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A GIS-BASED SPATIAL DISTRIBUTION ANALYSIS OF ROAD TRAFFIC ACCIDENT BLACK SPOTS IN ZARIA, KADUNA STATE

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ABSTRACT

This study analyzed the spatial distribution of road traffic accident black spots in Zaria, Kaduna State, using data from the Federal Road Safety Commission (2006 – 2014) and field surveys. Accident locations were mapped using ArcGIS 10.1 with Kernel Density Estimation to identify high-risk zones. Results revealed black spots along Zaria-Kano Road (Yan Karfe, Dogarawa, Zabi, Anur Mosque) and Zaria-Sokoto Road (Polo Field, MTD, Palladan, Zango). The highest concentration of accidents occurred between 2012-2014, with 85% of fatalities along Zaria-Kano Road. Black spots were associated with poor road design and condition. The study recommends improved road infrastructure and emergency healthcare services at critical points.

Key words: GIS**,** Spatial distribution, Road Traffic, Accident, Black Spots.

1.0 INTRODUCTION

The growth and development of a nation depends largely upon the capacity of its transport system to move persons and goods to desired locations safely [1]. The provision of roads and transportation facilities are fundamentally important to the development of a country as well as the well-being of its inhabitants. Road transport is the most common used mode of transportation in Nigeria and accounts for more than 90% of the sub-sector and 3% contribution to the Gross Domestic Product (GDP). In developing countries like Nigeria, the performance of road sector has

not been satisfactory despite its enormous potentials for growth and development (New Nigeria, 2009). 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 effects of road transport in the nation's economy [2].

Road traffic accident as any vehicle accident occurring on a public highway which includes collisions between vehicles and vehicles, vehicles and animals, vehicles and pedestrians or vehicle and fixed obstacles [3]. Road accidents are among the leading causes of death in many countries, partly as an inherent consequence of the increasing mobility of today's society. Among all accidents, road traffic accidents claim the largest toll of human life and tend to be the most serious problem world over [4]. Worldwide, the number of people killed in road traffic accidents each year is estimated at almost 1.2 million while the number of people injured could be as high as 50 million [5].

The number of reported cases of fatal road traffic accidents in Nigeria has shown an increasing trend from 12,212 accidents in 1995 to 13,913 in 1996 and 15,418 in 2004 indicating an increase of 13.9% in fatal road accidents from 1995 to 1996 [6]. According to the Annual Abstract of Statistics (2008) between 2003 and 2007, a total of 225.891 accident cases were reported by the Nigeria Police Force, out of which 29,490 were fatal, 39065 were serious cases and 23,380 were minor cases.

Accidents often occur at sharp bends, potholes, and poorly maintained sections of roads [7]. The locations that have abnormal high number of crashes are described as crash concentrated, high hazard, hazardous, hot spot or black spot. Hotspot 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 spots 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 [8].

The road system, human and vehicular factors are the three elements that are inter-linked through geo-referenced traffic events which provide the basis for road safety analyzes as well as attempts to reduce the number of road traffic accidents and improve road safety [9]. Black spot safety is the task of improving road safety through alterations of the geometrical and environmental characteristics of the problematic sites in the existing road network. More specifically this task involves targeting and treating intersections and road sections with an unusual high number of accidents, the so-called black spots [10]. Black spots safety work may be divided into three phases which include; targeting black spots on the road network, prioritising the black spots to treat with safety improving measures and before and after studies of the effect of treatment [11].

Kaduna is known to be one of the cities associated with high traffic volume given that it serves as a link to other cities of the North and Southern parts of the country, as a result, much use of various automobile by its residents to meet their transportation needs. This might have resulted in an increase road traffic accidents in recent times especially at certain locations along major roads in the state. The situation has become more worrisome and a source of concern to everyone especially its negative effects on the socio-economic activities. Hence, the need for efficient movement of people and goods is for sustainable economic development in the state.

In Zaria, there are roads that facilitate the movement of people and goods for different reasons to meet up their needs. In doing this, often it results into road traffic accidents which among the causes are; careless driving (human factor), vehicular condition and sometimes road way factor. Recently the road factors consisting of potholes, poor culvert and sharp bends among others have resulted in the development of road traffic accidents black spots i.e. locations/segments along the road with high occurrence of road traffic accidents. The development of these road traffic accident black spots has further worsened the fatalities of road traffic accidents hence, the need to examine road traffic accident black spots in Zaria. This gap in knowledge that this research work intends to fill.

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2.0 AIM AND OBJECTIVES OF THE STUDY

This study analyzed the spatial distribution of road traffic accident black spots in Zaria, Kaduna State with the aim of informing measures to improve road safety. The objectives of the study are to:

i. map road traffic accident black spots using GIS.

ii. analyze spatial patterns and severity of accidents across routes.

3.0 STUDY AREA

Kaduna State is located between latitudes 9º 2' N 11° 33' N and longitudes 6° 10' E and 8° 50' E of the Greenwich meridian. 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 3.1).

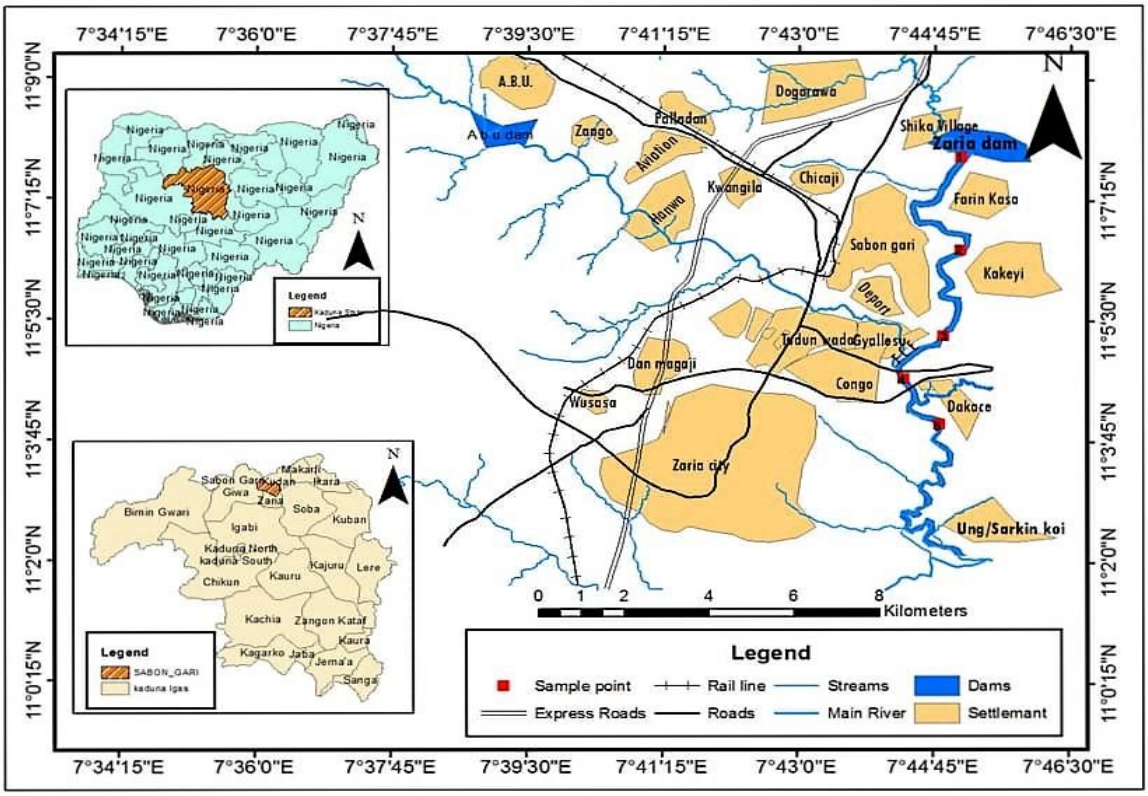


Figure I. The Study Area

Source: Modified from the Administrative Map of Kaduna State

4.0 METHOLOGY

This section discussed the various methods employed in generating data for the study; it also explained the type of data, source of data, and the methods of data analysis.

4.1 Reconnaissance Survey

A reconnaissance survey was carried out to get acquainted with the study area and Federal Road Safety Commission officers who assisted in identifying the road traffic accident black spots.

4.2 Types of Data Used

In accordance with the stated objectives, the data used included;

(i) Accident location
(ii) Accident type
(iii) Time of the accident
(iv) Number of accident
(v) Cause of accident
(vi) Condition of the road at road traffic accidents black spots

4.3 Sources of Data

In carrying out this research, the researchers made use of both primary and secondary sourced data.

4.3.1 Primary Sources of Data

Primary data on the coordinates of the location of road traffic accident black spots along the study area was acquired using handheld GPS, which was used to create map showing the road traffic accidents black spots accident locations. Field Observation was also carried out by the researcher to get relevant data on the road characteristics at the road traffic accident black spots.

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4.3.2 Secondary Sources of Data

This involved the sourcing of information through the use of documented materials such as road accident report collected from Federal Road Safety Commission. Journals, textbooks, proceedings of seminar on road accident black spots and its management which gave a background to the literature review in the study.

4.4 Data Analysis and Presentation

Both descriptive and inferential statistics test was used in analyzing the data for this study. All statistical analysis was carried out using SPSS version 20 statistical programme and Microsoft Excel 2007. The statistics used in achieving the objectives of the study was as follows:

The objective was achieved through the use Kernel Density Estimation (KDE) in ArcGIS 10.1 to determine the road traffic accident black spots along the route. KDE provided an estimate of the proportion of total accidents that can be expected to occur in any given map location. It works by first overlaying an area of interest with a fine rectangular grid. It then calculates an estimate of the density of accident in each grid cell which is based on a weight function - the kernel. The kernel is a function of specified shape and bandwidth (or search radius). The KDE is given by the equation below [12]:

$$f(x,y) = \frac{1}{nh^2}\sum_{i=1} K\left(\frac{d_i}{h}\right) \quad \text{..... (i)}$$

Where $(x,)$ is the density estimate at location (x,y), h is the search radius (bandwidth or kernel size), n is numbers of observations (total number of accidents), K is the kernel function and di, is the distance between the location (event point) (x,y) and location of the ith observation. The mean and standard deviation of the Kernel Density Estimation was used to determine the blackspot and also a raster map was generated, where the intensity of traffic accidents is represented by continuous surfaces. Lighter shades were used to represent locations with a lower traffic accident

density, while darker shades represent locations characterized by the highest traffic accident density.

5.0 RESULTS AND DISCUSSION

5.1 Introduction

This segment determined the Road Traffic Accidents (RTA) black spots along Zaria-Kano and Zaria-Sokoto Expressways and mapping of the black spots using the Kernel Density Estimation (KDE).

5.2 Spatial Distribution of Road Traffic Accident Black Spots

This section presents the spatial distribution of road traffic accident black spots in the study area. Kernel Density Estimation method in ArcGIS 10.1 environment was used to determine the road accident black spots with a search radius of 500m which was based on the black spots identification criteria for highways given by [13]. The Hot-spot analysis was done for route to see the sections of road or locations where there is concentration of accidents. Figure 2 presents the black spots map generated by Kernel Density Estimation from the FRSC data and coordinates obtained during the field observation from 2006-2014 whereas Table 1 shows the frequency of road traffic accidents at the various black spots during the period.

The result of the density estimation identified four (4) different black spot locations each along the two study routes. The black spots along Zaria-Kano route include, Yan Karfe, Dogarawa, Zabi and Anur Mosque while Polo Field, MTD, Palladan and Zango accounts for those along Zaria-Sokoto route. This shows that the number of road traffic accident black spots in Zaria-Kano (dual carriage way) and Zaria-Sokoto (single carriage way) during the period are the same.

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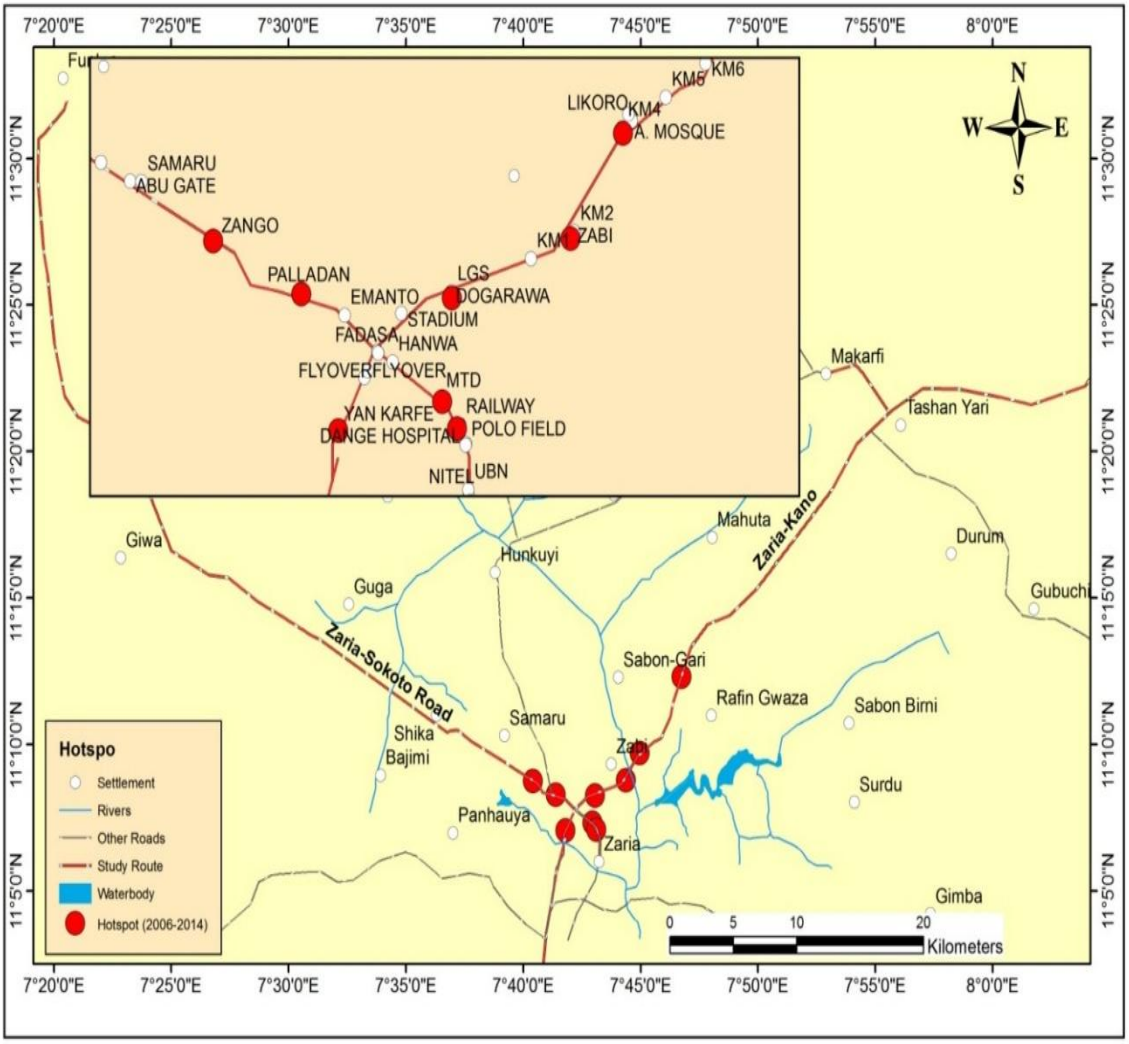


Figure 2: Road Traffic Accident Black spot by Kernel Density Estimation from 2006-2014.

Source: Author Analysis, 2016

Table 1 shows that about 66% of the road traffic accidents that occurred during this period took place in the black spots identified along Zaria-Kano road with Dogarawa (23.8%) recording the highest number of accidents. Palladan (11.3%) recorded the highest number of accidents that took place along Zaria-Sokoto road. This indicates that although the number of road traffic accident black spots during this period for the two routes were the same, more road traffic accidents were recorded along Zaria-Kano road than Zaria-Sokoto road. This supports the finding of [14] that road

traffic crashes on dual carriage roads accounted for 54.3% while 45.7% occurred on non-dual carriage roads.

Table 1: Frequency of Road Traffic Accidents at the Black Spot (2006-2014)

Route	Location	No. of Accidents	Percentage (%)
Zaria-Kano	Anur Mosque	34	20.2
	Zabi	21	12.5
	Dogarawa	40	23.8
	Yan Karfe	16	9.5
Zaria-Sokoto	Polo Field/ Railway	18	10.7
	MTD	12	7.1
	Palladan	19	11.3
	Zango	8	4.8

Source: Author Analysis, 2016

This shows that most road traffic accident black spots were located at road intersections and sharp bend. This is inconsistent with the finding of [15] that most of road traffic accidents hotspot points were located at intersections between N6 and N4 with villages and small cities like khessibia, Hassine, Oggaz and Sig. Also the recording of higher number of road traffic accidents recorded along Zaria-Kano road than Zaria-Sokoto road could be attributed to difference in the volume of traffic handled by each of these routes.

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The general objective of the study was to analyze the spatial distribution or pattern of road traffic accident black spots in Zaria, Kaduna State. The study made a number of findings from the results which includes;

i. The density estimation identified four (4) different hotspot locations each along the two study routes. The black spots along Zaria-Kano route include, Yan Karfe, Dogarawa, Zabi and Anur Mosque while black spots along Zaria-Sokoto route include Polo Field, MTD, Palladan and Zango. The study shows no difference in the number of road traffic accidents black spots in Zaria-Kano (dual carriage way) and Zaria-Sokoto (single carriage way) during the period. Although the number of black spots was the same along both roads, accident frequency was higher along Zaria-Kano road, particularly at Dogarawa which accounted for 23.8% of cases. This may be attributed to higher traffic volume or poor design features along the dual carriageway.

ii. The study reveals that more than half of the road traffic accidents recorded between 2006 and 2008 occurred at the black spots identified along Zaria-Kano where most recorded similar accident frequencies. For 2009-2011, four (4) black spots were identified along Zaria-Kano road whereas Polo Field/Railway was the only black spot along Zaria-Sokoto road. About 70% of the road traffic accidents recorded from 2012-2014, occurred at the six (6) black spots identified along Zaria-Kano, four (4) were identified along Zaria-Sokoto road.

iii. The study reveals that road traffic accidents at the black spots along the routes were characterized by both deaths and injury. It was found that number of persons death and injured as a result of road traffic accidents were much in the hot spots along Zaria-Kano road.

iv. This study revealed that the road designs of most hotspot locations were characterized by sharp bends, U-turn and intersections. Similarly, other road conditions like presence of potholes, eroded road shoulder and stationary vehicles were found at the various black spot locations.

6.2 Conclusion

Road Traffic accidents tend to occur more at dangerous locations. Its concentration in occurrences suggests spatial dependence between accidents and other causes. These locations often termed black spots can be detected by several geo-statistical techniques of which among are kernel density

estimation. This identification and analysis are an important step in traffic accident prevention. It can be concluded that both the dual and single carriage ways have the same number of road traffic accident black spots across the years although, on the temporal basis slight difference were recorded. Also, road way characteristics were discovered to be one of the contributing factors to the fatality of road traffic accidents at the various black spot locations.

6.3 Recommendations

Based on the outcome of this research on the spatio-temporal analysis of road traffic accident black spots, the following are recommended:

i. Emergency healthcare services should be available at various black spots locations on the highways. This will ensure that adequate first aid treatment is given to accidents victims as a result, reduction in fatality rate;
ii. FERMA should urgently rehabilitate eroded shoulders and potholes along identified black spots.
iii. Road safety signage and realignment of dangerous bends should be prioritized.
iv. Finally, deploy traffic officers to control movement at accident-prone intersections.

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