SPATIO-TEMPORAL PATTERNS OF VEHICULAR ACCIDENTS IN ACCRA (GHANA)

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ABSTRACT

Growing trends of motorization, coupled with increased mobility and the mismatch between people and activity areas have contributed to traffic congestion and many road safety issues. Transportation infrastructure is seen as one of the crucial systems as far as the movement of people, goods and connection between activity areas are concerned. A major unfortunate occurrence in the transportation system is traffic accidents which account for many injuries, disabilities, property damages and deaths. On this account, this research sought to identify hazardous road locations within the Accra Metropolis through spatial, temporal and spatio-temporal analyses of reported vehicular accidents. It also went a step further to find locations within the city is the first step toward minimizing vehicular collision. The location-specific causes provided insight into the locations and type of countermeasures needed to curtail the problem with the intent of providing a conducive atmosphere for all road users. This, in the long run, rectified a major setback of limited incorporation of spatial and spatio-temporal analyses in current accident studies in Ghana.

Two main research strategies were adopted in this research. First, an exploratory study which used quantitative methods in analysing secondary point data of accidents to identify hazardous road locations. A generalized ordered logit model was used to investigate the impacts of accident, built environment and road features on accident severity. Findings from the model suggested that, as the number of vehicles involved in a crash increases by one, the accident severity decreases by 1.5266 units as against an increased severity of 1.5382 units as the number of casualties involved increased by one. It was also recognized that the severity of crashes rise at locations with streetlights (0.2686) in contrast to locations without streetlights (0.1182). Additionally, four spatial techniques were utilized in identifying the hazardous road locations. It is believed that it is through different representations and visualizations that greater understanding of crashes within the Metropolis can be realized. A bubble map, Kernel Density Estimation (KDE), Network Kernel Density Estimation (NetKDE) and Local Moran's Index were employed. The first three techniques were able to identify accident hotspots but were unable to determine the significance of these hotspots. Based on this, the Local Moran's Index was espoused in finding significant hotspots. The identified significant hotspots aided in discovering the hazardous road locations known as "hot zones."

Secondly, an explanatory study was initiated which primarily focused on the use of qualitative methods in analysing primary data on location-specific causes of accidents. Eight hot zone locations were visited where 400 questionnaires were administered to workers and residents along that segment. Though the locationspecific causes identified along these segments were not different from what has been stated in literature, each location had at least one major cause which needed immediate attention to rectify the situation. The issues of underutilized safety facilities, absence of safety facilities, encroachment, user behaviour, violation of traffic rules, ineffectiveness of traffic regulations, street hawking, road design and driving under the influence of alcohol were some contributory factors identified. The overall countermeasures needed to address the situation fell into four main categories. These are; (1) road infrastructure development, (2) road safety education, campaigns and awareness programmes (because most Ghanaians prioritise convenience over safety), (3) safety regulations, enforcement and traffic strategies and (4) vehicular safety and technical specifications.

The combined effects of the different approaches make this research substantial for governmental and safety regulatory institutions to make use to develop plans and strategies needed in minimizing road traffic accidents within the Metropolis of Accra.

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"The ultimate measure of a man is not where he stands in moments of comfort and convenience, but where he stands at times of challenge and controversy."

Martin Luther King Jr.

"...in Christ I live and move and have my being...Acts 17:28." "I am nothing without you Lord."

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1. INTRODUCTION

Over the years, several studies have been conducted with the aim of reducing vehicular accidents. Many of these studies were geared towards the locations of hotspots/hot zones and possible reasons for their clusters, which were mostly aggregated to fit an administrative boundary (Loidl, Traun, & Wallentin, 2016). In many accidents modeling attempts, the aggregation of these point incidents sometimes leads to some spatial biases (MAUP, ecological fallacy) with respect to shape and size of the reference unit which affects modeling choices and results (Thomas, 1996). Eckley and Curtin (2013) argued that, incidents occurring closer to each other in space but separated by the time of occurrence, such as the hour, day, week, month, seasons or even years do not necessarily characterize a significant cluster in space. Correspondingly, these authors also claimed that incidents happening instantaneously in time but are spatially apart, do not necessarily imply clustering. A mere clustering of vehicular accidents or events occurring simultaneously at distinct locations and separate times do not necessarily call for attention. But how significant these clusters are, is what needs critical look, especially spatio-temporal clustering. Spatio-temporal clustering simply means incidents that are closer to each other in both space and time. It is therefore ideal to analyse the spatial patterns and temporal dynamics of these accidents separately before initiating the spatio-temporal analysis. The understanding of these spatio-temporal patterns and variations would be recognized as a milestone towards crashes minimization and prevention. This research, therefore, sought to analyse the spatial, temporal and spatio-temporal patterns of vehicular accidents in Accra (Ghana).

1.1. Background and Justification

Increased mobility and the mismatch between people and activity areas have contributed to traffic congestion and many road safety issues (Yang, Zhao, & Lu, 2016). Transportation infrastructure is seen as one of the crucial systems as far as the movement of people, goods, and connection between activity areas are concerned. A significant unfortunate occurrence in the transportation system is traffic accidents which account for many injuries, disabilities, property damages and deaths (Yordphol, Pichai, & Witaya, 2005). The WHO (2015) contended that 1.2 million lives are lost to road traffic accidents yearly, which has an enormous impact on health, development and economic growth. This report also stated that governments all over the world spend at least 3% of their Gross Domestic Product (GDP) on road accident reconstruction and recovery. Regardless of these efforts, actions to battle this global issue by some countries have been futile.

Though all road users are at risk of being injured or killed in a road traffic crash, there are distinctions in fatalities between different road users. The vulnerable road users such as pedestrians (including traders/hawkers and stray animals) and cyclists are at greater risk than vehicle occupants and frequently bear the highest burden of injury (Loidl et al., 2016). This is the case especially in Global South cities, where, the greater the diversity and intensity of traffic mix, the more the lack of separation from other road users. Fatalities arise when at least one person dies instantly or 30 days after the occurrence of road traffic accident (NRSC¹, 2015). Road Traffic Accident (RTA)/vehicular collision is an undesirable event that occurs between objects on the road of which at least one is a moving vehicle (Cham et al., 2015). This happens when a moving vehicle swerves off the road, collides, runs over, or crashes into another object or person. This is mostly because of the interactions between humans and their living environment. The urban environment is said to be an indispensable component in road safety analysis. Variations in urban

¹ National Road Safety Commission

transportation system are mainly the outcome of the complex interactions among numerous elements of the urban environment and human activities in space and in time, principally transportation and urban land use interactions (Rodrigue, Comtois, & Slack, 2009). These urban elements according to Taniguchi, Fwa, and Thompson (2013) comprise of three major components namely: vehicles, roads and road users. The interactions between, or a failure in any of these components is likely to result in RTA.

In the urban environment (roads), poor road designs such as inadequate signage and uneven pavement have been recognized as vital traffic elements influencing driving behaviour (Wang, Quddus, & Ison, 2013). For instance, sharp curves may affect drivers' ability to predict the path of the road in advance (Ariën et al., 2013). Similarly, weather, topographical conditions and poor road maintenance resulting in potholes, poor drainage, malfunctioning traffic signals, faded or missing lane markings, burned-out streetlights, debris on road and poorly maintained bridges are some accident-causing factors. Regarding road users, tiredness, lack of experience, risk-taking (not putting on a seatbelt, over-speeding, drunk-driving, wrongful over-taking) and distraction/negligence on the part of drivers', are determinants that contribute to vehicular accidents (Soltani & Askari, 2014). In relation to vehicular conditions, the ability of vehicles to protect their occupants significantly influences the consequences of injuries. Additionally, mechanical problems are factors which cannot be over-emphasized (Mehaibes, 2012). Defective brakes, tire blowout, faulty steering system and worn tires are but few common mechanical shortcomings likely to lead to an accident (Wang et al., 2013). The interactions between these traffic elements happen at a particular location in time.

Vehicular accident data sometimes have some attributive information which when explored exhibits some spatial and temporal patterns. This is because the determinants (traffic elements) of vehicular accidents changes in space and with time (Shahid, Minhans, Puan, Hasan, & Ismail, 2015). To lessen vehicular accidents and enhance road safety, it is vital to understand the where and when of these incidents. An improved understanding of the spatial, temporal and spatio-temporal patterns of vehicular accidents is likely to make accident reduction actions more effective. Backalic (2013), apparently justified the significant difference between spatial and temporal dimensions of reported traffic accident data. According to the author, space is immobile, and it is grounded in locating and counting the number of road accidents within a delineated area. The temporal dimension, on the other hand, is a dynamic process which needs to be traced or explored over time to identify variations or patterns. Shahid et al. (2015) also stated that spatial patterns could, however, be defined in terms of rural-urban differences. For instance, the number of vehicular accidents in urban areas tends to be higher, however, with a low degree of injury whereas, in rural areas, the number appears to be lower, but with a very high degree of casualties. Alternatively, vehicular accidents are often seen to follow some patterns with respect to the day, week, months, seasons and yearly trend (Loidl et al., 2016). These characteristics vividly tell that these incidents have some spatial and temporal components associated with them. To improve traffic safety measures, it is vital to analyse vehicular accidents in a way that events that are closer to each other in both space and time can be identified.

1.2. Problem Statement

Road traffic accidents are penalties for improved mobility in modern society (Anderson, 2009). Although road safety is globally recognized, vehicular incidents are barely explored on various spatial, temporal and spatio-temporal scales. This enables a detailed understanding by zooming in from the city-level to the location of a single crash (Loidl et al., 2016). Many traffic accidents research mostly aggregate these incidents to fit some administrative spatial units such as countries, states, etc. (Lovelace, Roberts, & Kellar, 2016; Shafabakhsh, Famili, & Bahadori, 2017) where aggregated statistics and demographic characteristics can serve as explanatory variables. However, aggregations often do not capture variations within the specific spatial units. Also, the spatial and temporal components of these crashes are frequently not studied explicitly during the analysis (Vandenbulcke-Plasschaert, 2011) and location-specific causes are hardly explored.

In Ghana, the predominant way of transporting people and goods is by road. The Ministry of Roads and Highways (2017) estimated that 98% of all passenger and freight movement within the country is by road. The Government of Ghana over the past decades has sought for an extensive road infrastructural development and maintenance programme with the goal of reconstructing and refurbishing the entire road network in the country (I,500km per year) (AfDB/OECD², 2006). These efforts have increased mobility as well as the number of road accidents. Road accidents are said to be the second leading cause of deaths in Ghana after malaria. As found in the studies of Oppong (2012), about 1909 people are killed in road traffic accidents yearly and 60% of which are within the economically active population (16-45 years). In response to the increasing road accidents, the National Road Safety Commission was established in 1999 to address the underlying causative factors. However, the efforts of the Commission have yielded limited success as reports still indicate a rise in annual road traffic accidents within urban areas.

Accra, the capital city of Ghana, like other urban areas in the country, experiences daily interactions between the urban elements and human activities due to high agglomeration of commercial activities. These interactions cut across different urban land use zones; commercial, residential, recreational and industrial areas and often cause severe conflicts between the use of space for pedestrians (traders /hawkers, animals), cyclists and motorists which frequently leads to vehicular accidents.

In respect to the massive human and economic costs resulting from vehicular accidents, understanding the spatial, temporal and spatio-temporal patterns of vehicular crashes occurring at the city level is central in creating a conducive environment safe and sound for all road users. The extent of details at the city-scale permits for additional directed thorough analysis and succeeding remedies. Road safety studies in Ghana focus on using statistical and non-spatial models as means of analysis and sometimes overlook the prevailing geographical (spatial) association between locations. Geographic aspects being omitted indicate that spatial and spatio-temporal analyses are scarcely tackled. Hence, limiting the number of research primarily on the spatial and spatio-temporal elements of vehicular accidents. Based on the connection between vehicular accidents data and spatial, temporal and spatio-temporal facts, this study investigated the patterns of crash occurrences on multiple temporal intervals, spatial scales, their space-time interactions and identified some location-specific causes.

1.3. Objectives of the Study

1.3.1. General Objective

To analyse the spatial patterns, temporal clustering and spatio-temporal interactions of recorded vehicular accidents in Accra.

1.3.2. Specific Objectives

To achieve the general objective, the following specific objectives are set for the research:

- 1. To determine the spatial patterns of recorded vehicular accidents in Accra (where)
- 2. To identify the temporal clustering of recorded vehicular accidents in Accra (when)
- 3. To assess the characteristics of the spatial and temporal components to identify spatio-temporal clustering
- 4. To identify location-based explanatory variables for the detected clusters (Hotspots/Hot Zones)
- 5. To reflect on the outcome of the analysis based on the suitability of the methods employed and the data used

² African Development Bank/ Organization for Economic Cooperation and Development

1.4. Research Questions

The outlined research questions are to be answered to achieve the specific objectives of this study:

- 1. To determine the spatial patterns of recorded vehicular accidents in Accra (where)
 - a. What are the appropriate methodological considerations for spatial analysis of vehicular accidents?
 - b. What is the spatial pattern of recorded vehicular accidents in Accra?
- 2. To identify the temporal clustering of recorded vehicular accidents in Accra (when)
 - a. Which methods are suitable for analysing and visualizing temporal clustering of vehicular accidents?
 - b. Which temporal intervals (categories (hourly, daily, monthly)) are relevant to the study?
 - c. When do these categorized incidents occur in Accra?
- 3. To assess the characteristics of the spatial and temporal components to identify spatio-temporal clustering
 - a. What are the appropriate techniques for determining spatio-temporal clustering?
 - b. Are there clustering locations which are close in both space and time?
- 4. To identify location-based explanatory variables for the detected clusters (Hotspots/Hot Zones)
 - a. What are the physical characteristics of the clustered locations?
 - b. What are the major causes of vehicular accidents in these locations?
 - c. Which countermeasures are needed to minimize road traffic accidents in these locations?
- 5. To reflect on the outcome of the analysis based on the suitability of the methods employed and the data used
 - a. Do the methods employed provide insight into the data?
 - b. Are there recommendations needed to improve the method used?
 - c. Are there improvements needed in vehicular accident data collection in Accra?

1.5. Hypotheses

- 1. The reported vehicular accidents are not spatially random within the study area (the points are more clustered or dispersed than would be expected under a random distribution) (Delmelle, 2009)
- There are significant spatio-temporal clustering of vehicular accidents in Accra (Eckley & Curtin, 2013)

1.6. Significance of the Study

The recognition of safety deficient locations within a city is the first step of assisting safety officials with their daily mandates. A critical setback faced by many road safety officials and agencies is where, which and how to put into action some precautionary measures aimed at minimizing vehicular accidents. This research aimed at identifying critical locations within the urban environment which are hazardous, then went further to determine some location-specific explanatory variables responsible for causing road accidents. This provided insight into the locations and type of countermeasures needed to curtail the problem with the intent of providing a conducive atmosphere that is socially sound, aesthetically pleasing and economically viable for all road users. Academically, the study helped in illuminating methods for analysing point data, specifically accident data and provided the significance of these methods. This would contribute to providing insight and help in understanding how and why traffic incidents happen within a delineated location and time.

1.7. Thesis Structure

This thesis consists of five chapters. Chapter one introduced the research by stating the background and justification for analysing vehicular accidents from a spatial, temporal and spatio-temporal perspective. This section also presented the primary research objectives and associated questions per objective. Chapter two concentrated mainly on some determinants of RTA both globally and locally (Ghana). This chapter also presented existing methodological approaches. It reviewed some methods on spatial, temporal and spatio-temporal analysis including statistical strategies that can assist in revealing patterns and dynamics associated with the where and when of vehicular accidents. The subsequent chapter focused on describing the study area, data needs, the existing data and means of obtaining primary data. It also gave a critical description of the used methods including their mathematical underpinnings and how they were operationalized. Chapter four presented the outcome of the adopted methodologies for the spatial, temporal and spatio-temporal patterns identified in the case study (Accra, Ghana). It also delivered a thorough discussion of the identified spatial, temporal, and spatio-temporal patterns and reflected on the methods used while chapter five concluded the entire thesis and specified some recommendations. Figure 1 shows a graphical representation of the entire process.



Figure 1: Thesis Structure

2. REVIEW ON METHODS AND DETERMINANTS OF RTA

2.1. Introduction

This section provides a general overview of some factors contributing to the occurrence of vehicular accidents globally and locally. These contributory elements together with the hazardous locations of these incidents helped in identifying and proposing countermeasures to minimize road traffic accidents. For this research, the word collision, crash, accident and vehicular accident were used interchangeably to represent incidents occurring on the road with at least one vehicle involved.

2.2. Road Traffic Accidents

Road Traffic Accidents (RTA) are among the principal difficulties faced by the world currently (Yazdani-Charati, Siamian, & Ahmadi-Basiri, 2014). With the vast misfortune resulting from RTA, studies have recurrently sought techniques to advance and adequately comprehend the factors influencing the probability of collisions. In the hope that better predictions about the likelihood of the event occurring can provide guidance for countermeasures meant at decreasing the number of crashes (Vandenbulcke-Plasschaert, 2011). Unfortunately, the lack of comprehensive data and appropriate methodological considerations on accidents and the typical features associated with the distinct transportation modes often impede researchers to expand their understanding of the elements contributing to the likelihood of accidents (Lord & Mannering, 2010).

The traffic elements according to Evans (1996) comprise of the complex interaction between human factors, engineering factors and automotive engineering. With regards to the descriptions given to these elements, they can be represented as road user/user behaviour, road design and vehicular conditions respectively. This author again mentioned that human factors are more important to consider in traffic safety than engineering factors. Whereas engineering factors have higher impacts on road safety than automotive engineering. Unlike other authors like Taniguchi et al. (2013), Vandenbulcke et al. (2014) and Dai and Jaworski (2016), who gave equal importance and relevance to each of the factors, Evans (1996) tries to concentrate on the importance of one element over the other. This writer mentioned that driver's behaviour which he referred to as "what the driver chooses to do" has a leading impact on safety than driver's performance (what the driver can do). Also, engineering factors like road design contribute to the occurrence of collision than the condition of the vehicle. His argument is entirely logical, but since the interaction is expected to happen among all the elements, it is ideal to give equal importance to all. For instance, a recognized mechanical defect on a vehicle would influence the behaviour of a driver on individual decisions such as speeding. And the availability of road signs (engineering factors) is likely to affect the actions of the driver. However, there seem to be more interactions between road user (human factors) and the other two elements (road design and vehicular condition). This is because the condition/design of the road and vehicle influences user behaviour more than the relationship between the road and the vehicle only. Figure 2, therefore, gives a clear visualization of this relationship. Where the thickness of the arrow indicates more interactions. Nevertheless, the vehicle and road user must be on the road before this interaction can occur.

To develop plans of action in reducing, preventing and improving safety on roads, the location and time where these elements meet to interact is vital towards sustainable road safety.



Figure 2: Relationship Between the Traffic Elements

2.3. Road Traffic Accidents in Ghana

Accidents materialize when traffic moves and the WHO (2015) attested that, 85% of road traffic deaths occur in low and middle-income countries where 81% of the world's population lives, but owns just about 20% of the world's vehicles. Accordingly, 60% of all RTAs in Ghana is attributed to speeding which is a primary cause of collisions (Coleman, 2014). 80% of these recorded accidents is accounted for by five out of the ten regions (Greater Accra, Ashanti, Eastern, Western and Central Regions) (AGD³, 2015). Most drivers (especially the informal minibus "trotro" drivers) do not adhere to the speed limits provided within certain locations and the lack of road signs at designated points also contributes to the non-adherence. This directly links to issues of engineering design and maintenance. The sub-standard and unpaved segments of some roads in Ghana results in poor drainage and multiple potholes (Coleman, 2014). Maintenance, on the other hand, is a whole dilemma on its own. This is evident in the poor conditions of most roads in the country. On 30th September, 2016, The Executive Director of CROSA (Centre for Road Safety and Accountability-Africa) said "...*it is surprising that most of these potholes are left unattended to until they get worse before they are attended to when it could have taken little efforts and resources to put them in order"* (GNA⁴, 2014). This is the norm in Ghana where situations are only attended to only and when they cause severe destructions.

Human factors are aspects which cannot be ignored in road safety analysis. Three human factors which influence the occurrence of RTAs have been recognized in Ghana. First, drivers' actions. Ignorance affecting the absence of, or inadequate understanding and deliberate negligence of driving codes, driving under the influence of narcotic drugs or alcohol, unlicensed drivers and conscious overloading (especially "trotro" drivers) highly influence RTAs in Ghana (GNA, 2007). "Trotro" is an informal commercial minibus for intra-city trips. These are the leading public transport providers in the country. The second human factor is in relation to enforcement officials. These personnel include police officers, customs officials, DVLA (Drivers and Vehicle Licensing Agency) personnel, magistrates, etc. Enforcement of traffic regulations is undermined by corruption among these personnel especially the police officials (Sangaparee, 2013; The Chronicle, 2015). They are noted to be taking bribes from people who infringe on traffic regulations and this has created an easement to road users because they are aware they can always pay their way out. Subsequently, creating an atmosphere for flouting of rules and contributed to the occurrence of crashes. The Global Corruption Barometer studies conducted on the perception of corruption in 2013 indicated that the Ghana Police Service on three consecutive times topped the list of the most corrupt in Ghana (Transparency International, 2013). Additionally, inadequate resourceful personnel in the enforcement unit is a contributing factor faced by many developing countries including Ghana (Mock, Kobusingye, Anh, Afukaar Francis, & Arreola-Rias, 2005). These influences the adequate and exact

³ Auditor Generals Department

⁴ Ghana News Agency

documentation of facts and the collection of data for analysis. Coleman (2014) specified that the case of data collection and data availability is highlighted as a drawback in developing countries.

The third factor is attributed to pedestrian behaviour and encroachment by informal activities. Some pedestrians also do not adhere to traffic regulations, crossing roads at unauthorized locations even when the zebra crossing is a few meters ahead. This situation has the propensity of resulting in unsightly incidents. Encroachment, especially by market women/men reduces road width. This happens when there is market spill-over or some sellers deliberately display their goods along roads with the aim of having the first contact with the customer. This mostly eats into the width of the road creating severe traffic congestions accompanied by high traffic mix and sometimes resulting in vehicle-pedestrian and rear-end crashes. These sellers and buyers on the street frequently disregard approaching vehicles.

There also exist some vehicular factors. As pointed out by Coleman (2014), the vast number of very old second-hand cars imported into the country somehow contributes to vehicular defects. The absence of suitable assessment options on their mechanical and maintenance condition makes second-hand vehicles a risk factor. Aged vehicles are highly susceptible to safety flaws and crashes (Blows, 2003).

2.4. Road Traffic Accidents Trends in Ghana

The number of road traffic accidents is indicated to have decreased by 0.5% from 2013 to 2014 while the number of fatalities has not been declining as targeted by the National Road Safety Commissions Strategies I, II & III (NRSC, 2015). This is because of the consistent average of 62 annual rises in fatalities since 1991. Based on regions, Greater Accra recorded the highest percentage (22.8%) of all fatalities in the country for 2014. Greater Accra has mostly been the region with the highest number of RTA (Figure 3) as well as the number of fatalities (Figure 4). Coleman (2014) affirmed that the category of road users in Ghana with the highest share of fatalities are pedestrians (40%), followed by motorcyclist (19.4%) then minibus ("trotro") occupants with 17.5% and car occupants (11.5%). However, cars are recognized to cause most accidents followed by buses (Hesse & Ofosu, 2014). Also, the fact that the percentage of motorcyclist with fatalities being the second highest calls for a critical look. This can be attributed to the relaxation of enforcement of road traffic regulations.



Figure 3: Number of Road Traffic Accidents from 2010 to 2014 (Data from NRSC, 2015)

A report published by the National Road Safety Commission (NRSC, 2015), suggested that the proportion of males involved in crashes are three times more than the percentage of women. Also, the 26-35 age groups continue to be over-represented in crash and fatalities statistics, indicating they are the population group most involved in crashes. Married working males, on the other hand, are typically those at substantial risk of traffic accidents and the worst month to have recorded the highest number of crashes is December. This may be attributed to the festivities within the month. Figure 3 presents the distribution of road accidents by region in Ghana. The bar chart indicates that the number of collisions occurring in the Greater Accra Region in relation to the other regions from 2010 to 2014 is far the highest. This throws more light on the extent of road safety problems in this region. Also, by comparing accident severity among the major cities in Ghana, Accra Metropolis is noted to have recorded the highest in all severity cases (Figure 4). It is, however, relevant to know that these figures are subject to the issue of under-reporting which is made up of underrecording and nonreporting of incidence. Greater Accra region and specifically Accra Metropolis requires in-depth studies to identify and understand the locations of these incidents as well as the underlying contributory factors. This would help devise countermeasures to reduce the high spate crashes among different road users on the mixed traffic system in Ghana.

The National Road Safety Commission in this regard recommended that to minimize the occurrence of RTAs, an integrated approach to road safety education, enforcement of traffic laws and regulations and engineering measures should be adopted. A typical example is the enforcement of the use of seatbelts by vehicle occupants. Which is difficult to implement especially with the uncontrolled informal minibus "trotro" operators. Also, the use of helmets by motorcyclist which fell on deaf ears to some illegal "Okada" riders (illegal use of motorcycle for commercial purposes). Concerted efforts should be directed at the identification and treatment of hotspots/hot zones on major road networks. In-depth research on main causal factors of road traffic accidents is needed for intervention programmes and projects to reduce RTAs.



Figure 4: Number of Accident Severity within Major Cities in Ghana (Data from NRSC, 2015)

2.5. Reviews on Data Related Works

On the quest for identifying some research work done in reference to accident data in Accra, a study by Gumah (2015) was found. This research concentrated on finding the causes and risk factors of accidents on the Accra-Tema Motorway after a spatio-temporal analysis. This was a research on one particular road which starts from the outskirt of the Accra Metropolis through to Tema, a suburb within the Greater Accra Metropolitan Area. Though the study was along one stretch of road, the researcher complemented the analysis with some remote sensing strategies by identifying the land cover change along the road for a period of time, then compared the changes to the number of accidents recorded at that period. This is so far, the only identified research within Accra which utilized the spatial aspect in accident studies. Other studies like Afukaar, Antwi, and Ofosu-Amaah (2002); Ackaah and Adonteng (2010) and Coleman (2014) were also identified, but the primary concern of these studies was using statistical and non-spatial models to describe road traffic situations in Ghana. The subsequent sections would discuss methodological approaches that are relevant in analysing traffic accidents.

2.6. Research Methods for Data Analysis

To develop competent remedies for minimizing vehicular involved incidents, one must first understand the characteristics exhibited by already occurred events. Over the years, safety studies have been conducted by applying numerous methodological approaches. With these methods contributing to novel insight into the features of vehicular accidents, certain methodological restraints do exist. These restraints create a setback on the appropriate techniques to utilize, to provide meaningful understanding for these occurrences. This section would accordingly review some contemporary methods and provide some importance and glitches regarding the identified methods and how the available data can be analysed. However, the purpose of this research is not to definitively determine the optimal methods for analyzing traffic accident data. The methods deemed appropriate for the data available would be applied, because the methods in this setting is a means to an end but not an end in itself.

Determining accidents hotspots and hot zones and supplementing it with location-specific data to understand the underlying phenomena are essential for suitable appropriation of resources for improving safety (Soltani & Askari, 2014). The identification of hazardous locations on roads present a more robust comprehension regarding variables of causal effects (Anderson, 2009) which contributes to the reduction of high density locations of accidents. A hotspot is a location with relatively high occurrence of vehicular accidents than its neighbouring locations (Yang et al., 2016). Hot zone on the other hand, refers to locations with high concentration of vehicular accidents based on contiguous road segments (Loo & Yao, 2013). That is, hotspots look at clustering on one road segment whilst hot zones consider the contiguity of more than one road segment. Moons, Brijs, and Wets (2009a) revealed that, combining hot zone approach in a hotspot analysis reveals a clear-cut image of hazardous locations. Since some contiguous road segments may be more dangerous to the road user than a mere hotspot location.

Ozkan, Tarhan, Eser, Yakut and Saygin (2013) in their work stated that to conduct steady analysis of point data and develop control strategies, firstly one must examine how the point incidents are distributed geographically. Secondly, the locations with high density of points are critically examined, then thirdly investigate their geo-statistical components. This can simply be grouped under spatial data analysis as visualizing spatial data, exploring spatial point pattern and modelling spatial point pattern by means of geo-statistic. This research would follow similar sequence in arriving at the final output. As pointed out by Bailey & Gatrell (1995), visualizing spatial point pattern or geographical distribution of point data is simply to plot the incidents on a dot map of which different visualization techniques can be apply to arrive at some subjective impression about the data. Delmelle (2009) prompted that, a visual inspection of a map through dotted map or scatter plots may not present a clear interpretation of the true pattern, especially when the

incidents occur recurrently in the same location. True patterns may go undiscovered, as such, presenting such incidents by means of bubble plot, where the size of the bubble symbolizes the frequency of the incidents is deemed ideal. The second step which is exploring spatial pattern or focusing on locations with high density points simply requires some point data analytical methods (K-function, kernel density estimation, spatial autocorrelation) to fulfil this step. The last, which entails modelling spatial point pattern or the investigation of their geo-statistical components is useful in conducting some statistical tests (Poisson, Monte Carlo Simulation, Regression Analysis) to explain and test the significance of the observed pattern.

2.6.1. Planar versus Network Space

After visualizing the spatial distribution of vehicular accidents, the determination of the spatial reference unit suitable for the analysis precedes the second stage (methodological consideration). A decision was taken on whether to use a planar or network space. The planar scale which is highly dependent on the use of Euclidean distance has been argued by many authors (Yamada and Thill, 2010; Vandenbulcke-Plasschaert, 2011 & Loidl et al., 2016) to be inappropriate for accident analysis. Yamada and Thill (2010), clarified this by citing an example that, assuming two crashes occur in a location, one on a highway and the other on a local road, they might be closer to each other in Euclidean distance, but presume a police officer investigating the occurrence needs to travel from the event on the highway to the local road. He would have to drive through numerous underpasses, overpasses, intersections to arrive at the second location. Under these conditions, the distance between these two events would be more appropriate to be measured using the shortest distance along the network instead of Euclidean distance (Yamada & Thill, 2010). The concept of spatial separation of events becomes relevant in this setting. Road accidents are constrained on a network and not any other location within the planar space. This clarifies why road accidents are better analysed using a network-based approach. However, this research concentrated on exploring different approaches for the analyses and determined the method that provided enough insight into the data. Both planar and network-based techniques were applied. After this, the appropriate spatial reference unit used was determined.

2.6.2. Aggregation versus Disaggregation

This brings a decision on whether to aggregate the data or not. Spatial analysis of vehicular accidents commonly bank on aggregating the data over precise spatial units and varying temporal resolutions (Vandenbulcke-Plasschaert, 2011). Whereas other studies fixate on individual single point in space, (with X, Y coordinates) with the intention to explore and understand the spatial distribution of these events over a stipulated timeframe (see; Myint, 2008; Yamada & Thill, 2004). These disaggregated methods are however unable to test for the significance of the point events if clusters are identified. The decision to aggregate the data is subject to the aim of the research, administrative convenience, time constraints, as well as the format of available dataset (Vandenbulcke-Plasschaert, 2011). Accident data and other explanatory or exposure variables are mostly collected by different institutions and agencies, with each having their own spatial units of which the researcher have no or limited influence. Predominant spatial units used across literature include the use of predefined or existing administrative unit (census tract, municipalities, regions or country), road nodes or intersections (Harris et al., 2013), road segments (Loo & Anderson, 2016b), voronoi diagrams (Loidl et al., 2016; Okabe, Okunuki, & Shiode, 2005) and quadrats (Shiode, 2008). The sole purpose for these writers aggregating the data was to assist in comparison. By comparing the incidents happening in one quadrat, voronoi or road segment to the other, makes the interpretation of the results more comprehensive. Also some of the aggregation methods provide direct means to test for the significance of identified clusters. Loidl et al. (2016) centred on aggregated data using voronoi diagrams as a means for comparison across the different spatial scales and temporal resolutions. He referred to this spatial unit as small aggregation or micro-scale (equal grid size of 2.3*2.7km) which was subject to the issue of the Modifiable Areal Unit Problem (MAUP). He justified his spatial unit by saying that large aggregated spatial units do not account for spatial variabilities. Most of these aggregations sometimes leads to ecological fallacy and MAUP.

After thorough reviews, both aggregation and disaggregation have their pros and cons especially, trying to aggregate disaggregated point data would result in loss of information about the point events. Methodologies for both approaches were employed in this research. Aggregation was only used for statistical tests, that is, test for significant hotspots. The spatial unit for aggregation was the road segments. This is because many writers have advised it to be the best form of aggregation and some dimensions of MAUP do not apply (Loo & Anderson 2016a). Nevertheless, many studies (Loo & Anderson, 2016a; Loo & Yao, 2013; Loo & Yao, 2011; Moons et al., 2009a; Moons, Brijs, & Wets, 2009b) have experimented using different equal road segment lengths. A problem regarding this method is that all segments below the defined threshold length (fragmented segments) are not considered in the analysis, which introduces an error term in the entire analysis process. The actual segment length of the network was the focus in this study. Now, the methods for identifying the hazardous locations (hotspots and hot zones) can be explored.

2.6.3. Spatial Analysis: Hotspots and Hot Zones

The identification of hazardous locations on roads presents a more robust understanding regarding variables of causal effects (Anderson, 2009), which contributes to developing countermeasures aim at improving road safety. The paramount ideology behind the concept of Hazardous Road Locations (HRLs) is areas having abnormally high incidences of traffic accidents involving death, injury or property damage than other locations (Loo & Anderson, 2016a). These critical sites, however, mostly comprised of a small portion of the entire road network regarding length but accounts for many shares of all traffic burdens. Given this, the identification, investigation/analysis and treatment of HRLs are considered as one of the most effective approaches to improve road safety. Loo (2009) claimed earlier studies which discussed the identification of HRLs using junctions, or together with nearby road segments as the unit of analysis failed to acknowledge their spatial coordinates, these intersections are in essence dealt with as non-spatial attribute of the entire process of HRL identification.

Methodologically, the identification of hazardous sites principally follows the link-attribute and event-based approaches (Loo & Anderson, 2016a). The link-attribute means of identifying HRLs first commence by dividing the entire road network into Basic Spatial Units (BSUs). The is because the technique (local autocorrelation) employed requires cutting up the road network into basic statistical units of standard length representing the spatial unit of analysis. The length of the BSUs is to be long enough to account for variations in the road environment. Aside the accidents, both geometric (road width) and non-geometric feature (traffic volume) of the BSUs can be stored in a relational database of the network. Crashes on a BSU can then be expressed using different intensity measures like accident density per road distance and accident count. By conveying accident information to the road network, additional data about the accident such as the accident type, degree of injury, number of injuries and number of fatality can also be visualized and analysed spatially by BSUs. Each BSU is either considered dependently or taken together with its contiguous BSUs as hazardous sites. For the former, identified HRLs are referred to as hotspots or black spots and the latter constitutes hot zones or black zones. Hotspots are locations with relatively high occurrence of vehicular accidents than their nearby locations (Yang et al., 2016). Hot zones, on the other hand, refer to sites with high concentration of crashes based on adjacent road segments (Loo & Yao, 2013). Thus, hotspots detect clustering on one segment while hot zones consider the contiguity of more than a segment. In other words, hot zones are spatially-related groups of hotspots (Young & Park, 2014) with consideration on the safety levels of neighbouring segments.

A striking point to note is that the difference between hotspots and hot zones is based not on the length of the HRLs. The distinction lies in the methodology (Loo & Anderson, 2016a). By using the link-attribute approach to illustrate a hot zone, if the standard size of the BSUs is 100m long, a hot zone will have a minimum length of 200m. However, a hotspot always consists of one BSU only with it extent determined by the standard length of the BSUs. Also, some hotspots may be clustered or contiguous, but network contiguity is not considered in the process of identification (Loo & Anderson, 2016b). When traffic accidents are assigned to the road network, significant positive spatial autocorrelation can be identified by mapping and creating statistical model to examine the attribute value such as accident count and density of the road segments or BSUs. One of the key advantages of the link-attribute approach is its ability to integrate several vital databases, such as accident database, traffic-flows, land use and even hospital database in a suitable network setting.

In the event-based approach, accidents are represented as points. This method can further be regrouped as distance-based which study distances between events and density-based that inspect the overall intensity of points. Repeatedly used distance-based approaches that directly examine the distances among accidents as spatial events includes the nearest-neighbour (Eckley & Curtin, 2013) and K-function (Vandenbulcke-Plasschaert, 2011; Okabe et al., 2005; Yamada & Thill, 2004). The alternative to this method is the densitybased measure and the quadrat/Voronoi diagram (Loidl et al., 2016) and the Kernel Density Estimation (KDE) (Shafabakhsh et al., 2017; Yang et al., 2016; Anderson, 2009) belongs to this type. The KDE methods are predominantly promising in examining crash pattern (O'Sullivan & Unwin, 2010). It essential concept is that accidents do not occur at discrete locations in space only. Instead, they can occur over continuous space or over a network. Nevertheless, using the event-based approach, hotspots are recognized lacking explicit regards of the network contiguity among the reference points with the opposite being true for hot zones (Loo & Anderson, 2016b). A hot zone is only identified when there are spatial interdependent HRLs at contiguous reference points. This is however in contrast to the notion of using hotspots to refer to short road segments and hot zones to refer to longer road segments. In brief, the link-attribute method focuses on aggregating the accidents over a predefined equal length segments and applying techniques such as local autocorrelation (Flahaut, Mouchart, San Martin, & Thomas, 2003; Moons et al., 2009a; Moons, Brijs, & Wets, 2009b) to identify HRLs whilst the event-based consider the accidents as a point event over a discrete or continuous space and using methods such as the nearest neighbour, K-function, quadrat/Voronoi diagrams and KDE to identify HRLs.

The event-based methods according to Bailey and Gatrell (1995) and Delmelle (2009), even though have their pros and cons, were developed chronologically (nearest neighbour, K-function, quadrat/Voronoi diagrams and KDE) to cater for the weaknesses of the preceding method. For instance, the nearest neighbour can be substituted with the K-function because the K-function defines the extent of clustering at an expanded range of scale which the nearest neighbour cannot. However, neither the nearest-neighbour, K-function nor quadrat determines the location of clusters. They only specify the overall tendency of the data (Delmelle, 2009). KDE, conversely, is among the methods that determine the locations, that is, geographical region of the tendency displayed by the data. With vehicular accidents restrained to a onedimensional space, it is optimal to consider the road networks in the KDE, hence, the Network Kernel Density Estimation (NetKDE) (Dai & Jaworski, 2016; Kaygisiz, ßebnem Düzgün, Yildiz, & Senbil, 2015; Xie & Yan, 2013; Xie & Yan, 2008). With the NetKDE just like KDE, the size of the kernel and the bandwidth profoundly influence results. This requires several sensitivity analyses to arrive at the appropriate thresholds. This imposes more considerable influence on the spatial distribution of the estimates. Also, there is no formal significant test for the identified HRLs with this method (Yao, Loo, & Yang, 2015). Moons, Brijs, and Wets (2009a) revealed that combining hot zone approach in a hotspot analysis reveals a clear-cut image of hazardous locations. Since some contiguous road segments may be more dangerous to the road user than a hotspot location. Flahaut, Mouchart, San Martin, & Thomas (2003) are among the ground-laying studies to present the spatial autocorrelation methods, Local Indicators for Spatial Autocorrelation (LISA). They did this by comparing the NetKDE approach with the LISA methods in the identification of hot zones. Primarily, the entire road network in the study area was divided into non-overlapping segments of equal lengths (BSUs), and the number of crashes per each BSU was estimated. Also, by employing the proximity weight matrix of zeros and ones (0-1) (or sometimes the actual network-distance), they could define the spatial relationship between all BSUs. From there the local spatial autocorrelation and NetKDE technique were computed to identify adjacent segments with high accident count. The two methods led to quite comparable results. But unlike hotspots whose length is always fixed, the length of hot zones varies depending on the number of contiguous segments of a similarly high number of collision counts.

Moons et al. (2009b) improved the LISA method by using the network-distance weight to determine the distance between adjacent BSUs. Yamada and Thill (2010) also applied both local Getis-ord GI* and Local Moran's I statistics to detect hot zones on highways in Buffalo. The results indicated the strength in using the network-constraint process in reflecting the effects of road accidents on linear traffic features which is not significantly different from what the already discussed authors did. Apart from the KDE and the spatial autocorrelation approaches, none of the other methods provide a direct means for the identification of hot zones. Although hot zones are hazardous to road users, in contrast to hotspots, there is no systematic methodology to identify hot zones on a road network but to consider contiguous network for the hot zone detection. Also, there has been no consensus on which of the two methodologies is more appropriate in identifying HRLs on the road; the hot zone approach has attracted many attentions in recent times. For it is economically sound to adopt a method which will help in the discovering of contiguous segments to make it easier in improving the whole road corridor rather than improving individually scattered locations across the network (Young & Park, 2014).

In a nutshell, due to the error term introduced as a result of dividing the entire network in the study into BSUs of equal length, the actual network length of the road dataset was used. Also, since the identification of the best method for detecting HRLs is not the main focus for this research, most of the reviewed methods were applied and compared in respect to the dataset to discover the method that gives more insight into the data. A global indicator was first used to check the overall tendency displayed by the data, whether there is a possibility of significant clustering or not. This satisfied the condition of the first hypothesis stated in subsection 1.6. Local indicator methods were afterward executed to find the locations of clusters. Concerning hot zones, due to the subjectivity in its definition, the nature and distribution of vehicular accident in the study area, its description for this case is not going to be considered as contiguous hotspot locations as discussed at length in the earlier paragraphs. Hot zones for this study are going to be significant hotspot locations with high frequency of vehicular accidents (using a location score) and at least one fatal accident. This definition is befitting for the case because if just contiguous hotspots are considered, an entire road of approximately 67km and majority of the roads in the CBD would be detected as hot zones. Which is economically unreasonable to present as locations which need immediate investment to minimize traffic accidents. Given that, this new definition gave a means to rank the locations detected based on the frequency of events occurring and the number of fatalities on the segments. This helped discover the critical locations where accident occurred often within all the five-year period of the dataset and also resulted in some fatalities. These locations are to be considered more hazardous than just spatially clustered hotspot locations.

2.6.4. Temporal Analysis

The methods used in the detection of hotspots and hot zones were applied on the temporal aspect of the data. Achieving this was by decomposing the data into different temporal components and applying the methods to perceive how the patterns change over time. This can be animated to reduce the enormous number of temporal maps.

2.6.5. Spatio -Temporal Analysis

There exist limited methods in studies on space-time interaction of spatial point data. Space-time interaction methods or tests are implemented to evaluate whether some events are clustered in space and time after distinct spatial and temporal clustering analysis. Popular among them is the Space-Time K-function (see; Delmelle, Casas, & Rojas, 2013) and the Knox test (see; Knox & Bartlett, 1964). The Knox test, however, appeared to be the most widely used method to assess incidents which are clustered in space and in time. This is because some studies view it as an elegant and attractive method (Baker, 2004; Kulldorff & Hjalmars, 1999) because it is straightforward and simple to calculate the statistics. This method essentially tests whether an observed pair of points is significantly different from what would be anticipated under random conditions (Delmelle, Kim, Xiao, & Chen, 2013). Baker (2004), defines Knox statistics as the combination of pairs of events that are close in both space and time. This method was adopted in finding spatio-temporal clusters. Although it is relatively straightforward, spatial and temporal analysis of the events were undertaken separately which served as a feed for the spatio-temporal analysis.

Two critical thresholds are needed before the Knox test can begin. The critical distance and time threshold. These thresholds are mostly user-defined and are sometimes subject to biases and errors. The time threshold which is decided from the temporal analysis, is highly dependent on the temporal components of the data, being it hour, day, week, month et cetera. This per se is easy to figure out by decomposing the data into varying temporal scales and observing which category is capable for detecting a judicious number of pairs of clusters. The distance threshold, on the other hand, has been subjectively decided by many authors (like Eckley & Curtin, 2013; Rogerson, 2001). In the study of Kalantari, Yaghmaei and Ghezelbash (2016), three methods were proposed for determining the distance threshold. The mean distance, Ripley's K-function, and the natural breaks classification of nearest neighbour distance. The mean distance was adopted. Also, to test the significance of the observed versus the expected results of the Knox statistics, a Monte Carlo Simulation (see Besag & Diggle, 1977) was initiated. The output of a Knox test is usually a 2*2 matrix known as the Knox test contingency table. This matrix gives four outcomes of pairs of events which are closer in both space and time, those close in space and far in time, far in space and close in time and those far in both space and time (Table 1).

| Table 1: | Knox | Test | Contingency | y Table |
|----------|------|------|-------------|---------|
|----------|------|------|-------------|---------|

| | | SPACE | | |
|------------|-----|----------------------------|-----------|--|
| | | Close | Far | |
| TIME Close | | Close (Space-Time Cluster) | Time only | |
| | Far | Space Only | Not close | |

Before all these analyses, descriptive and statistical analyses (regression) were estimated to first understand the data and figure out the effects of some explanatory variables on predicting accident severity and how each of these factors contributes to accident severity.

2.7. Summary

In summary, both a planar and network-based approaches were adopted in this research. Also, both disaggregation and aggregation methods were employed. This helped in determining the method that fit best, given the purpose of the research and nature of the secondary data. The road segments are the spatial unit of analysis for aggregation. Planar KDE, NetKDE and Local Indicators of Spatial Association (LISA; Local Moran's I and Getis-ord GI*) were implemented to detect hotspots. Hot zones were considered to be significant hotspot locations with high accident frequency and at least one fatal injury. Temporally, the data was decomposed into different temporal intervals and the methods for detecting the hotspots and hot zones were enforced to see how the patterns change over time. Finally, Knox test was introduced to determine the events which are close in both space and in time. The significance of this approach was tested using MCS. The software used for the entire research process are; ArcGIS, Arcscene, Excel, R-software package, Clusterseer, SANET (Spatial Analysis on a Network) by Okabe and Sugihara (2012), Epicollect5 and SPSS.

3. STUDY AREA, METHODS AND DATA

3.1. Research Approach

The primary research approach employed here is a mixed methods technique. Mixed methods are fundamentally about quantitative and qualitative methodologies. These two methods can be applied in a research simultaneously or sequentially. Triangulation is seen as the path to which these two approaches can be integrated as long as the confirmation procedure of a completed research is essential (Tonon, 2015). Triangulation is the combination of different methodologies in research to interpret the same phenomena (Denzin, 2009). These mixed methods have various techniques for data collection and analysis. However, for this study, the mixed methods focused on QUAN+qual. QUAN+qual is one of the nine classifications of mixed methods approach proposed by Bryman (2012). These classifications simply indicate which method precedes the other or how concurrently they appear in the research. The upper and lower case indicates priority and the plus sign depicts the mixed methods would occur concurrently throughout the research. The "QUAN" which means quantitative is capitalized to indicate emphasis/priority. Implying that, the research focused on quantitative methods involving various statistical and GIS analysis and quantitative data collection methods. The "qual" representing qualitative was used in the research to review literature and institutional documents as well as subjectively describe the physical characteristics of the cluster locations (hot zones) after field work and the outcome of the Focus Group Discussion (FGD) and a key informant interview. In a nutshell, the qualitative approach would complement the quantitative findings.

The type of research employed in this study is data mining which sought to determine unexpected patterns in large data sets. This is sometimes referred to as Exploratory Spatial Data Analysis (ESDA). It is a method that facilitates the discovering of patterns and identification of clustering and proposes hypotheses on causal relationships (Delmelle, Kim, et al., 2013). This method is mostly followed by a confirmatory analysis which uses statistical means to test the significance of the patterns. The exploratory study is a milestone for further in-depth explanatory analysis because it helps to generate hypotheses.

3.2. Study Area

The study area is Accra Metropolis, specifically Accra Central. It is in the south-central part of Ghana, Greater Accra Region. Accra lies along the Gulf of Guinea and serves as both the national and regional capital with high concentration of economic and administrative activities. The City has 1,310 km of paved roads out of 1,632 excluding residential roads (ASIT⁵, 2014). These paved roads mostly lack road markings and signs. However, the available network is unable to satisfactorily handle the fast-growing vehicle fleet. Major roads are congested continuously daily. Accra's most congested roads include the Kaneshie-Mallam-Kasoa Highway (also known as Dr. Busia Highway), Achimota-Amasaman Road, Legon-Madina-Adenta Road, Spintex Road and High Street in Accra's CBD (ASIT, 2014). On these streets, it sometimes takes 4hours to cover a 30minutes trip. Despite the high congestion rate, traffic accidents are still on the rise. As pointed by Van Den Bossche, Wets, and Brijs (2005), accidents occur in relation to traffic flow. This may be attributed to the high traffic mix where all road users muddle through the already busy street. It is therefore not surprising that, the Figure 3 and Figure 4 indicates that the region, as well as the city, has the highest occurrence of vehicular accidents with high severity among the various regions and major cities.

⁵ Association for Safe International Road Travel

Rendering to the 2010 Population and Housing Census, Accra Metropolis has a total population of 1,848,614 persons, which accounts for 46.1% of the regional population due to high in-migration from other regions (GSS⁶, 2010). The report was stated that the population density of Greater Accra Region is 1,235.8 persons per square kilometre. Figure 5 shows the contextual scope of Accra from a national and regional context.



Figure 5: Contextual Map of Study Area

3.3. Available Data and Description (Secondary Data)

Secondary data of reported vehicular accidents and road networks in Accra is the main data source for this research which was complemented by some primary data which assisted in identifying some location-specific contributory factors. The following section briefly describes the content of the secondary data. The vehicular accident data available, is a five-year period, from 2011 to 2015. This was collected through a joint initiative of the Building and Road Research Institute (BRRI), Ghana in collaboration with the Ghana Police Service. BRRI is among the thirteen research institutes of CSIR (Council for Scientific and Industrial Research), Ghana. The original data is a text-based record on a spreadsheet. For this study, only reported crashes with at least one vehicle involved was considered, resulting in a dataset of 12,166 incidents within the stipulated time frame. However, only 5,742 have X and Y coordinates. Approximately, 52.8% of the records were not used for the spatial analysis in the detection of hotspots and hot zones. Though, these were included in all statistical, descriptive, and non-spatial analysis to provide a more reliable outcome. In addition to the location of the incidents, each crash observation contained some attributive information excluding personal details. This indicates a major limitation with the data and as such, no personal or demographic characteristics (gender, age, economic status, nationality) of the victims were considered in the analysis.

⁶ Ghana Statistical Service

Some of the location and accident characteristics include the day, month and time of the accident, number of vehicles involved, number of casualties, lighting condition, accident severity (which were categorized into four classes), availability of road separation, road geometry and weather condition among others. These served as explanatory variables (predictors) for the statistical analysis. Another limitation recognized is in relation to unavailability of exposure variables (traffic volume, distance traveled, etc.). These types of variable are rarely available in road safety studies due to the less attention paid by scientists, policy makers and planners (Iacono, Krizek, & El-Geneidy, 2010) and Accra is no exception. Table 2 indicates the number of accidents per year as well as the number of people killed and injured for the spatial analysis (5,742 incidents). Some of these events caused damage to properties only without anyone being killed or injured.

In addition to the accident locations, a digital representation of the road network was utilized. This is because road accidents are restrained to a network and not any other location within the urban space. This road network was obtained from CERSGIS (Centre for Remote Sensing and Geographic Information Services), University of Ghana, Legon and validated and updated using Open Street Map (OSM). The original data is a shapefile which contains the different road categories. These are mainly motorway, primary, secondary, tertiary and trunk roads. It also had some attributive information about physical characteristics of the road network. This road network was used as the network-space for the analysis. Other secondary data were acquired from journals, books, electronic websites, official documents, annual reports and other websites. Figure 6 gives the methodological sequence for the entire research.

| Year | Total accidents | Number of People Killed | Number of people Injured |
|------|-----------------|-------------------------|--------------------------|
| 2011 | 1261 | 64 | 936 |
| 2012 | 1396 | 96 | 923 |
| 2013 | 1008 | 59 | 667 |
| 2014 | 1068 | 56 | 792 |
| 2015 | 1009 | 74 | 606 |

Table 2: Accident Data Description

3.4. Statistical Analysis

Among the essential tasks in traffic safety is the determination of the causes of road accidents, with the purpose that preventive regulations can be put in place. Given that, this section describes the use of the generalized ordered logit regression model to examine the risk of different severity levels sustained under vehicular accidents. This gives a general understanding of automobile crashes that have occurred and possible contributory factors. The model is applied to identify the factors affecting the severity of vehicular accidents in Accra. These elements are grouped into three categories: road user, road and vehicle as described in section 2.2 and 2.3. However, the elements provided in the dataset is made up of the accident, built environment and road characteristics only. The unit of analysis is the accident which is made up of all 12,166 records. Accident severity is, usually, defined as a categorical variable. The categorized values represent the level of severity in an ordinal scale of damage only, minor, serious and fatal injury with increasing intensity. Fatal includes a situation of death immediately or after 30 days of the incident whereas serious injury results in either an immediate or later detention in the hospital as an in-patient (Clifton, Burnier, & Akar, 2009).



Figure 6: Methodological Workflow

This type of regression model was deemed appropriate for the analysis because of the nature of the dependent variable. With the dependent variable (accident severity) being discrete with more than two categories, the binomial logistic regression was inappropriate, hence the multinomial (logit) regression with ordered scale. This model helped account for the ordinal nature of the dependent variable (Williams, 2016). It also accounted for the parallel regression assumption, which assumes that the relationship between each pair of outcomes groups is the same, which other regression models violated (Clifton et al., 2009). This assumption allows the explanatory variables to have a varying effect on the estimated intercepts and coefficients. Crash severity was coded as 1 for damage only, 2 for minor injury, 3 for serious injury and 4 for fatal crash. The intercepts, for this case four categories, leads to a k-1 (where k is the total number of ordinal classes/levels), which is 4-1 intercepts generated. The four ordinal scale of damage only (1), minor (2), serious (3) and fatal (4) were partitioned into the first set of 1 versus 2,3,4 (damage only vs. minor, serious, fatal), the second being 1,2 vs. 3,4 and the last estimated as 1, 2, 3 vs. 4 (Michalaki, Quddus, Pitfield, & Huetson, 2015). Regarding the coefficients of the independent variables, if any of these variables happen to be categorical, which is true for the dataset, the first class or level is frequently used as the reference or base case to which the significance of the other levels is compared to. This model has also been considered by Bahrololoom, Moridpour, and Tay, (2016); Williams, (2016); Michalaki et al., (2015); Clifton et al., (2009); Kockelman and Kweon, (2002). This regression model combines the independent (explanatory/predictor) variables to estimate the probability that a particular event would occur and also estimate the contribution

and significance of each predictor. The generalized ordered logit regression model in its simplest form as specified by Bahrololoom et al. (2016) is given in Equation 1 as:

Equation 1: Generalized Ordered Logit Model

$$Y_{i} = \frac{EXP (\alpha_{i} + \beta_{1}X_{i1} + \beta_{2}X_{i2} + \dots + \beta_{n}X_{in})}{1 + EXP (\alpha_{i} + \beta_{1}X_{i1} + \beta_{2}X_{i2} + \dots + \beta_{n}X_{in})}$$

Where:

- Y_i representing the predicted severity sustained at accident location i
- α_i represents the model constant or intercept for location i
- β The unknown parameters associated with the explanatory variables
- X_i the explanatory variables describing the accident at location i
- n is the number of explanatory variables

Ten explanatory variables were considered to influence accident severity. Except for the 'number of vehicles involved' and 'number of casualties,' the remaining eight factors were all categorical variables of different levels ranging from three to eight levels. These were all coded as dummy variables. In the process of accident severity modeling, the 80-20 rule was used to divide the entire data set of 12,166 observations into two. 80% of the data represented the training sample (9762 observations). This was used to calibrate the prediction model and the remaining 20% which is the testing sample (2404 observations) was used to validating the model. The first part of the model was run using the 80% training dataset. The significance of each of the variables was inspected. With a 95% confidence interval, the less significant variables were removed one after the other to check statistically how the model improved. However, since majority of the variables were categorical, of different levels, if at least one level is highly significant and the others not, that variable was maintained in the final model because removing those variables did not improve the outcome of the model. Eight out of the ten variables were used for the final model. Also, the first levels in each variable category were used as the baseline or reference. The regression was estimated with five missing observations. After the final model was calculated, the remaining 20% of the data was used to test the model performance and a confusion matrix was generated to identify the correctly predicted observation. The output of this section has been detailed out in section 4.3.

3.5. Spatial Analysis

3.5.1. Geo-Validation of Vehicular Accidents on the Network

High precision of the spatial location of accidents is essential for any significant spatial analysis, ranging from basic locational pattern visualization to modeling complex spatial trends (Loo & Yao, 2012). It is, therefore, a requirement to geographically validate these accident locations before any scientific spatial analysis can commerce. With road traffic accidents being constrained to a network space, the locations of all accidents are expected to directly intersect with the network, but sometimes due to both technical and non-technical reasons, they are doubtful to intersect with the network centreline (Loo, 2006). By using Boolean operations, it was realized that most of the accident locations (5742) did not intersect with the network centrelines. Not less than 99% did not intersect with the segments. Topological tools were operationalized to snap the accidents to the nearest road segment. Regarding the point aggregation on the segments. To overcome this, the minimum and maximum XY coordinates for each road segment were calculated. All accidents at the meeting point of at least two segments were selected and randomly assigned to any of the minimum-maximum XY locations such as the left (smaller minimum x) or upper (larger

maximum y) and so on. The aggregated actual crash rate which is the real count of accidents occurring on each road segment was computed.

3.5.2. Hotspot and Hot Zone Identification

With road accidents restrained to a network, of which some of the methods to be used are to be adapted to, a road network dataset was built. With a total length of roads within the Accra Metropolis being 2,594.02km (17,681 segments), topological rules aided in finding all disconnected segments of the road and manually edited to ensure connectivity. With methods like the global and local autocorrelation which considers the neighbour structure to identify clusters, two major shortcomings were observed. First contemplation was, which of the segments are to be regarded as neighbours. Is it going to be the first order, second, third or other subsequent neighbourhood structure? The second limitation was the optimal distance weight function for defining the neighbourhood structure. After several deliberations and sensitivity analysis for determining the level of connection (number of neighbours) for each segment, a 1km distance based range was arrived at. Moons et al., (2009b) happened to be part of the writers who also defined the neighbourhood connection based on a 1km range over the network. In this instance, all segments within the stipulated threshold distance were considered as neighbours. Based on the dense network configuration, this resulted in a minimum of 1 and a maximum of 30 neighbours.

Also, the second issue mentioned was the determination of the optimal weight function. A sensitivity analysis was carried out by Moons et al. (2009b) by comparing four different weight functions (Epanechnikov-like kernel (E-like), the inverse of squared distance $(1/d^2)$, the inverse of distance (1/d) and the inverse of square root distance (1/sqrt(d))). It was detected that the inverse of squared distance yielded a promising result where the less nearby a location is to the location under investigation the less weight it receives. This weight function was adopted for this case and the weights were normalized using row-standardization where the sum of weights for each segment and its neighbours sum up to 1. The global Moran's I was executed to estimate the possibility of statistically significant cluster for the entire study area. The estimated distance weight matrix based on the 1km range and inverse distance squared served as the conceptualization of spatial relationship.

With the report generated by the global parameter (Appendix 1), four different local methods were used to identify the location of these clusters. First, a bubble map was used, where the size of the bubble symbolizes the frequency of accidents occurring at that location. This is a disaggregated spatial distribution of the recorded vehicular accidents in the study. The extent to which automobile crashes are concentrated within the Accra Metropolis becomes conspicuous when visualized with the bubbles. Similarly, a planar KDE and NetKDE were implemented to identify which of the methods provides enough insight into the data. Since the KDE methods convert the discrete points into continuous event in space or over a network, the output generated was a surface showing the intensity of point at that location. These methods require dividing the study area into grids of user-defined cell-size. A kernel function is used to compute the density of traffic collision within a user-defined bandwidth/search radius (Yao et al., 2015). This method computes the density of point features around each grid cell. The density of the cell is calculated as the value (number of accidents multiplied by weight) of accidents per unit area (Steenberghen, Dufays, Thomas, & Flahaut, 2004). These thresholds demanded a user-defined initiative because thresholds used in literature may not ideally provide enough intuitiveness for the data. Since this is a density estimation of which the length or size of the network plays (for NetKDE) a vital role, the network is segmented automatically into equal length and the density of collisions is calculated per segment. In account of this, a sensitivity analysis was performed to identify the optimal bandwidth (search radius) and cell size appropriate for the data set. For both the KDE and NetKDE a bandwidth of 200m and a cell size of and 10 square kilometres was used. These defined the region (neighbourhood) to which the kernel was calculated. These thresholds also determined the smoothing

and extent of clustering. The mathematical formula by Xie & Yan (2008) for planar KDE is given in Equation 2 and that of NetKDE is stated in Equation 3.

Equation 2: Planar Kernel Density Estimation

$$\delta_s = \sum_{i=1}^n \frac{1}{\pi r^2} k(\frac{d_{is}}{r})$$

With:

- δ_s representing density at location s
- r represents the bandwidth or search radius
- k shows the weight of point i at distance d_{is} (kernel function)

 d_{is} Distance from location i to s

Equation 3: Network Kernel Density Estimation

$$\delta_s = \sum_{i=1}^n \frac{1}{r} k(\frac{d_{is}}{r})$$

The only distinction between the two equations is the formula for calculating the area of a circle (πr^2) for KDE, because it is calculated over a planar space while NetKDE only contains the search radius (bandwidth). Also, the NetKDE estimates the densities over the network space and not any other location within the urban space. A major limitation of the three methods (bubbles, KDE and NetKDE) is that there is no means for testing for the significance of the identified hotspots. Also, while the distance from location 'i' to 's' is determined over the network for the NetKDE, that of KDE is estimated using Euclidean distance.

To identify significant clusters, the fourth method which is local autocorrelation was implemented. Even though both Getis-ord GI* and Local Moran's I measure spatial association between an event and its neighbouring structure, this is based on different approaches (Steenberghen et al., 2004). The local Moran's I was favoured in this research because many studies confirmed a more stable result in comparison to other indices. The Moran's Index was used to evaluate the degree of spatial interdependence between a variable under study and its neighbourhood (Moons et al., 2009a). Just as the global version of Moran's I was estimated in the previous paragraph, the local version was also assessed using the same parameters. 1km neighbouring structure and inverse of squared distance (using the same distance weighted matrix normalized using row-standardization) and Equation 4. The mathematical underpinning for the local detection of significant hotspots at a specific location is given as;

Equation 4: Local Moran's I

$$I_i = \frac{n}{(n-1)s^2} (x_i - \bar{x}) \sum_j wij(x_j - \bar{x})$$

With:

- n representing the total number of road segments
- x_i number of accidents on segment i
- \bar{x} the average value of accidents for the entire study area
- w_{ii} the weight representing the proximity between location i and j, with all wii = 0
- S^2 symbolizes the variance of the observed values

To test the significance of the identified hotspots, the total number of accidents within the study area were randomly distributed over the network space. This was simulated for a sufficient number of times (1000times) to arrive at an approximate distribution. The resulting normal distribution of simulated points for each segment allowed to only select the highly significant hotspots from the actual data based on the p-value and z-score from the simulation. Only locations with positive significant (p<0.01) high-high clusters were selected as hotspots.

Identification of hot zones as defined in subsection 2.6.3., location score based on accident frequency for the five-year period data was estimated for each of the significant hotspots detected. Each segment was given a score of 1 if an accident occurred there in 2011. The same score was assigned to the later years. These were summed up at the end of the five years and all locations with a score of 5 were selected. This shows the hotspot locations where accident occurred each year for the five years under consideration. To refine the choice by making the locations more critical, fatal crashes were introduced. The refined locations now had at least one fatal accident. These were termed hot zones. A severity index for the hot zones was calculated. This was to help rank and select the most dangerous accident locations. With the social cost emanating from the different severity levels being unequal, different weights were assigned to each level. These weights were shaped by Geurts, Wets, Brijs, & Vanhoof (2004), who used a combination of weighting values of 1 for light injury, 3 for serious injury and 5 for deadly injury (1_3_5). Truong & Somenahalli (2011), reported on a weight of 3 for fatal, 1.8 for serious, 1.3 for minor and 1 for damage only (3_1.8_1.3_1). 9 for fatal, 3 for injuries and 1 for damage only (9_3_1) was the weights given by Soltani & Askari (2017). These authors all had different weights allotted because there is no developed optimum weighting system (Truong & Somenahalli, 2011). In reference to these reviews and the nature of the crash data for the study area, weighting values were deduced. Equation 5 shows the severity formula and the weight assigned to each level of severity and "i" depicts segment under study.

Equation 5: Severity Index

Severity $Index_i = (1 * Damage only_i) + (3 * Minor_i) + (6 * Serious_i) + (9 * Fatal_i)$

3.6. Temporal Analysis

The data was decomposed by yearly interval and the methods for identifying hotspots were executed to observe how the hotspot locations changed over time. Also, bubble map was used to visualize the morning and evening rush periods to identify locations with rush period clusters.

3.7. Spatio-Temporal Analysis

It is often beneficial to test for spatio-temporal clustering of events when the available data has some spatial as well as temporal components. Spatio-temporal clustering is different from spatial plus temporal clustering. It counts the number of pairs of events nearer in space and time than would occur under random distribution. It complements hotspot clustering analysis (Eckley & Curtin, 2013). Spatial, temporal, and spatio-temporal analyses give distinct outputs which supply more insight into the data. The pairs of clusters discovered by this type of analysis are mostly not detected or explained by performing different spatial and /or temporal analysis. This is in a way a correlation analysis to find incidents which are nearer in both space and time. Availability of spatial and temporal clustering does not necessarily imply spatio-temporal clustering (Kalantari et al., 2016). The main idea behind the identification of spatio-temporal clusters is because events which are clustered in space and time could have been triggered by the same underlying spatial or temporal factors. Finding such events might contribute to the understanding of the nature of accidents in the Metropolis. The Knox test which is the method used discovered only statistically significant pairs of events. These pair of clusters can only be detected by specifying a distance and temporal threshold. These thresholds
decide in which instance the null hypothesis as stated in section 1.5. can be rejected. These thresholds profoundly influence the results of this statistical test. All pairs of events which occurred within these thresholds are detected. Their significance is tested through a Monte Carlo Simulation. The Knox test is a global test, but it is possible to display the pairs of events contributing to the global spatio-temporal clustering. The mathematical rule for the test as stated by Eckley & Curtin (2013) is given in Equation 6 as;

Equation 6: Knox Statistics

$$\mathbf{X} = \sum_{i=1}^{n} \sum_{j=1}^{n} \delta_{ij} \tau_{ij}$$

Where:

- n is the total number of collision
- δ_{ii} being the adjacency in space (δ) between event i and j
- τ_{ii} stands for event i and j occurring within the time threshold τ

An approach which can aid in deciding the temporal threshold as proposed by Eckley & Curtin (2013) is dividing the total number of accidents (5742) in the study area by the different temporal components. This gave a general idea about the number of accident available at each temporal interval. This is shown in Table 3. The choice of minute is likely to lead to many intervals with zero values and the choice of year, month and week would dramatically increase the number of events per interval. Day, in this case, was chosen as the best and most expedient temporal interval for this study with approximately 3.4 events per interval. The critical distance as proposed by Kalantari et al. (2016) was determined by using the average distance from one crash location to the other. The average nearest neighbour test was estimated to find out the mean distance between points. This resulted in an observed average distance of 10.89 meters (Appendix 2). This served as the critical spatial distance for the spatio-temporal analysis. This was held constant at a point while the critical temporal distance changed from 1 day to 7 days. Other spatial threshold distances were also used to recognize how the number of events considered spatio-temporal clusters changes as the spatial and temporal distance changes. At some point, the temporal thresholds were also held constant. A 999 permutation of MCS was used to find the significant clusters.

| Temporal Components | Number of intervals | Number of Accidents per interval (5742) |
|---------------------|---------------------|---|
| Year | 5 | 1,148.5000 |
| Month | 60 | 95.7000 |
| Week | 240 | 23.9300 |
| Day | 1,680 | 3.4200 |
| Hour | 40,320 | 0.1400 |
| Minutes | 2,419,200 | 0.0024 |

Table 3: Temporal Intervals

3.8. Primary Data Collection

The primary data collection was undertaken after the secondary data analysis. The secondary data analysis aided in detecting the accident hot zones. Essentially, the primary data collection was embarked to satisfy two main goals. First, it helped in recognizing some location-specific contributory factors to these already discovered hot zones. This reinforced the understanding and interpretations of the outcomes of the secondary data analysis. Secondly, it aided in identifying ways of improving accident data collection in Ghana and how the geographical/spatial aspects of accident analysis can be incorporating into current accident

studies in Ghana. The primary data collection was done in three stages. First, a field observation was carried out to find the physical and infrastructural characteristics of the selected hot zone locations using an observational checklist and photography. This was analysed subjectively through qualitative description to explain the physical and infrastructural conditions of the sites. Secondly, some residents and /or workers along these hot zone locations/sites were randomly sampled to obtain some location-specific explanatory variables and plausible causes for the high automobile crashes. This was achieved through questionnaire administration.

Lastly, a focus group discussion and key informant interview were organized for some road safety institutions. The findings from the secondary data analysis, observations and location-specific causes of accidents from field visit were presented to these individuals. The quality of the data, methods for analysing the data and the findings from the analysis were presented to them and deliberated upon, their views were then called for, especially on how to improve accident analysis in Ghana. These shed light on how to advance accident data collection techniques and ways of analysing it, find potential causes, and means of minimizing the number of accidents in the hot zone locations.

3.8.1. Reconnaissance Survey

The first 10 hot zone locations as specified by the severity index ranking was to be the focus segments for data collection. However, the three days (from 27th, November 2017 to 29th, November 2017) reconnaissance survey redirected some of the selected segments. The length of some of the segment increased by merging it with its adjacent segments also identified as a hot zone, while other sites were selected based on the presence of some target group (like drivers). Five out of the first 10 hot zone sites were along the Dr. Busia highway and the other 5 sparsely distributed along the Ring-Road Central, Liberation Road and Olusegun Obasanjo High street. It was recognized that some of these segments were not vibrant locations to acquire a reasonable number of people to interview. This, together with the fact that some aspect of the questionnaire targeted drivers, slightly changed the strategy for selecting sites. The first 5 locations (popularly known as Mallam Market, Dansoman Junction, Busia Junction (all three along the Dr. Busia Highway), Airport First (a segment on the Liberation Road) and ECG (Electricity Company of Ghana, a segment on the Olusegun Obasanjo High street)) as per the severity index ranking did not change in any instance. These areas were active enough to interview a reasonable number of people except the 5th location (ECG). This segment had two main land uses along it. Which are public facility (Electricity Company of Ghana, Roman Ridge District Office) and educational (The Accra Girls Secondary School) with no residential facilities and fewer people with the exception of some few street peddlers selling closer to the nearby traffic light.

In view of this, an adjacent segment, locally known as Pig Farm Junction, (the 9th hot zone segment) had diverse activities and active enough, so it was merged with the 5th segment as one hazardous location. The 6th and 7th segments per the severity index were not considered since they were in close proximity to the 1st (Mallam Market) and 2nd (Dansoman Junction) segments respectively and believed that similar responses would be obtained (Tobler's first law of geography (Tobler, 1970)). Also, the 8th segment happened to be one segment of a significant flyover in Ghana popularly known as "Dubai or Kwame Nkrumah Circle." Even though all the connecting segments forming the flyover were detected as hot zones, they had different ranks as per the severity index. All these connecting segments were perceived to be one and merged to form a location (known as Kwame Nkrumah Circle). These resulted in six segments with two market locations (Mallam Market and Kwame Nkrumah Circle). Commercial vehicle drivers are readily available to interview often at marketplaces which is also their stations of operation. Two other sites regardless of their rank were selected because they were also major retail sites. In all, eight locations were visited with four of them being predominantly residential facilities with its ancillary land uses. An observational checklist was created for the

eight locations. The checklist was the same for all eight sites but had an aerial photograph of the different segments and its environs. Appendix 3 shows a sample of the checklist for the 1st location (Mallam Market).

3.8.2. Research Assistant Training and Pilot Survey

Three final year geography students from the University of Ghana, Legon aided in the questionnaire administration. The idea of selecting final year geography students was to ensure that the assistants have a view of the phenomenon being studied, have some practical hands-on research projects and some experience in data collection. The assistants on the 30th of November 2017 were trained on some data collection ethics and how to navigate the Epicollect5 application used for the data collection to ensure data quality. Each question in the questionnaire was discussed to provide understanding. The researcher together with the assistants brainstormed on how to translate the questionnaire into "Twi" to create common grounds and ensure consistency among assistants and researcher. Each question was also deliberated upon to come up with a strategy to approach the question to ensure respondents understood and gave the right responses. After the training, a pilot survey was carried out at Kwame Nkrumah Circle which happened to be the closest site. This aided in familiarizing oneself (researcher and assistants) with the questionnaire and paying attention to the responses given to each of the questions. A brief meeting was undertaken after the piloting where the questionnaires were adjusted, and some questions rearranged in response to some consents from the piloting.

3.8.3. Questionnaire Administration

The questionnaires were designed in reference to the fourth objective of this research. Which is identifying some location-specific probable causes of road traffic accidents along the selected hot zone routes within the Metropolis. Participants for the survey were chosen randomly. This is because it is problematic to estimate the population at risk along a road segment since road users fluctuate extensively in time and space. This made it difficult to generate or obtain a sampling frame for participants selection (Assunção, Tavares, Correa, & Kulldorff, 2007). The target group were predominantly residents and workers (especially commercial shops/ tabletop sellers and petty traders along the selected route because it is believed they are directly exposed to the road than workers in office buildings) along the chosen hot zone sites. Figure 7 shows some respondents interviewed. Also, the purpose of the primary data collection was not for any rigorous statistical analyses but to gather some information on why specific locations are hazardous than others, and primarily support the analysis of the secondary data and help explain some trends. The questionnaire covered some fundamental questions concerning road user's perception of possible causes of automobile crashes, some road safety alleviation actions and how useful some safety rules and regulations are in Accra (Appendix 4). The questionnaires were semi-structured with open-ended and close-ended questions. According to Bryman (2012), a close-ended question pursued to restrict the interviewee to select predefined fixed options such as using the Likert scale while the open-ended allows respondents to give their own opinions to the specified question. This mostly comes with an extensive variety of responses. With open-ended questions, the researcher had the responsibility of making meaning out of it to facilitate better interpretation. A sum of 400 questionnaires was administered in the eight locations within 12 days of which the locations of respondents were picked (geocoded). 60 questionnaires were administered at each of the four market locations due to the availability of people and 40 for the other four non-market locations.

After obtaining consent for participation in the survey. Participants were first asked if they work, reside or use that route regularly and if their answer was negative, they were exempted. Each interview lasted for 30 to 45 minutes and others especially those administered along segments closer to markets took almost an hour to an hour and a half because most times these sellers had to halt the interview and attend to their buyers or had to pause the interview to call on buyers. The research was conducted in Twi and only on few

occasions was the English language used which was based on the language used by the respondent in answering the questions.



Figure 7: Some Respondents Interviewed

3.8.4. Observation and Photography

Observation is the systematic collection of appropriate information about places, people, and things by looking and making meaning out of whatever is being seen (Bryman, 2012). Photography, on the other hand, is highly recommended in gathering illustrative data on a phenomenon being surveyed. Observation and photography gave indispensable information which supported in explaining some major causes of vehicular accidents along the selected segments. This was an exceptional approach to single out some physical and infrastructural characteristics of the road environments as well as behaviours of different road users. It was carried out along the eight locations. This approach enhanced the findings from the secondary data analysis by offering essential information about the investigated hot zone sites. The observational checklist (Appendix 3) was used to systematically identify similar factors along the eight locations. These included factors such as road design and infrastructure like availability of road signs, road curvature (straight, slightly curved, or curved), road separation (availability of different routes for different road users), junction design (type of junction and the availability of a traffic light) and topographical features like gradient of the road (flat or hilly). The predominant behaviour shown by different road users were observed and subjectively described. Illustrative photographs complemented the physical and infrastructure conditions at the sites. These were down through a transect walk along the segments. This aspect was solely done by the researcher.

3.8.5. Focus Group Discussion

Focus Group Discussion (FGD) is a group-based interview where participants deliberate in-depth about a specific theme (Bryman, 2012). An FGD was organized in the premises of the National Road Safety Commission (NRSC). Members from the research and evaluation department of the Commission were on board as well as the Administrative Manager. The findings from the secondary data analysis were presented to them. Their comments from the findings were welcomed. The discussion began with the main aim of the commission in improving road safety in Ghana, their major setbacks and ways of making Ghana safe with respect to road accident. Appendix 5 shows a guide on some points that were covered in the discussion. The researcher in this instance acted as a facilitated interested in finding things such as how the participants interacted within the group and responded to each other's views. The discussion was recorded and

transcribed. This is because there was the need to keep track of who said what at which point in time even though they are referred to as participants in this research to ensure anonymity. This session aimed to know the clear path to road safety in Ghana.

3.8.6. Key Informant Interview

The key informant interview was undertaken through a Skype conversation. The Chief Research Scientist of the Building and Road Research Institute (BRRI) Ghana was interviewed. An expert view was desired to reflect on the methods used in the secondary data analyses. This was to ascertain whether the methods give enough insight into the data. The methods adopted were thoroughly explained to the interviewee. The interviewee's views on the methods were called for. Also, since the data was acquired from the same department of the institutions, it was worth asking for the quality of the secondary data, means of collection and ways of improving the collection medium. The interview ended with the effective ways of incorporating geographical/spatial analyses in accident studies in Ghana. Appendix 6 indicates a guide to some key points discussed.

3.9. Post Field Work Data Analyses

The data obtained from the interviews were prepared and coded into SPSS to aid in easy analysis. However, in responding to the fourth objective of this research a qualitative analysis was used to convey the message adequately. Section 4.7 presents the findings from the primary data collection.

3.10. Research Design Matrix

Table 4 shows the research design matrix. This displays the objectives together with the specific research questions. It also indicates the required data, the source of the data, how it was analysed, the software used and the anticipated results per research question.

3.11. Ethical Considerations

The ethical issues thought-out are in respect to the secondary data acquisition and use and the primary data collection. The recorded vehicular accidents data is anonymous by reason of not containing any personal information about the victims. This kind of information is very confidential and sensitive to distribute without restrictions. All the secondary data used for the research gained informed consent before it was procured from the lawful institutions. The content and the institutions from which these data were collected has been stated in subsection 3.2.

Also, in connection with the primary data collection, Fox, Suryanata, Hershock and Pramono (2006) attested some ethical etiquettes to be carried out. First, the objective of the data being collected is to be explained; then informed consent is sought from anyone directly involved with the survey. Finally, any consequences in connection with the data being obtained should be explained to all respondents. These protocols were followed in all aspects of the data collection. These ethical etiquettes were also described to the research assistant to follow during the questionnaire administration. The researcher also adhered to confidentiality, anonymity and privacy of the respondents where necessary. Also, all online books and publications used have been rightfully acknowledged.

| RESEARCH | REQUIRED | DATA | DATA | SOFTWARE | ANTICIPATED |
|-----------------------------------|---------------------|----------------------|-------------------|--------------------|---------------------|
| QUESTIONS | DATA | SOURCES | ANALYSIS | REQUIRED | RESULTS |
| OBJECTIVE 1: | To determine the s | spatial pattern of r | ecorded vehicular | accidents in Acc | cra (where) |
| What are the | Methods for | Literature: | Descriptive | Internet | Methods for |
| appropriate | analysing point | Online Search / | Analysis | Browser | point spatial |
| methodological | spatial data | Publication | | | analysis (such as |
| considerations | | Portals | | | Bubble Map, |
| for spatial | | | | | KDE, NetKDE, |
| analysis of | | | | | Local Moran's I) |
| vehicular | | | | | |
| accidents? | | | | | |
| What is the | Vector and excel | Secondary Data | Statistical | R-Software | Tables and Maps |
| spatial pattern of | data on | from BRRI & | Analysis | ArcGIS | showing the |
| reported | recorded | CERSGIS/OSM | | Arcscene | spatial |
| vehicular | vehicular | | Spatial Analysis | SANET | distribution of |
| accidents in | accidents | | | | accidents in Accra |
| Accra? | Road Network | | | | (Identified |
| | | | | | hotspots/hot |
| | | | | | zones) |
| OBJECTIVE 2: | To identify the ten | nporal clustering o | f recorded vehicu | lar accidents in . | Accra (when) |
| Which methods | Methods for | Literature: | Descriptive | Internet | Methods for |
| are suitable for | analysing point | Online Search / | Analysis | Browser | point temporal |
| analysing and | temporal data | Publication | | | data (such as bar |
| visualizing | | Portals | | | charts, line |
| temporal | | | | | graphs, Bubble |
| clustering of | | | | | map, KDE) |
| vehicular | | | | | |
| accidents? | | | | | |
| Which temporal | Methods for | Secondary Data | Descriptive | Excel | Charts showing |
| intervals | temporal | from BRRI | Analysis | | different temporal |
| (categories | decomposition | | | | perspectives |
| (yearly, monthly, | based on | | Temporal | | |
| weekly, hourly, | available data | | decomposition | | |
| daily)) are | (recorded | | D | | |
| relevant to the | vehicular | | Descriptive | | |
| study? | accidents) | | Statistics | | |
| When do these | Recorded | Secondary Data | Descriptive | Excel | Charts and Maps |
| categorized | vehicular | from BRRI & | Statistics | | of temporal |
| incidents occur | accidents data | CERSGIS/OSM | | ArcGIS | (vearly and rush |
| in Accra? | Road Network | , | Spatial Analysis | | period) hotspots |
| OBJECTIVE 3 : ⁷ | To assess the char | acteristics of the s | patial and tempor | al components t | o identify spatio- |
| temporal cluster | ing | | | - | |
| What is the | Methods for | Literature: | Descriptive | Internet | Methods for |
| appropriate | identifying | Online Search / | Analysis | Browser | identifying spatio- |
| technique for | spatio-temporal | Publication | | | temporal |
| identifying | clustering | Portals | | | clustering (such as |

| | 1 | | 1 | 1 | 1 |
|----------------------|---------------------|-------------------|----------------------|-----------------|--------------------|
| spatio-temporal | | | | | Knox Statistics, |
| clustering? | | | | | K-Function) |
| Are there | Recorded | Secondary Data | Spatial Analysis | ArcGIS | Pairs of events |
| clustering | Vehicular | from BRRI & | | | closer in space |
| locations which | Accident | CERSGIS/OSM | Statistical | Clusterseer | and time |
| are close in both | | | Analysis | | |
| space and time? | Road Network | | | | |
| | | | | | |
| OBJECTIVE 4 : | To identify locatio | n-based explanato | ory variables for th | e spatio-tempor | al clusters |
| (Hotspots/Hot z | zones) | | | | |
| What are the | Built | Fieldwork | Descriptive | Observational | Physical |
| physical | environment | | Analysis | Checklist | contributory |
| characteristics of | Characteristics | (Observation & | | | factors to the |
| the clustered | of cluster sites | Photography) | | Digital | occurrence of |
| locations | | | | Camera | vehicular |
| | | | | | accidents |
| | | | | | Images of the |
| | | | | | location |
| What are the | Location- | Fieldwork | Basic Statistics | SPSS | Description of |
| major causes of | specific causes | | | | the location- |
| vehicular | of vehicular | (Questionnaire | Descriptive | Excel | specific causes of |
| accidents in | accidents | & FGD) | Analysis | | crashes |
| these locations? | | | | | |
| Which | Location- | Literature | Descriptive | - | List of |

countermeasures

are needed to

minimize road

these locations?

Do the methods

provide insight

into the data?

Are there ways

to improve the

methods used?

improvements

accidents data collection in Accra?

Are there

needed in vehicular

employed

employed and the data used

accidents in

specific

countermeasures

Expert

Knowledge

Expert

Knowledge

| Expert | Key Informant | Descriptive | - | Ways to improve |
|-----------|---------------|-------------|---|-----------------|
| Knowledge | Interview | Analysis | | accident data |
| | | | | collection in |
| | | | | Accra |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Analysis

Descriptive

Descriptive

Analysis

Analysis

Fieldwork

& FGD)

Interview

Interview

(Questionnaire

Key Informant

Key Informant

OBJECTIVE 5: To reflect on the outcome of the analysis based on the suitability of the methods

countermeasures

minimize road

Insight provided

from the data

based on the

methods used Ways to improve

the methods used

needed to

accidents

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4. RESULTS AND DISCUSSION

4.1. Introduction

This section presents the results of the analysis and visual representations for the case study detailing out descriptive analysis of the secondary data, spatial and temporal patterns and spatio-temporal clusters. In addition, some location-specific causes of accidents found during field visits have been briefly reviewed. Every visualized graph/chart, map or picture tells a story of the space-time traffic safety situation within the study area. Seeing the visual representations and interpretations allows for a greater understanding of the distribution of vehicular accidents within the Accra Metropolis. To draw comparisons with findings of similar studies, each result is discussed in view of existing literature.

4.2. Descriptive Analysis

The entire spreadsheet dataset of 12,166 recorded accidents from 2011 to 2015 was used for all illustrative graphs in this section. The data were categorized by year, month, week, hour and accident severity. This was done to find out the instances within these temporal components with the highest number of automobile crashes. Figure 8 displays the yearly distribution. The total number of accidents was at its peak in 2012 and gradually decreased from 2,862 to 2,033 in 2014 and increased in 2015. This could be a result of safety measures or natural manifestation. The critical issue to consider is if it was because of safety measures, why did it fail in 2015? This needs further investigation to find the reasons for this fluctuation.



Figure 8: Number of Accidents Per Year

The data was re-classified into months to examine its trend (Figure 9). As illustrated by the bars, April, May, September, November, and December are seen to have the highest number of accidents. The peaks in April and December could be because of the festive activities in these months. April happens to be commemorated as Easter where many schools and workers are on holidays, which is similar to Christmas in December. This is not different from what was stated by Shahid et al. (2015), that more accidents take place in festive periods and school holidays. Correspondingly, April through to November happens to have some rains, which can be a contributory factor. November through to mid-January, on the other hand,



happened to experience the Harmattan season. This is characterized by dry, cold, and dusty winds which block visions and very dangerous especially for drivers to see the path ahead of them.

Figure 9: Number of Accidents Per Month

Figure 10 illustrates the day of the week occurrence of automobile crashes. The number of accidents is seen to slowly decline from Monday through to Thursday, then rapidly increase from Friday to Saturday and at it barest minimum on Sunday. Three peaks are noticed. These are Saturday with the highest crashes occurring followed by Friday then Monday. This could be because most social activities in Ghana take place from Friday through to Saturday while Sundays are habitually for religious activities with limited travel and less commercial vehicles (Trotro) on the road. These results verify a previous study by Erdogan, Yilmaz, Baybura, and Gullu (2008) and Erdogan, Ilçi, Soysal, and Korkmaz (2015) where more accidents are recorded on weekends as against weekdays.



Figure 10: Number of Accidents Per Day of the Week

There is a distinct difference in the hourly distribution from 12 am to 11 pm (Figure 11) of vehicular accidents in the Metropolis. The accident frequency throughout the day shows a gradual increase from 7 am to 8 pm with other fluctuations within this time-frame. However, the highest number of recorded crashes is realized at 4 pm - 5 pm which happens to be a peak hour when many schools and offices close for the day with workers and others rushing to get to their destinations. This undoubtedly results in a high traffic volume. Also, a steady decrease is recognized from 8 pm to 11 pm. The morning peak which is experienced from 6 am to 9 am shows a steady increase and continues in that trend until the highest peak at 4 pm - 5 pm, then declines as it moves closer to the night. The frequency of accidents at dawn is 4% of the total crashes and at night when it is dark, it increases to 6% of the total number of accidents. Implying that at least 2% more accidents occur at dusk than dawn. It is noted from this that, there is a direct relationship between the number of crashes and traffic volume (Vandenbulcke-Plasschaert, 2011). The number of collisions at dawn and dusk are comparatively low due to low traffic volumes at these hours.



Figure 11: Number of Accidents Per Hour

In Figure 12, we see the same distribution but in yearly terms where 2012 as already declared recorded the highest number of accidents. All the annual trends per hour are noticed to follow the same pattern with a recognized peak from 7 am to 9 am (morning rush), 4 pm to 5 pm (evening rush) then 7 pm to 8 pm. These trends suggest that more crashes occur at peak hours. Automobile crashes increases at the beginning and ending of schooling and working hours as found by Erdogan et al. (2015). The number of accidents is also seen to be high during the day as compared to dawn and dusk. This proves the power in numbers, with relatively high traffic volumes during the day.

The number of casualties injured because of vehicular accident as portrayed in Figure 13 appears to follow the trend of the total accidents recorded per year. As the number of accidents per year increases, the number of casualties injured that year also increased and vice versa. The number of casualties killed, on the other hand, is not very substantial. It signifies a gradual increase at a decreasing rate. However, it deviates from what is seen between the total accidents and the number of people injured in 2014. The total number of crashes and the casualties wounded decreased in this year while the number of people killed increased from 127 to 174. This is in line with what was stated in the NRSC 2015 annual report that even though the number of crashes declines, fatalities have been on a consistent rise per annum since 1991 (NRSC, 2015). If this trend has been detected, why has it remained so? Have previously applied measured failed or nothing



has been done about it? This requires critical investigation to study this occurrence through which sustainable measures could be implemented to minimize these fatal injuries.

Figure 12: Number of Accidents Per Year and Hour



Figure 13: Number of Casualties Killed and Injured Per Year

Figure 14 is seen to follow a claim by Shahid et al. (2015) who reported that the number of vehicular accidents in urban areas tends to be higher, but, with a low degree of casualties. The graph shows this case with high property damage than casualties (minor, serious and fatal injuries). Fatal crash which is the least recorded appears to be the severity type with the highest social cost, followed by serious injuries which sometimes leads to life-long disabilities of its victims. In a Metropolis like Accra where the CBD and its surrounding towns experience low traffic flow daily (thus, high traffic congestion), accidents which occur in such vicinities are likely to result in more damage to property like rear-end crashes than a fatal or serious injury. Many of these fatal and serious injuries are expected to occur on major highways or less dense locations with high traffic flow. Fatal and serious accidents can be said to follow high traffic flow. A major

concern of traffic safety is to minimize the intensity of these severities. Safety official should primarily concentrate on reducing accidents at locations with high fatal and serious injuries. Damage only, on the other hand, causes economic losses to both the government (when public infrastructure is destroyed) and victims.



Figure 14: Accident Severity

4.3. Statistical Analysis

This section examines how statistical models can help detect contributory factors to vehicular accidents severity based on accident, environmental and road characteristics of the crash locations. Understanding the circumstances to which any road user is possible to be killed or severely wounded in vehicular accident is of great concern in traffic safety. This statistical model aimed to explore the function of variety of factors on crash severity using the generalized ordered logit regression model. The regression model combines the predictors to estimate the likelihood that a event would occur, the severity level that may emanate and also estimate the contribution and significance of each predictor. Section 3.4 gives a detailed description of how the model was estimated. 80% of the data was used as a training sample to build the model and the remaining 20% was used to validate the model. The categorical ordered levels of the dependent variables are damage only, minor, serious, and fatal. The estimated results include the constants/intercepts, coefficients, t-values as well as p-values as shown in Table 5. The coefficients communicate that an increase or decrease in accident severity is because of a unit change in the predictor. On account of the dependent variable levels being ordered with increasing intensity, a positive coefficient implies a rise in that predictor results in a higher or an increase in severity (such as fatal or serious injuries) while a negative coefficient suggests an increase in that predictor leads to less severe incidents (such as minor and damage only injuries). As high positive coefficients result in more fatal accidents, low negative coefficients result in more damage only. That is, the effect of a predictor would either increase or decrease crash severity.

| Categories | Explanatory Variables | Value | T-value | P-value |
|--------------------------|--|---------|----------------|---------|
| Accident Characteristics | Number of vehicles involved | -1.5266 | -36.7402 | 0.0000 |
| | Number of Casualties | 1.5382 | 50.5361 | 0.0000 |
| | Day of the Week, Reference: Monday | - | - | - |
| | Tuesday | 0.0793 | 0.9746 | 0.3297 |
| | Wednesday | 0.0988 | 1.1966 | 0.2315 |
| | Thursday | 0.1706 | 2.0478 | 0.0041 |
| | Friday | 0.1558 | 1.9362 | 0.0528 |
| | Saturday | 0.0804 | 0.9919 | 0.3213 |
| | Sunday | 0.2047 | 2.4800 | 0.0131 |
| Environmental Factors | Weather, Reference: Clear | - | - | - |
| | Fog/Mist | 0.7123 | 3.1262 | 0.0018 |
| | Rain | -0.9064 | -2.5527 | 0.0107 |
| | Dust/Smoke | 0.6819 | 1.2260 | 0.2202 |
| | Dazzle | 0.1992 | 0.8319 | 0.4055 |
| | Other | 0.0277 | 0.3075 | 0.7585 |
| | Light Condition, Reference: Day | - | - | - |
| | Night with no streetlights | 0.1182 | 1.8462 | 0.0649 |
| | Night with streetlights off | 0.0315 | 0.1808 | 0.8565 |
| | Night with streetlights on | 0.2686 | 3.9845 | 0.0001 |
| Road Characteristics | Road Geometry, Reference: Not a Junction | - | - | - |
| | Cross Junction | -0.0943 | -1.4418 | 0.1494 |
| | "T" Junction | -0.1110 | -1.9554 | 0.0505 |
| | Staggered Junction | 0.2344 | 1.4321 | 0.1521 |
| | "Y" Junction | -0.3510 | -1.1587 | 0.2466 |
| | Roundabout | -0.7254 | -4.2566 | 0.0000 |
| | Railway Crossing | -0.9312 | -0.8047 | 0.0421 |
| | Other | -0.4279 | -2.5474 | 0.0109 |
| | Road Surface Type, Reference: Paved & Good | - | - | - |
| | Paved with Potholes | 0.1556 | 1.2122 | 0.2254 |
| | Gravel | -1.8556 | -2.2915 | 0.0219 |
| | Earth | 0.3103 | 0.9663 | 0.3339 |
| | Road Surface Condition, Reference: Dry | - | - | - |
| | Wet | 1.0007 | 1.6081 | 0.1078 |
| | Muddy | 2.7997 | 2.5851 | 0.0097 |
| Intercept | Damage only Minor | -0.5130 | -0.8148 | 0.4152 |
| | Minor Serious | 1.5511 | 2.4634 | 0.0138 |
| | Serious Fatal | 3.4949 | 5.5372 | 0.0000 |

Table 5: Results of the Generalized Ordered Logit Regression Model

Out of the ten estimated variables, eight proved to be statistically significant, hence formed the final model. The two insignificant variables excluded from the final model are 'road description,' which suggests the geometry of the network whether curved or inclined and 'roadworks' which specify whether the accident was as a result of any undergoing roadworks. These were insignificant because, with the confidence interval of 95%, the possibility of these two variables contributing to accident severity is by random chance greater than the predefined confidence interval. Also, all categorical predictors with at least one level being significant were maintained in the final model because eliminating them did not significantly improve the

model outcome. The insignificant variable levels have been highlighted in red in Table 5 .Starting with the 'number of vehicles involved' as presented in Table 5, the negative coefficient indicates that for the case under consideration, the 'number of vehicles involved' decreases the severity of the incident. Preferentially, as the number of vehicles involved increase by one, the severity decreases by 1.5266 units. This is rational because the possibility of more vehicles or nearby infrastructure being damaged under such circumstance is greater than a fatal injury resulting. In contrast, the coefficient for the 'number of casualties' involved is likely to produce more severe injuries because it is positive. Thus, as the 'number of casualties' involved increase by one, the severity also increases by 1.5382 units. The 'number of casualties' does not necessarily have to be vehicle occupants. It might include pedestrians and other road users.

Correspondingly, with the remaining predictors which are all categorical, the interpretation is similar, but comparison is made in reference to the base case or reference line. This is because they were all dummy coded. For instance, Monday served as the reference point to which all the other levels were compared to in the predictor 'day of the week.' The t-test and p-values suggest that Tuesday, Wednesday and Saturday, (as highlighted in red) in reference to Monday are not significant. Which could be interpreted as any change in severity is not significantly different when the day changes from Monday to any of the insignificant days. The severity of the incident is not predicted by these days but as a result of a random chance. For the other levels, the t-tests and p-values are significant, and the coefficient values are positive. So, it can be interpreted as, severity increases as the day of the incident changes from Monday to Thursday (0.1706), Friday (0.1558), and Sunday (0.2047). These coefficient values entail that these predictors are possible to result in severe injuries. Sunday in comparison to the other days is the highest. This could be attributed to the fact that Sundays are habitually for religious activities in Ghana with limited travel and less commercial vehicles (Trotro) on the road. This suggests less traffic congestion and high traffic flow. Which has earlier been explained that more severe injuries (fatal and serious injuries) are seen to follow high traffic flows than congested streets.

Again, as the weather changes from clear to fog/mist, it is predicted by the model that any crash that occurred at that moment to be more severe while less severe crashes result as the weather changes from clear to rainy. This finding was buttressed by a ground truth during fieldwork. Figure 27 gives rankings made by some interviewed drivers. These drivers ranked the meteorological conditions under which they are most cautious when driving. Raining was the first, followed by windy then foggy conditions. Their main reason for these choices alludes to the fact that the roads become slippery and the rains sometimes reduce visibility making them extra cautious with reduced speed when driving under rains. Hence, reducing the severity of any incident that occurs. This discovery is also consistent with the study by Savolainen and Mannering (2007). Furthermore, an intriguing thing about the model is in reference to the lighting condition. This is because it predicted more severe injuries at night when streetlights are on as against the same circumstance without streetlights. This variable is also highly significant. The only conceivable explanation for this could be because streetlights in Ghana attracts people especially petty traders, table-top commercial food vendors and hawkers at night. No matter where the streetlight is situated, it would attract people. Streetlights located on road median, on a congested road or traffic light signal point predominantly attract street hawkers while those along the road attracts a variety of informal commercial activities. These types of activities also attract buyers. In a situation of any incident, together with the agglomeration of people at that point, the number of victims are anticipated to increase as against locations without streetlights. It has earlier been explained that, as the number of casualties increase, the possibility of more severe injuries resulting is high. This is very different from some findings from RSPA7 (2017). Where streetlights improved road safety,

⁷ The Royal Society for the Prevention of Accidents

because some pedestrians and other vulnerable road users would be at greater risk as a result of decreased visibility, but the situation is different in Accra. Are the streetlights serving their purpose?

In addition, as the geometry of the road changes from not being a junction (roadway) to different forms of junctions, the incident is expected to result in less severe accidents as projected by the model except for staggered junctions which is unfortunately insignificant. However, staggered junctions without proper road signals or traffic lights generally confuse road users (drivers, pedestrians, hawkers, cyclist, etc.). This also suggests that the type of junction does not necessarily increase the severity of crashes per the model. This falls in line with the findings from Savolainen and Mannering (2007) and Shibani and Pervin (2016) who discovered that the number of casualties is high at junctions, but accident fatality is greater on roadways than junctions. Furthermore, due to the lack of railway infrastructure (e.g. semaphore signals) in the country, railway official sometimes have to manually alert road users especially drivers on approaching trains. In instances where there is no official, the location sometimes becomes chaotic. This occasionally creates panics among drivers especial those approaching the railway line to act involuntary without consideration for other vehicles leading to incidents with reduced severity. Wet and muddy road surface conditions are possible to result in more severe accidents than a dry surface. This could only suggest that drivers are only cautious when it is raining and becomes indifferent when it stops raining and the roads are just wet. However, a road being wet does not necessarily imply water, it can also be other greasy substances like oil (cooking/car oil) or other vehicular fluid which mostly make roads slippery and brakes unable to respond. Unpaved muddy roads in Ghana are danger zones. These are logical and possible to be the situation everywhere.

| Severity | Damage only | Minor | Serious | Fatal |
|--------------|-------------|-------|---------|-------|
| Observations | | | | |
| 1 | 0.081 | 0.329 | 0.419 | 0.171 |
| 2 | 0.783 | 0.183 | 0.029 | 0.005 |
| 3 | 0.007 | 0.047 | 0.233 | 0.713 |
| 4 | 0.166 | 0.444 | 0.306 | 0.084 |
| 7 | 0.823 | 0.150 | 0.023 | 0.004 |

 Table 6: Predicted Probabilities by the Model

Table 6 illustrates a small sample of probability values predicted by the model for some observations (accidents). These probability values suggest that with the combined effects of predictors, what type of severity (fatal, serious, minor and damage only) is likely to result. This provides an idea about the combinations of variables/factors that may culminate in a type of severity so as to develop countermeasures in reducing the effects or preventing these variables from concentrating at a location. Ideally, these are categorised into the different severity levels to give an indication of the joint variables that needs urgent attention. That is, the combined factors to focus on first.

Observation 1 was predicted to be a serious injury because the model indicates approximately 42% chances of it being a serious injury as compared to the probabilities of the other severity levels given the combined properties of factors (variables/elements) at that location. Incident 3 was predicted to be a fatal accident with 71% chances in comparison to the other severity levels. Likewise, crash number 7 with 82% chances of being damage only. Comparing these predictions to the actual data set, two out of these five observations were realized to be falsely predicted. This then called for means of estimating the number of observations correctly and misleadingly predicted. A confusion matrix was used for this estimation.

| Prediction | Damage only | Minor | Serious | Fatal |
|-------------|-------------|-------|---------|-------|
| Damage Only | 4960 | 846 | 342 | 66 |
| Minor | 75 | 1359 | 985 | 401 |
| Serious | 1 | 185 | 139 | 71 |
| Fatal | 0 | 109 | 121 | 58 |

Table 7: Confusion Matrix for Predicted Model

A confusion matrix was generated for all the four levels of dependent variables for the training dataset (80%). This array is to give a bright idea of the number of accident severities correctly predicted and the misclassified ones, thus, the accuracy rate of each severity level. As presented in Table 7, the diagonal values depict the accurately predicted observations. For example, 4960 observations were correctly predicted as damage only while 75 were predicted as minor and 1 as serious injury. Also looking at the fatal accidents, the number of misclassified observations is more than the correctly classified ones. This introduces the possibility of errors in the model. Based on this, a misclassification error for the training dataset (80%) was calculated. The formula is a simple arithmetic of one minus the sum of all diagonal values divided by the sum of the entire matrix. A misclassification error of 0.3295 was obtained. This proves that approximately 33% of the incidents were misclassified.

Table 8: Confusion Matrix for Model Validation

| Validation | Damage only | Minor | Serious | Fatal |
|-------------|-------------|-------|---------|-------|
| Damage Only | 1228 | 223 | 71 | 26 |
| Minor | 27 | 362 | 230 | 109 |
| Serious | 0 | 45 | 41 | 14 |
| Fatal | 0 | 31 | 24 | 14 |

The model was tested using the remaining 20% dataset and a confusion matrix was also generated for the model validation (Table 8). A misclassification error of 0.3272 (approximately 33%) was obtained from the model validation. This shows that there is no major difference between the misclassification error from the training dataset and the validation dataset. This discloses consistency in the created model. Thus, 80% of the data used for generating the model and the 20% for validation shows the model is behaving consistently with similar misclassification errors. The model is however usable because almost 77% of all incidents were correctly predicted.

4.4. Spatial Analysis

Spatial analysis fixated on the 5742 geocoded locations. Global Moran's I was first estimated to identify statistically significant clusters for the entire study area. The proximity weight matrix as explained in subsection 3.6.2. aided in this assessment. The global index decides whether or not to reject the null hypothesis of Complete Spatial Randomness (CSR). The result of the statistical test necessitated the rejection of the null hypothesis stated in section 1.5. Indicating that the point incidents under study exhibit statistically significant cluster rather than a random pattern. With an extremely high z-score of 38.94, a p-value of 0.00 and a Moran's Index of 0.13 at a confidence interval of 99%, it is implausible the observed pattern of automobile crashes is as a result of a random process. Implying there are clusters (Appendix 1). Further spatial analyses were undertaken to identify the clusters. First, a bubble map was used to show the spatial distributions of accidents in Accra. The size of the bubble symbolizes the frequency of incidents at that location. It was recognized that the 5742 crashes occurred at 1098 different location with some locations with more than one incident. This was found through points with same coordinates. 445 locations recorded only one incident and another with as many as 111 incidents. The accidents within the study area by visual

interpretation are not evenly distributed but highly concentrated around the Central Business District (CBD) and some major arterials (Figure 15). In all, the Dr. Busia Highway and the Ring-Road Central recorded the highest incidents within the five-year period. The concentration at the CBD is relevant because it reflects high agglomeration of socio-economic activities of road users. Large sums of people always commute to this location for various social and economic activities. This is in line with the finding from Loo and Yao (2011) and Olajuyigbe and Ogan (2014).



Figure 15: Bubble Map of the Spatial Distribution of Recorded Vehicular Accident (2011-2015)

A planar KDE was also utilized in the point pattern exploration. While the bubble map shows hazardous points, the planar KDE displays areas within the Metropolis experiencing high occurrences of automobile crashes. The densities were classified using the natural breaks (Figure 16). The "Very Low" category denotes a density value of 0 - 7.80 accidents per square kilometre. "Low" is 7.80 - 30.10, "Medium" being 30.10 -66.82, "High" of 66.82 – 128.07 and "Very High" refers to 128.07 – 283.98 accidents per square kilometre. The categories from "Low" to "Very High" can be said to be hotspots with the "Very High" being the most dangerous areas. It becomes very visible of the crash densities on the Dr. Busia Highway, which is the clusters from the concentrated CBD towards the western parts of the Metropolis. The discovered hotpots on this road could be because major commercial activities such as the "Kaneshie Market" and "Malam Market" are along it. It is known that such activities attract traffic. Additionally, other highly congested distributor/access roads (outlets) which connect many of the residential locations to this Highway can be found along this route. These outlets may include "Dansoman Junction," "Darkuman Junction" which leads to "Kokompe," a location where second-hand car spare parts are sold and "Odorkor Junction." "Darkuman Junction" and "Odorkor Junction" serves as a connection between Dr. Busia Highway and the National Road 1 (N1-George Walker Bush Highway). With all the hotspot clusters following the road network, those at the CBD are closer, showing the dense and compact nature of the road network in that area.



Figure 16: Planar KDE of Hotspot Areas

Since traffic accidents are constrained to a network space, a NetKDE was also estimated to find hazardous road segments (Figure 17). NetKDE for this study is more fitting than the planar KDE. This is because the latter include locations outside the limits of the network space which is possible to miscalculate the density values (Vemulapalli, 2015). For example, the planar KDE estimated a "Very High" density value of 128.07 - 283.98 collisions per km² while that of the NetKDE estimated to be 23.73 – 50.50 incidents per kilometre. This shows the KDE is possible to generate a false alarm when used to detect hotspots on linear features. Findings from Xie & Yan (2008) showed similar misleading density values when KDE was used to estimate densities on a linear feature. A different visualization approach was used for the NetKDE. Visually, the planar KDE displays one instance of accident at that location while the 3D NetKDE presents the number of crashes that happened at that location by using perpendicular bars. With each tall peak being that segment's density. Viewing in 3D with colours (classification), height and width at various locations allow for a better understanding and ability to see how densely clustered certain road segments are within the city. The pattern reflects the high rate of vehicular accidents along major roads as shown in the animated 3D NetKDE video of the hotspot locations in the attached link (<u>https://voutu.be/wELF_LRZbw</u>). Even though Dr. Busia Highway is still seen to be the most concentrated with automobile crashes, other locations at the eastern parts of the city also have some judicious amount including red vertical bars which symbolizes "Very High" accident locations. The clusters at the CBD can be seen from the image to have recorded five very high incidents from 2011 to 2015. It is by diverse representations that better understanding of collisions in the Metropolis can be apprehended. All the three approaches and visualization techniques used were able to detect the hotspots rightfully. However, one disadvantage of these methods is that there are no means of detecting whether the identified hotspots are significant or not. Hence, a different approach which can aid in detecting significant hotspot was employed.



Figure 17: NetKDE (3D) of Hotspot Locations

The approach is the local Moran's Index. This method needed linking the attribute of the accident to the road segment. In this case, the unit of analysis was the segments instead of the points. This helps in finding particular segments of the road network to visit in terms of further investigation or even identifying the segment which requires immediate investment to minimize traffic accidents. The weight matrix and procedures used for estimating the global index was also used here. This was to help identify the neighbourhood structure of the segment under consideration. Four outcomes were realized after the process was executed. The "low-low cluster" (with no segment selected as low-low), "low-high outlier" (3 segments were identified as low-high) "high-low outlier" (4 segments), "high-high cluster" (264 segments) and "not significant" (17,410 segments). Adhering to the first law of geography which says that "Everything is related to everything else, but closer things are more related than distant things" (Tobler, 1970). The focus was geared towards segments with high-high cluster. This means segments with high concentration of accidents and its neighbours also having the same high concentration.

To check the significance of these high-high segments, Monte Carlo simulation of 1000 iterations was used. With a 99% confidence interval, all segments with a z-score greater than 2.58 and a p-value lesser than 0.01 were selected to depict the significant hotspot segments. For visualization purposes, just the significant "high-high clusters" are shown in Figure 18. This is because the number of segments identified by the other class types is too small and unrecognizable on the map. All segments are separated by junctions with varying lengths. One disadvantage of using these segment lengths as the unit of analysis is that, when a little part of a segment has more accidents concentration, regardless of the length of the segment, the entire segment would be noted as a hotspot. However, it has an advantage of knowing the exact extent of the segment for further investigation.



Figure 18: Significant Hotspot Segments

This approach makes it very noticeable of some hotspot locations in the eastern parts of the city. These locations were however not that obvious from the earlier techniques used. The Liberation Road is the major detected hotspot in the eastern part of the Metropolis. The Liberation Road connects to the National Road 1 (N1 - George Walker Bush Motorway) and National Road 4 (N4) at the Tetteh Quarshie Interchange. The N1 is a very prominent road which other regional roads are connected to and links all the coastal regions of Ghana. While the N4 connects the Capital City to many of the Land-locked Regions. The Liberation Road is known to carry heavy traffic daily because of its connection to these two major roads. Therefore it is entirely logical that this route is quite noticeable here. Out of the total of 17,681 segments, just 241 were found as significant hotspots (with p values lesser than 0.01 and z-scores greater than positive 2.58). The average crash intensity was estimated to be 20.69 points per square kilometre with a total land area of 277.48 square kilometre. Based on the identified hotspots, hot zone locations were derived.

The definitions of hot zones as suggested in literature presuppose about 67km of roads in this instance are discovered as hot zones. To overcome this, a hot zone was identified to be significant hotspot locations with high accident frequency and at least one fatal injury. This definition created a clear-cut distinction between hotspots and hot zones for this case. A location score was estimated to identify the significant hotspot locations with high accident frequency. This led to location values ranging from 1 to 5. The segments with a score of 5 were selected as the first step towards the determination of hot zones. These represented the segments where accidents occurred every year from 2011 to 2015. These newly selected segments were further refined by only concentrating on roads which have recorded at least one fatal injury over the five-year period. The combined strength of both approaches is expected to result in effective hot zones discovery. Out of the 241 segments revealed as highly significant hotspots, 59 of them were discovered to be hot zones (Figure 19). This approach actually zooms into locations which demand further investigation to answer questions such as; why did accidents occur every year (from 2011 to 2015) on these segments and not others, and what are the possible contributory factors?



Figure 19: Hot Zones

These locations are considered critical or dangerous because of the frequency of accident occurrence and resulted fatal injuries. Figure 19 shows the identified hot zones which demand critical investigations. Fewer locations within the CBD and some points at the eastern parts of the study area were detected as hot zones. This could be because there were low accident frequencies within these locations and also, other injury type occurred other than fatal injury. The hot zones were further ranked to identify the top most critical areas which would assist in selecting locations for further investigations. This ranking was done based on a computed severity index using different weights. The weights were apportioned chronologically starting from the less intense form of severity to the highest severity level. Figure 20 portrays the severity score for each of the segments. The index value ranges from 24 to 415, where the higher the value, the higher the severity. Also, the red shows the highly dangerous segments and the green being the least. Based on these, a strategy was devised to select locations for further investigations to identify some location-specific contributory factors. The selection process has been explained in subsection 3.8.1. Other less severe locations were also visited and their infrastructure conditions compared to the severe locations.



Figure 20: Severity Index

Figure 21 displays the spatial distribution of the four severity levels. The upper right map, represented by red bubbles illustrates the distribution of fatal injuries. With this distribution, although the CBD has very high concentration of traffic accidents, the distribution regarding fatal injuries is not extremely high as compared to those on the Dr. Busia Highway. The upper left map, shown by the orange bubbles indicates how serious injuries which sometimes leads to life-long disabilities are distributed in the Metropolis. Despite the usual known cluster points, there appear to be some clusters with big size bubble at the north-eastern corridor of the map. This displays the concentrations on the Olusegun Obasanjo High Street. The lower right and lower left maps represent by yellow and green bubbles show the minor and damage only severities respectively. This shows how minor and damage only injuries are much concentrated at the CBD, on the Ring-Road Central and on a major flyover (interchange) along the Ring-Road Central popularly known in Ghana as "Dubai." Damage only presents other interesting results and locations which were not very obvious from the previous analyses. A big size bubble is spotted on the north of Dr. Busia Highway which happened to be a junction on the N1 (George Walker Bush Highway) locally know as "Kwashieman Junction." This together with the clusters at the CBD are noted to be routed with heavy traffic mostly during the day. With high traffic congestion, where most vehicles are stagnant for hours, the rate of damage only is expected to be higher than any other form of severity as the maps signposts. High congestion, lack of traffic personnel and impatient of some drivers (especially the "Trotro" drivers) is likely to result in more vehicle-to-vehicle (part of damage only severity) collision such as rear-end, head-on and side-impact (Tbone). Concerning the map descriptions, the maximum occurrence for fatal, serious and minor injuries at a location was 10 while damage only recorded a maximum of 100 incidents per location.



Figure 21: Spatial Distribution of Accident Severity

4.5. Temporal Analysis

Temporally, the data was decomposed into yearly components to investigate how the location of identified clusters (hotspots) changes over time. A planar KDE was used for this process. Figure 22 shows the yearly planar KDE from 2011 to 2015. 2011, 2012, 2013 and 2014 are seen to exhibit similar pattern with different intensities. 2011 however, exhibits move cluster patches along the Liberation Road. The clusters in 2012 are obvious to concentrate at the CBD predominantly. It can be concluded that more accidents occurred at the CBD in 2012 than any other location. The map for 2015 is seen to display hotspots along the Dr. Busia Highway with a very high cluster point at an intersection on the George Walker Bush Motorway (N1).

In adherence to some temporal aspects described in Figure 11 and Figure 12, two rush periods were observed. The morning rush which starts at 7-9am and the evening rush of 4-6pm. These two peak periods were visualized using bubbles to observe traffic accident concentration at these hours. Though the visual representation of the two rush periods of morning and evening looks quite similar (Figure 23), the frequency in terms of the size of the bubbles are different. While the number of accidents at the intersection where the N1 intersects with Busia Highway is exceptionally high during the morning rush, it is relatively minimal during the evening (yellow circle). Also, the number of accidents on the Ring-Road Central for the evening rush appears to be greater than that of the morning rush even though both have a considerable high number of occurrences on the popular "Dubai" flyover (blue circle). Evening rush recorded more crashes on the Olusegun Obasanjo High Street than the morning rush (green circle).



Figure 22: Vehicular Accident Hotspots per Year



Figure 23: Vehicular Accidents at Rush Periods

4.6. Spatio-Temporal Analysis

The Knox test calculates significant combination of pairs closer in space and time, termed as spatio-temporal clusters. The outcome of this test is a 2*2 contingency table with four possibilities. According to Table 9, 393 denotes the significant number of pairs closer on both space and time. 27,650 shows the events that are closer in space (place of occurrence) but far in time. 57,085 represents the number of accidents that are far in space but closer in time and the last, 16,397,283 are events far in both space and time. The target, however, is events closer in space and time. The outputs in Table 9 is as a result of the specified thresholds (spatial distance ≤ 10.89 and a temporal distance ≤ 1 day). The test selected all significant pairs of accidents which are at a maximum of 10.89 meters (Appendix 2) away from each other and occurred a day apart. This led to 393 pairs of events in the first quadrant. There is a possibility the same factors caused these pair of incidents. 150 out of the 393 pairs of spatio-temporal clusters happened to fall within the identified hot zone locations. These are significant clusters because the simulation generated p-values of 0.001 for all points. This, therefore, required the rejection of the null hypothesis as stated in section 1.5.

Based on these spatio-temporal clusters, two pairs of crashes were observed. With the first pair, the first incident occurred the 7/05/2015 at 8:00 pm. The lighting condition was dark. However, the streetlights were on and the weather was clear. Two vehicles were involved in this crash where the first vehicle ran into the second vehicle and resulted in a fatal injury of a person dying. The second incident happened the next day on 8/05/2015 at 7:15 am. This was during the day and the weather was clear as well. This involved a vehicle where the driver lost control and ran into the road median and resulted in a minor injury. With these two events being lesser than 10 meters and a day apart, there is a possibility the same contributory factor could have triggered them. It is imaginable there could have been something (like a pothole) on the road which the drivers tried to swerve but unfortunately led to an accident. Another pair from a different location was recognized to have occurred on the same day 28/07/2012. The first happened in the morning with clear weather at 9:30 am. The second occurred at 8:30 pm. It was dark and there were no street lights. One vehicle was involved in each case. The incidents resulted in property damage when the vehicles ran into a nearby ditch. The nearby ditch, in this case, could have been the contributing factor because the recorded distant as detected by the spatio-temporal clustering was approximately 2.8 meters apart.

Table 9: Knox Statistics

| | | SPACE | | | | |
|------|-------|-----------|----------|--|--|--|
| | | Close Far | | | | |
| TIME | Close | 393 | 57085 | | | |
| | Far | 27650 | 16397283 | | | |

A sensitivity analysis was carried out by applying varying spatial and temporal thresholds. To demonstrate this, the crashes providing significant spatio-temporal clustering at a spatial distance of 10.89, 50 and 100 meters and temporal distances of 1, 2, 3, 4 day(s) are given in Table 10. These different thresholds were used to test how the number of significant pairs changes as the thresholds changes. The spatial and temporal distance (10.89m) was held constant at different scenarios to observe the difference. When the critical spatial distance (10.89m) was held constant, it was realized that the number of significant pairs increases as the temporal distance increases. For instance, with a distance of 10.89m, the number of spatio-temporal clusters increased from 393 to 542 and 757 as the days between them changed from 1 day to 2 and 4 days respectively. The same trend was observed when the temporal distance 10.89m to that of 50m at a day apart, 28 more pairs were added as the spatial distance increased. It can be concluded from this sequence that as the temporal and / or spatial distance rises, the number of pairs of clusters also rises. This sequence is not different from what was obtained by Eckley & Curtin (2013).

| Spatial Distance (m) | Temporal Distance (Days) | Observed Knox Value |
|----------------------|--------------------------|---------------------|
| 10.89 | 1 | 393 |
| | 2 | 542 |
| | 3 | 644 |
| | 4 | 757 |
| 50 | 1 | 421 |
| | 2 | 588 |
| | 3 | 699 |
| 100 | 1 | 498 |
| | 2 | 685 |

Table 10: Spatio-Temporal Clusters with Different Spatial and Temporal Distance

4.7. Primary Data Analysis

4.7.1. Demographic Characteristics of Respondents

With a total of 400 questionnaires administered, 56% (225) corresponded to the responses from females as against 44% (175) by males. Majority of the interviewees were within the age group of 35-44 years with the least being the elderly in the age group above 65 (Figure 24). The youngest road user interviewed was 19 years old and the oldest being 70 years old. Many of the respondents especially those interviewed along segments closer to markets were within the "none" or "primary" as their highest educational levels. Secondary education was the highest with 31% of the respondents falling into this category as against Tertiary with 10% (Figure 25). 86.3% of the respondents argued to have witnessed an accident along the segment. The period within which most accidents occurred was an open-ended question which came with varying responses. These were coded to fit 7 classes (Table 11). Approximately, 40% of the respondents suggested most accidents occur in the morning and evening which can be attributed to the rush periods within the day. Others (31%) reported it to occur any time of the day without any regular pattern. All the eight locations had streetlights. However, 40% of them were poorly lit. Some respondents attributed this to the lack of maintenance of safety facilities by safety officials. Other retorted they have never seen the streetlights along their segments ever on. "…*it is always off; maybe it is for beautification and not safety, it does not make the place active at night,*" one interviewee said.



Figure 24: Age Group of Respondents

Figure 25: Educational Attainment of Respondents

4.7.2. Road Safety behaviour of Respondents

This section describes briefly some road safety behaviour of the different road users interviewed. Starting with seatbelt, 29% of respondents hardly put on seat belts (Table 11). Some claimed especially the commercial drivers to only put it on whenever they see a police officer, then quickly take it off as soon as they pass by. Others declared they hardly put on seat belts because they are not available in many commercial vehicles in Ghana. Also, during random checks by police officers, they only check if the driver is wearing and are not concern about the passengers. On issues of road users bending traffic rules, 88.3% of the respondents strongly disagree while 0.5% strongly agrees. This 0.5% respondents contended it is sometimes worth the risk but only with reasonable motives such as emergencies or saving a life.

Also, a total of 94 drivers were interviewed and 28 of them had more than 10years driving experience. 3 of these drivers claimed to have violated traffic rules, of which references were made to the operating system of most traffic lights. "*The traffic light can turn on as late as 11pm for pedestrians to cross when there is no pedestrian around, in such case, I just cross without stopping.*" This was a response from a private car driver questioned. The commercial drivers who alleged to have violated traffic rules, related the incident to an emergency situation like taking a woman in labor or a sick person to the hospital. Correspondingly, routine vehicular maintenance appeared to be a thing for the rich and affluent only. This is because 64 of all the drivers interviewed just visit the workshop only when their vehicles are faulty since it is costly for regular maintenance (Table 11). Some commercial drivers purported to be doing the maintenance themselves to save money.

| Characteristics | Value | No. of Respondents | Percentage (%) |
|----------------------|--------------------------|--------------------|----------------|
| | Morning | 31 | 7.80 |
| | Afternoon | 14 | 3.50 |
| | Evening | 31 | 7.80 |
| Period of the day of | Morning and Afternoon | 28 | 7.00 |
| most accident | Morning and Evening | 159 | 39.80 |
| | Afternoon and Evening | 12 | 3.00 |
| | Any time of the day | 125 | 31.30 |
| | No streetlights | 0 | 0.00 |
| Lighting Condition | Streetlight (Poorly lit) | 161 | 40.30 |
| along the segment | Streetlight (Well lit) | 236 | 59.00 |
| | Never | 83 | 20.80 |
| | Very Rare | 117 | 29.30 |
| Wearing Seatbelt | Occasionally | 95 | 23.80 |
| 8 | Often | 35 | 8.80 |
| | Always | 70 | 17.50 |
| | Drivers Onl | ly (n=94) | |
| | Below 1year | 15 | 15.96 |
| | 1-5years | 26 | 27.66 |
| Driving Experience | 6-10year | 25 | 26.60 |
| | Above 10years | 28 | 29.79 |
| Visit to Washel | Routine | 30 | 31.91 |
| visit to workshop | Only when Faulty | 64 | 68.09 |

Table 11: Safety Behaviour of Respondents

Additionally, respondents were asked to rank some variables which are believed to profoundly influence road traffic accidents. 350 out of the 400 respondents perceive drivers' behaviour to be the first element which affects the occurrence of accidents (Figure 26). Some reasons given to this was the belief that, actions of a driver on the road, either positive or negative have it consequence of resulting in an accident or not. The second factor perceived to highly influence the occurrence of a crash is pedestrians/hawkers attitude on the road. Irresponsible attitudes of some pedestrians such as refusing to use available safety facilities along roads, in essence, make them also liable. The third and fourth elements are perceived to be vehicular and road conditions respectively. These respondents think these four aspects profoundly influences the occurrence of accidents than the weather condition and traffic volume.



Figure 26: Respondents Perception on Factors Influencing RTA

Again, 99% of all respondents interviewed indicated that indeed accidents do occur along those segments. Which justifies the appropriateness of the applied spatial methods in identifying accident-prone location. To validate this, 86% of them stated to have personally experienced an accident at that location. In reference to the relationship between street lighting and informal commercial activities, 73% of the interviewees claimed to be aware of such connection. This question was triggered by the findings from the regression model. Which stated that the probability of a severe injury occurring at locations with 'streetlights on' at night is higher than locations without streetlights. These respondents proclaimed to be aware of the dangers imposed as a result of these activities under streetlight. However, it was understood that people are forced to undertake economic activities at these hazardous locations because of livelihood. The most rational countermeasure from the FGD was to improve the economic situation in the country through job creation, especially for the unskilled labour force because expelling them from these locations would just worsen the economic hardship and not ideally solve the issue.

In like manner, the 94 drivers interviewed were asked to rank the meteorological conditions under which they are most cautious when driving and raining was rated the highest (Figure 27). This was followed by windy and foggy conditions respectively. Some drivers stated that the roads are most slippery during these periods and the rains sometimes decrease visibility which urges them to be extra careful with reduced speed. This follows the finding from the statistical analysis in section 4.3 when the model predicted less severe accidents when raining. The caution taken by these drivers under such meteorological condition influences

the severity of the crash, making resulting incidents less severe. Nevertheless, most of these drivers were indifferent in their actions when the temperature is very high.



Figure 27: Meteorological Conditions in which Drivers are most Cautious

4.7.3. Physical Characteristics of Hot Zone Locations and Road Users Perception on Major Causes of Accidents

The questionnaires were administered at eight distinct sites as described in section 3.8.1. Though some of the segments were along the same highway, the perceived causes of accidents expressed by the respondents are entirely different. The succeeding paragraphs qualitatively describe the physical characteristics of these locations, major causes of crashes along the segment and some countermeasures needed to minimize road traffic accidents in these locations. The section addresses the fourth objective of this study.

Mallam Market

The road along the Mallam Market (Dr. Busia Highway) is one of the hazardous locations in Accra. Based on its built environmental characteristics, there is an available pedestrian walkway and footbridge which are to reduce the incidence of high traffic mix. The pedestrian walkway, however, has been encroached by market activities (Figure 28) which sometimes forces some pedestrians to use the highway as a walking path. There is also a road median which separates the opposing lanes of traffic and the speed limit along the segment is 50km/h. Geometrically, the segment is straight with a flyover (Appendix 7) of which some respondents claim big trucks have been somersaulting unto the ground. It is a tarred road without potholes and slightly inclines as one moves up the flyover. The dominant land uses along the segment is commercial, a market to be specific, together with its complementary auxiliary activities.

A 2.16minutes YouTube video (<u>https://youtu.be/pazxzxC6s3Q</u>) published by GreenBook Ghana (2016) (edited to fit context) vividly describe the traffic situation along the Mallam Market. Accident occurrence was previously attributed to the lack of safety facilities (zebra crossing /footbridge). Many appeals were made to the government to rectify the situation and on Wednesday, 2nd December 2015, a pedestrian footbridge was commissioned (Ministry of Roads and Highways, 2015). But this did not remedy the situation because, upon field visit, it was realized that majority of the people expected to be using the safety facility (footbridge) were not doing so. Vehicular-pedestrian accident according to the survey is the dominant type of crashes mostly encountered and this is because some road users have refused to use the footbridge. The video even shows how with the presence of the footbridge, some pedestrians were still endangering their lives by not using it. The footbridge is disability friendly (Figure 29), and the section for the disabled is

spacious enough to accommodate the activities of market-aids (locally known as "Paaopaa"). These are individuals who mostly assist sellers and buyers by carrying their loads on wheel-barrows or local carts (known as "truck") for a fee. One market-aid interviewed said, "...*pushing my wheelbarrow along the inclining height of the footbridge is more difficult than lifting it across the road median.*" This tells why some of the market-aids have refused to use the footbridge. Also, a gentleman seen crossing the road without using the footbridge during the survey was asked why he did that and he said, "...using the footbridge makes your entire journey three times longer." Another interviewee, a seller in the market alleged, "I have a waist problem, so I cannot climb the footbridge, I prefer crossing the road." This together with other exciting responses gotten from the interviews suggested that the provided safety facility is underutilized.

It was later understood from the FGD with members of the National Road Safety Commission (NRSC) that most pedestrian footbridges in Ghana were constructed without proper planning. One participant of the FGD stated;

"...the designing stages in road construction is only done by experts in their offices with no idea of what is actually happening on the ground. These experts just decide and agree to put for instance the footbridges one kilometre apart without consulting any member of the beneficiaries. A typical example is the footbridges on the N1 (George Walker Bush Highway). None of the 6 provided footbridges on that road (especially the path leading to Lapaz) was positioned appropriately. Take a look at the number of people who crosses the N1 in front of "Las Pamas-Lapaz," but the location of the footbridge is like a kilometre away. Nobody would be willing to walk that distance to use a footbridge. So, the problem is not only about user behaviour but many times the design...."

The FGD also brought to board that sometimes during such projects, it is advisable to consult some of the beneficiaries to know their views. It is always ideal to plan with the people and not planning for them. Other respondents attributed accidents to superstitious beliefs. They claim such incidents are inevitable when planned by forces of nature.

In terms of countermeasures to improve the situation along the Mallam Market, some of the respondents suggested building a tall wall along the road median so pedestrians would have no choice other than using the footbridge. Others suggested police officials be put at vantage points to arrest all pedestrians not using the footbridge. Also, there is an urgency to educate Ghanaians on the need for safety.



Figure 28: Encroached Pedestrian Walkway

Figure 29: Disability Friendly Footbridge

Dansoman Junction

The segment along Dansoman Junction is an unavoidable location with respect to road accidents along the Dr. Busia Highway. This is a dual carriage with about four lanes per each carriageway and connected to this is a busy access road. The road infrastructure along this stretch, from a distance looks adequate and sufficient, but upon second glance, some inevitable loopholes can be identified. With all its existing infrastructure, there is no pedestrian crossing. Pedestrians are compelled to use traffic lights intended to direct vehicles. Also, most of the road signs available along this segment have been heavily encroached by poster advertisement. Figure 32 shows the conditions of some road signs along the visited sites. One respondent made it clear that authorization is mostly given to these individuals by officials of the local assembly, by paying an amount before they mount their advertisements on the road signs. The proof of whether this claim is valid goes beyond the scope of this study, but it is worth investigating in future studies. The dominant land uses along this road is commercial (warehouses, companies, petty trading) and residential. As an inescapable reality in Ghana, most prime locations have their pedestrian walkways encroached by petty traders (table-tops, kiosks, containers, vulcanizing shops, etc.) and Dansoman Junction is no exception.

In respect to the primary causes of accidents, four main causes were found. They are traffic light jam, obstructed view from trees, no zebra crossing and poor drainage system. The traffic light jam and the poor drainage system seemed to be the dilemma of the drivers interviewed while the obstructed view and zebra crossing were from the pedestrians. According to the drivers, the traffic lights at the junction is very unreliable because it goes off most often and causes a lot of confusion among drivers. One driver retorted "it is like a disco light." This respondent spoke about how a policeman trying to reduce the confusion brought about by the jammed traffic light lost his life. "... a disoriented taxi driver ran into him in the middle of the road; the policeman is a very good friend of ours whom we mostly call whenever the traffic lights misbehave. Due to this most policemen shun this location...". The Junction also happens to be downstream of the Dansoman Township and has a lot of drainage problems. From the interviews, it was understood that the road always floods anytime it rains. This is attributed to the narrow and heavily choked drains (Figure 30). From the pedestrians' perspective, the major causes of accidents along the segment are lack of pedestrian crossing and obstructed view from trees lateral to the pedestrian walkway (Figure 31). These trees are to promote walkability. Throughout the survey, this was the only location which was comfy in walking because the tree gave shade from the scorching sun. However, the respondents claim the trees are unkempt because it takes months for them to be trimmed. They mostly obscure the road when not trimmed and reduces visibility during the day and at night, together with the poorly lit streetlights.

Some interviewees suggested that with the vibrancy of the location and large road width, the only solution is to construct a footbridge because just a zebra crossing would not eliminate the problem as drivers in Ghana do not know how to prioritize other road users especially pedestrians. Also, it was suggested that with such a busy place, having a constant police official or any member of the MTTD (Motor Transport and Traffic Directorate) at the junction who would help calm the situation in terms of any traffic light jam would be ideal. It was understood that the traffic light jam is a result of faulty traffic lights and frequent power outages. In the matter of flooding, it was suggested by some drivers that roads are to be constructed to meet planning standards and not just to cut-down cost. This is because they believe the size of the drain provided along the highway does not meet the standard. In essence that it is unable to efficiently drain the road after heavy pouring of rain. Some respondents made mention of how they organize themselves to desilt the choked drains along the segment.



Figure 30: Condition of drains



Figure 31: Trees along the segment



Figure 32: Conditions of some Road Signs in Accra

Busia Junction

This was the third most hazardous location as per the severity index. A segment also along the Dr. Busia Highway. It runs from Busia Junction towards Odorkor Junction. The Junction has a 'Y' design (traffic island) where informal commercial activities take place. Street names were the only road signs along the segment. It is tarred with no potholes and predominantly residential and commercial land uses. As usual, some of the commercial activities were on the pedestrian walkway but at a minimal rate as compare to other locations. A major concern of the respondents was the unavailability of a zebra crossing and commercial drivers' refusal to use the provided bus stop. Instead, drivers prefer stopping exactly at the junction where the traffic island forms the 'Y' design. One respondent poured her heart out upon being questioned and said

"...we do not have a zebra crossing here though this place is very active throughout the day. It is not safe to cross the road at any time of the day. During rush hour, when there is heavy traffic congestion, you might think it would be easy to cross the road because the vehicles are barely moving, but do not try because those two-wheeled motorcycles which meander through vehicles during congestion are more dangerous than the vehicles themselves. They are always in a hurry and disregard any other road user. Also, during off-peak, we have to deal with very fast-moving vehicles. It sometimes takes me 5 to 10 minutes to cross the road. Drivers are not disciplined enough to give us way. You have to calculate how fast you can run then run to cross the road if a car is at a reasonable distance you think you can beat. It is less difficult to cross the road only when the school children close from school. This is because the schools in this vicinity have collaborated and employed a semaphore who helps the kids to cross by stopping the cars with his flag, but sometimes the cars don't stop..."

It was understood from another respondent that several appeals had been made for a zebra crossing, but the only feedback they got was that the road is a highway and highways are not supposed to have zebra crossing or speed rumps. This happened to be the only countermeasures retorted by the respondents to curb the issue. In the matters of commercial drivers refusing to use the bus stop is because of the actions of passengers. One "Trotro-mate" questioned said anytime they stop at the bus stop and tell passengers to disembark, they refuse and beg the driver to move forward a bit before they dismount. Which lands the commercial vehicles at locations they are not supposed to stop. Also, passengers in this area always wait for vehicles precisely at the junction ('Y' traffic island) and not at the bus stop. To tame this situation, all road users are expected to change their attitude since there is always a blame game in term of safety because each any every road user has someone to blame for safety issues.

Airport First

Airport First is a segment along the Liberation Road. The Liberation Road is a bustling road in Accra because it connects many suburbs to the CBD. It also has some major landmark such as the presidential seat of government (The Flagstaff House), the Accra Polo Grounds, 37 Military Hospital and the Airport City among others. The segment is a dual carriage with three lanes per carriageway. There is the availability of pedestrian walkway and crossing as well as a road median. The land uses along this segment is highly heterogeneous ranging from residential, commercial, educational, recreational, civic and culture, etc. The segment is bounded by two junctions. A 'cross' and a 'T' junction which happened to be a prime spot for street hawkers/peddlers, beggars and street children offering services like cleaning vehicle's windscreen for a fee. High traffic volumes and over-speeding coupled with the issue of tailgating are some of the perceived causes. Tailgating is when there is insufficient safety distance between vehicles on the road. Reckless and impatient conduct of some drivers makes them driver very close to other vehicles in such a way that they are unable to react in time in case of sudden change in speed. This accounts for many rear-end collisions. Virant & Ambrož (2016), made mention of tailgating as one of the primary causes of road accidents.



Figure 33: Effectiveness of some Traffic Regulations

As a countermeasure, it was suggested by some respondents to keep sufficient safety distance between vehicles. Preferably, the "two-second-rule" which Virant & Ambrož (2016) explain as a distance as long as the distance traveled by the vehicle at its current velocity in two seconds.

Additionally, it was realized that many of the vehicle-pedestrian crashes along the segment was as a result of the activities of street hawkers (Figure 39), street children and beggars. Some of the street vendors alleged the hardship condition in the country propels them to go onto the streets to generate some income. This further justifies why about 60% of the respondents perceive regulations on street vending to be the least effective traffic rule in Accra (Figure 33) because anyone can go onto the street for any purpose such as selling/hawking. In conjunction with the issues above, street begging by both children and the old seems to be a very lucrative job for not just some Ghanaians but immigrants from Chad, Mali, Niger and Sudan. These foreign beggars, unlike the Ghanaian beggars, have devised a strategy in training their little children to do the begging by making the children run after people and beside vehicles to harass people and vehicle occupants for money. The main plots by these kids are to approach their victim with a miserable and depressed face, but if that does not work out, then grab the victim's clothes or stand in front of vehicles to prevent them from moving then start to cry. Some of these kids can be as young as 5years, hauling the busy streets of Accra for money and most of them are run over by vehicles. This can be minimized only if the appropriate institution sees to it that these children especially are off the streets.

ECG (Electricity Company of Ghana)

This segment is along the Olusegun Obasanjo High-street. The Olusegun Obasanjo High-street is a connection between the N1 (George Walker Bush Highway) and the Liberation Road. This is a dual carriage with a road median and streetlights which are poorly lit and mostly faulty. There are pedestrian walkways and some street peddlers, who happened to be on most busy streets with traffic lights in Accra. This is because they habitually wait for the traffic light to signal vehicles to stop then hop unto the streets to sell. The pedestrian walkways are also the path used by cyclists because a cyclist was spotted and questioned. The cyclist spoke about the risk involved in cycling in Accra. This is because there are no provisions made for cycling facilities. The cyclist said he only cycles within his neighbourhood and hardly go beyond a kilometre away from home because that would be considered suicide.

On Sunday, 26th October 2014, a news article published by Akwei (2014) narrates an incident of how a pool of water in front of ECG caused an accident. According to the article, some eyewitnesses reported the driver of a minibus lost control, hit the pedestrian pavement and somersaulted three times before crashing a light pole. These eyewitnesses alleged the pool of water on the road was triggered by shabby works of a contractor responsible for renovations at the ECG station. The shabby works affected the entire drainage system along the highstreets generating stagnant pool of water on the road which was there for months, making the location accident-prone and unsafe.

Apart from this incident, respondents along this road did not attribute the events to design factors (except the issue of street lighting) but to human factors which varied from each respondent. Some common causes realized were in respect to intoxication, fatigue driving, inexperienced teenage drivers and distracted drivers (talking on phone and texting while driving). Drivers and occasionally pedestrians who are under the influence of alcohol or any hard drug are at a higher risk of causing accidents. "...a driver ran into a nearby provision (groceries) kiosk and almost killed a little boy buying toffee from the kiosk; we believe the driver was drunk because he smelled of alcohol and some people claimed they saw him coming out of the "Shakazulu nightclub"" This was a narration by a respondent who had experienced an accident caused by intoxicated driver. Some respondents complained about teenagers without much driving experience yet being permitted by their parents to drive and put the life of every road user at that moment (space and time) at risk. Similarly, drivers fond of receiving calls and to the extreme of texting on their mobile phones while driving and fatigue driving were also identified. These dangerous behaviours exhibited by some drivers are some accident causing factors most respondents never forget to talk about. Some interviewees made mention of how to rectify the situation by police officials discharging their duties appropriately via arresting offenders instead of taking bribes from them.

"...when the Ghana police is involved, you can always buy your way out...," one respondent said.

Kwame Nkrumah Circle ("Dubai")

The Kwame Nkrumah Circle is located within the centre of the City of Accra. It is part of a long stretch of road known as the Ring-Road and a major transportation hub within the city. Many transportation terminals and stations can be found here. The numerous commercial activities within the vicinity make it a major attraction point. Before the construction of the flyover (Figure 34), the location was previously experiencing a lot of congestions which resulted in many delays and lengthy travel times. The traditional peak and off-peak periods did not exist during that era. Congestion periods were prevalent at all times of the day, and during the rainy season, the "Odaw" River which crosses the Ring-Road West (Appendix 8) gets flooded and usually prevents access for all road users and worsens traffic flow. This also came with consequences such as road accidents. These necessitated the construction of the interchange/flyover. The interchange was completed in 2016. Though there is maximum traffic flow at the location now, pedestrians' volume is still extremely high. This location was detected as a hot zone because of its previous infrastructure and design deficiencies (before the construction flyover).

Even with the improved condition, accidents do still occur. This is because the flyover came with its own challenges like vehicles especially big trucks falling from the flyover at a height not less than 15 feet onto the ground. These incidents were very predominant the year the flyover was commissioned. Some respondents declared these events are as a result of drivers not obeying traffic rules. Other retorted that such heavily loaded trucks are not permitted to use the flyover yet some blatantly disregard this. This location has excellent road infrastructure for every road users at the right location with the exception of cyclist, yet, human actions make it difficult to ensure safety. A 49seconds video (<u>https://youtu.be/xQpy6NAcAOo</u>) recorded during the field visit shows pedestrians crossing the road at an unauthorized location. Within the 49second of the video, three pedestrians crossed the street at that point. How many people are going to risk
their lives in crossing the street in a day? In like manner, Appendix 11 shows a commercial "Trotro" driver picking up pedestrians at the same unauthorized location. When are some Ghanaians going to put safety first?

The perceived sustainable way to ensure road safety in Ghana is through education, safety campaigns, awareness creation and discipline. These factors need more attention to aid in minimizing road accidents than the proliferation of road infrastructure which seems to be the goal of every government that comes into power.



Figure 34: Kwame Nkrumah Circle Interchange (Source: myjoyonline-Ghana (2016))

Kaneshie Market

This segment is also along the Dr. Busia Highway and runs from Kaneshie Market to Kaneshie First Light. Upon arriving at this location, some of the accident causing factors can quickly and visually be detected, unlike other segments. The elements observed by the researcher were not different from what was reported by the interviewees. To start with, three types of encroachments which are likely to have road accident as its consequences were recognized. First encroachment by market activities (Figure 35) and "Okada" drivers on pedestrians' walkway. Mostly pedestrians, when faced with these challenges, have no option other than using parts of the carriageway as a walking path. "Okada" is a two-wheeled motorcycle used illegally for transporting people. Since the activities of these motorcyclists are illegal, there is no designated location or station for them, so they tend to use the pedestrians' walkway especially at the Kaneshie First Light. Not only is sitting on these motorcycles dangerous but some people and even sometimes the conductors themselves do the wear helmets. One "Okada" driver interviewed said he mostly wears his helmet and have an extra one for passengers, but most female passengers refuse to wear it because they claimed it spoils their hairstyle.

Secondly, encroachment on the carriageway by commercial "Trotro" drivers (Figure 36) which mostly reduces the road width. Though there are two designated stations for these commercial drivers, it is unable to adequately serve them. This forces some of them to use the lane closer to the walkway as a station especially the long distant drivers heading Cape Coast and Takoradi (Central and Western Regions of Ghana respectively). Figure 38 also presents how two lanes have been used as a bus stop/station by these drivers and just one lane is designated to ensure free flow of traffic. Lastly, the two available footbridges which are not disability friendly have been heavily encroached by hawkers, preachers and beggars (Figure 37). Attached is a link which shows a video captured during field visit using a hidden camera on the footbridge (<u>https://youtu.be/7VttUS0vJeU</u>). This tells all the story and situation on the footbridge. This causes human

traffic on the footbridge. The video was recorded on a Sunday, the only day with fewer people in markets yet the congestion on the footbridge is apparent.



Figure 35: Encroached Pedestrians Walkway at the Kaneshie Market



Figure 36: Encroachment on Road Width by Commercial "Trotro" Drivers



Figure 37: Encroachment by Commercial Activities on the Kaneshie Footbridge

Sharma (2016) and Chauhan, Varshney and Saraswat (2017) made mention in their research of how the issue of encroachment does not only infringe and violate the rule of law in a country but how they result in road traffic accidents. Though these footbridges are unattractive to use based on some disadvantages of being too narrow, disability-unfriendly and heavily encroached, it is not underutilized, unlike the Mallam Market footbridge. This is because, from the onset of road construction, a wall was built to separate the two carriageways, putting pedestrians with no choice other than using the footbridge. However, some pedestrians are stubborn to the extent that no matter the remedy brought on board, they will always have a way around it. Figure 38 shows some pedestrians including a schoolboy (in the two shades of brown school uniform) climbing the wall to cross the road. "Indiscipline is indeed a disease." Additionally, Figure 39 displays the activities of street hawkers at the Kaneshie First Light going about their business on the busy

Busia Highway. To redeem road accident situation at Kaneshie Market, education and awareness creation alone would not be enough, but in addition to extensive infrastructural development.



Figure 38: Behaviour of some Pedestrian at the Kaneshie Market



Figure 39: Street Peddlers at Kaneshie First Light

Agbogbloshie

Agbogbloshie portrays a high traffic-mix segment, where all road users muddle through the already busy street. This massive encroachment and high traffic mix are attributed to market spill-over and the deliberate attempt of sellers displaying their goods on the walkways with the aim of having the first contact with customers. This forces all individuals expected to use the walkway onto the already busy street. The width of the carriageway is compromised creating severe congestion of vehicular and human traffic (Figure 40). Generally speaking, it is the only visited segment where pedestrian walkways are entirely invisible though available. Commercial drivers along this segment complained about how they waste time being caught up in human traffic, which affect them financially. This is because of high fuel consumption and overheating from motionless mode causes vehicular breakdown. Though this condition is unbearable for some road users, it calms the severity of any collision that occurs. Respondents spoke about the fact that the types of accident which materialize along the segment are mostly vehicle-vehicle, vehicle-motorcycle (scooter/tricycle/bicycle) and very minimal vehicle-pedestrian crashes. Also, incidents that occur mostly

result in minor injuries or damage to property. Though the occurrence of these incidents is rampant, it is scarce for a fatal incident to occur even though once a while it manifests. The perceived relationship between traffic congestion and traffic accident occurrence as stated by the respondents contradicts the findings of Wang, Quddus and Ison (2009) who argued that traffic congestion has no effects on accident frequency which may be the case for their study.

Another concern was in respect to the three-wheeled cargo tricycle known as "Abobo Yaa" that ply the road. These are supposed to be non-commercial tricycles for carrying goods, though some Ghanaians have illegally commercialized it. This is a major means of transporting goods in Ghana especially for market produce and small-scale manufacturing companies such as sachet water manufacturers. They heavily rely on these to efficiently distribute their products to customers. Most conductors of these cargo tricycles are inexperienced drivers without licence, yet, freely ply roads in Ghana endangering all road users. Also, it is worth mentioning that too old and faulty vehicles, impatient and reckless driving by some conductors of vehicles, tricycle and motorbikes and pedestrians who walk along busy streets with earpiece/headphone in their ears listening to music were among some of the grievances of the respondents. One observation made was in connection with priority given. With everyone on the busy street, it hardly occurs to see any road user making way for the other. It is not surprising that respondents perceive priority given as one of the ineffective traffic regulations in Accra (Figure 33).

Some perceived countermeasures retorted by the respondents were in reference to expanding the market, to accommodate all seller. This is to prevent them from selling on walkways. Others mentioned random police checks for licence from tricycle conductors. This is believed to put them in line of acquiring licence before driving.



Figure 40: Traffic Mix at Agbogbloshie

4.8. Methodological Reflection and Quality of Secondary Data

This section presents views from an expert in road safety research in Ghana. The focus was on the suitability of the methods and techniques applied in the secondary data analyses. It also described the state and quality of accident data and means of collection in Ghana. Ways of improving the data collection methods have also been touched on, as well as, paths for effectively incorporating spatial/geographical dimensions in accident studies in Ghana.

4.8.1. Methodological Reflection

At this stage, the methods adopted were briefly explained to the expert. Who thereafter stated that for areawide cluster analysis of accidents, the chosen methods are appropriate. This is because they provide enough insight in locating the exact segment with high accident occurrence. The spatial and visual representations enable for easier comprehension of the accident situations within the metropolis and easier to instantly identify the critical locations for further investigation. These methods contrast with the traditional approach used by the National Road Safety Commission (NRSC) where the number of accidents are assigned to the road names in a matrix. Their approach is unable to identify the specific segments with high occurrences.

4.8.2. State and Quality of Accident Data in Ghana

Pertaining to the state and quality of the secondary data, it was understood that previously, the link-node method was used in accident data collection in Ghana. With this approach, all the road segments known as "links" within the metropolis were numbered. These links were separated by nodes which are the intersections, junctions and flyovers. The nodes were also numbered. Occurring incidents were assigned to either the links or nodes, depending on the location of the incident. It was an aggregated method where the total number of accidents were assigned to a link or node. This method was seen as a conventional approach and needed upgrading. It was later upgraded to an improvised approach known as "grid reading." The police collaborated with Building and Road Research Institute (BRRI) to effectively undertake this process. The BRRI is, however, responsible for training personnel from the Motor Transport and Traffic Directorate (MTTD), an agency under the Ghana Police Service on how to effectively collect accident data. Regarding the grid reading approach, when an incident is reported to the police/MTTD, they visit the site and investigate the incident, they then fill the accident report form. A sketch and description of the location of the incident are made based on certain landmarks and important structures at a location. Question number 77 on the accident report form states exactly what should be recorded, and it reads;

"77. Site Location Sketch: Mark road names, junctions, prominent buildings, landmarks, etc. Indicate distance from crash site to these points."

A sketch and a brief description of the location is then outlined on the form. The form is later sent to the premises of the BRRI. The location is visited by officials of the BRRI based on the descriptions and sketch on the form (Question 77) if available. Paper maps are carried along, where the location is manually pinpoint onto the paper map. This is made in conjunction with the given sketch and description. The coordinate of the point is approximated by reading the grids on the map. The content of the accident report form and obtained coordinates are then transcribed onto a spreadsheet as the final accident data. In situations where such descriptions and sketches are unavailable, it becomes impossible to ascertain the coordinates. This justifies why about 52.8% of the data used for this research were not geocoded. This method was preferred to the previous approach because the approximated point location of the incidents was obtained instead of aggregating them on a node or link. The technique, however, can be rendered redundant, tedious and time-consuming making the entire process lengthy and inefficient in cases where such descriptions are unavailable.

To overcome the deficiencies in this approach and crave ways to effectively incorporate the spatial/geographical dimension into accident analysis, a contemporary technique was proposed but has not been initiated yet. This technique is a World Bank initiative to support the National Road Safety Commission (NRSC) to upgrade their current accident database application to a web-based. As part of the support, the police shall be resourced with handheld Global Positioning System (GPS) facilities to accurately collect points from crash locations whenever visited to investigate the scene. This would make the quest more efficient and eliminate the issue of redundancy and other setbacks. The project is to be piloted first in Accra before later extending to other parts of the country. Officials from MTTD would be efficiently trained to

collect all personal/demographical characteristics such as gender, age, type of vehicle, nationality, etc. of the victims since these are already available on the accident report forms to improve the means of collection. The aforementioned would benefit the NRSC, BRRI, MTTD of the Ghana Police Service, road agencies and the general public at large. This together with experts and practitioners knowledgeable in spatial analysis and accident studies would profoundly improve accident data collection and research in Ghana.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

This study examined the spatio-temporal patterns of vehicular accidents in Accra Metropolis via the use of a regression model, spatial, temporal and spatio-temporal techniques. The results did not only highlight the perilous accident locations and periods of occurrence but also significant factors influencing the occurrence in selected cases. It also addressed a major setback of having limited studies integrating spatial dimensions in accident research in Ghana and ways of improving that. This chapter presents the conclusions derived from the analysis by reflecting on the objectives and research questions and further provides recommendations on what needs to be done, research limitation and avenues for future studies.

5.2. Conclusion

The study first investigated the various factors influencing crash severity through a regression model. To ensure better data representation, all 12,166 incidents were used. The generalized ordered logit regression model was adopted due to the nature of the dependent variable. The independent variables fell into three categories of accident characteristics (number of vehicles involved, number of casualties and day of the week), environmental factors (weather condition and lighting condition) and road features (Road geometry/junction type, road surface type, road surface condition, road description/curvature or inclination and roadworks). Two of the factors (road description/curvature or inclination and roadworks) were excluded in the final model because they were statistically insignificant. The results from the model are found to be coherent and consistent with earlier studies. However, the factor 'lighting condition' happens to deviate from current literature. The coefficient of this variable suggests that no matter the lighting condition at night, more severe injuries are likely to occur though, locations with 'streetlights on' at night are expected to record much severe crashes than locations with 'no streetlights.' This, as being reemphasized is not surprising for the study area since streetlights tend to attract a lot of informal commercial activities at night. Arguably, this affirms that some safety facilities are failing their intended purpose of ensuring safety.

In terms of spatial analysis, well-known methods used by road safety researchers were considered and reviewed; Global Moran's I, bubble map, KDE, NetKDE and Local Moran's I. These methods were employed to provide enough insight in the distribution of accidents within the Metropolis. 5,742 geocoded accident points were used. The global indicator estimated the tendency of the entire dataset which led to the rejection of the null hypothesis of CSR. The bubble map, which is a disaggregated visualization approach aided in generally displaying the distribution of accidents in the study area. This approach though useful could be more suitable for analyzing accident locations at intersections instead of roadways. The reason being that, intersections are mostly represented as nodes on road network graphs, and this technique shows concentration of events at a point and not along a segment, where the size of the bubble depicts frequency of occurrences at that point making it unfit for the case. However, it is a very easy method to compute without any mathematical underpinnings like the other applied methods. Moving on, issues with accident density being overestimated by the KDE approach proved it inappropriate. This is because this approach assumes accidents do not occur at discrete locations in space only. Instead, they can occur over continuous space which is untrue for the case and resulted in the adoption of the NetKDE. With crashes constrained to a one-dimensional space, the NetKDE was presumed to ascertain more accurate hotspots. It proficiently identified accident hotspots. However, the size of the kernel and the bandwidth of these two density techniques profoundly influenced results. It required several sensitivity analyses in arriving at these

thresholds and imposed more considerable influence on the spatial distribution of the estimates. Also, these three methods were unable to determine the significance of the identified hotspots.

The Local Moran's I enabled to rectify this. Unlike the other methods, the Local Moran's I is an aggregated approach which considers the number of accidents per road segment as well as the length of the segments. All parameters (such as the proximity weight matrix) needed for estimating the results of this approach were manually calculated and computed. Going through the computing process provided new intuition into the data even though tedious. It offered enough knowledge for better understanding of the outcome and also guided in effectively interpreting the results. The unit of analysis for the local index was the road segments which were clearly defined in terms of its extent and guided in segment selection for further ground-truth investigations. The issue of double counting during aggregation especially points located at the intersecting points of two or more segments was one shortcoming identified for this method. A strategy was devised to rectify this shortcoming. This method is deemed appropriate for this research. Though not entirely recommended for all accident studies because it is case specific. That is, it satisfied the purpose of the study and suited the obtained secondary data. Accident data comes in different formats together with varying research purposes of which this approach may not be appropriate. Ideally, it is useful to attempt different techniques to identify the method that satisfies the purposes of the research and ideal for the available data. 241 significant hotspots were estimated by the Local Moran's I. Out of the 241 hotspots, 59 were detected as hot zones. The identified hot zones showed concentration of accidents on the Dr. Busia Highway, the Liberation Road, Ring-Road Central and the Olusegun Obasanjo High Street. These locations reflect segments with high agglomeration of socio-economic activities of road users. The nature and characteristics of the hotspots/hot zones segments did not deviate from what other studies found.

Decomposing the data and visualizing as maps as well as graphs gave a better understanding of the timebased incident pattern. The temporal analysis revealed a time-based pattern of more accidents occurring in 2012 within the five-year period (2011 to 2015). Correspondingly, more crashes occurred on Fridays and Saturdays than any other day because most social activities (such as weddings, funerals, parties, etc.) in Ghana take place on these days, with 7-9am and 4-6pm being the morning and evening rush respectively. It was discovered that there were more accidents on the Olusegun Obasanjo High Street during the evening rush than the morning rush. It also revealed that in 2015, more accidents occurred on the Dr. Busia Highway than any other location.

The study also demonstrated a useful application of Knox statistics in spatio-temporal analysis. This method was adopted because it is widely used in epidemiology literature, simple and straightforward in calculating statistics. A critical distance and time threshold were the parameters needed for the test estimation. The results provided exceptional understanding of incidents closer in space and in time. By critically observing the prevailing conditions contributing to the occurrence of crashes for several pairs of incidents which were lesser than a day apart and not more than 10.89 meters away from each other, it was concluded that events closer in space and in time might have been caused by the same factor. However, a sensitivity analysis was carried out using different critical distances and time thresholds. These thresholds were used to test how the number of significant pairs changes as the thresholds changes. Fortunately, majority of the identified pairs of events fell within the identified hot zone locations. This is a very insightful approach though extensively used in epidemiological studies. It would be beneficial for more crash studies to adopt this method because it gives a new perspective and insight into crash analysis with respect to space-time interactions.

It is also worth mentioning that, many previous crash studies lacked evidence-based location-specific causes of accidents. This has been achieved in this study through the administration of 400 questionnaires in eight hot zone locations. Participants for the survey were chosen randomly. This is because it is challenging to

estimate the population at risk along a road segment since road users fluctuate extensively in time and space. This made it difficult to generate and obtain a sampling frame for participants selection. However, a strategy was devised to ascertain the actual population at risk during the interview. An FGD and key informant interview were also carried out to attain views from experts within the road safety field. Though the identified location-specific causes of accidents along the eight segments were not different from what has already been stipulated in literature, no two segments were similar in terms of major causes.

One cause recognized was underutilized safety facilities. It was realized from the survey that road users within locations without safety facilities (footbridge or zebra crossing) were beseeching for one, while other locations with these facilities present were being underutilized. This is mainly because of road user's behaviour; design deficiencies and absence of beneficiaries' involvement in developmental works. Similarly, it was observed that most road users within the Accra Metropolis prioritise convenience over safety. Other identified causes include but not limited to attitude of drivers not prioritizing other road users, inexperience and teenager driving, distracted and fatigued drivers, over-speeding, malfunctioning safety facilities, unsanctioned offenders due to bribery and corruption, the use of road signs for other purposes such as advertisement, superstition and the issue of encroachment. The width of most roads and pedestrian walkways, as well as footbridges in the Metropolis, were encroached by vested interests of all sorts (food vendors, hawkers). Road encroachment is not only an infringement and violation of rule of law but results in accidents as few literature have stated. Most literature, however, failed to recognise the issue of encroachment in road traffic accidents because it seems to be a problem for countries in the global south.

This research has also proven that even with the deficiencies in accident data in Ghana, the improvised approach together with the right expertise, the limited spatial/geographical dimensions can be overcome to generally improve accident studies in Ghana. Also, the outputs generated in the study can be updated and refined for planning purposes. This knowledge can allow planners and engineers to focus on these high-risk areas and time periods together with the identified location-specific causes for safety-focused intervention in minimizing road traffic accident.

In summary, the regression analysis provided insight into factors contributing to accident severity which aided in structuring parts of the respondents' questionnaire. Also, the spatial analysis helped in identifying accident hot zones for further investigation. Location-specific causes and infrastructural deficits were determined through the field visit. Likewise, the temporal analysis gave rise to the rush periods which informed the researcher of the time to be available at the sites to observe the interactions between road users during these periods. The FGD enlightened on the shortcomings within the current safety programmes and ways of improving it while the key informant interview reviewed the deficiencies and current accident data collection and research in Ghana as well as the way forward.

5.3. Recommendations

The results from the research discovered many issues regarding vehicular accidents within the Accra Metropolis ranging from data deficiencies to combined elements of road users, roads and vehicles interacting to cause accidents. Based on the findings, the following recommendations are made;

1. **Road Accident Data:** the study advocates for uniform accident reporting system that can be used as a working database (web-based) and feedback mechanism for road traffic accident data. This is to ease accident modelling, with the view of making road accident forecasting and spatial analysis possible in Ghana. This can be done through the use of contemporary technologies and applications. The use of mobile applications for instance, by civilians to update any incident and crowdsourcing can aid complement the collected data to minimize the issue of underreporting of incidents. Officials of the MTTD and BRRI responsible for accident data collection should be

trained on the use of various applications like GPS devices to collect the appropriate data and attributes onto the web-based database.

- 2. Road Safety Research and Knowledge Dissemination: this study also recommends rigorous accident studies (spatial) from varying perspectives and methodological approaches in different parts of the country. It is believed that finding the problem areas and causes of the problem is the first step towards eliminating the problem. This can again, assist in identifying where opportunities lie for improvement. By adequately disseminating this information to the rightful bodies, it can support transportation officials understand the prominent reasons behind the occurrence of accidents, focus deeper on the population at risk, accident-prone areas and pinpoint which road, human and environmental characteristics contribute to the occurrence of more crashes. The findings from these studies could reinforce transport policy makers in devising safety programmes and efficiently allocating road funds. This may be beneficial in ensuring sustainable road safety.
- Road Infrastructure Development: locations within the Metropolis with absence of and 3. deteriorating road infrastructure (such as traffic light, street signs/road markings, zebra crossing and speed rumps) needs to be built, renovated and upgraded in conjunction with regular maintenance. This infrastructure should be designed, renovated and constructed in a way that it offers assistance and protection for the road user. This is because, road user behaviour is profoundly influenced by surrounding environment, which can lure them to make safer choices. Additionally, during these developmental works, agencies in charge should try their possible best to plan in alliance with some direct beneficiaries instead of planning for them to prevent underutilized safety facilities. Furthermore, highways/motorways and traffics passing through heavily dense residential areas should be seen as guest in these areas and the design of facilities should clearly indicate that the primary function is residential. To improve pride of place in accident-prone residential areas. Thus, the functionality of some of these highways and motorways should be lowered to pave way for the construction of safety facilities such as zebra crossing, raised junctions and speed rumps on them. Though this measure may appear expensive, it is socially and economically profitable because it may prevent medical cost resulting from accidents, loss of life and life-long disability, property damage and production loss among others.
- 4. Road Safety Education, Campaigns and Awareness Programmes: the study also proposes compulsory education, safety campaigns and awareness programmes for all road users in Ghana. Road users are not only physically vulnerable but also make mistakes and do not always abide by rules. This makes the human being an important course in ensuring safety. A human-centered approach such as these initiatives is necessary to effectively communicate to road users on the need to be discipline on roads. Road users in Ghana prioritise convenience over safety while others, especially commercial drivers do not know the meaning of some road signs. These initiatives can be done through the various media channels and by organizing workshop for commercial drivers (most of these drivers are members of some sort of association within their stations of operation). These actions are prime in ensuring sustainable road safety because human attitude towards safety is a major arena to venture in minimizing the occurrence of accidents. It can also aid in regulating human activities along major roads.
- 5. Safety Regulations, Enforcements and Traffic Strategies: road safety personnel must safeguard that some basic safety rules and regulations such as wearing helmets, using seatbelts, running the red light and drunk-driving are enforceable and punishable by law. In that, all offenders are rightfully sanctioned without loopholes for offenders paying their way out. These may serve as a constant reminder in guaranteeing discipline on roads. Also, initiating traffic calming strategies

within some locations with high traffic mix especially the CBD (Agbogbloshie) to prevent all road users from competing for space is worthwhile. This would slow down or reduce vehicular traffic and improve pedestrians' safety. As for reducing vehicular speed, an advanced approach of speedcheck-cameras could be installed on segments which have been detected as accident hot zone to enforce an allowable average speed. This would ensure that all vehicles travel at a similar and consistent speed and reduce over-speeding and improves road safety. Also, specific proactive measures need to be put in place to cater for the inevitable, instead of waiting for such unforeseen circumstances to occur first.

6. Vehicular Safety and Technical Specifications: the MTTD of the Ghana Police Service, needs to perform period and random checks of vehicle specifications, licence of drivers, roadworthy and other essential details about vehicles. Constant checks for airbags, seatbelt reminders and other vehicular technologies are needed in eliminating the risk of serious crashes. Random licence and roadworthy inspections are likely to put unqualified drivers and vehicles not meeting minimum standards off the road, especially the motorised three-wheeled cargo tricycles (Abobo Yaa) and two-wheeled motors. All road users should be equal before the law without loopholes for bribery and corruption.

5.4. Limitations

A principal limitation of this research is in reference to the accident data (secondary data). With approximately 52.8% of the data without X, Y coordinates, major locations especially the N1 (George Walker Bush Motorway) and Okponglo Junction (a popular junction in front of the University of Ghana-Legon), prominent locations in Accra known by many as accident-prone areas, were undetected in the analysis.

5.5. Future Studies

This research focused on accident studies within the Accra metropolis without analysing concurrently accidents on roadways and those on intersections/junctions. As part of further research, the focus can be on a comparative study of accidents on intersections (which are the major conflicting points of the urban traffic flow) and roadways. Also, in future research, to ensure data quality, the accident data can be complemented with hospital data, and for the primary data collection, some road users admitted to hospitals due to their involvement in a vehicular accident can be interviewed.

Future studies can compare the number of accidents on a road to the Average Annual Daily Traffic (AADT) on that road. This will scientifically help to prove the relationship between traffic low, congestion and road crashes. It would assist to test the hypothesis being speculated that there is an inverse relationship between traffic accidents and traffic congestion. This needs to be studied within this case area for solid conclusions. This study can be extended in aspects of modelling the content of the observational checklist collected from the field. This checklist contains the built environment and road characteristics (such as length of road, streetlighting condition, presence of traffic light, number of lanes, presence of footbridge or zebra crossing, encroachment, speed limit, slope, speed rumps, police station, intersection, etc) of the visited segments which can be modelled to indicate segments with high and low risk of traffic accident. It could help in identifying the combined characteristics which makes a place hazardous. Also, topographical maps can be used to calculate the actual inclination/gradient of a road instead of observation as used in this study.

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APPENDICES

Appendix 1: Spatial Autocorrelation Report







Appendix 3: Observational Checklist

PART 1: ROAD ENVIRONMENT OBSERVATION AND PHOTOGRAPHY

Physical and Environmental Characteristics of the road segment

Road Name / Segment Number



| Variables | Categories | Description | Remarks (Photographs/video) |
|-----------------------|-----------------|----------------------|-----------------------------|
| Road | Road Separation | Availability of | |
| Design/Infrastructure | | different routes for | |
| | | different road users | |
| | | Availability of | |
| | | pedestrian crossing | |
| | | Presence of road | |
| | | median | |
| | Speed Limit | Maximum Speed | |
| | | allowed | |
| | Road Curvature | Straight | |
| | | Slightly Curved | |
| | | Curved | |
| | Junction Design | What type of | |
| | | junction | |
| | | "Cross" | |
| | | "T" | |
| | | ₩ "Staggered" | |
| | | 丫 "Y" | |
| | | "Roundabout" | |

| | | Flyover | |
|---------------|--------------|-------------------------|--|
| | | Railway Crossing | |
| | | Others | |
| | | Availability of traffic | |
| | | light | |
| | Road Signs | Availability of road | |
| | | signs/road markings | |
| | | Visibility of the road | |
| | | signs/road markings | |
| | Road Surface | Туре | |
| | | Condition | |
| Topographical | Gradient | Flat | |
| Conditions | | Slightly Hilly | |
| | | Hilly | |
| Land uses | Presence of | Number of different | |
| | diversified | land uses available | |
| | activities | | |
| | Encroachment | Has the width of the | |
| | | road been | |
| | | minimized because | |
| | | of encroachment? | |

Appendix 4: Respondents Questionnaire

INSTITUTION: ITC, UNIVERSITY OF TWENTE **STUDENT:** MAVIS AGYAKWAH **INTRODUCTION**

This survey is in aid of completing a Master of Science degree in Urban Planning and Management on the topic: "Analysing Spatio-Temporal Patterns of Vehicular Accidents in Accra (Ghana)" at the Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente (The Netherlands). Thank you for agreeing to take part in this survey aimed at identifying some location-specific causes of road accidents in Accra and possible ways of minimizing its occurrences. This survey should only take 30-45 minutes to complete.

PART 2: ALL ROAD USERS

 1. Do you live or work along this road (or both)?

 YES

 NO

 (Do not proceed with the interview)

2. If "YES", how long have you lived/worked here?

.....

3. Do accidents occur along this route?

| YES | |
|-----|--|
| NO | |

4. If "YES', which period of the day do most accidents occur?

| • • • • • • • • | | ••• | ••• | ••• | • • • | • • • | • • • | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | • • | •• | •• | ••• | • • • | ••• | ••• | • • | ••• | •• | •• | | ••• | ••• | • • | ••• | ••• | ••• | •• | ••• | • • | ••• | ••• | •• | ••• | •• | • • | •• | | ••• | • • | ••• | ••• | • |
|-----------------|-----|-----|------|-----|-------|-------|-------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|
| • • • • • • • • | ••• | ••• | •••• | ••• | • • • | ••• | ••• | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | ••• | •• | •• | ••• | • • • | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | •• | ••• | •• | ••• | ••• | ••• | ••• | •• | ••• | ••• | • |
| • • • • • • • • | | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | •• | •• | •• | ••• | • • • | ••• | ••• | •• | ••• | ••• | •• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | •• | ••• | •• | ••• | | •• | ••• | •• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | • |
| | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | •• | ••• | ••• | ••• | •• | •• | •• | ••• | ••• | ••• | ••• | ••• | ••• | •• | •• | ••• | ••• | ••• | •• | ••• | ••• | ••• | •• | ••• | ••• | ••• | ••• | •• | ••• | •• | •• | ••• | ••• | ••• | •• | ••• | ••• | • |
| 5. | | In | yc | our | vi | ew | 7, V | vh | y i | .s 1 | the | e a | ıb | ov | re | th | e | C | as | e? | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ••• | ••• | | • • • | • • • | • • • | ••• | | ••• | ••• | •• | ••• | ••• | ••• | •• | •• | •• | •• | | | ••• | ••• | ••• | •• | •• | | ••• | ••• | •• | ••• | ••• | ••• | •• | ••• | ••• | ••• | | •• | ••• | •• | •• | •• | | ••• | •• | ••• | ••• | • |
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

6. What is the lighting condition along this road at night?

| No streetlights | |
|---------------------------|--|
| Streetlights (Poorly lit) | |
| Streetlights (Well lit) | |

7. Are you aware of the connection between street lighting and informalities (Informal commercial activities)?

| YES | |
|-----|--|
| NO | |

8. What are your thoughts about this connection/relationship and traffic safety?

9. What do you think can be done to help improve the situation?

10. What are the general behaviours exhibited by these road users which are likely to lead to a traffic accident?

| Commercial Drivers | |
|--------------------|--|
| (Trotro) | |
| Private Drivers | |
| Pedestrians | |
| Motorist/Cyclist | |
| Hawkers | |

11. Which of these factors highly influence the occurrence of accidents? (*Multiple answers should be ranked with 1 being the highest*)

| Drivers Behaviour | |
|--------------------------------|--|
| Pedestrians/Hawkers Attitude | |
| Vehicle Condition | |
| Road Condition | |
| Weather Condition | |
| Number of vehicles on the road | |

12. Have you experienced or witnessed a traffic accident before?

| NO | |
|----|--|

13. If "YES", what triggered it?

| • | |
|---|---|
| 14. What do | you think are some of the causes of vehicular accidents on this road? |
| a) . | |
| b) . | |

c) d)

e)

15. In your opinion, how effective/enforceable are these rules and regulations in reducing road accidents along this route?

a. Speed Limit

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

b. Traffic Lights

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

c. Road Signs / Road Markings

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

d. Parking Regulations

| 0 0 | |
|----------------------|--|
| Not Effective at all | |
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

e. Wearing of seat belts

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

f. Wearing of helmets by motorist/cyclist

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

g. Wrongful Overtaking

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

h. Street vending on highways

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

i. Drivers giving priority to other road users

| Not Effective at all | |
|----------------------|--|
| Not Effective | |
| Satisfactory | |
| Effective | |
| Very Effective | |

16. What are some suggestions you think can help reduce traffic accident?

.....

PART 2: DRIVERS ONLY

17. How long have you been driving?

| < 1 year | |
|-----------|--|
| 1-5years | |
| 5-10years | |
| >10years | |

18. During which of these meteorological conditions are you most cautious when driving?

| Raining | |
|------------------------|--|
| Windy | |
| High Temperature | |
| Foggy (low visibility) | |

19. Give reasons for your choice

| •••• |
|----------|
| •••• |
| •••• |
| •••• |
| •••• |
| |

20. How often do you visit the workshop or mechanic?

| Routine | |
|------------------|--|
| Only when Faulty | |
| Others (specify) | |

21. How often do you wear your seatbelts?

| Never | Very Rare | Occasionally | Often | Always |
|-------|-----------|--------------|-------|--------|
| | | | | |

22. Why?

23. Is it sometimes important to bend some traffic rules?

| Strongly | Disagree | Neutral | Agree | Strongly |
|----------|----------|---------|-------|----------|
| Disagree | | | | Agree |
| | | | | |

24. Why?

25. Have you ever violated any traffic rule?

| YES | |
|-----|--|
| NO | |

26. If "YES", under what circumstance did you violate the rule?

27. Do you think a driver's behaviour is a key factor in road safety and why?

 28. What kind of drivers' behaviour is likely to result in road accidents?

| | | |
|-------|------|-----------|
| | | |
| | | |
| | | |
| | | |
| ••••• | | ••••• |

PART 4: RESPONDENT PROFILE

| 29. | Gender | |
|-----|--------|--|
| | Male | |
| | Female | |

- 30. Age.....
- 31. What is your highest educational level?

| None | |
|----------------------|--|
| Primary | |
| Secondary | |
| Tertiary | |
| Vocational/Technical | |
| Others | |

32. Any additional Information?

| • • • • • • • • | ••••• | | • • • • • • • • • | ••••• | | | | | |
|-----------------|-------|------|-------------------|-------|------|------|------|------|-----------|
| • • • • • • • • | ••••• | | | | | | | | • • • • • |
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Appendix 5: Focus Group Discussion Guide

INTRODUCTION

My name is Mavis Agyakwah an MSc. Student at the Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, The Netherlands. I am undertaking a research entitled *"Analysing Spatio-Temporal Patterns of Vehicular Accidents in Accra (Ghana)"* with the aim of identifying some accident hot zones within the Accra Metropolis and go further to identify some location-specific explanatory factors for these incidents and possible ways of minimizing its occurrences. The purpose of this Focus Group Discussion (FGD) is to gather in-depth information about your institution (The National Road Safety Commission, Ghana) and its main roles in improving road safety in Ghana. This will take a maximum of an hour and thirty minutes (1hour and 30minutes). Thank you for agreeing to take part in this discussion.

Guiding Points for Focus Group Discussion

Present findings from analysing secondary (PowerPoint Presentation), call for their views on the findings

- 1. What is the role of your institution in Road Safety?
- 2. What is the current road safety situation in Accra?
- 3. What accounted for the fluctuations in the number of accidents from 2013 to 2015?
- 4. What are the primary cause of these incidents?
- 5. Are road safety regulations and rules effective and adequate, Why?
- 6. What are your perceptions about road safety in Accra?
- 7. What are the possible ways of improving road safety in Ghana?
- 8. What are the challenges you face in executing your roles?

Appendix 6: Key Informant Interview Guide

KEY INFORMANT INTERVIEW GUIDE

Present findings from analysing secondary

- 1. Quality of the secondary data
- 2. How the accident locations were picked
- 3. Why some incidents are geocoded and others not
- 4. Specifically discuss the methods used for the secondary data analysis and whether the methods give more insight into the data than what is being used currently
- 5. Recommendations to improve the methods used
- 6. Improvements needed in vehicular accidents data collection in Ghana
- 7. Which ways can we best include the geographical aspects in or current accident studies



Appendix 7: Segment along the Mallam Market with Location of Respondents



Appendix 8: Segment at Kwame Nkrumah Circle with Location of Respondents



Appendix 9: Segment along the Kaneshie Market with Location of Respondents





Appendix 10: A speed Limit Sign Facing the Pedestrian Walkway Passenger at an Unauthorised Location