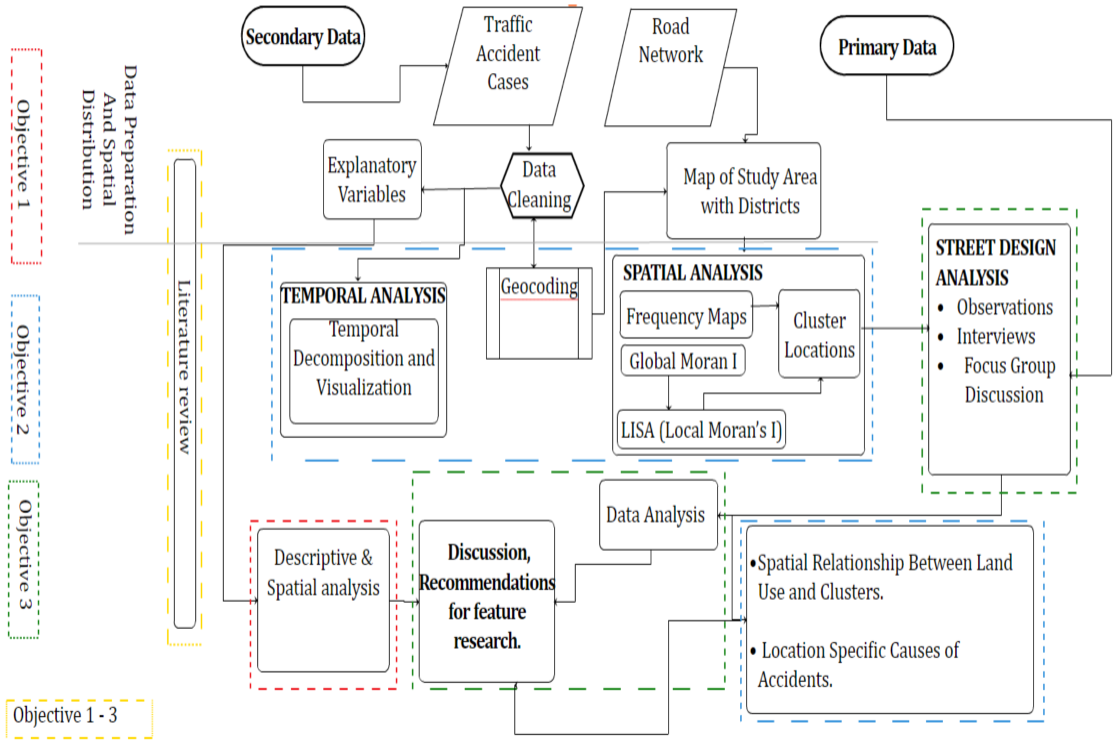

Figure 3-C Methodological Workflow

3.4. Descriptive Analysis

The geocoded point data was matched with variables of the recorded accidents. This was to aid in relating each accident location to its variables and ease the analytical process. This section describes the use of descriptive analysis of the associated accidents data in the study area. Exploratory graphical analysis and descriptive statistics have been used to evaluate data (de Andrade et al., 2014). de Andrade et al. (2014) examined the prevalence and descriptive characteristics of fatal traffic accidents in a Brazilian highway, temporal description was carried out by hour, day and month. With respect to weather condition, it was observed that most of the fatal accidents occurred during clear skies conditions which constituted 51% while 20% occurred under cloudy weather conditions. A heat map was used to compare the number of fatality by crash type during the study period. The available data for this analysis is deficient in record-keeping, hence it limits the use of complex methods for analysis. The section descriptively gives understanding to vehicular accidents that have occurred and their possible causes. The unit of analysis in this section is the accidents, this is analysed based on the accidents causes which are categorised into three. These categorise are; the human, vehicle and environmental factors, as has been described in sections 2.1 and 2.3. The factors provided in the data set are mainly explanatory variables. Categorical independent variable in the data set to be used in the analysis are; number of people injured, number of people killed, number of people involved in an accident. Descriptively, variables responsible for accident were explored, identified and visualised graphically. This gave more insight to the where, when and what causes are related to the accidents.

3.5. Temporal Analysis

The decomposition of accident data was performed using the Microsoft Excel Software. The data was decomposed based on day, month and yearly intervals. This was to help in understanding the temporal variation between the periods and hours to which traffic calming measures could be effected.

3.6. Spatial Analysis

Spatial statistical methods are exploratory methods that are used to spatially analyse data. Statistical mapping has been considered key to understanding the spatial and temporal occurrence of accidents by various researchers (Plug et al., 2011; O'Sullivan & Unwin, 2002; Levine et al., 1995b; Moons et al., 2008; Moons et al., 2009b). The statistical possibilities of ArcGIS is explored specifically to better understand spatial autocorrelation method in accident analysis. Factors causing accidents are visualised spatially and clusters of this accidents examined. The steps through the cluster analysis are provided in subsequent sections.

3.6.1. Snapping points to segments

The road network of the study area was used for the process of positioning the traffic accidents data on the road network this was to check the location accuracy of the points on the segments (Dereli & Erdogan, 2017). After georeferencing of the accident data has been carried out, miss-specification of its spatial variables had to be corrected. This is vital to assess and validate the spatial locations before any scientific analysis of this nature is carried out (Loo, 2006). In this step, the accident locations was checked in ArcGIS using the select by location tool. This tool allows you to select features based on their location relative to features in another layer. Almost 99% of the accident points did not coincide with the network centre line. To geo-validate the point locations, the snap editing tool was used in the ArcGIS to move the point locations to coincide exactly with the line vertices. The snapping rules specified is to control whether the input vertices are snapped to the nearest vertex, edges, or endpoint within a specified distance. In this analysis, only the vertex was assigned this was in other for the tool not to modify the data input to an undesired result. The parameters used in this case were, lines (roads, input feature), points (feature), vertex (type) and 10 (unknown distance). In the snap environment parameter, if no unit is entered with the distance (i.e., 10 instead of 10 meters), the linear or angular unit from the input feature's coordinate system is used as default. Loo (2006) describe the snapping procedure to allow generation of precise accident count and density on each centreline for further analysis. These parameters were considered based on the nature of the data used, and might differ in other instances. The output was verified using the selection tool, and it was observed that 1664 points out of 1713 accident points were selected, which is, 97% of the locational points. These were snapped to 652 segments out of a total of 11,244 segments.

Aggregating the points to the road segments gave rise to increased number of road segments resulting to double counting. This is because accidents can happen at meeting points of an end node of a segment and the start node of the following contiguous segment. When counted towards both segments, double counting arises (Loo & Anderson, 2016b). Loo (2009) suggested resolving this issue of double counting by assigning accidents to one of the segments through random selection or through predefined rules. Loo & Anderson (2016b) recommended the minimum and maximum x (xMin and xMax) and y (yMin and yMax) coordinates of each segment to be calculated. And afterwards assigning the accidents to one of the segments according to their locations, such as the left (smaller xMin), the right (larger xMax), the upper (higher yMax), the upper (higher yMax), and the lower (smaller y Min). Other methods were explained that solve the issue of double counts in aggregation. For this research, a method was devised to deal with the double counting found during aggregation that gave the actual number of High-High segments.

To understand the road network and its connection to accident points, the attributes of the network was explored. This was to provide additional understanding on the number of accidents that had occurred at segments and intersections and needing attention or investigation Table 4 shows the road types, total number of segment and intersections in the study area for the primary and secondary roads, trunks, services and residential. The motorways were joined to the primary roads because there seem to be connectivity between the two types of roads. Table 4 does not give the total number of segments and accidents to be used in the research as other attributes (barricades, stairs etc.) contained in the road data are not included on the table.

Table 4 Characteristics of Traffic Accidents on Segments and Intersections Author (2018)

Road Type	Total Segments/Links	Segments/Links with Accidents	Total Accidents on Segments/Links
Primary Route	223	79	**459**
Primary Links	291	75	**120**
Secondary Routes	482	83	455
Secondary Links	109	14	39
Trunk Route	82	13	38
Trunk Links	20	1	1
Tertiary Routes	156	33	120
Tertiary Links	7	-	-
Services (open spaces & parking)	179	26	63
Residential Routes	7481	88	143

3.6.2. Cluster analysis

The identification of the appropriate method for clustering is one of the specific objectives of the study. As stated in section 2.6.3., the network space characterises point events in a one-dimensional linear space which is the road network. This is because accidents are constrained to a linear road network which affects the assumed expected level of clustering under a completely random condition. Since techniques that ignore network constraints can falsely identify accidents clustering, the focus is then on micro-scale in networks as this reveals details that might not be detectable on the macro-scale. As already noted in section 2.6.5., Loo & Anderson (2016b) has explained the methods commonly used to determine dangerous locations in traffic collision as the local spatial autocorrelation method following the link-attribute approach. The road network for the study area in parts of Abuja metropolis has a total length of 3,237.68km (11,244 segments). Having the road accidents constrained to the road network, some of the disconnected segments noticed, were manually edited (digitized) to ensure connectivity. This was to ensure adequacy to adapted methods and parameters used.

The Global Moran I was first used to determine the overall tendency of the integrated accident data i.e., the possibility for statistically significant clusters (test of significance of Complete Spatial Randomness) for the entire study area. The road segments were used as the basic unit of analysis. The two important things to consider were the number of neighbours and value of weights. For the value of weights, using the Inverse Distance, nearby neighbouring features have a larger influence on the computations for a target feature than the features that are far away. Since the analysis is to take nearby incidence into consideration, this was an ideal choice (in respect to the surrounding environment). This is agreeing to Tobler's law of geography (1970) "All things are related, but nearby things are more related than distant things". Therefore the contiguity of an area with its adjacent neighbours plays a vital role. However, Moons et al. (2009b) clarified assigning all locations in a neighbourhood of a certain locations a weight equals to 1, and other locations a weight value of zero. This does not account that locations are not uniformly spread. But it only seems natural to account for the distance between locations to determine local autocorrelation. In their analysis, different weight function were compared, it was realised that the inverse distance and the inverse distance squared had very little difference in the number of hotspots (about 3%). After contemplation on the distance threshold to be used for this research, it was observed that a default parameter gave almost a 1 km (911m) threshold distance for the study area. It was then concluded that a 1 km distance threshold would be assigned. This was necessary because each data point is analysed in terms of its neighbouring data point defined by a distance threshold. This distance has also been proved by researches to yield a positive result. Moons et al. (2009b) and Truong & Somenahalli (2011) are among researchers that have used this distance threshold. Spatial weights were standardised using the row standardization where each weight is divided by its row sum (the sum of weight at each location and its neighbours sum up to 1). This aided in establishing the extent to which the observed spatial pattern was clustered. The result is shown in Figure 7-B in the Appendix section.

To identify the location of road accident clusters, two local methods were employed, firstly, frequency maps were used to visualize accident patterns and location of clustered accident points in the study area. The frequency loops gave the true interpretation of event occurrences especially at locations where accidents had occurred repeatedly within the 5 year study period. In this case, the size of a loop symbolises the number of accidents occurrence in the location. It was obvious that clusters were seen distributed around specific locations of the study area. A disadvantage with this method is that it does not give significant clusters. Spatial statistical unit (roads) make it possible to consider not only the attributes of identified clusters but also those of white zones. A **white zone** is considered in this research as a hot zone location that has respondent positively to safety measures which has been put in place.

Secondly, LISA was used to determine accident clusters in the study area, further in-depth analysis of the accident clusters gave more understanding of contributory factors to accidents as well as measures that have produced positive results at a white zone location. Parameters used from the Global Moran I were used in the local spatial analysis (LISA). A 1 km threshold distance was used, the inverse distance normalised by row standardization and equation 1. The local indices are considered to be LISA if they meet two conditions

- It needs to measure the extent of spatial autocorrelation around a particular observation, and this for each observation in the data set.
- The sum of local indexes needs to be proportional to the global measure of spatial association (Moons et al., 2008).

The local version of Moran's I at location i that satisfies the above two requirements is written mathematically as follows;

Equation 1: Local Moran I

$$I_i = \frac{n}{(n-1)S^2}(x_i - \bar{x}) \sum_{j=1}^{n} w_{ij}(x_j - \bar{x})$$

Where
$\bar{x}$ = mean value of accidents
S^2 = variance of observed value
n = total number of segments and
x_i = representing the value of interest of variables (accidents) on segment i.
w_{ij} = the weight representing the proximity between location i and j, with $w_{ij} = 0$

The local indices were generated for better clarification of clusters in the study area. This was also to select only highly significant clusters, using the p-value and z-score. To do this, permutations (499) were used to determine how likely it is to find the actual spatial distribution of accident points. And so for each permutation, the neighbourhood value were analysed randomly and the Local Moran I value calculated. Only locations with significance of $p < 0.01$, that is high-high clusters were selected. A limitation found with the method was the selection of a whole segment as a hotspot when just a part has accident concentration, however this is backed up by literature as stated in section 2.6.5., that it is more cost effective to treat multiple intersections along a corridor than single segments distributed around a network. The aggregation resulted in double counting on some segments and intersections that had more than one accidents points. This segments replicated during aggregation and gave rise to a higher number of segments. This do not render the result invalid as the location of hotspots still remain the same but increases only the number of hotspots segments. The error term in number of High–High (H-H) hotspots generated was overcome by devising a method were each replicated segments were counted serially as one segment. Only the H-H significant hotspots were considered because they are the main focus of the analysis.

To identify the hot zones as defined in section 2.6.5., as a location based on accident frequency during the 5 year period. This was carried out by assigning a location score of either 1 or 0 to a hot spot segments dictated. For example, 1 was assigned if accidents occurred and 0 if no accident occurred within the 5 year period (2013 to 2017), this was done for all the years. Cluster locations that had a total score of ≥ 3 years were selected. Fatality was introduced in other to refine and ascertain the severity of the cluster locations. Similarly, fatality score (2 and 0), 2 was assigned if death occurred in an accident while 0 was assigned if no death occurred. Locations with ≥ 3 year's fatality were selected. The selection procedure is fit for the purpose of helping meaningful resource allocation for road traffic problems. Although data on traffic intensity is not available in this case to ascertain high traffic on this routes, it has been said that naturally more accidents are anticipated on high–traffic highways (Yamada & Thill, 2007), also, freeways are said to have higher traffic intensity than regional roads (Flahaut, 2004). This was confirmed in this research by Table 4 where it was discovered that more accident occur on the primary segments and links (of the highways) in the study area. These hot zones were selected on 3 major express roads in the study area namely; Musa Yar'Adua Express (Airport road), Nnamdi Azikiwe Express and Murtala Mohammed Express (Kubwa Express). These are qualitatively analysed and visually presented in the results section.

3.7. Primary Data Collection

The next step was the primary data collection, by the researcher. The results of the secondary data analysis were used in the identification of location sites for the field survey. The primary data collection in general aided in the identification of specific causes of accidents in a location complemented the interpretation of the results of the secondary data analysis. The street survey was used to identify features of the urban design that may cause traffic accidents, after spatial clusters of accidents were identified. This was carried out in stages and includes; observation, interviews and a Focus Group Discussion (FGD), to get additional information to enhance the secondary data and provide an in-depth clarification of the problem of study. Field survey was undertaken to answer to objectives 2 (d) and 3.

3.7.1. Reconnaissance survey

The survey was to explore the sites conditions and infrastructure. The investigation of the 3 major highways in the study area focused on the 14 identified hot zone locations. The two day reconnaissance survey, conducted from 9th May to 10th May 2018, started with a one day online study using Google Earth and an existing orthophoto map of the study area to examine the highways and corresponding segments. This provided a better insight to the exact hot zone locations prior to the survey visit. The second day was the visits to individual sites, stating with Umar Musa Yar'Adua Express, which had 3 hot zone locations; Kuchingoro Junction, MRS Gas Station, and National Space Research and Development Agency

(NASRDA). The second site was the Nnamdi Azikiwe Express which had 9 hot zone locations to be visited. These hot zone locations are; Apo Roundabout, Ahmadu Bello Way, Garki junction (Area 3 junction), Independent Avenue flyover, Zone 7 Bus stop, Berger Roundabout, Mabuchi junction, Banex junction, and Nicon junction. The third site was Murtala Muhammed Express which consisted of 2 hot zones locations; Federal Housing junction (flyover), and Gwagwa intersection were visited. It was observed that 2 of the 14 hot zones locations were minimal activity areas, and were located on the Nnamdi Azikiwe express namely; the Independent Avenue flyover and Zone 7 Bus stop. Prominent land uses around the Independent Avenue flyover are the National Stadium and the National Hospital (public facilities). The Zone 7 Bus stop had offices, a school and residential buildings. These two locations had similar characteristics of a site with minimal activities, they were still considered as individual locations for the data collection exercise. The other 12 locations were seemingly vibrant locations with various activities ongoing. A common feature recognised in all the 14 hot zones were the presence of adjacent or connecting hot spot segments at each location, these were termed as a location. From the observations made, an observational checklist was developed for the field survey. The 15th location known as the Dei-Dei junction, was a white zone earlier described in section 3.6.2. It was identified from researcher's local knowledge of the area and was confirmed by the FRSC officials. The site amongst all was still the most active site visited in terms of activities and population seen around the segments.

3.7.2. Interview

Not all occurrences are accessible to the researcher for direct observation (Groenendijk & Dopheide, 2003). For this reason, data was further collected through communication with individuals, using unstructured interview. In trying to get more information about the complex issue of the traffic accidents around the specific hot zones, the interview was initiated with residents, pedestrians, drivers and workers around the cluster locations as target group. With this, it was difficult to obtain a sampling frame for the selection, because population growth fluctuates in space and time for all geographic areas making it difficult to define at risk population especially for pedestrians (Kulldorff & Hjalmars, 1999; Assuncao et al., 2007). This is indicated as population shift bias. Based on this, individuals were selected randomly along hot zones, junctions, intersections and segments. The open ended interview gave the respondents freedom to respond freely (Bryman, 2012) and in their own languages.

Hot zone locations with activities and land uses like malls, plazas, corner shops, petty trade stands and junctions leading to suburb areas had a reasonably higher number of people and more respondents, compared to the other 2 locations that had minimal activities. The data collection process lasted for 2 weeks, and some locations were visited more than once and at different time periods, especially those with more vibrant activities. This was to investigate situations at different periods. For instance, during morning rush hours (8am to 9am), the afternoons (12pm to 2pm) and evening times (4pm to 6pm). The interview with each interviewee lasted approximately 20 to 30 minutes. When the interviewee expressed more interest on the subject matter, the time spent extended to about 45 minutes. In situations where the interviewees are brief, they hardly spend 10 to 15 minutes and yet gave reasonable answers. The choice of language preference was not a barrier in the interview process as the interviewer (researcher) was a Nigerian, from the middle belt region where Abuja is situated.

Hausa and Pidgin English is commonly spoken in this part of the region and is understood by many dwellers. The basic language used for the interview was English. Open questions and responses also allowed the interviewer to clarify misunderstanding to preconceived answers to some questions. The interview encouraged rapport between the interviewer and respondent (Groenendijk & Dopheide, 2003). Perception of road users on possible causes of vehicle accidents at specific locations were enquired, as well as why road users engage in some unruly behaviour and miss-use of public facilities. Questions on likely built environment characteristics liable to accidents at locations were also asked. A draft of the sample questions for interview is given in appendix 7.5. The purpose of the interview was to obtain some location specific understanding on likely causes of accidents associated with selected hot zone locations and to relate the secondary data provided to the generated results. The interviews were recorded by the use of a voice recorder. This aided in giving full attention to interviewee and avoided interruption of the interviewee, thereby reducing the time spent when a complete process of manual jotting is used. The recording process also helped in keeping track of each interview per location. This is to be analysed qualitatively, Figure 3-D shows highlights of respondents.

3.7.1. Observation

Observation is a useful way to gain understanding of people and the world, it is suitable for occurrences that can be directly observed or measured (Groenendijk & Dopheide, 2003; Johnson & Onwuegbuzie, 2004). Street observation to find road (infrastructural and design) characteristics and land-use related to findings from the secondary data analysis and occurrences were investigated through observation enriched with photography. Photography complemented the physical infrastructure on the site and illustratively show the road user behaviour. The process was undertaken systematically during the interview. Street designs, land-use and interaction of road users with traffic and traffic facilities were considered in the process, thereby reflecting the subjective perception of the human and environmental factors. These were chosen to be observed in this research because they are important and play significant roles in road safety (Dai & Jaworski, 2016; Agbonkhese et al., 2013; Yang, Zhao, & Lu, 2016; Machado et al., 2015). An observational checklist, which consists of list of street infrastructure to be assessed at the 14 locations, and land-use availability were identified. This process was carried out using the count method as stated in section 2.8, important information about the investigated zones were used to augment findings from the secondary data analysis. The information includes junction designs, road curvature, speed limits, road signs, road surface condition, road separation and different land-uses around hot zone locations. These were subjectively described and descriptively studied. The checklist used is presented in Appendix 7.4. Identified land-uses were analysed using the count method to indicate prominent land-uses at 1 km hot zone location serving as trip generators, with the assumption that vehicles and pedestrians around the 1 km distance are exposed to accidents.

Figure 3-D Preview of respondents at some of the locations Author (2018)

3.7.2. **Focus group**

A Focus Group Discussion (FGD) is described as a small group of people who engage in collective discussion of a topic previously selected by the researcher. Focus Groups (FGs) have been used in some studies to understand more about the factors that influence decision making. It is usually between a small number of people of between six to twelve and is based on a specific set of criteria (Clifton, Planning, & Handy, 2001). For the purpose of this research, a FGD was organised to relate outcome of the secondary data collected from the organisation to the officials present. It was held at the Federal Road Safety Commission (FRSC) Headquarters in Abuja, Nigeria. Attendants were staff of the department of Policy Research and Statistics (PRS) and other key officers of the organisation (inclusive were retired officials and stake holders). It was a group of 15 members of the FRSC and was organised by the researcher. It started by a self-introduction, topic introduction and then a presentation of the findings of the secondary data analysis was made to the group. Afterwards, the importance of GIS as a tool for traffic safety analysis and the significance of a workable database in the FRSC was made known to the group. Its purpose was to get fundamental information about likely factors causing accidents and what measures the organisation has put in place to reduce accidents. The views and comments of the safety officials after the presentation were noted. A focus group guide helped the process, this guide is presented in Appendix 7.6. Although the small sample size does not allow for broad generalization or statistical testing, it did allow in-depth exploration of selected issues in the meeting. Discussions were recorded to ensure accurate record, interactions and identification of responses. Figure 3-E shows highlights of FRSC officials at the FGD. The FGD helped with understanding the FRSC status in safety of roads in Nigeria.

Figure 3-E Preview of FGD with FRSC officials Author (2018)

3.8. Research Design Matrix.

The research design matrix shown on Table 11 in the Appendix shows the research objectives with each of the specific objectives. It also displays the data type, data source and software required for the analysis. The anticipated output for each objective and specific questions are also displayed as well as the description of methods used.

3.9. Ethical Consideration

Ethical issues were considered in areas of data collection, especially during the secondary data collection. Proper consideration was given based on informed consent for the collection of the main vehicle accident data of the study area. The recorded and reported cases of accident data have no names attached and so no personal information of individuals is available. Since appropriate consent was sought before the collection of data from the FRSC, adequate measures were also taken to ensure data safety and confidentiality. Likewise, accident point data collection, the process for the secondary data cleaning and processing lasted for about 4 weeks. Prior to that, the aims and objectives of the study were discussed with the research assistants before involving them in data processing and the need for strict data security and confidentiality was emphasised. Open ended questions interview with pedestrians, residents, workers and drivers (commercial and individuals). The interview always begins after due consent have been obtained from the interviewee. If a positive response is received, the next question succeeds, if the interviewee responds negatively he or she was exempted. FGD with FRSC officials was considered sensitive. Materials received from planning and safety organisations alike, were solely entrusted to the researcher and were to be used only for research purpose. The researcher sought the approval of key officials prior to the FGD, and data confidentiality was respected. The next section present results and discussions and it sheds more light on the analysis performed.

4. RESULTS AND DISCUSSION

4.1. Introduction

This chapter presents analysis and visual representation of results. Findings are discussed with reference made to relevant literature for comparison based on similar studies. Details of descriptive analysis of secondary data, temporal and spatial patterns of vehicular accidents and causes are discussed. An overview of the location specific causes of accidents realised during the field visit are also qualitatively discussed. Graphs, maps and pictures are used to describe and give more insight into the temporal and spatial variation of vehicular accidents. To answer to part of sub-objective 2, the independent effect of the different built environment characteristics were investigated individually and per accident location, land-uses identified were analysed spatially and discussed in relation to the findings of the secondary data analysis (cluster locations). Further elaboration on efforts towards improving road safety in Abuja is made to give a better understanding on measures taken and recommendations.

4.2. Data Analysis

Graphs are used in this section to analyse the number of accidents and variables presented in the data. Factors causing accidents in the study area are categorised and graphically displayed. While accidents data is disaggregated into different temporal intervals to view how accidents occurrences changes with time, spider graphs are used to visualise and understand temporal clusters at different time intervals in the study area. This section provides answers to objective 1 and sub objective 2a.

4.2.1. Analysis of accidents variables

Figure 4-A shows the annual number of accidents from 2013 to 2017. The total number of accidents in the study area gives an understanding of the number of accidents occurring over a period of time. Although Figure 4-A shows that in 2015 and 2016 similar number of accident occurrences (390 incidents), were recorded. In 2013 and 2014, number of accident occurrences were 395 incidents respectively while in 2017 the number reduced to about 276 incidences (Figure 4-A).

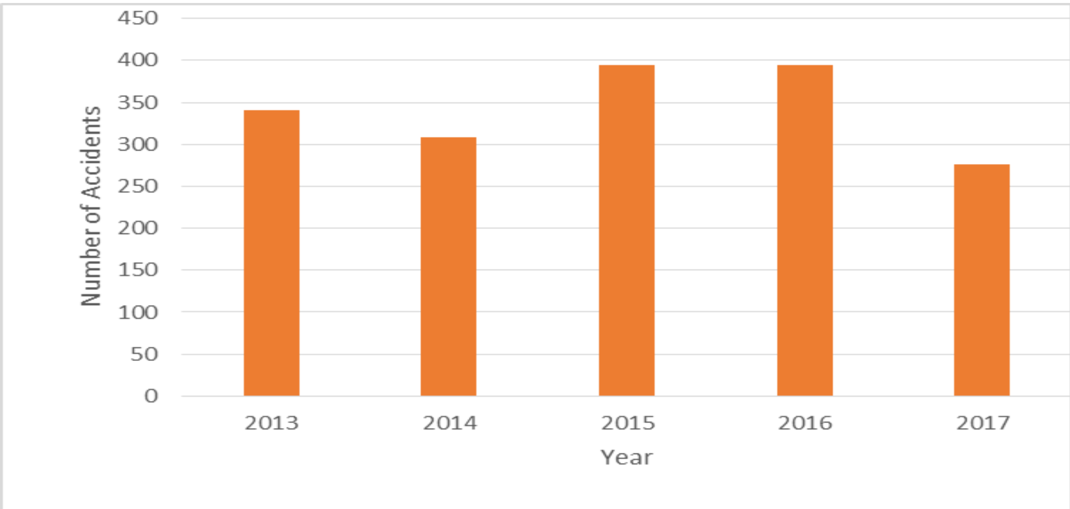

Figure 4-A Total Yearly Accidents Author (2018)

However, Figure 4-B shows the total number of victims involved in accidents as well as the number of accidents occurrences. There appears to have been a larger number minor injuries in road accidents in 2013, 2015 and 2016 compared to 2014 and 2017. Generally, more people were involved in road accidents in 2013, 2015 and 2016 compared to 2014 and 2017. The trend between the numbers is clearly seen to be uneven in all the years in relation to the number of accident for each year excluding 2015 and 2016. Although with very little changes between the years, the number of victims reduces as accidents reduces per year.

Though the number of accidents remains almost the same in 2015 and 2016 in the study area, the number of victims were different with 2015 having a higher number of killed and the year 2016 having the highest number of injured. The lowest data statistics of casualties were recorded in 2017. The reason for this reduction is not clear, but could likely be due to safety measures incorporated in the previous year (2016). As stated in the FRSC (2016) annual report, a public enlightenment strategy was deployed in 2016 to sensitize the public's awareness on road safety. This might have had a positive impact on 2017 leading to accidents reduction. Nevertheless, the reasons can only be determined after additional studies which can help in detecting the underlying reason and proving effectiveness of the measures applied. The number of minors involved as well as the total number of people injured or killed varied slightly as shown in Figure 4-B

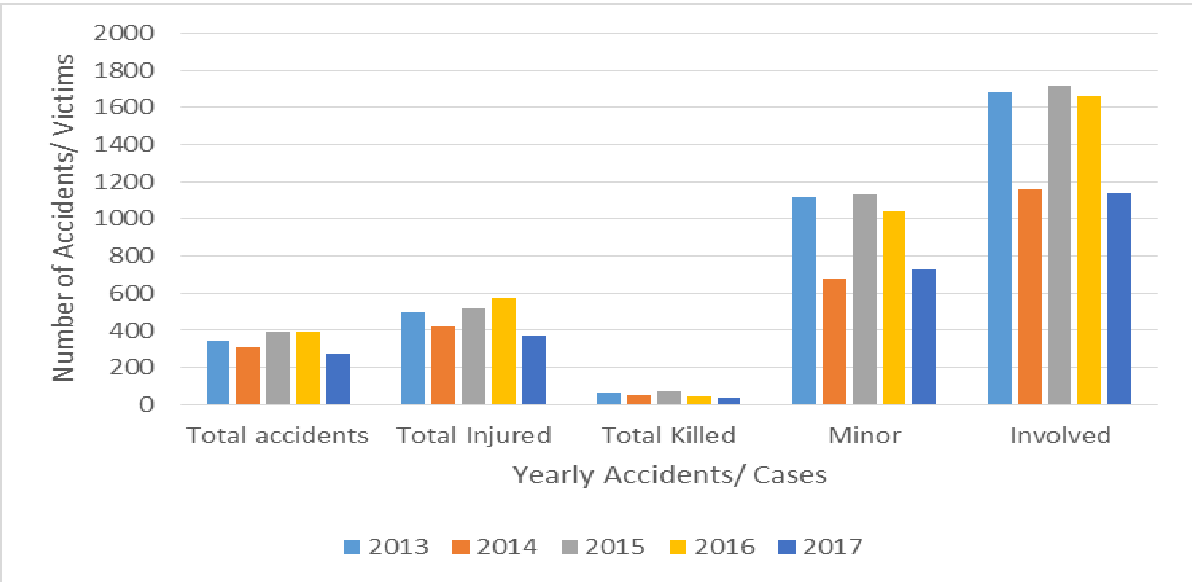

Figure 4-B Yearly Number of Accident Victims Author (2018)

Regarding number of accidents with minor injuries (people who were neither injured nor killed), this number has been on a high side all through the years. This also gives understanding that the rate of severity of accident is on the low side.

4.2.2. Factors influencing road traffic accidents

The randomness in the number of accidents depends on the nature of accidents which depends on factors that cannot be easily predicted. Therefore, a five year period was studied to ensure an illustrative accident sample (Moons et al., 2008). Exploration of factors causing accidents in the study area was carried out to achieve the first sub-objective of the study. After each of the georeferenced point data was matched manually on the excel spreadsheet to its attributes, the accident data was further explored to investigate the association between them at a specific point in time. It was noticed that the causes were not far-fetched from the earlier reviewed factors causing accidents in Abuja (section 2.3). The accident causes are presented in Table 5. Table 6 shows that the human factor has the highest value of 1547 accidents, followed by vehicle factor with 562 accidents and environmental factor with 38 accidents.

Table 5 Classification of causes Author (2018)

Human factor	**Environmental factor**	**Vehicle factor**
Speed Violation (SPV) Sign light Violation (SLV) Dangerous Driving (DGD) Fatigue (FTQ) Wrongful Overtaking (WOV) Route Violation (RTV) Hit and Run (HR)	Obstruction (OBS) Weather (WTH)	Loss of Control (LOC) Tyre Burst (TBT) Mechanical Deficient Vehicle (MDV)

Individually, it is seen that SPV has the highest number of accidents occurrence of 936 in the study area (Table 6), this is consistent with a study by Jones et al. (2008), where the authors also observed that violating speed limits has caused a lot of damage to both humans and materials. This was followed by LOC which had 400 accidents cases, then DGD with 357 accidents cases and SLV with 164 accident cases. Figure 4-C shows a graph of the 3 elements or causes and number of accidents. It can be seen that SPV is associated with 154 deaths in the study area out of a total of 265 number of death, for the period 2013 to 2017, which is about 58% of the number of people killed (this is spatially represented in section 4.3). It was also observed that out of 1713 accidents, 534 accidents were associated with accidents caused by a combination of SPV and other factors. For instance, an accident might be caused by tyre burst (TBT) and speed violation (SPV) or sign light violation (SLV) and brake failure (BF) or dangerous driving (DGD). Naturally, this can be assumed to cause more severity in incidences, either in permanent disability or death.

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Table 6 Causes of accidents in Study Area Author (2018)

Categories	**Human Factor**					**Environment Factor**		**Vehicle Factor**		
Accidents causes	Speed Violation (SPV)	Dangerous Driving (DGD)	Sign Light Violation (SLV)	Route Violation (RTV)	Hit and Run (HR)	Weather (WTH)	Obstruction (OBS)	Mechanical Defect (MDV)	Loss of Control (LOC)	Tyre Burst (TBT)
Number of accidents	936	357	164	73	17	4	34	92	400	70
Total	1547					38		562		

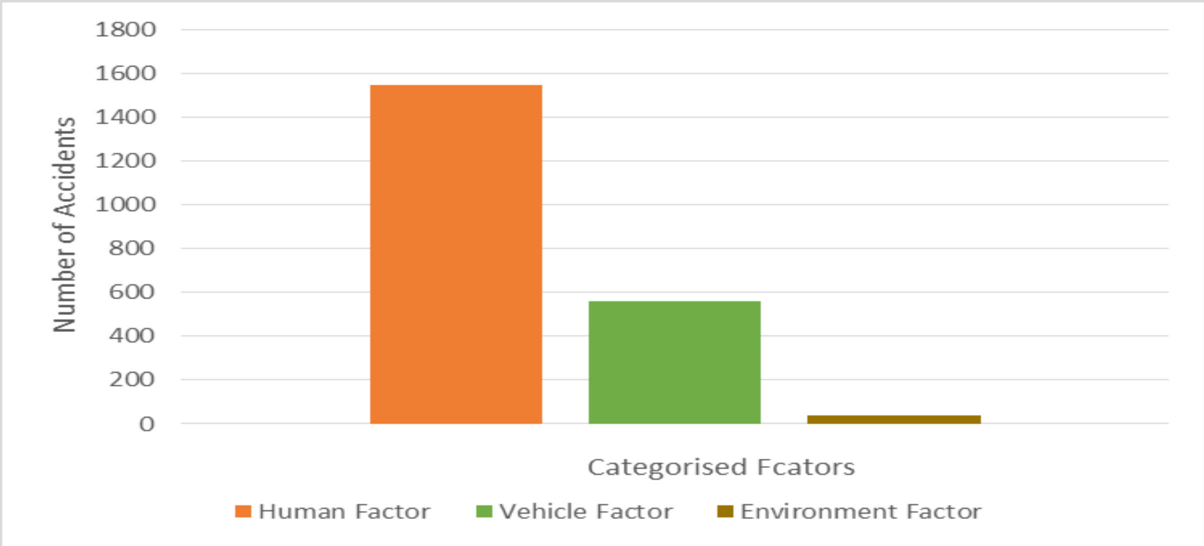


Figure 4-C Categories of accident factors Author (2018)

4.2.3. Time-based analysis

Temporally, accident data for the years 2013 to 2017 was decomposed into months, days and hours to help in identifying peak periods and seasons that accidents occur the most. This was carried out to answer sub-objective two of the study. Graphically, distribution of accidents hourly, weekly, monthly and annually are presented in Figure 4-D. The figure shows data collected over a 5 year period (2013 to 2017). Generally, more accidents occurred in the study area during the daylight periods (06:00 to 18:00 hours). At about 17:00 to 24:00 hours, a decline in the number of accidents was observed. Within the daylight periods, accident peaks were observed between 07:00 to 08:00hrs and 17:00 to 18:00 hours, which are the morning and evening rush hours respectively. Vehicular movements in the city are usually at the highest within these time windows. It was also observed that accidents were highest within 11:00 to 12:00 hours (25-32 incidences). This period coincides with the time when commuters traveling into Abuja City from neighbouring states and cities would normally arrive. Drivers from other locations who are not used to the city road networks are an added road risk and could increase the tendency of accident occurrences. A sharp decline in accident incidences was observed between 12:00 to 13:00 hours. The reason for this decrease is currently not clear, but the period coincides with the time period when most commercial and private offices are on lunch break all across the city. After the lunch-time decline in accident incidences, a steep increase was observed between 13:00 to 16:00 hours after which the number of incidences began to reduce. The peaks observed at 15:00 to 16:00 hours corresponds with school closing hours when vehicular and pedestrian traffic is higher than usual in the city. This analysis is in line with a research by Kingham, Sabel, & Bartie (2011), who investigated the impact of school run on road traffic accidents. The author concluded that commuter rush hours were perhaps unpredicted, but found school rush hour periods worth further investigation. Generally, the graph showed variable accident incidences within each time window as well as in each of the years, confirming that crash rates do not occur at uniform rates throughout the years as stated by Kingham, Sabel, & Bartie (2011).

The total yearly average of accident occurrence per hour is shown in Figure 4-Ea. It can be clearly seen that traffic is at its peak on the major roads around the central area, between the hours of 11:00-12:00. This is believed to be the time window when commuters as earlier stated, arrive into the city from other neighbouring states and towns. As mentioned in section 3.2, the major roads in the study area are linked to other states in the country and the central area of the city as well. In Abuja, majority of the inhabitants leave in the suburbs and commute to work daily in the city area. Due to a free flow of traffic in the early hours (4:00 to 7:00) of the morning compared to the peak periods, commuter leave their homes as early as 4:00 to enable them get to their various places of work on time. Generally, the hourly annual rate of accident was observed to reduce within the day light periods (06:00 -18:00 hours) in the order: 11:00-12:00 > 15:00-1600 > 13:00-14:00 > 14:00-15:00 > 12:00-13:00. The monthly average of accident incidences is shown in Figure 4-Eb. The highest monthly average of accidents was observed in the month of July (35 incidences), followed by April, November and December (Figure 4-Eb) which had 30, slightly over 30, and less than 30 accident incidences respectively. In Abuja, July and August are often months when rainfall is intense the study area this period of increased rainfall is also characterised by an increase in accidents occurrence. This observation agrees with the findings from a study by Jaroszweski & McNamara (2014) on the influence of rainfall on road accidents in urban areas. The authors attributed increased accidents rates to typical rain days. A similar study by Jung, Qin, & Noyce (2010), in their study on rainfall effect on single vehicle, it was concluded that rainfall had a significance influence in the increase of accident severity. This observation is particularly significant in this study because SPV has been identified as the main accident causing factor and when combined with rainfall could result in accidents being more severe.

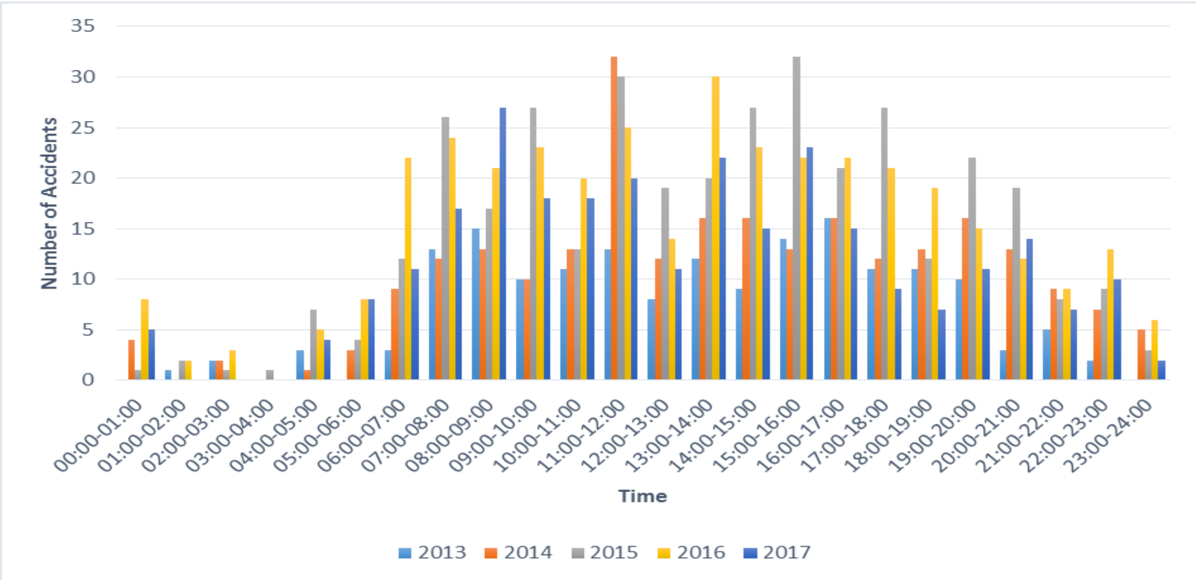


Figure 4-D Annual Hourly Rate of Accidents Author (2018)

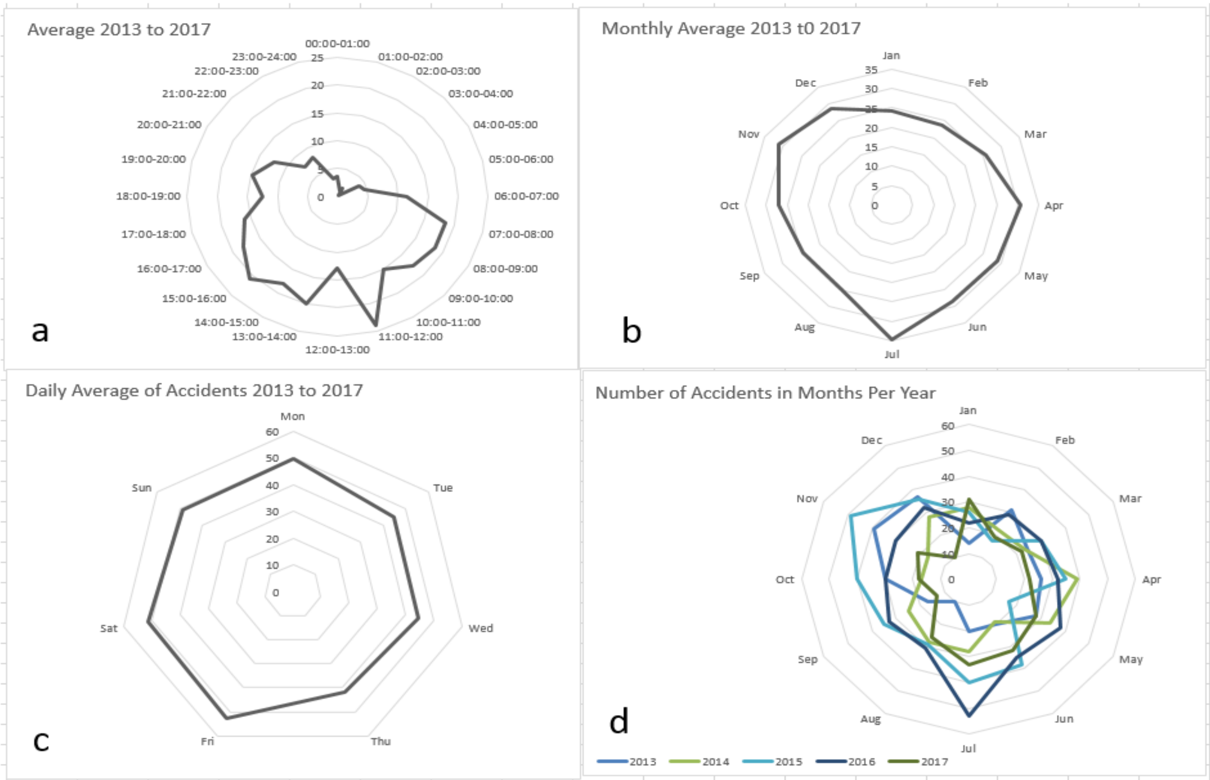


Figure 4-E Temporal Variation of Accident Occurrence Author (2018)

The annual monthly accident rate shown in Figure 4-Ed. also has peak periods around November and December, these are periods when a lot of people are travelling for holidays and there is a high volume of vehicles on the roads. The daily average is shown in Figure 4-Ec, the highest peak was observed on Fridays (greater than 50 incidences), followed by Saturday, Sunday and Monday which had an average of about 50 accidents. In the study area, **Fridays** are usually considered **informally** as a half working day. Being the start of the weekends people normally travel to visit family, friends and for relaxation and recreational purposes on Friday. Additionally, Fridays are days set aside for the weekly Muslims Jumat-prayers. This Muslim religious rite is observed between 12pm until 3pm on Fridays and is usually characterised by a very high pedestrian and vehicular traffic around Mosques in the study areas. Due to insufficient parking lots, in Abuja, vehicles are seen parked on the roads thereby blocking the free flow of traffic during the prayers. This sometimes causes anxiety and apprehension in people that get trapped in the usually chaotic traffic situation and results in accidents. Similar activities are, clubbing, weddings and church services which are activities that normally attract a high number of commuters during the weekends. Generally, the high peak of accidents on Saturdays and Sundays can also be attributed to over speeding due to the fact that there are less vehicles on the roads within the study area. **Mondays** have a higher accident peak compare to Tuesdays Wednesday and Thursdays, this can be attributed to the start of the work week when people return from weekends, journey to get back to their work places on time. Commuters who could not travel back on Sunday are usually in a hurry to get back on Monday, hence could be potential road hazards.

4.3. Spatial Analysis

Secondary data, acquire from FRSC and other agencies was used in this section to visualise cluster of accidents locations, using the point pattern distribution. The accidents were linked to their various causes to establish how different patterns are associated with the different causes of accidents at various locations. This section aims to achieve sub-objective 2b, 2 c and part of 2 d of this study which are on spatial distribution of accidents and cluster locations.

4.3.1. Spatial visualization of accidents

Using the parameters as stated in section 3.6.2., the Global Moran was first used to confirm the extent of clustering in the study area, this led to the rejection of the null hypothesis of no clustering in the study area. The test was to nullify the assumption that the distribution of accidents was completely spatially random. The result generated was with a z-score = 236, Moran I = 0.66, and p-value = 0.000000. It gave a < 1 % likelihood that the clustered pattern could be the result of a random chance. Based on the hypothesis that if there were no accidents, the spatial distribution would be random. The generated result hence assumed there were clusters in the study area. To further identify the distribution of accident points and cluster patterns, frequency loops was employed as explained in section 3.6.2, where each loop symbolises the frequency of accidents in the particular location. Different severity types; number of people injured, number of people killed, and number of minor accidents were visualised. The spatial distribution of 1713 road accidents points from 2013 to 2017 within the study area was first visualised as shown in Figure 4-F. It was observed that though accidents are randomly distributed around the study area, they appear to occur along the major roads and are concentrated more around the central area (CBD). This is likely because of the high socio-economic activities going on in the core area of the city. The frequency loops categorized locations with high accidents occurrences. This is shown in Figure 4-G, which shows the frequency of accidents per location. It was observed that a total of 669 accident occurred at different individual locations, while the remaining 1044 occurred in clustered locations with more than one incidence at a point (this was found in events points that had the same coordinates). This gave a total of 950 accident point locations from the entire 1713 accidents and gives a better understanding of the concentration of accident points in the study area. The major routes in the study area seem to have concentration of point at some locations (circled). Although Figure 4-G visualizes accidents in loops showing the frequency per location, it also visualizes an uneven distribution of clusters at some specific locations. Further investigation could provide better understanding regarding this.

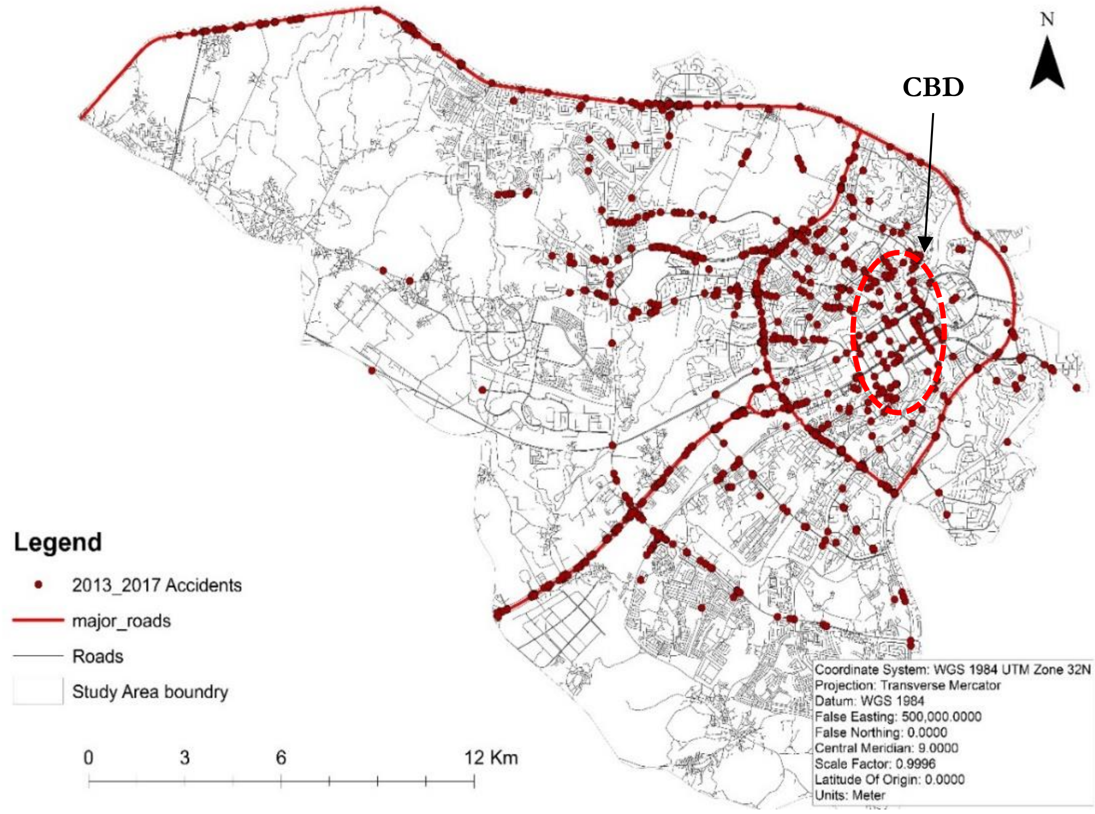


Figure 4-F Accident point location distribution 2013-2017 Author (2018)

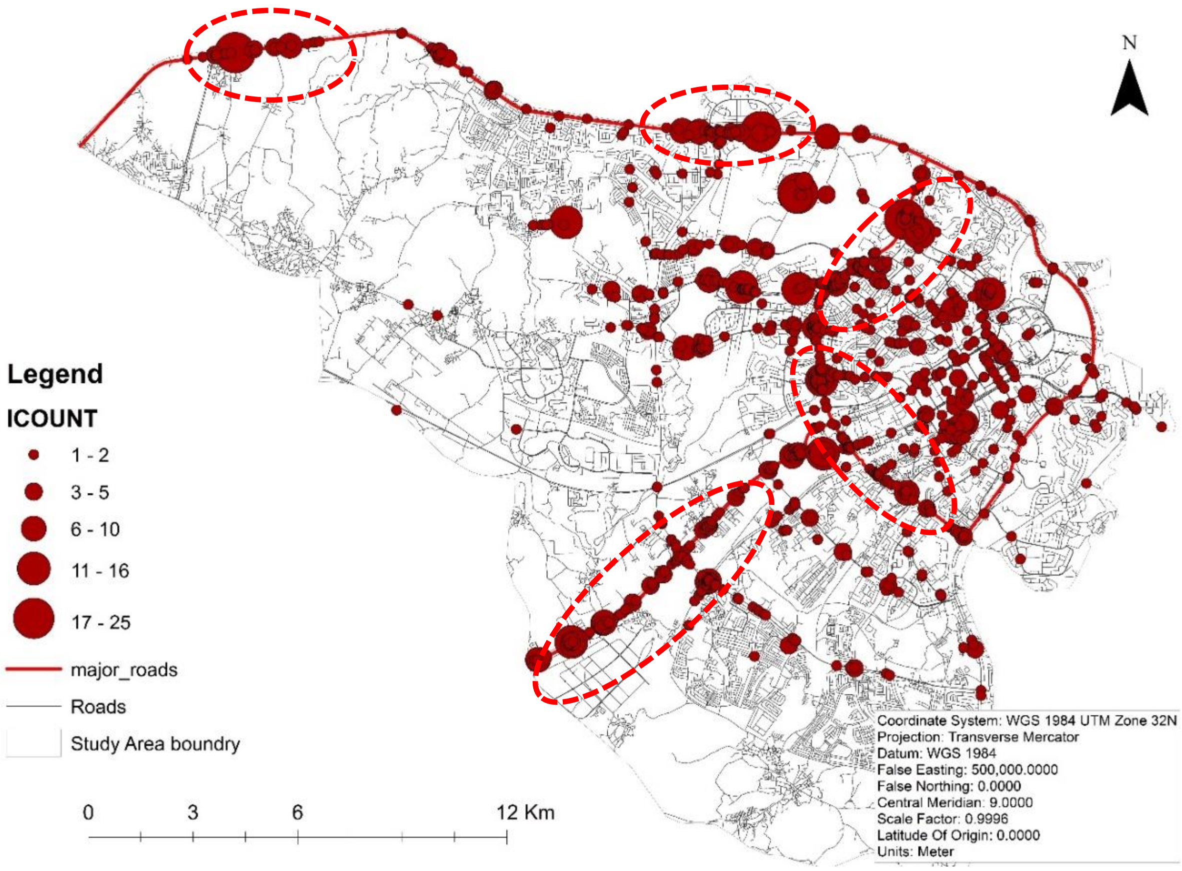


Figure 4-G Accident concentration by frequency 2013-2017 Author (2018)

The spatial interaction between factors present in the accident record data from 2013 to 2017 shows that factors are not evenly distributed, but rather aligned along the network of accident locations. The framework of this research explained in section 2.1, further gives insight on the severity of accident, as these factors are observed to interact with each other and influence the occurrences and severity of accidents (Li et al., 2007). The four factors selected for visualization have higher number of accidents occurrence compared to the others in the study area; these factors were related to the number of fatal accidents and number of people killed. SPV (which caused 936 accidents, Table 6), was found to be associated with 154 fatalities and 186 deaths. Figure 4-H, shows the spatial distribution of SPV related to fatalities. It was visually observed that SPV is distributed, having clusters along the major roads and in some inner parts of the study area. Fatality distribution was also observed along the roads, having clusters, especially along the Nnamdi Azikiwe route. SPV was also observed to have concentrations around the city centre. This is most likely because of the high population and concentration of activities in the area. Figure 4-I visualizes accident causes related to SLV. SLV with 164 accidents (Table 6) was associated with 22 fatal accidents, distributed along the routes. SLV was responsible for a majority of the accidents along the major roads, with few clusters observed along the Nnamdi Azikiwe route. It was also observed to be a leading cause of accidents, having a higher concentrations around the central area compared to DGD and LOC which might be because of the presence of intersections and junctions, which are prominent features around the city centre. To mitigate this, vehicles drivers will have to adhere to traffic lights and signals when negotiating a bend or approaching a junction. Although the central area was not part of the street survey, it was observed that Abuja has some functional street lights around the city centre. SLV has the lowest number of accidents visualized, it was associated with 30 fatalities in the study area.

In Figure 4-J is the visualization of DGD with 319 accidents point locations. DGD was found to be associated with 40 fatal accidents that have claimed 54 lives around the study area. Fatality due to DGD appears to be more also along the Nnamdi Azikiwe express and Shehu Musa Yar'Adua express, and is sparely distributed around the study area. Although DGD and LOC have similarities in their frequency, these two factors have different number of accidents (319 and 400 respectively). LOC have 400 accident associated also with 40 fatal accidents and 58 deaths. It was observed that the LOC has more accidents along the Shehu Musa Yar'Adua road and more fatality on the same route and on the North-North region of the study area (Figure 4-K), with a concentration around the major roads and inner city. A common characteristic seen in all the factors is that they occur more along the major roads. Apart from visualizing some of the factors, the spatial visualization of accident attributes of victims and fatal accidents was also considered. This distribution is observed per location, using the frequency loops, the visualization is seen in subsequent figures.

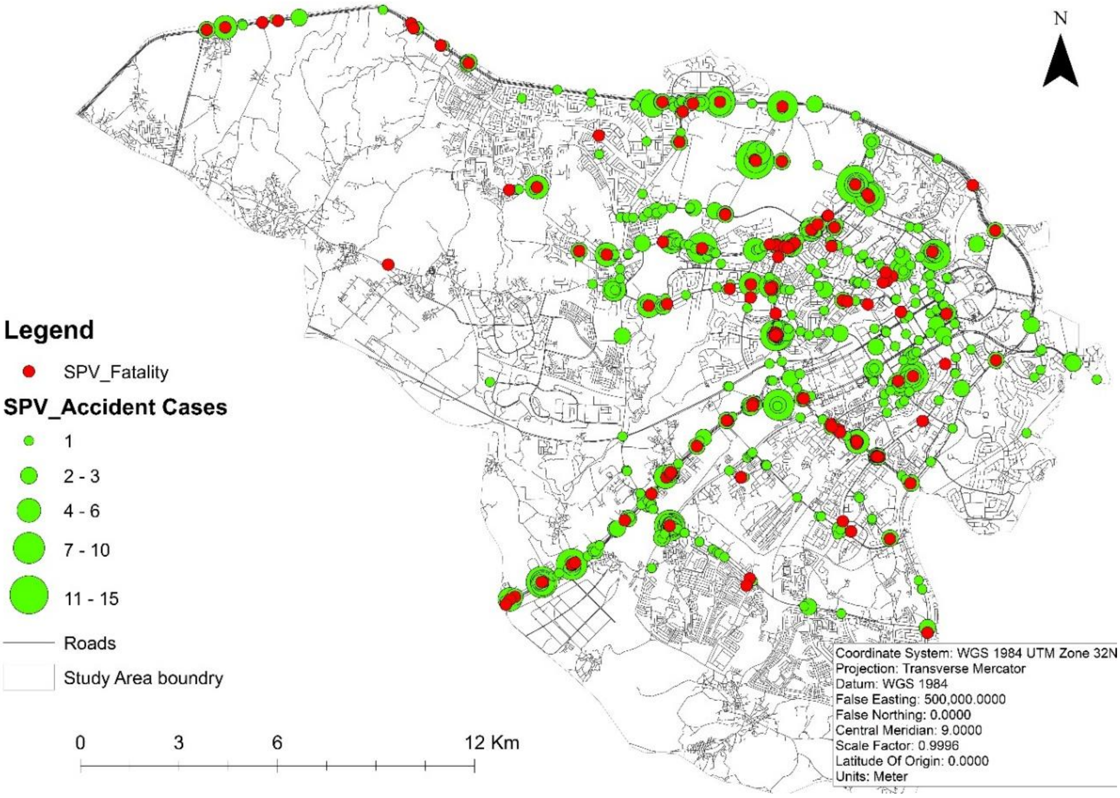


Figure 4-H Speed Violation associated with fatal accidents 2013 to 2017 Author (2018)

Figure 4-I Sign Light Violation associated with fatality 2013 to 2017 Author (2018)

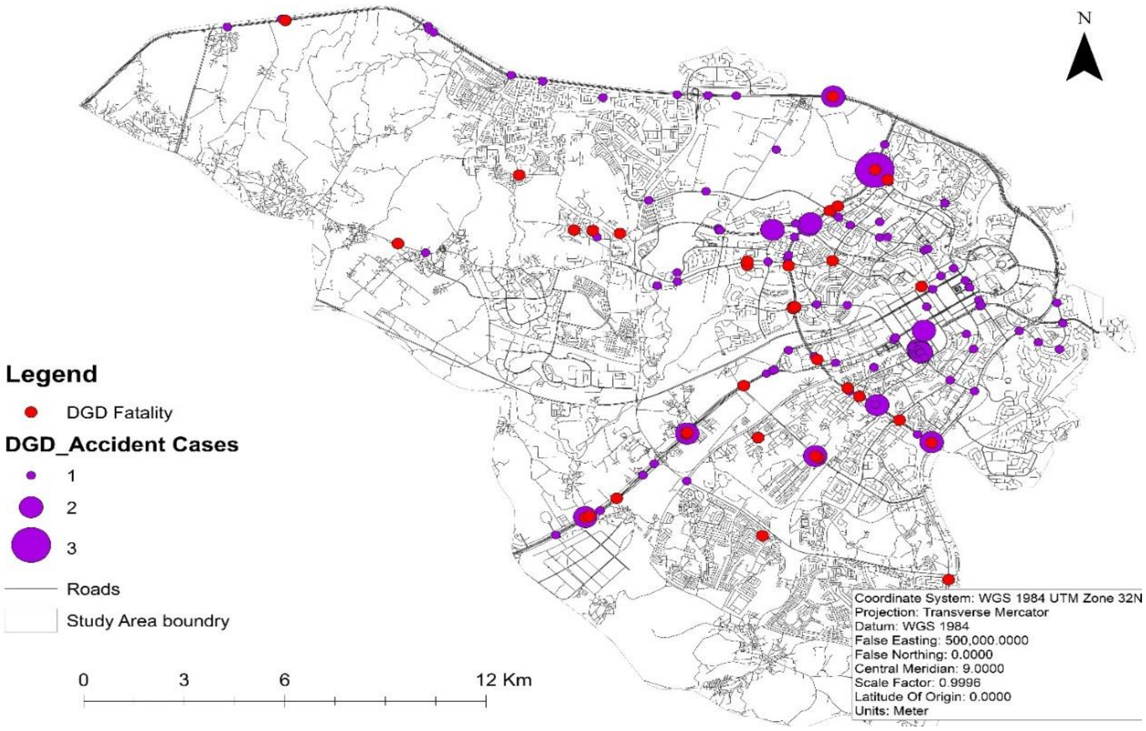


Figure 4-J Dangerous Driving associated with fatality 2013 to 2017 Author (2018)

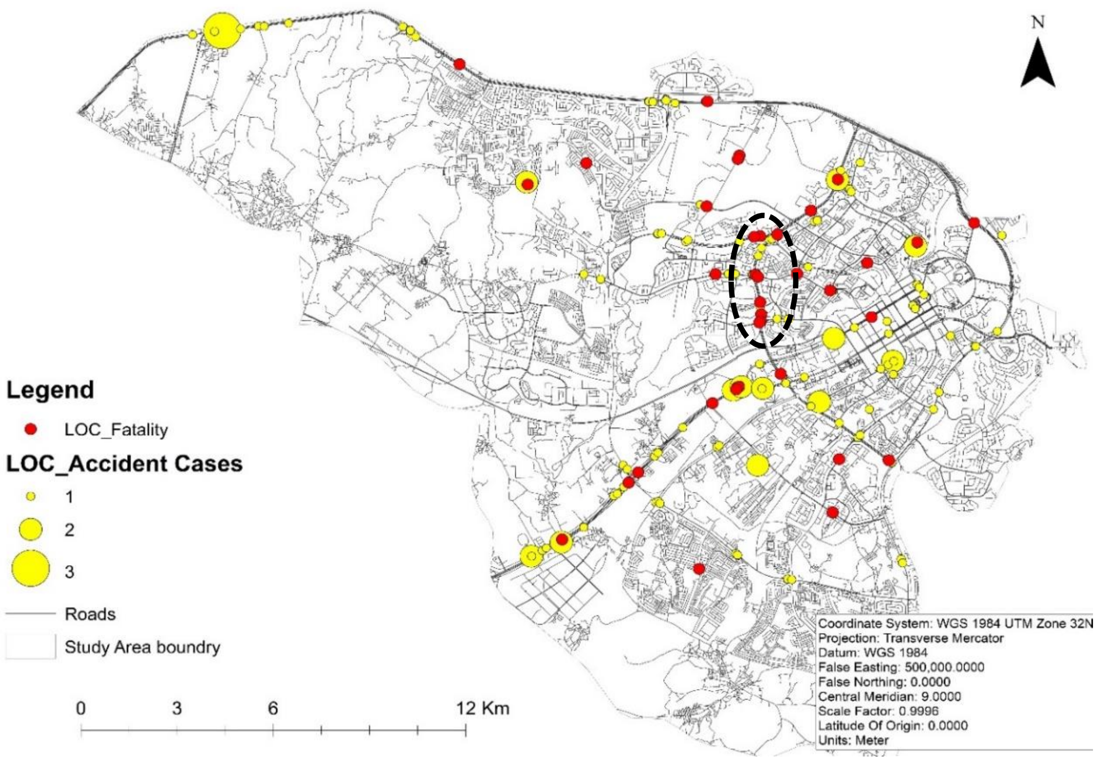


Figure 4-K Loss of Control associated with fatality 2013 to 2017 Author (2018)

Aside visualizing some of the factors, the spatial visualization of accident attributes of victims was also considered. This is to see visually distribution per location. Using the frequency loops, the visualization is shown in the next figures. The interesting thing about the frequency loops is that they tells a story about each visualization it they are applied to, depending on the result anticipated.

In Figure 4-L, the total number of victims injured distributed around the study area is visualized with concentrations around the 3 major roads and the central area. Abuja is a city with so many continental hotels situated especially around the central area. Around these hotels, are a lot of commercial activities, including businesses and relaxation and recreational parks and gardens which attract people to the central area of the city. The sizes of the loops determines the number of people injured at the specific location, while the frequency of loops at each location gives the number of times accidents have occurred along a segment. The total number of injured (2386 victims), the biggest loop signifies high number of injured at the location.

The concentration seen in the distribution of the number of minor accidents is higher around the North region of the Nnamdi Azikiwe express. The spatial distribution of minor accidents, i.e., number of victims neither injured nor killed, is visualized in Figure 4-M. It was observed that in 2013 to 2015, the total number of minor accidents was 4,702 in the study area. Though visually, the distribution of the number of minor accidents seems to be less than the injured because the largest frequency loop for minor accidents has a higher number of victims assigned. This implies that, a larger loop in minor accidents has about 16 to 24 victims while that of injured ranges from 10 to 20.

Figure 4-N shows the spatial distribution of total number of fatal accidents (209) in the study area that has occurred within the periods 2013 to 2017. Using the frequency loops, the number of fatal accidents were visualized and this time, each loop symbolizes the number of fatal accidents that have occurred on a segment. It was observed that the largest loop is seen along the far North end of the Nnamdi Azikiwe express, with other loops subsequently clustered along the Shehu Musa Yar'Adua express and distributed along other roads.

Lastly, Figure 4-O shows the distribution of the total number of killed victims (265) in the study area from 2013 to 2017. This is slightly higher than the number of fatal occurrences. It is possible because more than one incidence of death can occur in a particular crash scene. In this case, the larger loop gives the total number of victims involved in a crash. Smaller loops signifies more occurrences of death per location.

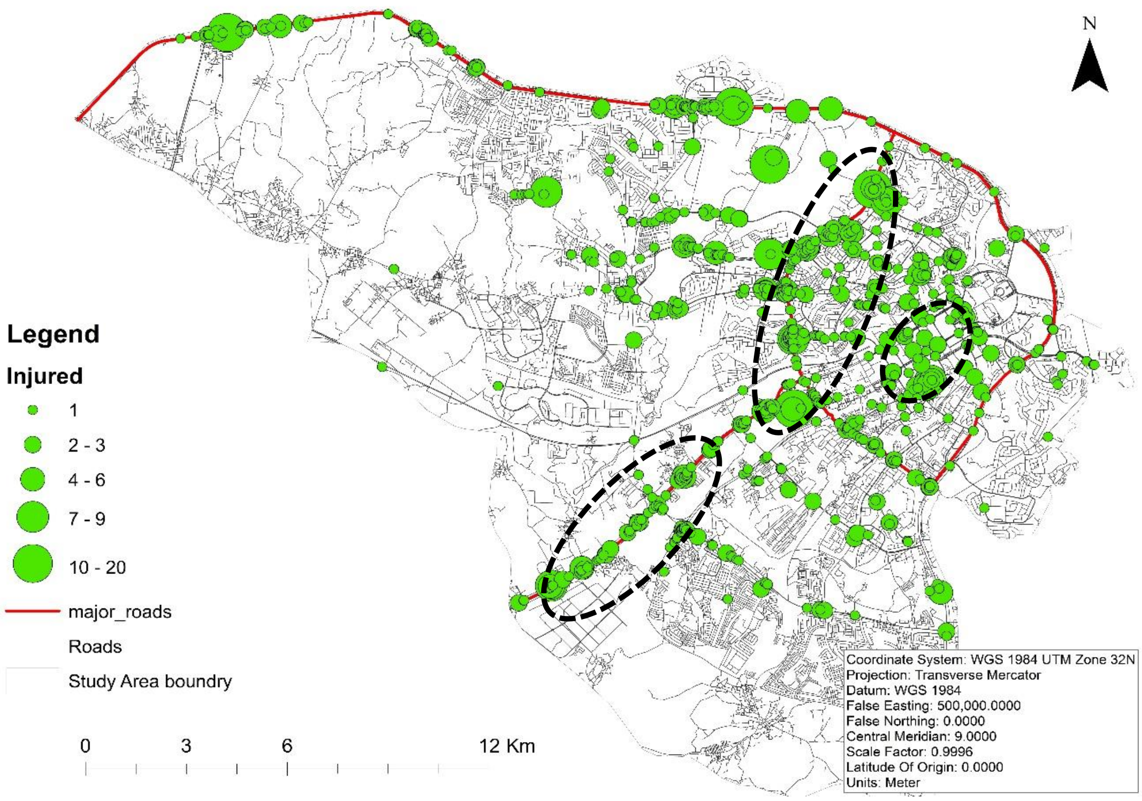


Figure 4-L Spatial Distribution of Number of Injured 2013 to 2017 Author (2018)

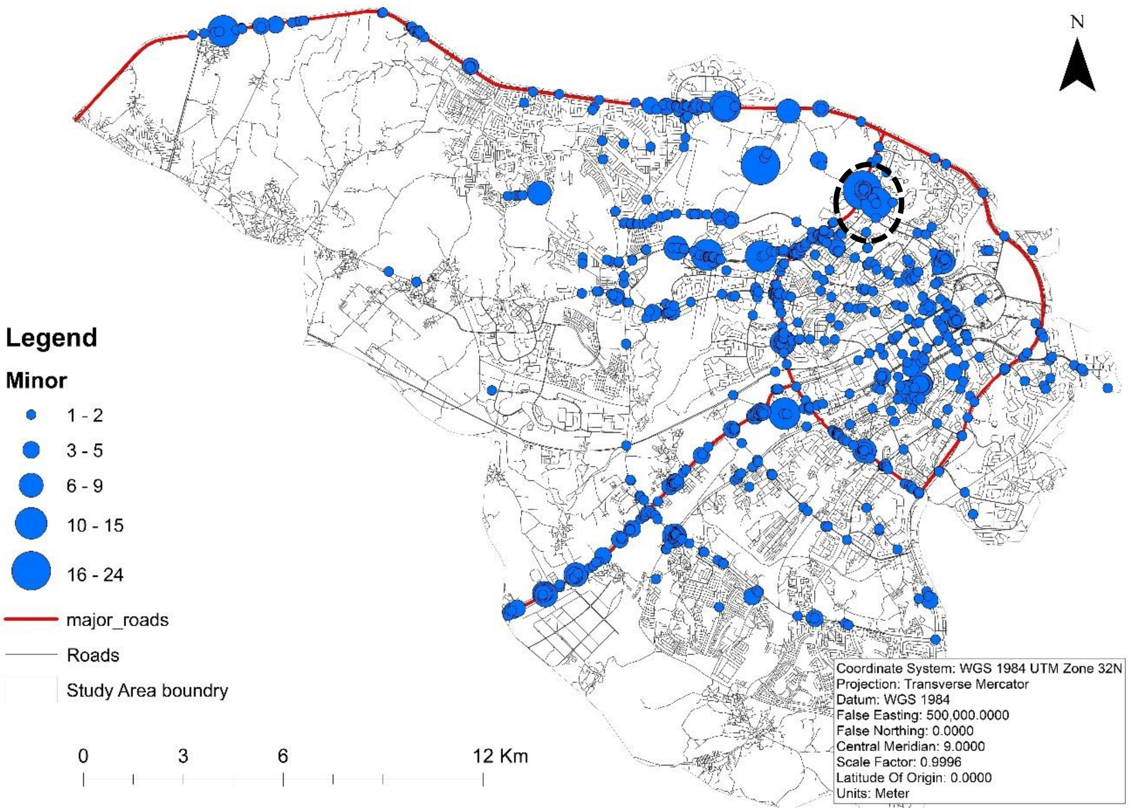


Figure 4-M Spatial Distribution of Minor Accidents 2013 to 2017 Author (2018)

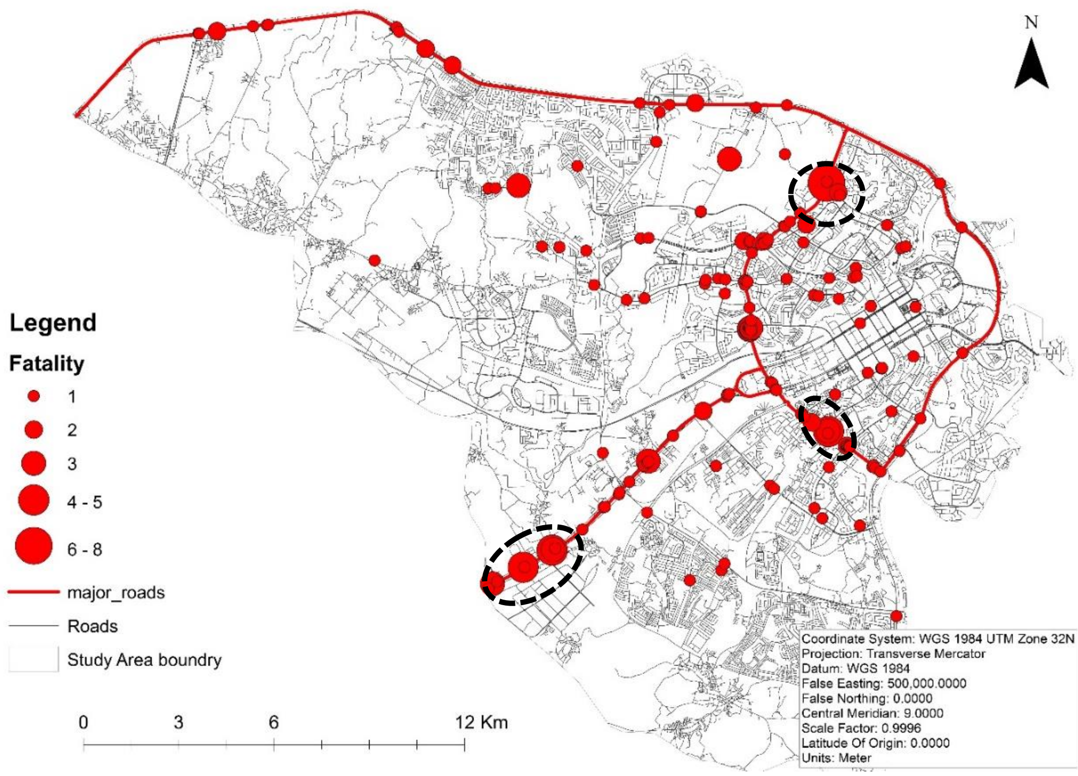


Figure 4-N Spatial Distribution of Number of Fatal Accidents 2013 to 2017 Author (2018)

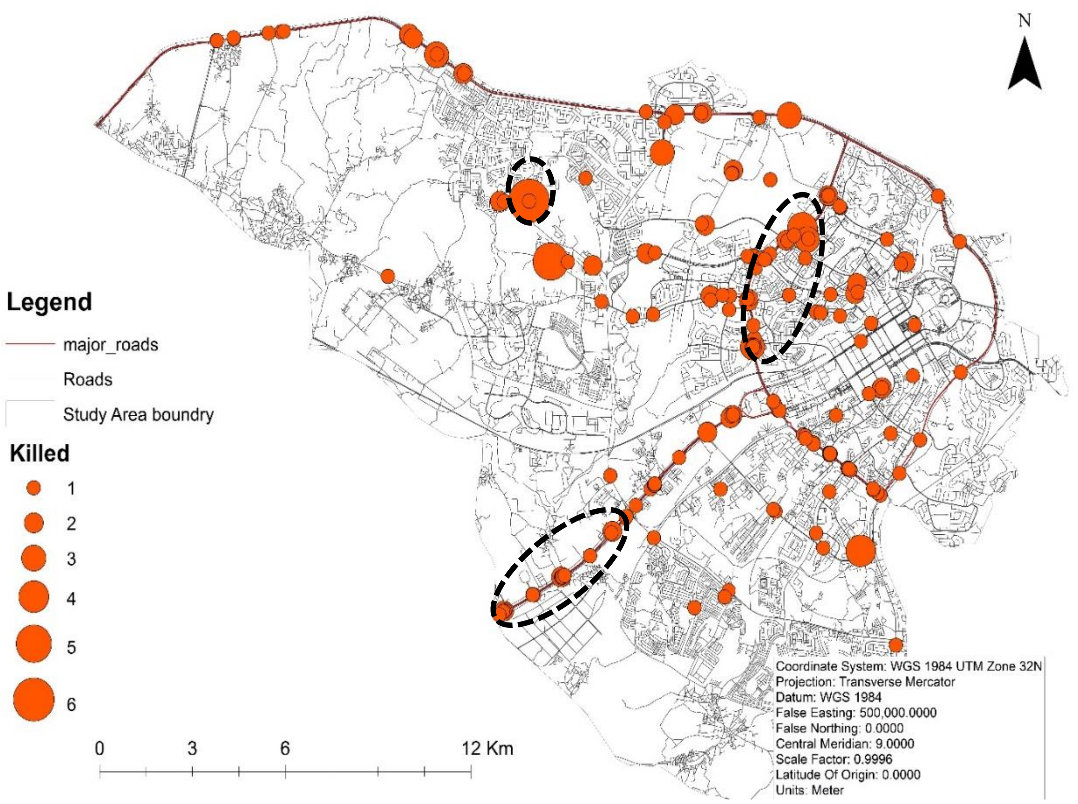


Figure 4-O Spatial Distribution of Number of Killed 2013 to 2017 Author (2018)

4.3.2. Local Moran index

In order to achieve sub-objective 2d, significant clusters were investigated using the Local Indices for Spatial Autocorrelation (LISA). This was also to guide in the street survey carried out and also to help in the selection of particular segments, junction or location that needs immediate intervention to improve safety on roads. LISA is an aggregated method, where the road network and number of accidents on the segments are put into consideration. The actual length of road was used during the analysis due to the limitation found with segmenting road as earlier stated in section 2.6.4. The parameters stated in section 3.6.2 for the LISA analysis were employed.

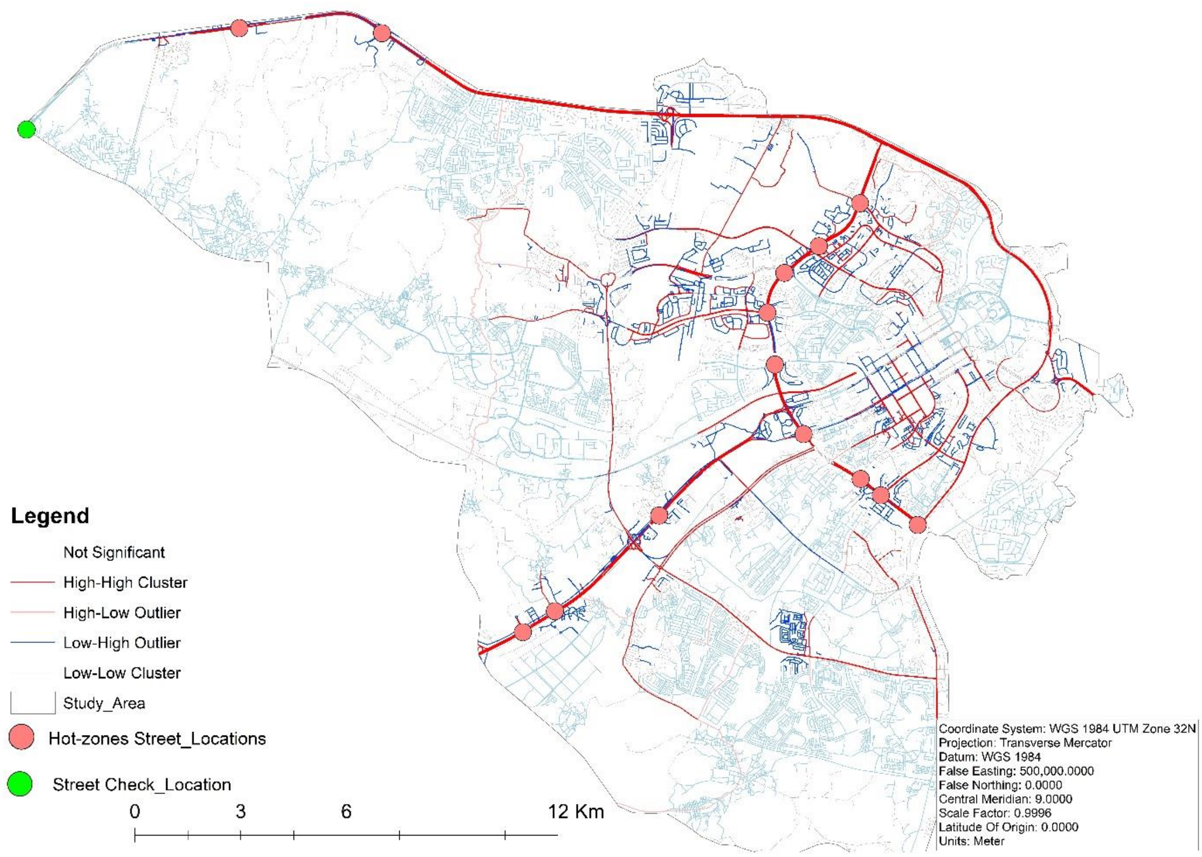


Figure 4-P Cluster map of study area showing hot-zones for street analysis Author (2018)

The results generated, gave an actual total number of 324 values of High-High (HH) cluster of segments (Figure 4-P). Other values were given of the classes of cluster outlier; 28 High-Low (HL) segments, 1165 Low-High (LH), 6078 Low-Low (LL), and 3662 Not Significant locations. The HH cluster is of interest in this study because, the LISA gives significance values as HH, which is one of its advantage. Although the frequency loops showed concentration of accidents at various locations, LISA has an advantage of giving the exact segment to focus in terms of immediate traffic safety intervention. The approach reveals hotspot segments of high accident concentrations in the study area. A pattern of clustered segments were noticed at the central area of the city, with more visible hotspots segments observed along the 3 major highways within the study area. According to Moons et al. (2008), this enable policy makers to allocate funds in the best possible way and it is important to know which of the locations need the most attention. The locations were further refined to view the most hazardous clusters.

To enable a reasonable number of cluster locations to work with during the field work and for the implementation of counter measures by safety officials, the hotspots were filtered to identify the most hazardous locations. The frequency of accidents through the 5 year period gave a total of 25 selected cluster locations on the segments and the introduction of fatality count on the hotspots. As detailed in section 3.6.2., this gave 14 locations considered as hot-zones which were investigated upon during the field visit. This were also termed as locations where safety measures have not been effective or implemented. These locations were considered as hot zones. The last location visited making it 15 locations was the white zone location. Although it was once a problematic accident hotspot to deal with, it was of interest to examine what measures were put in place to make it now a cold spot (accident free location). Figure 4-P shows cluster locations with street locations that were visited for observation. It shows the white zone in green at the far North-West of the study area. This street locations were visited to acquire information like, street characteristics, observations photographs, conduct interview to get the perception of the people on hot zone locations and to know land-uses around this locations serving as trip generators. Additionally, to acquire information specifically about the location specific causes of accidents. In the next section, results and discussion on street visit and subsequently the FGD is related

4.4. Analysis of Street Design (Primary Data Analysis)

The analysis presented in this section is to answer the last part of sub objective 2 d, that is, on the relationship of the built environment with high accidents cluster locations. Environmental audit variables are gotten from accident database, road database and objective data sources, they can also be gotten from clusters of accidents locations, which allow one to target specific areas for further investigation (Dai & Jaworski, 2016; Mohamed, Saunier, Miranda-Moreno, & Ukkusuri, 2013; Stavrinos, Byington, & Schwebel, 2011; Moudon, Lin, Jiao, Hurvitz, & Reeves, 2011). The later was the case in this research, where the 14 cluster locations were targets for further investigation on the specific location causes. The variables selected in the built environment audit were categorised in two; road infrastructure/design and land-use. These were selected because previous studies suggests their correlation with accidents in the built environment (Mohamed, Saunier, Miranda-Moreno, & Ukkusuri, 2013; Stavrinos, Byington, & Schwebel, 2011).

4.4.1. Description of checklist observations

After the street visit, the results of the observed physical characteristic of the street locations, were not farfetched from what other researchers had discovered. At the end of the street survey, this was assessed and an overall percentage score calculated for each variable and location (Table 7). Each location was identified by the given serial number 1 to 15.

From the assessment on Table 7, a percentage >50 is termed a variable having higher influence on accident occurrences for the entire 14 hot zone locations visited. This threshold is in relation to how many locations a variable has influence accidents at. The observed 14 locations were detected to have 86% of T-junctions, this percentage influenced accidents on 12 hot zone locations. 64% was observed of staggered junctions. This influenced accidents at 9 different hot zone locations. Road signs and markings had 71% influence on accidents along the hot zone segments. These were seen at 10 hot zones and seem to influence accidents at these locations. Asphaltic surfaces had a 93% influence on the accidents locations, this is to attest the fact in a research by Chen, Saeed, & Labi (2017) that "higher roughness is generally associated with lower expected frequencies, likely because drivers are generally likely to drive more carefully on pavements with very poor conditions". 13 hot zones were associated with asphaltic surfaces, just1 location (Apo Roundabout) located along the North-eastern part of the study area on the Nnamdi Azikiwe Express was seen to have roughness (under reconstruction). Lastly, for the land-use, all 14 locations had land-uses, this had the highest percentage of 100. This agrees with the notion that, areas with high-density development and commercial land-uses would expect to see high number of accidents because by nature, they attract greater number of commuters (Clifton et al., 2009). Other variables having a lesser percentage (<50%) were said to be less prominent to the selected cluster locations (hot zones).

Table 7 Checklist analysis for the built-environment analysis Author (2018)

Availability of Variable = 1

No Variable situated = 0

Road Infrastructure/designs			Street Locations (Cluster Segments)															% Influence of variables.
Variable	**Illustration**	**Signs**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**	**13th**	**14th**	**15th**	**%**
Junction designs	U-turn		0	0	1	0	1	0	1	0	0	1	0	0	1	1	0	42
	T-Junctions		1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	86
	Roundabout		0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	14
	Traffic lights		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Staggered Junctions		0	1	1	0	0	0	1	1	1	1	1	0	1	1	1	64
	Flyovers		0	0	0	0	1	0	1	0	1	1	1	0	1	0	0	43
Road curve	Slight curved		0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	30
Speed limits	Speed limits at specific segments		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	7
Road signs	Road signs and markings		1	1	1	0	1	1	1	1	1	0	1	1	0	0	1	71
Road surface	Asphaltic		1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	93
Road parting	Pedestrian bridge.		1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	79
Land-uses(trip-generators)		_	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	100
% built-environment influence		%	42	58	58	17	58	42	67	50	67	58	58	42	67	58	-	-

[2]Kuchingoro Junction (1st), MRS Gas Station (2nd), National Space Research and Development Agency (NARSDA) (3rd), Apo Roundabout (4th)Ahmadu Bello Way (5th), Garki Junction (6th), Independent Avenue Flyover (7th) and Zone 7 Bus Stop (8th). The others were; Berger Roundabout (9th), Mabuchi Junction (10th), Banex Junction (11th), Nicon Junction (12th), Federal Housing Junction (13th), and Gwagwa Extension (14th).
[3](Dei Dei Junction) 15th

[2] Locational Street names of hot zones
[3] White zone location

These variables are; U-turns (42% influence), roundabout (14% influence), traffic lights (0%), flyover (43% influence), road curves (30% influence), and speed limits (14% influence). The percentage of each variable per 14 selected sites also depicts the influence of the variable on accidents on the selected highways. In this step, the research is deficient in the investigative part where accident cases could be related to each of the investigated built-environment variable. Although it is not part of the objectives for the study, it is an important analytical step that will shed more light on severity of each built-environment variable per number of accidents. This can be looked into in future studies. Individually, some variables had lesser impact on accidents as single variables for instance roundabouts (4th and 9th locations).

It was realised that different locations with similar variable had different influence on accidents. For instance, the 4th and 9th locations (i.e., Apo Roundabout and Berger Roundabout) on Nnamdi Azikiwe Express. These locations had the same results (14%) when considered as observed built-environment variable, but had different percentages per hot zone location (17% and 67 % respectively). With the built environment variables, it is assumed that a lesser availability of variables per location indicates a lesser exposure to accidents at the location. This is corroborated by a study by Ossenbruggen, Pendharkar, & Ivan (2001) where they found that the probability of an accident is almost twice more likely at a site using traffic control than at a site without traffic control. This is also seen in the number of fatality that was introduced in the hot zone selection at the 4th location had 3 year fatality while the 9th has 5 years fatality, depicting severity of crash to be higher at the 9th location which has higher number of traffic control variables. Land use as a single variable of the built environment reflects a 100% in the evaluation. This indicates that locations with commercial, residential and public facilities are likely to have more accidents concentrations, this is also corroborated by Priyantha Wedagama et al. (2006) who modelled land use with the rational that it generates and attracts trips, with the conclusions that priority should be given to reducing accidents retails out-lets, probable shops (during working hours), clubs and bars, community land uses (at non-working hours)

Furthermore, land uses (e.g., hospitals, restaurants, companies, motor parks, suburbs, gas stations, cemeteries, and places of worship) were identified using a 1km buffer from the high ways and cluster locations (Figure 4-4-Q). It was realised that the 2 hot zone locations along the Murtala Mohammed express were associated with suburbs (Federal Housing junction and Gwagwa intersection), those are the 13th and 14th locations. Two locations were also observed to be associated with suburbs along the Shehu Musa Yar'Adua express (Kuchingoro junction and MRS Gas Station), these are the 1st and 2nd hot zone locations. Suburbs are high activity areas with offices, residential, commercials and public places, these are high trip generators and can result to an adjoining road segment becoming a hot zone for accidents because of its high influx of commuters to the area. The 3rd location on along the Shehu Musa Yar'Adua express had offices as land uses associated to the accident segments. There were different land uses noticed at each 1 km buffer from the crash location along Nnamdi Azikiwe express which has the highest number of hot zone locations (9 locations). These are further elaborated on Table 7. The results are descriptively and qualitatively presented to enable proposal for solutions and improvement of safety. It also gives in-depth understanding of the relationship of accidents clusters at the street level (Cho, Rodríguez, & Khattak, 2009; Clifton et al., 2009). One disadvantage with the qualitative approach used in this aspects is that the results can only be used for the investigated locations and cannot be generalised for other non-observed roads in the study area.

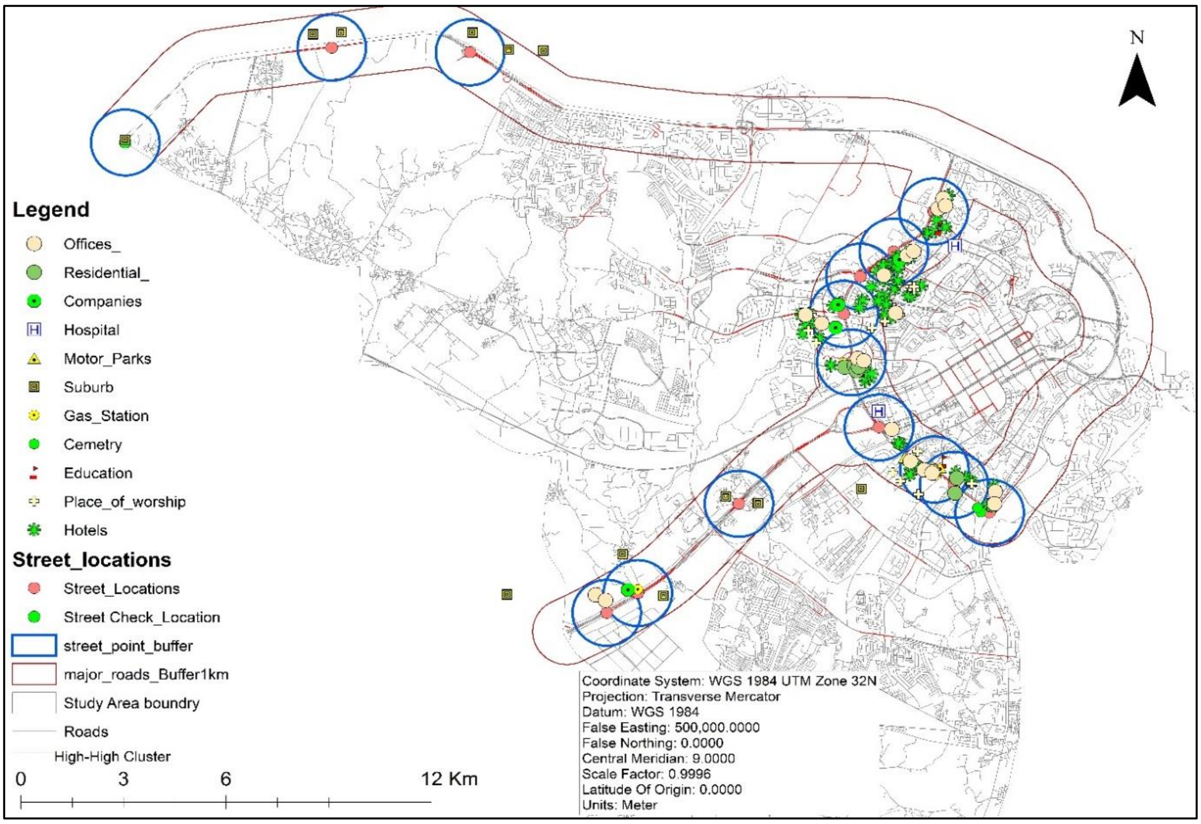


Figure 4-4-Q Land-Uses 1km from hot-zone locations Author (2018)

Table 8 Land-uses at cluster locations are shown, these are based on field observation, interview with pedestrians, residents and workers around the hot zone locations, and identified using Google Earth. It was found out that among land-uses identified on this locations especially locations on the Nnamdi Azikiwe Express, commercial land-uses were dominant in 71 % of the location (10 hot zone locations). The other 39 % (4 hot zone locations) were identified with suburbs and traces of commercial activities also physically observed.

Table 8 Land-uses at cluster locations Author (2018)

Street Locations	Land-Uses Available (1km buffer)	Number per land-use available
Independent Avenue (7th)		
	Institution	2
	Commercial	2
	Facilities(Parking)	1
	Recreation	3
Maitama Junction (12th)		
	Commercial	**5**
	Residential	1
	Recreation	1
	Institution	1
	Offices	3
NARSDA (3rd)		
	Gas station	1
	Commercial	**4**
	Industrial	1
	Offices	3
Garki Junction (6th)		
	Religious	2
	Commercial	**13**
	Gas Station	1
	Offices	2
	Institution	1
	Residential	2
	Recreation	5
Berger Junction (9th)		
	Station(Motor park)	1
	Commercial	**9**
	Religious	4
	Offices	3
	Gas Station	2
	Institution	1
	Recreation	2
	Industrial	3
MRS Gas Station (2nd)		
	Gas Station	1
	Religious	1
	Commercial	**5**
	Industrial	1
	Suburb	1
Zone 7 (Bus stop) (8th)		
	Commercial	**11**
	Religious	2

Continuation of Table 8

	Offices	2
	Recreation	2
	Institution	1
	Gas station	1
	Residential	2
Kuchingoro (1st)		
	Suburb	2
	Gas Station	1
	Religious	2
Ahmadu Bello Way (5th)		
	Utilities (Cemetery, Motor Park)	5
	Residential	2
	Commercial	**7**
	Offices	2
	Recreation	1
	Institution	1
Apo Junction (4th)		
	Offices	2
	Utilities	2
	Commercial	**4**
Mabushi Junction (10th)		
	Offices	5
	Commercial	**18**
	Recreation	1
	Religious	2
	Suburb	1
	Institution	2
Federal Housing Junction (13th)		
	Suburb	
Gwagwa Extension (Intersect) (14th)		
	Suburbs	2
Bernex Junction (11th)		
	Offices	1
	Commercial	**24**
	Gas Station	1
	Recreation	2
	Religious	1
Cold Spot Area		
Dei-Dei	Suburb	
	Commercial Activities	

4.4.2. Street analysis

As stated earlier, the major roads were selected for the street analysis, Umaru Musa Yar'Adua Way, Nnamdi Azikiwe Express and the Murtala Muhammed Express. The interview, observations and FGD discussion helped in this section to qualitatively look into factors influencing accidents. Illustrations are also shown related to observed human behavioural attitudes that influence accidents and accidents severity. This shares more light on the main objective of the study.

4.4.2.1. The Umaru Musa Yar'Adua Express

This is usually called Airport road because of the presence of the international airport on the route (location not part of the study area) and is situated in the Central region to the West of the study area. The route had three location segments selected for street analysis.

Kuchingoro Junction (1st)

The first location visited on the express was the Kuchingoro junction, Kuchingoro is a suburb along the Umaru Musa Yar'Adua express in Abuja. Inhabitants of Kuchingoro are parts of the commuters on this route who have to use to the Umaru Musa Yar'Adua express during their day to day activities. When one of the residents was interviewed on the causes of accidents around the area, he attributed it to tyre burst influenced by high speed. These were his words "… *Tyre bust is mostly the cause of accidents in this area. It happens every day. Speeding contributes to accidents in this area. A Pedestrian Bridge should be constructed to reduce accidents around here, because the one they have is a distance away….*" It was observed that the pedestrian bridge was only about a kilometre away, but the pedestrians preferred to walk across the highway in other to cross to the other side where the settlement is located.

Another interviewee said *"…..Speeding contributes immensely to accidents around this area, I was a victim of an accident on that very location, where my motorcycle was hit by a vehicle (Pick-up Van), the reason was that the drive of the van did not signal before negotiating the bend, speeding should be reduced….."* he pointed at a staggered junction on the segment in which the vehicle turned into. Figure 4-R, show pedestrians crossing a 10 lane express way on foot to the Kuchingoro suburb after dropping from a taxi. Some of the commuters go as far as putting a plank of wood across the water drains found between the lanes in other to aid crossing to the adjacent lane (Figure 4-Sa). A pedestrian bridge can be seen in the background in Figure 4-Sb. This was a common situation at almost all the hot zone locations. The pedestrian bridges were situated at a distance away from the settlements. When this was brought up in the FGD, one of the participant said *"….. most of the road constructions and designs are given out as contracts to companies, the government does not care to make it a collaborative task so that ideas can be shared between responsible organisations in relation to proper planning, and sometimes the road design and road construction are done by different companies. This led to some of the pedestrian bridges being situated the way they are, currently the government has the option of counter measures to reduce the rate of accidents by constructing new pedestrian bridges where necessary…"*

Figure 4-R Pedestrians crossing at Kuchingoro Author (2018)

One other physical characteristic observed was the presence of a staggered junction, this is shown on Figure 4-Sc. This type of junction are prominent features along the major roads and potential causes of road accidents, because vehicles using staggered junctions will need to slow down and use a signal sign to indicate their direction. Vehicle with no break lights or functioning signal lights could become road hazards to other vehicles or create a situation for a potential accident.

Plank used by pedestrians to support crossing

Pedestrian bridge location

Staggered junction

Irregular parking at the T-junction

Figure 4-S Street observation, Kuchingoro Author (2018)

Another observation was the irregular parking of taxis and motorbikes at the junction, to pick up and drop off passengers, this is shown in Figure 4-Sd, doing that on a highway is very risky and could be a potential cause for accidents.

MRS Gas Station (2nd)

The second location was the MRS gas station located along the same route. This location has the local land uses characterised with, a gas station located at the junction, shopping mall, church, offices and a residential settlement called Galadimawa. It has also a road intersection as a physical road characteristic. An interviewee in the area attributed the cause of accidents in the location to high speed from oncoming vehicles and inadequately trained drivers. He expressed himself in these words *"……Speed is the major cause of accidents on the roads in Abuja, this is because of the way the roads are. A lot of people speed, and because the drivers are poorly trained and impatient, they tend not to know what to do at certain junctions, points and how to switch lanes"*. He went on to say *"Nigerians do not really know a lot about how to use the roads they drive on, a lot of people do not read road signs…."* Basically, he thought of poor lighting as a contributor to accidents at night, because a lot of accidents happen at night hours which are not usually taking into records. Although most of the major express roads are lite, the arterial roads, junctions where they meet and roundabouts have no light, stating that as a problem. Figure 4-T shows the built environment around the specific cluster location. The intersections were part of the road design and as such the 3 major routes used for the field work have them constructed on. They are found to be a contributory factor to accidents in Abuja.

Figure 4-T Segments showing intersections at MRS junction (Air-port road Abuja Nigeria) Author (2018)

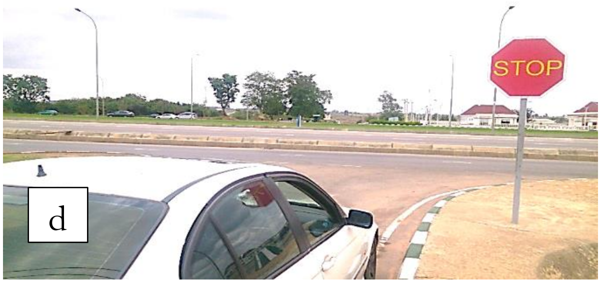
National Space Research and Development Agency (NASRDA) (3rd)

The third location on the Umaru Musa Yar'Adua express visited, was a T-junction at the National Space Research and Development Agency (NASRDA) in Abuja. The T-junction is directly at the entrance to the research agency, which is the main land use around this location and includes offices. Adjacent the agency is a gas station. The nearest suburb to this location is the Galadimawa settlement, because the location is just after the MRS gas station. The accident data from 2013 to 2017, it shows 4 years period of fatality at this location excluding 2015. An interview with a pedestrian around the location confirmed the occurrence of accidents on the segments. He attributed the accidents to making phone calls while driving and fatigue; these were his words *"………Private cars have more accidents than commercial vehicles on this route, fatal accidents occur around this area which are mostly caused by tyre burst and sometime tiredness or answering calls…"* When asked about the street lighting of the area, he confirmed the words of the previous interviewee who spoke about the major roads having streetlights. He said "*….street lights area very effective, even more effective than the residential homes in this area…"* Figure 4-Ud, shows the T-junction with a road sign, vehicles could be mindful of driving into the express road. Further observation of the location had the following street design elements, Figure 4-Ua, U-turn, Figure 4-Uc, pedestrian bridge, and Figure 4-Ud, staggered junction. A similar occurrence seem to be the use of planks on the road by pedestrians to aid with crossing the high ways (Figure 4-Sa)

A U-turn at the segment

A staggered intersection

Pedestrian bridge from afar and



Road sign at T-junction

Figure 4-U Street Designs at T-junction Author (2018)

4.4.2.2. Nnamdi Azikiwe Express

Nnamdi Azikiwe express cuts across the study area from the North-East to the South-West. It was chosen as one of the routes for the street observations because of the high number of accident fatality on the road. Locations visited on this route were, Apo roundabout, Ahmadu Bello way flyover, Garki junction, Independent Avenue, Berger junction, Zone 7 junction, Mabushi junction Banex junction and Nicon junction. The road signs observed and accident causes on each of this locations were not farfetched from that of the earlier visited sites. The perception of people towards the accident causes are considerably different.

Apo Roundabout (4th)

Apo roundabout is located at the Western region of the study area. It links traffic to the Murtala Muhammed express and to other suburbs around Abuja. At Apo roundabout, it was observed that the roundabout was under construction but still in use. Although Apo roundabout have had fatal accidents for 3 years, an interviewee confirmed it has been a less fatal spot, as the construction of road have been ongoing for some time, and this has calmed the traffic around the area. But was also learnt that accidents still occur at the location. He attributed the causes to "….*drivers carelessness resulting at sudden accidents and unfit vehicles on the road…..".* He said the location was poorly lighted at night and so accidents easily occur around the night time and rated the location as dangerous at night. Other activities noticed were stopping of vehicles to mount and dismount passengers at the roundabout and hawkers (Figure 4-V). Associated land-uses serving as trip generators around the location were seen to be hotels, offices and cemetery.

Activities at roundabout

Construction work at roundabout

Figure 4-V Street activities at Apo roundabout Author (2018)

Ahmadu Bello Way (5th)

The location consist of a flyover and is situated along the Nnamdi Azikiwe express. It consist a U-turn and a T-junction. Accident causes in this area have been attributed to over speeding and reckless driving. The drivers around this location interviewed complained of road signs and speed limits not applicable on roads, probably pulled out by rain or accidents which are never replaced. They said the road signs help because of the nature of the roads in Abuja. One of the drivers said, *"…. Driving recklessly causes accidents and the road signs that are not there should be replaced…"* another of the driver said, *"….Over speeding is the main cause of accidents around here, when you are on high speed you are unable to control yourself in the case of obstruction or pedestrian crossing. For instance we are not supposed to park here and wait to pick up passenger, I might take off and accidentally run into an upcoming speeding vehicle, resulting in an accident. This can happen between cars, motorcycles or tricycle. For pedestrians, they do not use the bridge and they end up being hit or killed by vehicles. ……"*

Figure 4-W Similar situation of activities around the flyover and roadside parking Author (2018)

It was observed that there were barricades along this specific route to stop pedestrians from crossing, but these barricades were vandalized. When the issue was brought up at the FGD, they related it to the bad attitude of people, because the pedestrians go to the extent of vandalizing the barricades to create space for passage. A respondent was asked the reason he parked along the street to pick up passengers, he said taxi drivers are been asked to pay fine and he had no money to pay the responsible organisation, this were his words "…..*There are charges embarked on taxis in parks, we can hardly pay those charges…"* It was later known that land-uses serving as trip generators around the location are hotels, banks and eateries (restaurants). At the flyover, similar activities as found in other junctions exist as seen in Figure 4-W, major observation is the absence of road signs and speed limits in some of these locations with complex road designs. One of the respondents poured out his mind saying, *"…….Speed signs will definitely help to prevent the amount of traffic on the way, and help to reduce accidents as well. This is because we do not actually have street signs, we do not even have traffic signs, and we do not have a lot of them. We do not have traffic signs that work at night, we do not have any aids to help you reduce speed or keep you conscious of the speed you are going, we do not have speed cameras, we do not have equipment that can electronically without people physically being there, aids that can actually make a driver to be better on the road. I.e. lighting, signs and enforcement. Enforcement can also come by way of speed cameras. Signs will help reduce accidents and improve driving generally…."* To help reduce accidents and increase road safety in Abuja, there has to be an extensive check of infrastructure, especially speed and road signs implementation on all the roads especially major roads in Abuja.

Garki junction (6th)

Garki junction popularly called the Area 3 junction was the next location of visit along the Nnamdi Azikiwe express road. The activities, street designs and land-uses of the area were not far different from the previous. In an interview with a respondent at this particular location, he attributed the cause of accidents to good roads around the city. These were his words *"……Over speeding, when you speed too much you are not able to control yourself. Phone calls, talking on the phone while driving, lack of confidence. Good roads increase the rate of accidents. People are not experts in driving…."* He further said *"….All the vehicles parked on the road side are parked illegally, only the once inside the park are legal….."*, when asked of his opinion over the vehicles parked around the road side close to a designated vehicle park for taxis. Figure 4-X, show activities around the location serving as trip generators.

Figure 4-X Designated parking and shopping complex at junction Author (2018)

It was noticed that even at the location where the motor park was situated, taxis and tricycles were found along the road dropping off and picking up passengers. Some of the pedestrians said it was faster for them than using the cars at the park. In the FGD with the FRSC officials, they related this to attitudes of individuals especially Nigerians. This were the words of one of the officials at the FGD;

"…..Attitude and behavioural change. Every one involve needs change attitude. Change is a factor. The FRSC official are dedicated to their duties, they put their lives at risk (during the harsh weather condition's) and even at late hours of the nights, they are called upon for evacuation in terms of accidents. There was a time I was involved in evacuation at midnight and the officials do this with limited resources. The FRSC go out of the way to seek alternative founding to keep the job going. Imagine FRSC organization not in the country, there will be a lot more casualties and probably we would have been dead by now…."

He assured the FRSC was doing their job as an organisation and at all times. Change as said, must be with the individual involved.

Independent Avenue flyover (7th)

The Independent Avenue flyover was the next location of visit. Situated along the Nnamdi Azikiwe route, it has the National Stadium and National Hospital as land marks around the area. It was observed that the flyover lacked street signs, just like the others. The street signs had a percentage score of 71, but probably that is not good enough for a city like Abuja, with its dense traffic road networks. The street signs and markings will help a lot in the reduction of road accidents in the city. With the street signs, it will guide visitors and road users on the appropriate ways to use the roads. Because of the inadequate road signs, dwellers in Abuja miss their routes. Although pedestrians and lots of commercial activities are not conversant with this location, it is still an accident prone location because of the land-uses and it serving as a link between Nnamdi Azikiwe road and the Umaru Musa Yar'Adua express. Because of the site of the National hospital around the area, it attracts people from all over the country who come in for treatments. Obstructions observed around this location liable to accidents were trees that were seen along the routes and U-turns at the flyover location Figure 4-Y shows possible physical obstructions on roads.

Figure 4-Y Physical obstructive view of trees Author (2018)

Zone 7 Bus stop (8th)

This is located on the Nnamdi Azikiwe road, where Olusegun Obasanjo way and Idris Gidado Street meet. Located around it as trip generators are, offices, hotels, parks, restaurants, schools, plazas, residential estates, churches and mosques. An interviewee confirmed that the accidents around the area had reduced, stating that the reason is due to the barricade fixed on the road to stop pedestrians from crossing. Infrastructure observed in the area were T-junctions. Because the area is mostly residential and consist of also a school, busy streets are likely to be observed during peak periods of going to work and school and closing hours.

Berger Roundabout (9th)

Berger roundabout is a major roundabout on the Nnamdi Azikiwe express, it links the Herbert Macaulay road with Obafemi Awolowo way. Berger roundabout formerly known as Berger junction has around it as land-uses recreation gardens, offices, motor parks, restaurants, banks and gas stations. Aside it being a route connector, it was known to be a dangerous place taken over by hoodlums and criminals who sell drugs and also prone to traffic congestion and accidents until it was contracted to a company were it got it famous name from Julius Berger in 2008 to build a recreation park (Digest Magazine, 2018) . Due to lack of maintenance, the activities of hoodlums around the area seems to have returned. On a visit to this area, the location seems to be the first encountered with a zebra crossing, but are zebra crossings in Nigeria really functional? Probably the researcher might say no to this question because of the experience had while crossing. An interviewee said *"….. I once travelled out of the country, on return, not having in mind that this was now Nigeria having waited for long, , I used the zebra crossing and an oncoming vehicle seem to appear on the road and asked if I* *was insane, immediately it occurred to me that ooh.. I am back in Nigeria…"* Some of this facilities are there but the road users are not trained to use or obey them. The zebra crossing laws are not adhered to by both driver and users.

Figure 4-Z Street marking at roundabout Author (2018)

Figure 4-Z a shows a zebra crossing at the roundabout, Figure 4-Z b, shows an extension of the zebra at the other end with taxis parked on the zebra crossing waiting for passengers and a view of commuters and commercial vehicles.

Mabuchi Junction (10th)

Most of the names were sourced before the reconstruction of the roads, Mabuchi junction is actually now a flyover. Mabuchi also depict the name of a settlement very close to the flyover. Mabuchi is a hotspot location that has recorded fatal deaths until 2017 (from acquired data source). Aside the settlement which was known to be close to the location, other areas serve as trip generators, these areas are, the Ultra-Modern Wuse market, which was said to be a distance across the express. The Wuse market is about 1.26km away from this junction, so the inhabitants of this settlement find it easier to walk across the road to this market place for their daily shopping or work. Other land-uses are, offices, a medical centre, school, other commercial plazas and residential properties. From observation Mabuchi junction presently lacks a pedestrian crossing, unless one located over 1km away from the junction. One was again said to be present a distance away, which was not visible. People are seen walk across the busy roads, resulting to accidents. In an interview with a respondent he said *"……pedestrians are mostly killed around this area, when they try to cross the road. This is due to lack of a pedestrian bridge around the area. Coming from the Wuse market to the residential settlement around here. They are mostly killed on a daily bases…"* Another observation was the presence of an intersection on the segment around the location. These could be another contributory factor. Figure 4-AA shows Mabuchi junction, it shows pedestrians trying to cross and cars parked along the road picking up and dropping off passengers.

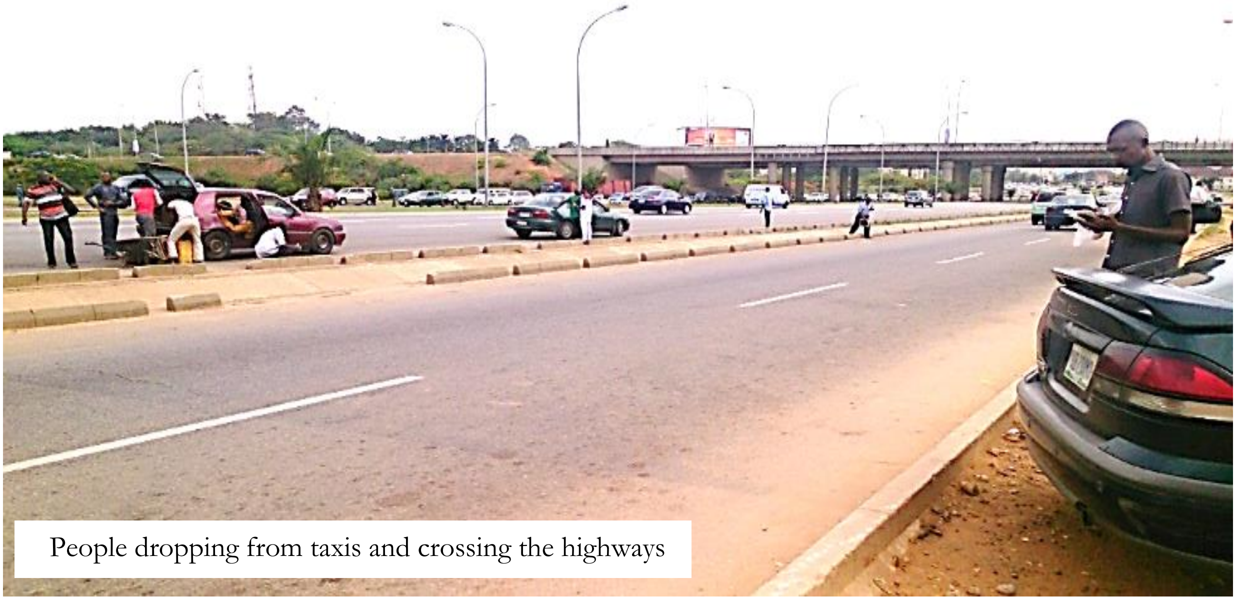


Figure 4-AA Mabuchi flyover Author (2018)

In this research, Mabuchi was found to be one of the most hazardous locations because of the frequency of fatality recorded in the number of years. It was found to have recorded a 5 year fatality rate from 2013 to 2017.

Banex junction (flyover) (11th)

This is also located on the Nnamdi Azikiwe express; it is a flyover where Ahmadu Bello way joins the Nnamdi Azikiwe express at Wuse II. It derived its name from the famous Banex plaza in Abuja. The said junction is close to the Banex and Sherif plazas. These are some trip generators already found to be connected to the area. The area is known for its high commercial activities and so has so many plazas around the area. Hotels, restaurants and the route also serve as a connector route to other places. Banex was also found to be one of the two most hazardous in terms of frequency of fatality in the 5 year period. These locations are close together, that is Mabuchi and Banex, and have similar characteristics. The only difference is that Banex junction is seen to be closer to a pedestrian bridge located less than ½ a km away (seen in Figure 4-FF). Yet pedestrians prefer to drop along the busy route and cross the express. An interview with some of the people around the area to causes of accidents and why pedestrians prefer to risk their lives, got results not far different from the view of other respondents. One of the respondent, a pedestrian said "……*The foot bridge has so many steps, I use the bridge but for today, I am fasting. I cannot use the bridge today because I do not have the strength to go up the bridge. It is easier and less stressful to drop from the taxi and walk across the roads. We know of course our lives are endangered but Nigerians especially love 'short cuts'*….". It is then quite obvious that some people do not mind losing their lives. A petty trader along the foot path said, *"….some passengers drop at the pedestrian bridge while some insist on dropping by at the junction to go through the footpath that leads up the flyover. And this leads sometimes to getting themselves killed…."* As rightfully stated, the coordinator, Abuja Metropolitan Management Council (AMMC) Umar Shuaibu said; *"…..government provides facilities for our convenience and usage, unfortunately we do not use them the way it should. Our people want bus stops located in front of their houses, they do not want to walk, and walking is good for our health ….."* (Digest Magazine, 2018).

A worker around the area, was asked why the location attracts commuters, this was his response, "….*There are a lot of plazas, business centers, Next Shopping Plaza and people come from the suburbs, Suleja, Bwari, Duste, Kubwa, they all come this way and go different directions for work, shopping and the road also link to so many other areas in the city* *center….”.* When taxi drivers were asked why they prefer to pick up and drop off passengers along the road than using the bus stops, their responses were that the bus stops provided are not spacious enough to contain the number of taxis at a particular period, especially at peak periods. It was said, often times, when they use the bus stops, other taxis pass by and pick up the passengers. A lot more was said about pedestrians being killed at the particular location by an eye witnesses, these were their words "*….Pedestrians are the most victims. I am an eye witness of a recent accident that just happened few days ago, where so many people here lost their lives. A big truck lost control and hit on the pillars under the bridge, so many of the pedestrians standing to cross and waiting for vehicles were killed. They were more than 10 in number…"* Another said, "*…..A lot of accident happen around this area, from the distance where the pedestrian bridge is located down to the flyover. The pedestrian bridge is for use, but the pedestrians prefer to drop at the road way and trek up to find their various directions. The drivers after parking, are not sometimes careful while taking off, and most times end up hitting the other, that happens often. Sometimes in a day accidents can happen in the particular location twice. A lot of pedestrians are killed around here, I am an eye witness because this is where I stay to do business. Government officials do not stay to enforce the law 24hrs, after sometime they go away, and then the whole process starts again…"* As most drivers attributed their parking on the roads to small bus stop sizes, each of the pedestrian bridges have bus stops. Suggestions were to make the bus stops to larger sizes. Figure 7-C at the appendix shows bus stops at some locations. On the other hand this were views from the respondents on what the government should do to curb this menace, "…: *The barricade should be reconstructed, although people vandalize it, security should be able to work around this areas for 24hrs as it is done in developed countries. The barricade should be completely covered and for the drivers, they should be fined, any driver caught dropping passenger anywhere along the road asides the bus stops should be dealt with. The officials should be stationed at locations to stop pedestrians from crossing….."*

In Figure 4-BB is Banex junction during the morning peak hours, commuters are seen transiting from the commercial vehicles boarded to their various destinations. Getting a closer view at the scene, it was realised that activities of petty selling and buying actually take place at the junction as shown in Figure 4-CC. The traders take advantage and are present at this location during this time to make quick profit from the sell of their goods. Some of the commuters go up the flyover across the road to board other transport to their destinations. Figure 4-DD, Shows vandalized barriers that were fixed on the road around Banex junction. From information gotten at the FGD, *"vandalising is carried out at early hours of the morning"* says an eye witness among the officials, big stones are used to hit on the iron wire until they get destroyed. Nothing could be done to the vandals as there are no laws put in place. Previews of some of the activity areas serving as trip generators are seen in Figure 4-EE which shows some section of the commercial area in which the major group of commuters trip to on a daily bases.

Figure 4-BB A view of Banex junction Author (2018)

Figure 4-CC A closer view of street activities at Banex flyover Author (2018)

Figure 4-DD Vandalized barriers Author (2018)

Figure 4-EE Activity areas serving as trip generators Author (2018)

Figure 4-FF Views of pedestrian bridge at Banex junction Author (2018)

Nicon junction (12th)

Nicon junction was the next point of visit. This is located at Maitama with its land mark as the Transcorp Hilton Hotel in Abuja. It was formerly known as NICON Noga Hilton Hotel, one of the first 5 star hotels in Abuja. Though it is some kilometres away from the junction, it serves as a trip generator. The area, is basically a residential area, other land-uses serving as trip generators around the area are offices, restaurants, recreation, schools and hotels. Street designs taken note of around the area were a pedestrian bridge (Figure 4-GG), almost a kilometre away from the junction and a T-junction. It was observed that Nicon junction had a similar problem of barrier vandalising as Banex. Other visible characteristics was the obstructions by use of concrete for road demarcation. From the perception of a resident around the area, views were given of how people risk their lives crossing the roads and end up being killed on a daily bases.

Figure 4-GG Pedestrian bridge and vandalised barriers at Nicon junction with obstructions Author (2018)

4.4.2.3. Murtala Muhammed Express

The Murtala Muhammed express, usually referred to as the Kubwa express, is located on the North of the study area. It is a major road that leads into the Federal Capital Territory from the North-West of Nigeria. Kubwa where it got the name Kubwa express from, is a suburb along the express road. Two hot spots were considered to be visited along this route. One is the Federal Housing junction and the second is Gwagwa intersection.

Federal Housing junction (flyover) (13th)

The Federal Housing junction is located around a suburb called Kubwa, it was chosen as a hotspot because of the rate of accidents and period of yearly fatality record in the particular location. Before Kubwa settlement is Duste Alhaji which is also a suburb along the express way. This two settlements are interlinked in terms of activities and road network. Before the construction of the flyover, traffic in Kubwa town use to be at its peak from 8am until 11am, when most commuters travel into the city for their work and businesses, and in the evenings from 4pm to 8pm and sometimes 9pm. The construction of the flyover and the 10 lanes and rehabilitation of the existing express roads, has helped in reducing the dense traffic network of the area. But the rate of accidents and fatality seems not to have reduced to the barest. To know what features are associated with accidents in this location, the street observation and interview gave more insight to this. It was understood that most accidents that happened in the location were associated with open drains constructed in the middle of the roads. The respondent said *"….: what causes accidents around this area are the gutters that are between the lanes. And at the junction, this is mainly because of speed and sometimes the drivers are drunk, the accidents are fatal….."*This fact is confirmed in a publication by Ipaye (2014) who described the road as a killer machine because of the open drainage constructed in the middle of the expressways. As at the course of the street observation, the killer culvert was at work, causing damages to lives and property, this is mostly as a result of over speeding. Figure 4-HH shows one of the accident scene at the Kubwa express. Because of the lack of signage along the highways, it is observed that vehicles over speed and lead to accidents which severity might be enhanced by the presence of open drains.

Figure 4-HH Accident on the Kubuwa express, car in an uncovered drainage Author (2018)

Figure 4-II shows the open drains situated in the middle of the lanes. Trip generators associated with the junction are, many residential estates, commercial business, offices, and gardens.

Figure 4-II Open drains in the middle of the roads Author (2018)

Gwagwa Extension (14th)

Gwagwa is also a suburb along the major route with an intersection as a hot spot location. As a suburb, it attracts commuters out and into the settlement. The physical infrastructure seen to influence accidents are the road intersections, same as the one in Figure 4-T, probably because the design was made by one person. This major street design have caused and are still causing harm to the residents and commuters of Abuja metropolis. More public enlightenment on the importance of sign lights (signals) while driving, could help to reduce the problem.

Dei-Dei junction (White zone) (15th)

Lastly a cold spot location was visited. This location was accident prone, with people being killed on a daily bases. The most amazing thing, this time around was that the pedestrian bridge was located less than 0.10km away from the junction. The people around this area still did not use the pedestrian bridge but preferred to run across the highway and get knocked down and killed. Curious to know what measures were finally put in place, the issue was brought up at the FGD, and the answer given was that the barrier used in the middle of the road was changed after they destroyed it and stronger metals were used to construct new ones that were not easy to destroy. A visit to observe and interview some of the residents around the area gave more understanding to the situation. It was observed that, the barriers were of higher quality than the ones seen previously in other locations. And amazingly, pedestrians were seen using the bridge to cross because they had no other choices. The respondent interviewed confirmed they do not experience any of such accidents anymore as that was in the past, before the barriers were put in place. On Figure 4-JJ, it shows the pedestrian bridge at Dei Dei and the new barrier still in good shape.

Figure 4-JJ Dei-Dei pedestrian Author (2018)

4.5. Improving Road Safety In Abuja

In this section, the FGD and annual reports gotten from FRSC helped in understand the efforts the organisation have put in place to improve safety on Nigerian roads. It will enable the completion of the research work by giving answers to sub objectives 3a and b of the research. It shades more light on measures put in place and other counter measures to consider based on the results of the field work and perceived view of individuals.

4.5.1. Measures Set for Realization of Safety on Roads

To understand the existing counter measures of the FRSC as the lead organisation for road safety in Nigeria, further discussions and question were asked for clarity on issues. It was understood that existing measures were surrounded by challenges faced by the organisation. Although the organisation has a lot of collaborative bodies, Establishments, Agencies, Non-Governmental Organisations, Multi-National Organisation, International Organisations etc. It is very important that, in tackling event problems especially road accidents in which lives of individuals are involved, to put in place valuable ideas and decisions from various departments, including spatial planning to enable achievement of sustainable goal. It was explained at the FGD that related to the political environment, that is, political will, FRSC have involved to the peak of the political environment, but said, much was still expected.

However, it was also realised that the effort on the concept of motorized road patrol themes system in Nigeria was brought up by the FRSC. This was to help in the humanitarian services the organisation is involved in. It was known that since 28 years of the road safety establishment, it was the first time it got the highest re-equipment of its operational arms by the Federal Republic of Nigeria with a total of 403 patrol vehicles and 16 motorbikes. 17 vehicles were donated by individuals, cooperate organisations and some state governments. A participant in the FGD said "……*government sees FRSC as one of those agencies, but it's more than that. Funding and providing some modern working tools is one step; however, maintaining those tools are most important, FRSC came up with the concept of motorized road patrol themes system, but they have various challenges that have brought down the motorized system*……" Facility maintenance is always a major problem especially if an organisation is solely dependent on other organisations or authorities.

It was also found out that the yearly lecture series organised by the FRSC to provide a platform to share information on road safety and input into the planning and execution of road safety policies and programmes was initiated in 2009. This was with the aim of creating public awareness on road safety for positive attitudinal change of drivers and the public. In relation to this, surveys were also carried out on the determination of the alcohol consumption among drivers in the six geo-political zones. This was because, from statistics available, it was revealed that the number of traffic fatality in 2007 was attributed to high alcohol abuse resulting to about 4,673 cases. Also, a record of 4,065 cases of fatality in 2010 one related to this, according to data in the 2012 FRSC annual report (FRSC, 2016). Though, the impact of alcohol on increasing risk of involving in an accident for vehicles and pedestrians was clear in this statistics, it was understood that alcohol is also associated with over speeding, thereby reducing driving efficiency. Based on this, the survey was carried out in 2016 on breath alcohol testing. Findings is said to have significant policy implication on the focus of FRSC in relation to causative factors of RTAs. Interventions like behavioural communication for drivers and enforcement activities were targeted at non-professional drivers in certain parts of the country where Breath Alcohol Consumption (BAC) was found to be high above accepted limits. Its long time effect is on the developed strategies by FRSC for regular BAC testing of drivers found guilty of offences by the FRSC and regular public information campaigns across the country.

Measures have been put in place to increase the response time to at least 15 minutes by establishing the corps medical and rescue services, a participant at a FGD stated *"….Almost all roads in Abuja are asphaltic, we do not work alone but with other organizations when it comes to response time, we have the zebra units all around. When the call centre is called, information is quickly passed to the zebra units and they move. FRSC guides Nigerian roads well to ensure safety of lives….."* this was aimed at reducing the response time of operatives to the scene of crashes to save more lives. In Figure 4-KK is a summary of nature of received calls in 2016 and Figure 4-LL shows total call summary from January to December 2016. These graphs are shown to further give insight to how these measures are helping in accident reduction. It is seen that calls received for accidents is second highest aside enquiries. And the call summary shows a peak in January and September but drops in April and December, probably indicating times of high peak of calls and can also help the organisation to times at which accidents can be at the peak when call summary is specifically meant for accidents.

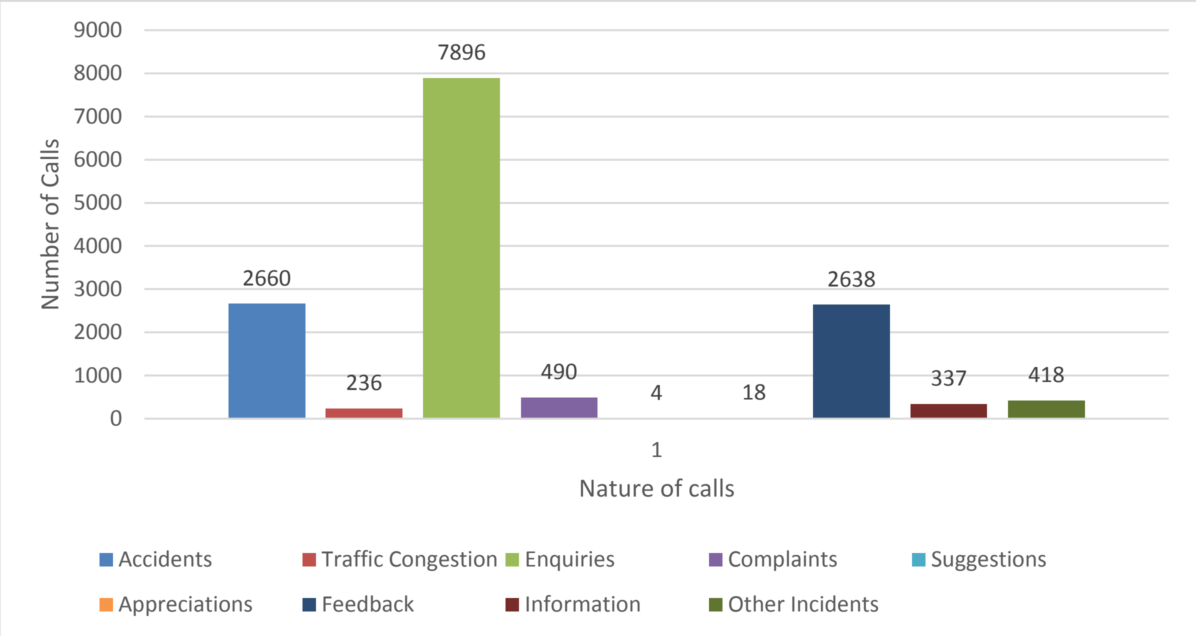


Figure 4-KK Calls received by the FRSC call centre from January to July 2016 FRSC (2016)

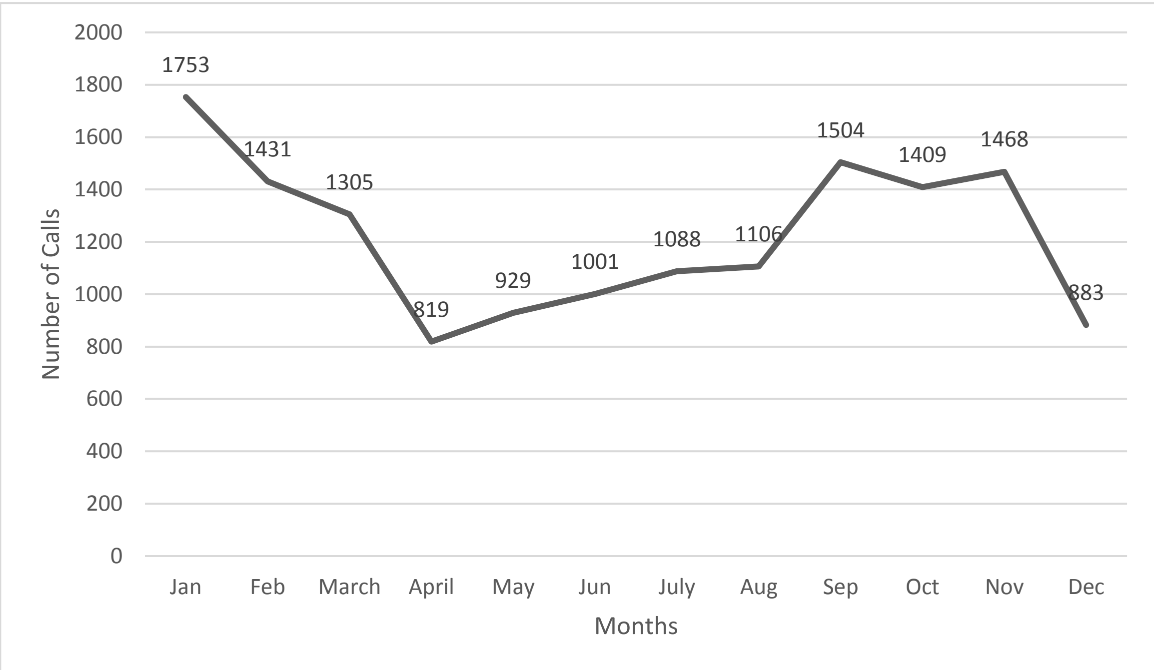


Figure 4-LL Call summary from January to December 2016 FRSC (2016)

The signage is an important element of consideration in measures to take for a better safety on roads. Although the discussion on this was contrary to the observations made on the major roads on road signs and speed limits *"….Every road has speed limits, but they do not obey them. It still boils down to attitudes. The people vandalize them. For instance, the barricades used on roads are being vandalized by the road users. I am an eye witness of a vandal as early as 5am when I was coming from the hospital with a very big stone hitting the barrier to destroy it and create way for pedestrians to cross. Damaging government infrastructure. It still narrows to the attitudes of individuals. Until Nigerians have an attitudinal* *change, we cannot move forward as a nation. Other developed countries have had their own past, I believe Nigeria will get there as a country, but it is a gradual process…."* Says a participant at the FGD. It was further understood that in 2015, the FRSC signage plant was commissioned and had begun production in 2016 to help close the gap in signage production in Nigeria. It was also known that since the establishment of the plant, there has been demand for the product across the country. Although in the check list analysis, street signs and markings had a 50%, speed limits had 0% (Table 7). The analysis of the signage done confirms that no speed limits was seen at any of this locations or close to the locations, this is in line with the FRSC (2016), where it was confirmed that most sections of the road were identified with issues with road signs and markings. For a complex road network like in the case of Abuja metropolis, there is need for adequate provision of road signs and speed limits for an effective transport system and safety on roads.

Other measures are; survey on tyres and tyre campaign and conference conducted by the FRSC. This was to promot safe tyre use in Nigeria to call on government to support local tyre manufacturing industries in Nigeria and also to train and certify vulcanizers on the right methods of fixing inflating tyres and share vital informations and ideas amongst stakeholders. Public enlightenment was another tool used by the FRSC in 2016 to reach out to the public. This was carried out through advocacy campaigns to schools, to produce cultured drivers at school age. Private and public institutions, motor parks, major streets in FCT were areas drivers were sensitized, including coporate and religious organisations. Highlights of some public enlightenment strategies in 2016 is shown in Figure 4-MM. The sensitization kicked off with awareness, on photo Figure 4-MMa, Figure 4-MMb is the tyre sensitization campaign. In Figure 4-MMc is the breath alcohol concentration test on a driver and Figure 4-MMd is the awareness on safety at a motor park in Abuja metropolis.

Figure 4-MM FRSC officials at Sensitization Campaign and Enforcement 2016 FRSC (2016)

An important measure the local safety organisation is trying to introduce is the use of bicycles in the Federal Capital City. The effort is based on the declaration made by the United Nations (UN) on the World Bicycle Day (WBD), to be held every 3rd of June yearly. All cycling associations, ministry of sports, all bicycle owners and the FRSC, headed the exercise, this was held on the 3rd and 4th June 2018. It was said to improve human health, it is simple, affordable and improve environmental sustainability. A 5 minutes video on road safety campaign radio programme aired by the Love FM Abuja, can be viewed on this link https://youtu.be/xSAhUZuq-RY. The radio enlightenment programme was aired in the local Nigerian English (Pidgin English) for easy understanding by all individuals.

4.5.2. Achievements, Strengths, Prospects and Limitations of FRSC

Since the establishment of FRSC in 1988, the organisation has undergone series of achievements in various sectors of the organisation. Amongst the various are recent achievements in its 3rd decade, the digitalization of work process gained momentum and FRSC became highly ICT driven by digitalization and automation of systems, upgrade in administration and personnel/career enhancement (Oyeyemi, 2018). Successfully implemented programmes include;

- Compulsory crash helmet and seatbelt usage nationwide.
- World Bank safe corridor project: this was in collaboration with the World Bank /Road Sector Development Team (RSDT) under the Federal Roads Development Programme (FRDP) to upgrade selected highways to safe corridor model from June 2008. Interventions focused on six selected corridors, among which Abuja metropolis was one.
- Introduction of annual lecture series aimed at creating public awareness since 2009.
- Introduction of national school bus policy and school bus standards to safeguard school children from RTAs especially during school hours.
- Improvement of driver's license and plate number scheme.
- Manpower capacity development; i.e. specialised and skilled training conducted for both management staff and junior officers.
- Emergency Ambulance services scheme; established call centre with toll-free 122 and creation of emergency ambulance points called zebras.
- An initiative intended to speedily evacuate victims of road accidents to health facilities for adequate medical intervention, with medical assistance offered while en-route/airborne (Flying doctors).
- Increment in basic health care services and establishment of more RTA clinics along high ways and zonal commands.
- Nigeria Road Safety Strategy (NRSS). Endorsed by the National Economic Council (NEC), with vision to ensure that RTA result in no death in Nigeria with a goal to reduce fatality rate by 35% by 2018.
- Revamping of driving schools through the Driving Schools Standardization Programme (DSSP)

Strengths of the organisation as stated in Oyeyemi (2018), lies on :

- Upgrade in Administration; Creation of Marshal Inspectorate Cadre and weekly management meeting.
- Digitalization and automation of systems; Connection of commands to National Headquarters V-SAT and automation of the payroll system upgrade.
- Introduction of e-dashboard management system; i.e. enhanced monitoring of road safety performance indicators on weekly basis for information management decisions and policy formulation.
- Personnel/Career Enhancement; Establishment of promotion board to ensure a well-trained and responsive workforce.

Prospects of the organization is focused on the achievement of the Vision 20:20:20 articulated by the Nigerian government towards taking the nation onto a path of sustainable social and economic progress of a truly prosperous and united Nigeria, placing her among the top 20 economies in the world by the 20:20:20

(Oyeyemi, 2018). The FRSC have the objective to optimize human and natural resources to achieving rapid economic growth, and translating the growth into equitable social development for all citizens, with relevance in 6 out of the 17 Sustainable Development Goals (SDGs). These are; goal 2, zero huger, by easing movement of farm produce. Goal 3. Good health and well-being, by ensuring that RTAs results in no death. Goal 4, Quality education, by achieving fully up-grade of FRSC academy to a centre of excellence in road safety management in Africa. Goal 11, sustainable cities and communities, FRSC intends to push through in conjunction with stakeholders, including Society of Town Planners, to ensure that schools, markets and all other activities conflicting with the road or traffic are eliminated. Goal 13, Climate action, FRSC will ensure periodic technical inspection of vehicles covering, identification of vehicles, exhaust emissions, noise emission and all other safety environment requirement in the UN rule and goal 17, partnership for the goals, FRSC will strengthen Nigeria Road Safety Partnership (NRSP) in line with national interest.

Limitations were seen in relation mainly to funding to aid in achieving the set goals and objectives and other prospects within the organisation base line projection from 2017 to 2028. These are, auto-logistic progressive projection in the decade patrol, commands/facilities expansion. Also, FRSC owned/permanent offices zonal, personnel projection base, improved data management, sophisticated fleet systems and graduated driver training programme, full arms deployment, etcetera.

4.6. Discussion

This study has confirmed that with the application of GIS and Remote Sensing, critical problems related to road traffic accident can be explored and important insight revealed of accidents causes. In order to conduct a reliable analysis for this research, the road accidents data had to be georeferenced, the geographical distribution of accident points had to be investigated, areas where clusters were observed of more dense concentration were found out and further investigated upon. The study has confirmed the association of the human, environment and vehicle factor in the road accident data for the study area 2013 to 2017.

Descriptively, it was found out that accidents had fluctuated in the 5-year period with stable accidents occurrence in the year 2015 and 2016 and a drop in the year 2017. Consistency was seen in the data as the number of people killed, number of people injured, number of minor, and number of people involved fluctuates with the years as the number of accidents especially in the year 2017. It was later found out that traffic calming measures introduced into the system in 2016 had probably taken effect in 2017 to result in the reduction of accidents in the study area. As it was also observed during the field work, this calming measures especially for the highways investigated takes place during the morning rush hours (from 7am to 10am). But from the time-based findings of the secondary data, it was also confirmed that accident peaks were also at 11 am to 12pm and also during the afternoon rush hours (from 3pm to 4pm). This entails that the time base analysis in this research can further aid in calming traffic on the highways especially at the hot zone locations at the designated time periods. From the analysis, it was found out that, though number of people involved in accidents was on the high side, fatality was on the low side in the study area. This has confirmed the effort of the safety organisation in the implementation and enforcement of some of the safety measures; for instance, the use of safety belt and helmet which is said to reduce rates of highway deaths (Loo & Anderson, 2016b). Factors causing accidents were classified into 3 categorise (human, environment and vehicle factor). It was realised that the human factor was the leading cause of accidents in the study area, followed by the vehicle and environmental factors. With the human factor, Speed Violation ((SPV) 936 accidents) was the leading cause of accidents, followed by dangerous driving ((DGD) 357 accidents), sign light violation ((SLV) 164 accidents), route violation ((RTV) 73 accidents), and hit and run ((HR) 17 accidents). It was realised that the number of causes were more than the number of accidents in the study area. This was because from investigations, some of these accidents had more than 1 causing factor.

The spatial analysis methods were used to visualise accidents distribution and patterns in the study area. The frequency maps showed high concentrations of accident points especially along the highways and CBD of the study area. The Nnamdi Azikiwe Express had the highest accidents concentration especially at the intersections. It was also found from the 1 km distance buffer that more activities happened along this route, this was confirmed by the street visits to this locations to ascertain the trip generators. Accidents causes in the study area were also visualised, it was realised that out of the 4 main causes (speed violation, dangerous driving, sign light violation and loss of control). Speed violation was seen to have the most accident clusters and fatality related cases in the study area especially along the central high way (Nnamdi Azikiwe Express). It was found out that most pedestrians bridges provided were not being used, insisted planks were laid across the drains to enable the pedestrians to cross and hence cause accidents. The Focus Group Discussion attributed this to wrong attitudes of individuals. Most pedestrians interviewed related it to personal choice and less stress free.

The Global Moran was seen to have assumed the entire study area as a single unit, as it calculated the entire distribution of accidents across the study area, it did not reflect the exact spatial unit or co-types at the local level. For this reason, LISA was then employed to view significant clusters. Hot zones gotten from the LISA analysis were used for the field work. The 14 cluster hot zones investigate gave the whys and wherefores and when of accidents occurrences. Infrastructural wise, the hot zones were seen to have specific location causes not farfetched from what has been realised by other researchers. The major problem detected was the lack of signage along the highways as earlier mentioned. Other characteristics found were lack of traffic lights, effects of U-turns, roundabouts, staggered junctions, T-junctions, inappropriate use and vandalization of provided infrastructure (pedestrian bridges and road barriers) by individuals. Inappropriate parking to dismount and mount passengers by commercial and private vehicle owners at hot zone locations. Others are obstructive view caused by trees at some segments, a similar occurrence noticed through the hot zones was the use of planks to aid in crossing the high ways and vehicles falling into open drains due to over speeding. It was also noticed that in providing facilities for pedestrian crossings in the study area, the elderly, physically disabled and impaired were not considered.

From the interview conducted, it was said that the open drains has led to a lot of property damage and injury, sometimes leading to death. Particularly along the popularly called Kubwa express (Murtala Mohammed express), why is this particular along this route? From the interviewee, it was realised that though such accidents occur along the segments at no particular periods, the street was sometime **not lighted** in the **night time** and **high speed** was a contributory factor. For the land-uses, it was realised that accidents were more likely to occur in areas with denser activities, population, more public transit stops and a high proportion of people taking public transit to work. These causes are directly related to the actual vehicle crashes of the study area and the perceived environment. It was also noticed that accidents locations were related to mixed land-uses especially along the Nnamdi Azikiwe express and suburbs along the Shehu Musa Yar'Adua express and the Murtala Mohammed express. It was generally confirmed from the qualitative view, that the built environment has a positive association with cluster locations of the investigated hot zones. This is confirmed by a studies by Vasconcellos (1996) who described the circulating space as unsafe in developing countries explaining the built environment as auto oriented, speed oriented and pedestrian hostile. The built environment is supposed to be adapted to ensure drivers mobility rather than changing it to ensure peoples safety.

Collaborative efforts by the local organisation with both local and international bodies have been ongoing. This has led to the implementation of some traffic calming measures especially at peak periods and to upgrade selected corridor highways amongst others. It was also discovered that safety measure implemented in the white zone area investigated, was a road barricade made of a high quality material that could not get easily destroyed by vandals. This made compulsory the use of the pedestrian bridge at this location and accident occurrence was controlled along the segment. Other measures are the motorised patrol team, yearly lectures, planning and policies refurbishments, public awareness on positive attitudinal change and surveys of alcohol consumption among drivers. Achievements, strength and prospects were seen towards compulsory implementation and awareness of use of the safety seat belt and helmet while driving, a responsive workforce and achieving the vision of a sustainable social and economic progress. Limitations were seen in relation to funding.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study represents an important contribution, to the pressing and complex problem of road traffic accidents faced by most developing countries. This is one of the first studies that have devised a method for the spatial accidents data collection and adopted spatial and temporal approaches to investigate areas of accidents occurrences. Relating the accidents clusters to specific location causes of the built environment in Abuja, Nigeria. The GIS tool used for this analysis, has helped in generating relevant information about accident distribution and causes in an urban context, indicating specific problem areas and aiming at improving the living standard of mankind. From the result of the quantitative and qualitative analysis, human factor was identified to be the lead cause of accidents in the study area.

Also, among the accident causing factors analysed, speed violation recorded the highest number of accident occurrences and fatalities. Accidents and fatalities were observed to decrease in the order speed violation, sign light violation, dangerous driving, and loss of control being the least. Accident clusters for each of the factor were observed to have occurred at specific locations within the study area. For instance, speed violation had clusters mostly around central route (Nnamdi Azikiwe Express). Based on LISA, the spatial clusters of the accident points within the study area was observed to be significant clusters (High-High clusters) almost at the same locations where the spatial clusters using the frequency methods were observed.

From the primary data collection of field analysis, the results of the street analysis showed that commercial activities were more dominant in the hot zone sites and thereby had more influence on accident incidences, i.e., most of the site visited had commercial activities which served as trip generators. For the infrastructure, traffic lights had a 0%, this can likely be a contributory factor to accidents on the highway. This finding is corroborated by Benoît Flahaut (2004), who found that the environment and road infrastructure played substantial role in accidents occurrence. Similarly, Soltani & Askari (2017), discovered that majority of accidents occurred in a number of specific zones encompassing major arterial roads and specific city activity centers. Others factors were street signs and markings, improperly installed speed limits, completely missing speed signs in all the sites. It was noticed that, individuals are responsible sometimes for their ill deeds. In the aspect of destroying the facilities put in place to secure their lives, they end up being killed due to their same action.

The research spatially discovered hot zone locations which can be used to draw attention to the need for better monitoring and development of immediate road safety intervention, it also provides important insights to policy and decision makers in improving road safety. The findings can be used to provide a baseline for more advanced GIS studies to follow in the domain of road safety.

5.2. Recommendation

Accident data system: For a standard database that can be used for exploratory, explanatory and exposure variable analysis, the organisations in Nigeria responsible for accidents data collection has to step-up its data collection system. This should begin with the organisations (NPF and FRSC) to acquire the equipment's (GPS) for spatial data collection and the training of staff involved in the spatial collection of road accidents data. The involvement of other attributes for the accident data for instance death and injury during hospitals care should be recorded. This will give more detailed information about accident victims and although the FRSC has a call centre for reporting accidents, this should be improved by having a web page that data could easily be uploaded e.g. pictures of accidents scene and other scene details including location can help with the issue of underreporting of accidents records.

Awareness and Campaigns: The FRSC, which is the lead organisation on safety is seen to be doing a lot on the alertness and promotion of safety on roads. More of these should also be geared towards the destruction and inappropriate use of infrastructure by vandals, pedestrians and other road users. Individuals should also be enlightened on the need for a positive attitudinal change. There should be a policy on the integration of education on positive attitudes of the driver in training schools before a driving certificate or licence is issued. This will alert individuals on the need for a positive attitude in the society, thereby assuring safety on roads and around the environment. This will go a long way to help with road safety improvement in the society.

Infrastructure: It is very important that roads signs and markings should be installed on specific road segments inspected and around the study area. They will help in guiding individuals on speed limits to travel. Redesigning bus-loading areas provided can help in the control of the rate of road side dismounting and escalation of passengers. This will give more available space for parking, putting into consideration the peak hours. Traffic calming measure should be effected especially at hotspot locations that need the most intervention e.g. areas that are crossed by roads with high traffic (Berger roundabout), Banex junction and Mabuchi junction. Also, road barricades of good quality material should be used around areas with high rate of commuters, pedestrians prefer the use of planks instead of pedestrian crossing. Pedestrian crossings should be provided in areas that need the most attention (Mabuchi junction). There should be better road engineering and design, good road safety education for motorist and pedestrians and enforcement of existing traffic laws.

The Built Environment: traffic accidents were seen to happen in places with mixed land-uses, in actual sense, mixed land-use reduces trip distance and mostly located around the city centres. Traffic calming measures in the areas with land-uses (use of speed humps, speed cameras, connection of more minor roads) appear to be the appropriate recommendation for this classification. Lack of signage and traffic lights is a major limitation found, these should be installed at appropriate road lengths and ensure compliance by road users.

Policy on roadworthiness should be intensified: Roadworthiness should be emphasised, to help automobiles be in a suitable operation standard. This should be checked by a taskforce management and strict laws made to prohibit offenders. This will help to keep vehicles in bad condition off the road. Particularly vehicles plying the roads with no functional speed limiter. The redesigning of road corridors in the FCC to include bicycle lanes should be included in the transport policy. This will encourage cycling and aid in sustainable development.

5.3. Limitation

A basic limitation noticed in the study was the lack of a standard workable database, this made the processing and interpretation of results more tedious. This limitation is one thing the organisation should consider in other to be able to get its data into a workable database format. This can be done by collaborating with other organisations involved in street address and post code locations, to develop a working address matching system. Another limitation found is the issue of under reporting. Death or the injured at the hospital or during hospital care are not recorded. The FRSC should intensify and be consistent in their data collection format in all the zones responsible, this will enable easy analysis of data and lessen bias in terms of the codding system.

Although subjectively, it was mentioned that accidents happen due to tyre burst or loss of control by vehicles. There was no quantitative measure for that in the primary data collection. This made the results a bit biased as the analysis was geared more towards two of the elements causing accidents (human and environment factor). However, from the secondary data analysis, the environmental factor seem to be the least causing accident factor in the study area. Similarly, study did not relate crash to the findings of the primary data collected, they were only associated to the specific cluster locations

5.4. Future Studies

The focus of this research was to identify accidents causing factors, and concentrated on high ways for specific location causes. Other studies can look into specific location causes on the secondary roads and further analysing accidents at junctions and intersections, higher accidents are seen to occur on the highway intersections, however, investigated regional links or intersections can help to proffer more safety measures.

The LISA was chosen for this analysis based on theoretical knowledge (literature review) of other methods used for hot spots analysis. Other methods could be tested to view the practical outcome generated. This can be based on methods like the Kernel Density Estimation, Network Kernel Density Estimation, Nearest Neighbour analysis and Sliding Window. Subsequent researches on road traffic accidents should acknowledge the built environment along with the persistent attempt of exploring accidents causing factors. This unveils the nature of the surrounding problem and gives the best possible results that can be used for proper implementation of safety measures.

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7. APPENDIX

7.1. Definition of black spots in selected European countries

Table 9 Definition of Black Spots Source; Elvik & Sorensen (2007)

Table 3: Overview of definitions of road accident black spots in selected European countries

Country	Reference to population of sites	Sliding window applied	Reference to normal level of safety	Recorded or expected number of accidents	Accident severity considered	Length of identific-ation period
Austria	No	Yes, 250m	Yes, by means of critical values for accident rate	Recorded, minimum critical value 3 – function of traffic volume	No	3 years
Denmark	Yes, detailed categoris-ation of roadway elements	Yes, for road sections – variable length	Yes, by means of accident prediction models	Recorded, based on statistical test – minimum 4 accidents	No	5 years
Flanders	No	Yes, 100m	No	Recorded, weighted by severity	Yes, by means of weights	3 years
Germany	No	No, accident maps inspected	No	Recorded, minimum values 3 or 5	Yes, by different critical values	1 year (all accidents) or 3 years (injury accidents)
Hungary	No	Yes, 100m or 1000m	No	Recorded, minimum 4	No	3 years
Norway	Not when identifying black spots	Yes, 100m (spot) or 1000m (section)	Yes, by means of normal accident rates for roadway elements	Recorded higher than normal by statistical test, mini-mum values 4 (spots) or 10 (sections)	Yes, by estimating accident costs and potential savings	5 years
Portugal	Yes, for one definition; no for the other	Yes, for one definition; no for the other	Yes, for one definition; no for the other	Recorded in one definition (minimum 5), expected in the other	Yes in one definition (by severity weighting), no in other	1 year or 5 years
Switzerland	Yes, open roads and junctions	No, fixed sections of variable length	Yes	Recorded, a set of critical values	Yes, by different critical values	2 years

Kilde: TØI report 883/2007

Table 9 shows different definitions of black spots in some selected European countries, it makes reference to population of roadway elements on roads and junctions. Length of Sliding Window applied (variable lengths, 250m, 100m, 1000m), reference to normal level of safety either by prediction model, accidents rate for roadway elements, critical value for accidents rates or none for some countries. It gives more understanding to various duration. It gives an idea of what methods are used in this various countries in the determination of blackspots.

7.2. Map of Nigeria showing Abuja municipality

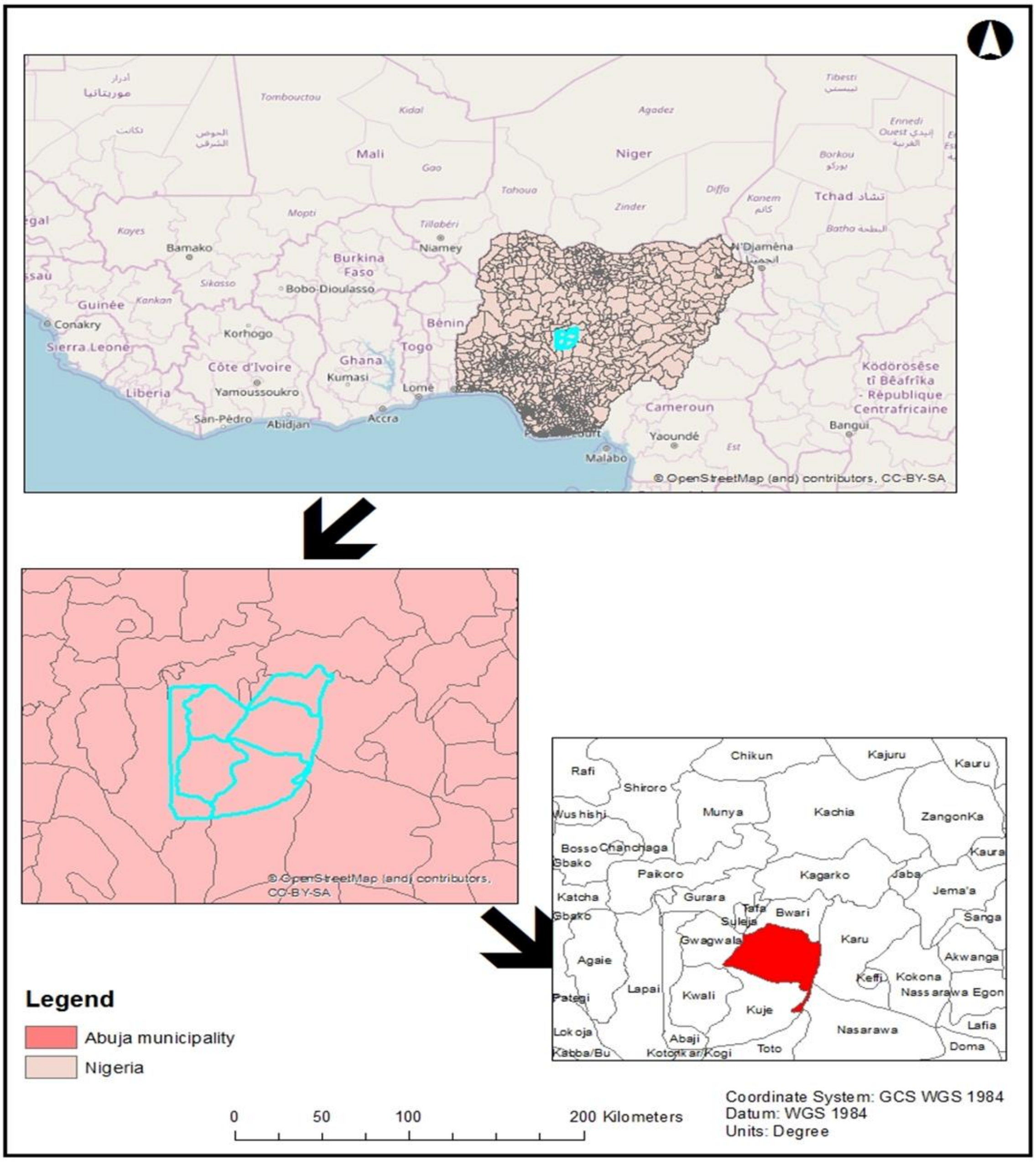

Figure 7-A Study area of initial point data extraction shown in red. Author (2018)

The initial extent of accident points extracted for the study is shown on A2, this gave an idea of the exact location on the map that had high concentrations of accident in Abuja.

7.3. Result of Global Moran I

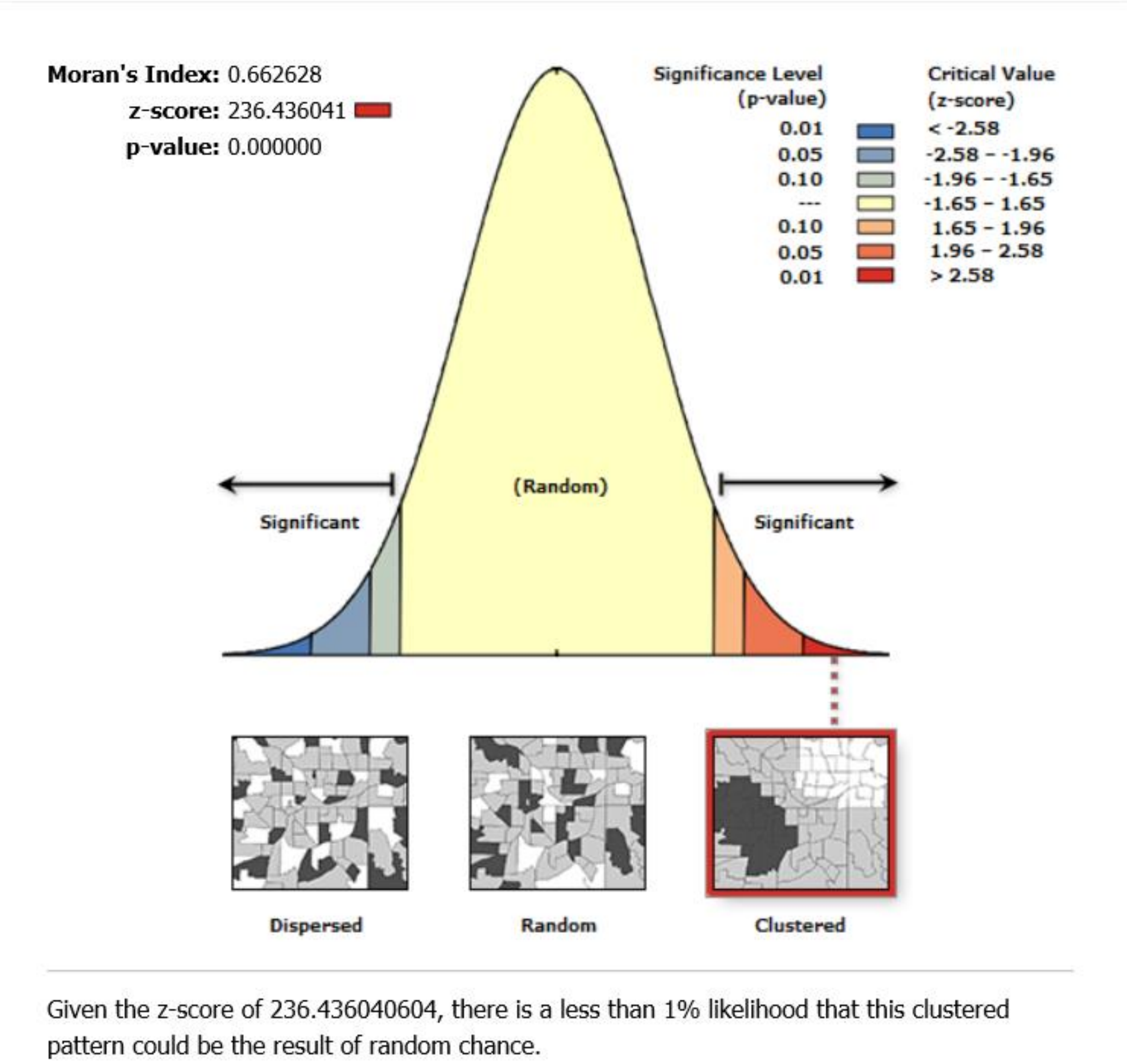

Figure 7-B Result of the Global Moran I Author (2018)

7.4. Observational checklist

Variable = 1

No variable = 0

Table 10 Observational checklist Author (2018)

Factors	Variables	Description	Cluster Locations														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Road (infrastructure/ design)	Junction designs Road curvature Speed limits Roads signs Road surface Road separation	U turn Cross junction Roundabout Traffic lights Staggered junction Flyovers Others Curved, straight or slightly curved Speed limits at specific road segments Roads signs, markings Type Condition Asphalt, concrete, recycling, gravel surface etc.															

		Different routes for uses e.g. Pedestrian crossing															
Land use	Recreation, commercial, etc.	Parks, retail shops, markets, plazas and malls.															

The checklist was use in the built environment audit to examine infrastructure and land uses related to the 14 hot zone locations of the study area. The 15th location which was also a white zone was included and investigated upon for positive measures seen (Table 10).

7.5. Draft of sampled questions (interview).

Introduction by interviewer.
I am by name, Makama Fatima Fibayi. An Msc student at ITC, university of Twente, Netherlands. I am undergoing a survey to aid in the completion of my Master Degree in Geo-Information Science and Earth Observation for Urban Planning and Management. This is on the Topic; "Exploring trend and spatial pattern of vehicular accidents in Abuja Nigeria. The interview is aimed at knowing and locating some specific causes of road accidents in Abuja. Also ways in which the occurrence can be reduced. The interview will last 5-10 minutes. Thank you.
Questions;

- What can you say are causes of vehicular accidents in this area?
- If speed limits are enforced on roads. Do you think this can help to reduce vehicle accidents?
- Do you a have functional speed meter in your vehicle?
- What do you think of the general behavior of road users around this area? (Commercial drivers, pedestrians, hawkers, tricycles/ motor bikes)?
- Why do you not use the pedestrian crossing? (Pedestrians)
- Why do you as a driver prefer to park on road sides to pick up and drop off passengers?
- What do you think attract commuters (people) towards this area?

7.6. Focus Group (Guide).

Introduction.
My names are Makama Fatima Fibayi. An Msc student at ITC, university of Twente, Netherlands. I am undergoing a research to aid in the completion of my Master Degree in Geo-Information Science and Earth Observation for Urban Planning and Management. This is on the Topic; "Exploring spatial pattern and trend of vehicular accidents in Abuja Nigeria". The research is with the aim of identifying accident clusters within Abuja metropolis and further identify physically, location–specific explanatory variables for this clusters and possible ways of minimizing occurrences.
The main purpose for the focus group is to obtain in-depth information about the institution (FRSC) and to understand its effort in improving road safety in Nigeria. The meeting will take a maximum of 1 hour 30 minutes. Thank you.
Presentation of findings: Power Point presentation (10-15minutes), call for their views.

Possible question to be related to the group;

1. What is the current road safety situation in Abuja?
2. What role do the FRSC play on safety on Nigerian roads?
3. What do you think accounts for the fluctuations of number of accidents between the years?
4. From the perception of the institute, what do you think are the causes of this accidents?
5. Are road safety rules effective and adequate?
6. What are challenges faced in executing your roles?
7. Are other organization involved in collaborative efforts?
8. What do you see as possible ways of improving road safety in Nigeria?

Data quality analysis

1. Quality of secondary data from the organization
2. How the locational point data were extracted (some left out unspecific)
3. Methods specifically used for the secondary data analysis (do they give more insight into data and study area than current methods used by organization?)
4. Improvements needed in vehicular accidents data collection in Nigeria
5. How to best include geographical aspect in accident studies.
6. Recommendations to improving methods.
7. Conclusion.

7.7. Some street facilities

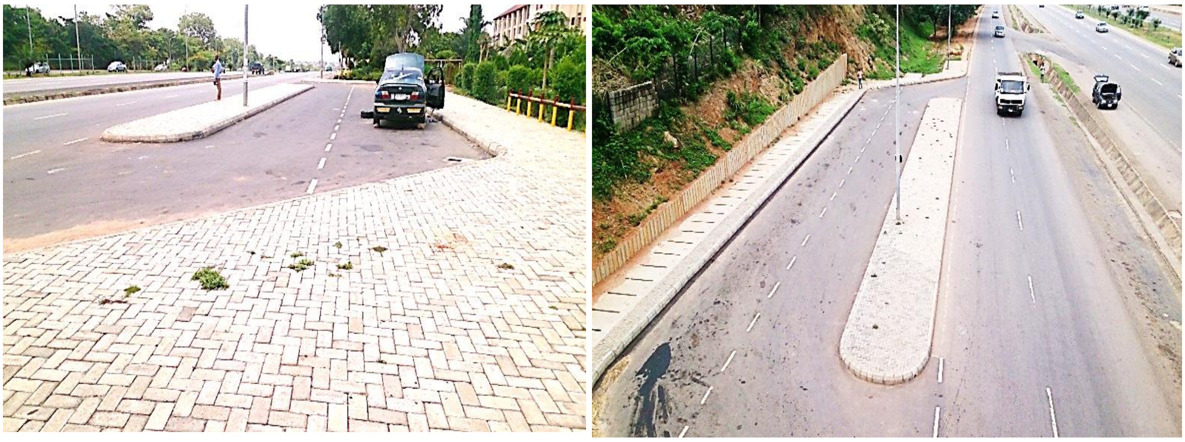

Figure 7-C Bus stop facilities left un-used Author (2018)

Figure 7-D Parking along roads instead of bus-stops. Author (2018)

Figure 7-C and Figure 7-D shows a bus stop at Banex junction left un-used, instead the taxi drivers prefer parking to pick up persengers along the road sides.

Figure 7-E Traffic Calming measures at peak hours, Murtala Muhammed road.   Author (2018)

In Figure 7-E, it is seen that traffic calming measures are ongoing during peak periods on Murtala Muhammed express. It was also observed that due to the corroborative efforts, most officials of various organisations are seen of their duty post.

7.8. Research Design Matrix

The research design matrix is a method of planning research projects in rows and columns which encapsulates the research design. It is a device that ensures that various components of a study including, goal, objectives, definitions, methods of analysis, hypothesis, variables and anticipated conclusions link together in a logical manner with no omission of essential parts (Choguill, 2005). The design matrix in Table 11, gives an overview of the sequence of the research including methods to be used and required data and output for analysis. The table gives a detailed insight into the research process, tools to use related to achieving the main objective.

Table 11 Research Matrix Author (2018)

RESEARCH OBJECTIVE	SPECIFIC QUESTIONS	DATA TYPE	DATA SOURCE	SOFTWARE REQUIRED	ANTICIPATED OUTPUT	METHODS
1. To analyze factors causing traffic accidents in Abuja	a. What are the factors influencing road traffic accidents in Abuja?	Recorded vehicular data/Point data	Federal Road Safety Commission (FRSC)/ Literature	Excel/Arc GIS	Graph/Tables Maps showing spatial factors causing accident maps	Data Exploration Descriptive Analysis Spatial Analysis
2. To identify the spatial distribution of traffic accidents in Abuja	a. Which methods are suitable for analyzing and visualizing temporal clustering of vehicular accidents?	Literature	Internet Browser	Internet Browser/ Microsoft Word	Method suitable for analyzing and visualizing temporal variation.	Literature Review
	b. Which methods are suitable for identifying the spatial distribution of vehicular accidents in Abuja?	Literature	Internet Browser	Internet Browser/ Microsoft Word	Methods for identification of spatial distribution of vehicles	Literature Review
	c. What is the spatial distribution of traffic accidents in the study area?	Geocoded accident data, Road Network	FRSC/ Google Map	ArcGIS	Maps with accident point data distribution (Bubble or frequency maps)	Spatial Analysis
	d. Are there spatial clusters of accidents in Abuja? Are these clusters more or less prominent for specific land-uses?	Vector point data (land- uses)/Road network of study area	Authors Fieldwork /Interview (open-ended question)/ Google Map	ArcGIS	Bubble maps, Local Moran I Cluster map, Maps showing 1km buffer of specific cluster locations from related land uses.	Spatial Analysis/ Descriptive Analysis
3. To understand the efforts in improving road safety in Abuja and provide recommendations	a.What are the existing measures of road safety and what other organizations are involved in collaborative efforts?	Literature FRSC/ Focus Group Discussion (FGD) with FRSC.	Authors Research Work/ Online Literature	Internet Browser/ Microsoft Word	Organizational Efforts	Literature Review FGD
	b. What are the attainments, strengths, limitations and prospects of Federal Road Safety Commission?	Literature FRSC/ FGD with FRSC staff	Online Literature/ FRSC	Internet Browser/ Microsoft Word	Positive objectives towards achieving success/ limitations	Literature Review/FGD
	c. What are possible suggestions and recommendations based on findings?	Author	Authors Research Work	Microsoft Word	Suggestions and Recommendations	Discussion Based on Findings.