SPATIAL ANALYSIS OF ROAD TRAFFIC ACCIDENT HOT SPOTS ALONG KADUNA-ABUJA HIGHWAY

BY

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ABSTRACT

The prime goal of highway safety managers is to limit the number as well as severity of traffic accidents by identifying and evaluating measures to improve hazardous locations or accident hot spots. The aim of the paper is to analyze road accident hot spots along Kaduna-Abuja highway using Road Traffic Accident Record, Kernel Density Estimation (KDE) were used to derive the density results of hot spot along Kaduna-Abuja highway which covers an approximate distance of 138km from Goningora in Kaduna to Tafa a border town with Niger state. The result identified 222 accidents on the route and eight (8) different hot spots along the route between the year 2010 to 2014, among which are Gonigora, Toll Gate, Sabon Gaya, NYSC, Konar Bature, Akilibu, Gidan Busa and Katari of which Toll gate was the most dangerous location on the route which accounted for 20.7% of the total road traffic accident cases. It is recommended that there is the need for regular maintenance of the highway, construction of road traffic signs along the highway especially at the hot spot locations and education of the drivers on meaning of such signs. Finally, the use of speed limit devices inside vehicles by drivers should be encouraged and police check on drunk-driving must be intensified on the highway to stem the high incidence of road traffic fatalities and injuries.

Key words: Accidents, Hot Spots, Kernel Density, Spatial Variation, Traffic

INTRODUCTION

An accident is occurrence in a sequence of events which usually produces unintended injury, death or property damage (Sharma, Singh and Mukherjee, 2011). Agbonkhese *et al.* (2013) stated that road traffic accident is an unexpected phenomenon that occurs as a result of the operation of vehicles including bicycles and handcarts on the public highways and roads. Accidents may be fatal, resulting in deaths of the road users (passengers, drivers or pedestrians), or minor when it is not severe enough as to cause substantial hardship. Accidents represent a major epidemic of non-communicable disease in the present century (Sharma, Singh and Mukherjee, 2011).

The role of transport in our daily activities cannot be overemphasized and without it, the necessities of life would be difficult to achieve. As wonderful as the role of transport may be in our daily activities, it has been noted to possess myriads of negative effects (Abdul and Ansa, 2012).

Bolade and Ogunsanya (1991) posited that despite the undisputed roles and impact of road transport in the efficient functioning of a society, one of the unavoidable negative consequences is accident occurrence. The high incidence of road accident tends to easily erode the positive effect of road transport in the nation's economy. This is why transport is described as the "maker and breaker" of the cities (Ogunsanya, 2002).

Hot spots, which are defined as relatively high-risk locations, are commonly identified on the basis of some specific selection criteria (Thakali, Kwon and Fu, 2015). Road accident hot spot analysis has traditionally centred on road segments or specific junctions (Thomas 1996, Cook *et al*., 2001) while area wide hot spots are often neglected (Anderson, 2007). One of the most commonly used selection criteria is defined by the expected collision frequencies at the sites of interest which emphasizes on maximizing the system-wide benefits of safety intervention targeted to the hot spots (Tarko and Kanodia, 2003). A number of studies have been conducted to relate traffic flow with road crash propensity. Jean-Louis (2002) showed that damage-only and injury-involved incident rates are higher in light traffic than in heavy traffic conditions. The author also compared the incident rates on the basis of time of the day and found that these rates do not depend on day time or night-time traffic.

Reshma and Sheikh (2012) pointed out that the locations that have abnormal high number of crashes are described as 'crash concentrated', 'high hazard', 'hazardous', 'hot spot or black spot'. Gregory and Jarrett (1994) opined that hot spot or a 'high risk site' is the number of personal injury accidents occurring in a 100m grid square or 100m length in a three year period on a particular class of road. Therefore, if 12 accidents are recorded over a period of three years on a 100m length of road, then the area is deemed a high-risk site. Accident black spot denote those places or spots that are prone to road accidents or where road accidents are more concentrated on a road network. This often contributes to worsen the severity of a road accident (Reshma and Sheikh, 2012).

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The Kernel Method divides the entire study area to a pre-determined number of cells and applies a circular neighbourhood around each crash. Density Estimation measures cell densities in a raster by using a sample of known points. Kernel Density Estimation associates each known point with a Kernel function. This can be expressed as a bivariate probability density function, a kernel function looks like a "bump", centering at a known point and tapering off to over a defined bandwidth or window area (Sabel, 2006). KDE includes placing a symmetrical surface over each point and then measuring the distance from the point to a reference location based on a mathematical function and then summing the value for all the surfaces for that reference location. This procedure is repeated for successive points. This therefore allows us to place a Kernel over each observation, and summing these individual

Kernels gives us the density estimate for the distribution of accident points (Fotheringham, Brunsdon, and Charlton, 2000; Anderson, 2009).

KDE calculates the density of events in a neighbourhood around those events. KDE allows some events to weigh more heavily than others, depending on their meaning, or to allow one event to represent several observations (Asgary, Ghaffari, and Levy, 2010). The main benefit of this approach lies in recognizing the risk spread of an accident (Anderson, 2009). The spread of risk can be defined as the area around a defined cluster in which there is an increased probability for an accident to happen based on spatial dependency. Secondly by using this density measure, an arbitrary spatial unit of analysis can be defined and be homogenous for the whole area which makes comparison and ultimately a taxonomy possible (Anderson, 2009). One of the attractive parts of the KDE method as compared to other variants of clustering methods is that it takes into consideration of spatial autocorrelation of crashes and it is believed to be simple as well as easy to implement. This could be one of the reasons that KDE method is being widely used in road safety (Thakali, Kwon and Fu, 2015). KDE in ArcGIS version 10.1 environment was therefore used in the determination of road traffic accident hot spots in this study.

Kaduna State serves as a link to other cities of the North and Southern parts of the country, as a result several inner and outer movements especially during the festive periods of Sallah and Christmas. This peak period movement is one of the factors that inundate the traffic landscape with Road Traffic Accidents (RTAs) along the major highways in Kaduna State (Balogun, 2013). Kaduna-Tafa (dual carriage way) linking Abuja, the study route covers an approximate distance of 138km. Due to the rapid growth of human population experienced, the numbers of vehicles on the road have led to increased traffic flow. Bala (2014) was of the view that the increasing number of traffic flows might also increase the number of road traffic accidents on the road. However, the relatively good condition of Kaduna-Abuja road which the drivers often takes advantage of by over speeding resulting to tyre burst and brake failure. This might have contributed to increased number of road traffic accidents along the study routes.

Li (2006) was of the view that accident is spatially distributed in nature hence the use of Geographic Information System (GIS) which provides the capability to store, update, retrieve, compare and spatially display data. The advancements in GIS and Remote Sensing can be put to effective use in accident analysis. In the same vein Deepthi and Ganeshkumar (2010) posited that GIS is useful in promoting linkage between various types of data and maps as well as able to visually display the results of analyses thus enabling sophisticated analysis and quick decision making. This necessitated the need to apply GIS and Remote Sensing in analyzing the road traffic accidents hot spots on Kaduna-Abuja road. The objectives are to locate and map road traffic accidents along the study route, determine the spatial distribution of road traffic accidents along the route and determine the road traffic accidents hot spots along the study route.

THE STUDY AREA

Kaduna-Abuja road is located from Latitudes 9º 20' N - 10° 29' N and Longitudes 7° 14' E - 7° 25' E Greenwich meridian. Kaduna-Abuja road has a distance of about 139km from the overhead bridge at Abuja junction Kaduna to Tafa. Kaduna state is bounded in the north by Kano, Katsina, Zamfara States in the west by Niger State, to the east by Bauchi State and in the south by Nasarawa and Plateau State (OSGOF, 2011). The state occupied a land mass of

about 48, 473.2km^2 (See Figure 1). The road is a highway that links Kaduna to Abuja. The road pass through Gonin gora in Kaduna metropolis through NYSC Camp, Doka, Katari, Jere and terminates at Tafa which is the boundary between Kaduna State and Niger State.

There are many economic activities going on in the state. Kaduna is the second largest commercial town after Kano in the north. There are economic activities going on in the state for example industrial, educational, hospitality. There are a lot of trading activities in Kaduna state. The present of various markets such as Abubakar Gumi, Central market, Kasuwa mata and general market Kafanchan all help in boasting the trading activities in the state. Transportation is especially not left behind in helping economics activities. A lot of Government and private transport companies are found in Kaduna state some of these transports goods and people within and outside the state. Road transport has been one of the most prominent transport systems in Kaduna state especially in recent times. It has served as a catalyst for economic development all over the State. The State has a network of local, state and federal roads.

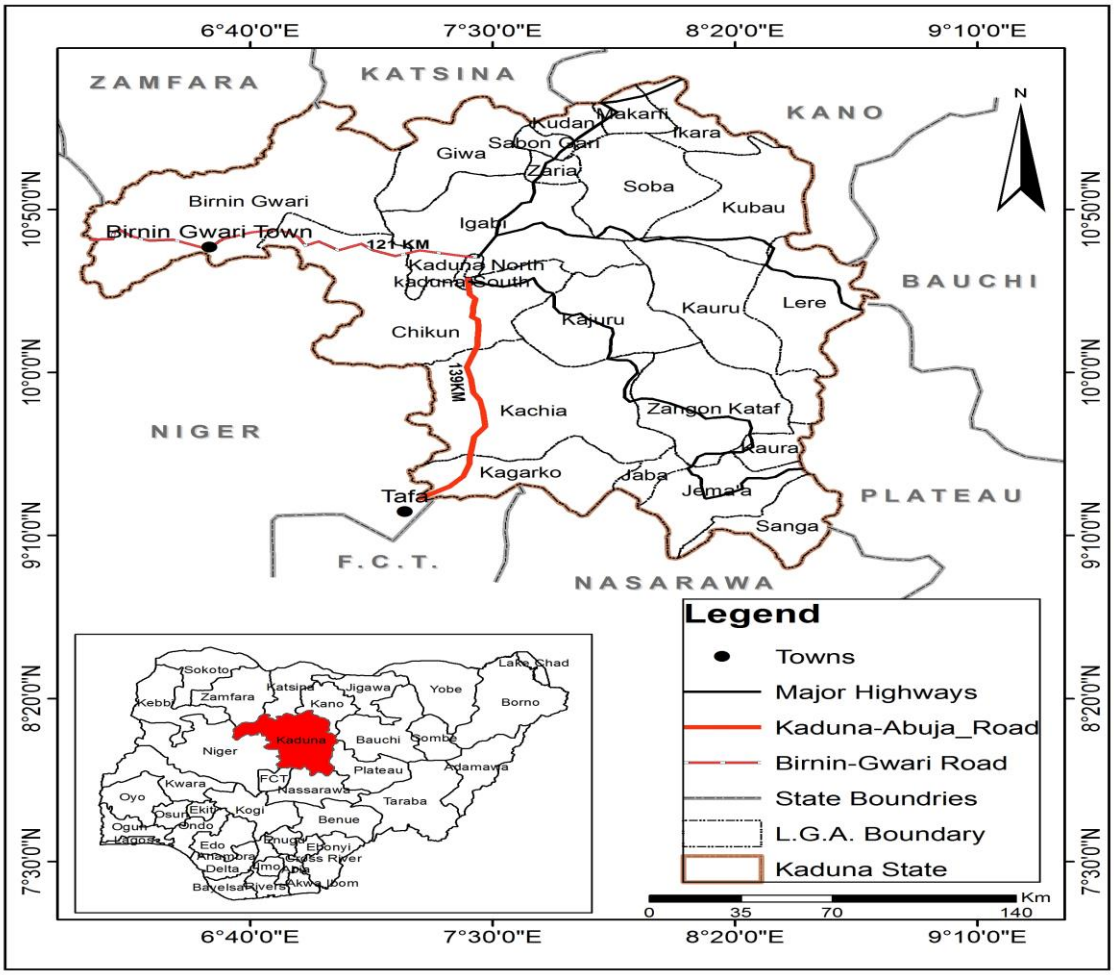

Figure 1: Kaduna State Showing the Study Route
Source: Adapted from the Administrative Map of Kaduna State

MATERIALS AND METHODS

Sources of data for this study included both primary and secondary sources. Absolute location of road traffic accident along the study area was acquired using a handheld GPS

receiver Garmin 12XL. The GPS was used to determine the geographical coordinates of the accident locations. The geographical coordinates was used to produce the accidents distribution map and map showing the accident hot spots along Kaduna-Abuja road. The accident records which are the secondary source of data were acquired from the Road Safety Commission for the year 2010-2014, and this was used for the analyses of the accidents that occurred during the period. Non-participatory observation was also used to identify the road conditions at various accident locations. Literature materials were obtained from textbooks, journal, both published and unpublished projects and FRSC bulletin, some of which were used for literature review.

The geographic coordinates of road traffic accidents locations was overlaid on the geo-referenced and digitized base map of the study route in order to map the distribution of road traffic accidents in the area. Kernel Density Estimation in ArcGIS 10.1 was utilized in mapping of the accident black spots along the route and also descriptive statistic in the form of frequency tables and charts where use to summarize the characteristics of road traffic volume in the study route according to the data collected during the traffic volume count survey.

RESULTS AND DISCUSSION

Spatial Variation of Road Traffic Accidents

The spatial distribution of road traffic accident along the study route was determined from the Federal Road Safety Commission (FRSC) records of 2010 to 2014 and also from the coordinates of the accident locations obtained with the aid of Global Positioning System (GPS). The coordinates of the accident hot spot was overlaid on the road map of the study route in ArcGIS 10.1 environment. Table 1 shows the frequency of accidents on Kaduna-Abuja Road. The data used to determine the spatial variation of traffic accidents was obtained from the records of Federal Road Safety Commission for 2010-2014 (See Table 1). GPS receiver was used to determine proper coordinates of the accident distribution and hot spots as in Figures 2 and 3.

Table 1: Spatial Variation of Road Traffic Accidents on Kaduna-Abuja Road

Location	No. of Accidents	Percentage (%)
Goingora	15	6.7
Toll Gate	46	20.7
Sabon Gayan	23	10.4
NYSC	13	5.9
Dutse Village	8	3.6
Zhipe Village	11	5.0
Konar Bature	15	6.7
Audu Jogon	8	3.6
Rijana	8	3.6
Sabon Maro	8	3.6
Akilibu	15	6.7
Gidan Busa	23	10.4
Katari	18	8.1
Total	**222**	**100**

Source: Authors' Analysis, 2016.

Figure 1: Accidents Locations along Kaduna-Abuja Road
Source: Authors' Analysis, 2016.

Road Traffic Accident Hot Spots on Kaduna-Abuja Highway

The Hot spot analysis was carried out for the route to show the section of the road or locations where there is concentration of accidents. Kernel Density Estimation method in ArcGIS 10.1 environment was used to calculate the density of accidents and in accordance with Gregory and Jarret (1994) locations with 12 road traffic accidents and above was mapped as hot spots.

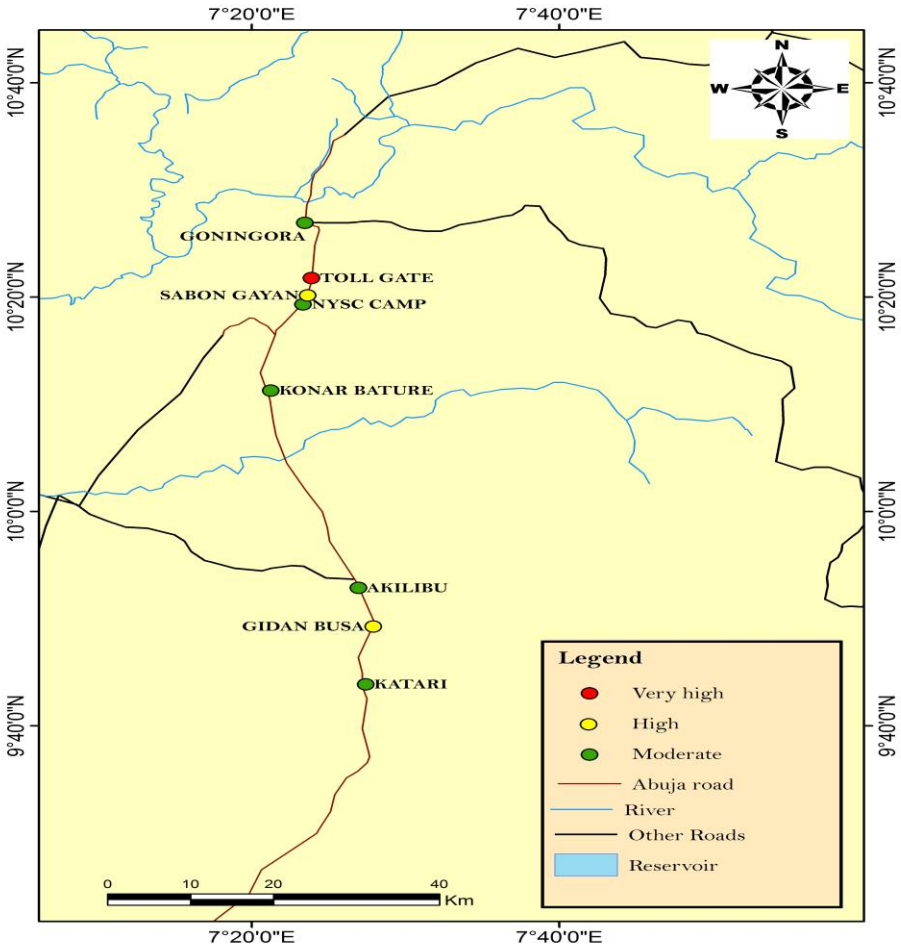

Figure 3: Road Traffic Accident Hot spot Locations along Kaduna-Abuja Road
Source: Author's Analysis, 2016.

Table 1 shows that Toll gate (20.7%), Sabon Gayan (10.4%) and Gidan Busa (10.4%) locations recorded the highest number of road traffic accidents along Kaduna-Abuja road while the least were at Dutse village, Audu Jogon, Rijana and Sabon Maro represented with 3.6% each.

The road traffic accident hot spot locations on Kaduna-Abuja highway are further shown in Figure 3 and of which Plates 1 to 5 shows some of the locations. The high record of accidents at Goningora and Gidan Busa was characterized by narrow bridges, washout and non-presence of side-rails. Toll Gate recorded the highest accident during the study period due to potholes, U-Turn and the presence of military check point. Sabon Gayan and Konar Bature are characterized by sharp bends, potholes and eroded shoulder.

Plate 1: Road Traffic Accident Location at Toll Gate (Kaduna-Abuja Road)

Plate 2: Narrow and dilapidated Bridge at Goningora (Kaduna-Abuja Road)

Plate 3: Potholes and sharp bend at Sabon Gayan along Kaduna-Abuja Road

Plate 4: Sharp bend at Konar Bature along Kaduna-Abuja Road

Plate 5: Narrow Bridge and Wash-out at Gidan Busa along Kaduna-Abuja Road

The distribution of the accident hot spots as shown in Figure 2 reveals that there were 8 hot spots along Kaduna-Abuja road among which are Goningora, Toll Gate, Sabon Gayan, Gidan Busa. Toll Gate hot spot location was the only identified very high risk area along the route. The mounting of military check point at this location during the study period (2010-2014) might be the possible reason for high occurrence of road traffic accidents at this point. The possible explanation as to why these hot spots locations have high frequency of road traffic accident could be presence of sharp bends, bridges, potholes and they are located in small townships and villages with high population density where vehicles stop for refuelling or passengers' recreations. Therefore, many accidents occur when careless drivers enter the

highway from these settlements or pedestrians doing petty businesses cross the road carelessly. Also intoxicated drivers and pedestrians might influence this.

The outcome of this study is not different from the study of Jobin (2015) that concluded that road traffic accidents hotspots are characterized by the fault in the design (sharp bends, narrow bridges) of the road, the roadway characteristics like; pot-holes, road blocks are the contributing factors for high frequency of accidents on highways. It is also similar to the findings of Lee and Fred (1999), they agreed that roadway characteristics like pot-holes, road side characteristics like; market, settlement and road design (sharp bends, narrow bridges and u-turns) among others are the principal causes of road accidents in some developing and developed countries of the world.

This study also corroborated with that of Mamman and Jediel (2014) whose study revealed that the concentration of road accidents were not evenly distributed along Kaduna-Zaria road, as more of the occurrences appear to be regular at some flash points, such as where there are sharp bends, sagging, U-turns and bad sections of the expressway.

CONCLUSION

Road traffic accident is identified as one of the leading cause of deaths along Kaduna-Abuja road. The result of the study shows that there exist spatial and temporal variations of road traffic accidents in the study area. While road traffic accidents tend to occur more at dangerous locations termed hotspots, its concentration in occurrences suggests spatial dependence between accidents and other causes. The analysis of the spatial variations of road traffic accidents as well as hotspots identification in the study area is therefore an important step in traffic accident prevention given the challenge of living safely in an ever motorized society. It is recommended that the use of speed limit devices inside vehicles by drivers should be encouraged and police check on drunk-driving must be intensified on the highways to stem the high incidence of traffic fatalities and injuries, regular maintenance of the highway is required as well as construction of road traffic signs along the highways especially at the hotspot locations and education of the drivers on meaning of such signs.

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