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# Spatio-Temporal Analysis of Road Accidents in Abuja, Federal Capital Territory (FCT), Nigeria Using Geographical Information System (GIS) Techniques

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## Authors' contributions

The work was carried out in collaboration between all authors. Authors AEO and OF designed the study while author AEO planned the field survey and wrote the first draft of the manuscript. Authors VO and SAA supervised the fieldwork and carried out statistical analysis including mapping. All authors read and approved the final manuscript.

Original Research Article

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## ABSTRACT

**Aims:** Road accidents have impacted adversely on the socio-economic development of cities in developing countries. Abuja, the administrative headquarters of Nigeria is known for regular occurrences of such accidents. This study attempted to identify factors responsible for these accidents and assessed their pattern with a view to mapping the black spots in the city using GIS techniques.

**Study Design:** The study was an attempt to investigate the various accident spots in Abuja, Nigeria in a bid to present a platform for proffering plausible solutions to the rampant road accidents in the city.

**Place and Duration of Study:** Abuja, Nigeria, between January 2011 to July 2011.

**Methodology:** Road accidents data from road users, National Union of Road Transport

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Workers (NURTW) and Federal Road Safety Corps (FRSC) were acquired using structured questionnaire. Also, secondary data including topographical map, quick bird image, accident records between 2009 and 2011, and GPS points of areas prone to road accidents were plotted on the Abuja base map. These data were integrated and analyzed using spatial analysis tools of ArcGIS 9.3. Table data were also imported into ArcGIS database. Overlay function and query operation were performed to determine the accident hotspots based on the frequency of road accidents and their spatio-temporal trend.

**Results:** Findings showed that Wuse maintained the highest black spots while Asokoro experienced the least. It was observed that accidents are caused by road, vehicle, driver and environmental factors.

**Conclusion:** The study recommends provision of functional traffic lights and defining danger times of high risk locations in Abuja.

*Keywords: Road accident; spatio-temporal trend; GIS; geospatial database; Abuja.*

## 1. INTRODUCTION

The rapid urbanization and motorization has resulted in deterioration of the environment, traffic congestion and major road safety issues. Transportation infrastructure represents one of the largest and most critical investments by any country. Based on the fact that movement of people and goods are vital to every aspect of the country's economy. Most unfortunate incidence in the transportation sector is the case of road accident that constitutes a major cause of death, injuries, disabilities and property damages in many countries [1]. Road traffic injuries (RTIs) are responsible for approximately 1.2 million deaths worldwide and 50 million injuries each year [2]. RTI rates are particularly high in the developing countries due to poorly maintained road networks and motor vehicles [3]. These rates are projected to rise as developing countries become increasingly motorized [4]. On average, over 15,000 crashes occur daily in the United States, most of which involve only damage to property [5]. The incidence of fatal road traffic accident is highest in the developing countries. Similarly, the prevalence of accident and injury related disability calculated using the Disability Adjusted Life Expectancy (DALE) is highest in sub-Saharan Africa and lowest in countries with established market economies [6].

Escalation in road accident rates is most evident in Africa, where ownership of motor vehicles is among the lowest in the world. It has been projected that, by 2020, road traffic deaths will rise 60% worldwide and 80% in Africa [7]. The World Health Organization [8] predicts that road traffic injuries will rank third among causes of injury related disability. The road traffic injury death rate is highest in Africa, 28.3% per 100,000 population compared with 11% in Europe. In Nigeria, virtually all the states have the unenviable record of increase in severity index between 1970-1974 and 1977-1986 [9]. The fatality index was lowest in the urban areas of the country even though they have more road transport accident cases; the 'Ember' months were not as dangerous as mid-year months; more accident were recorded when salaries are paid; highest on Friday and lowest on Saturday and highest between 10am and 6 pm and lowest between 1am and 5 am respectively [9]. The most affected population of road transport accidents are the young adult male aged 20-29 years [10]. This is corroborated in the viewpoint expressed by [7] that more than 75% of road casualties are in the 16 to 65 years age bracket and children are often injured as pedestrians.

Moreover, the financial loss following death or injury of the Nigerian youth is difficult to quantify in monetary terms but must run into millions of Naira annually. It is this sort of loss that no nation least of all a developing country can afford especially when it is remembered that it is on this group of people that national growth and prosperity depend. When compared with such other conditions as communicable diseases, it can be seen [10] that deaths from road crashes outweigh recorded deaths of these other conditions. Notwithstanding the staggering effect of accident on the population and the concern expressed by the public, the government efforts to stem the tide have not matched the magnitude of the problem. Road accident is a multi-causation event which needs to be handled intricately. Thus, proper and systematic preventive and proactive measures should be proposed to minimize road accident problems [1].

It is worthy of note to say that accidents are caused by multifaceted factors comprising the road, vehicle, driver, environment and other factors arising from these four factors. The approach towards solving accident problems have also been multifaceted comprising enforcement, enlightenment, engineering, and environmental approaches. These approaches have been appropriately coined the 4 Es. Following these approaches traffic management problems have been solved in the past by continuously widening the road, optimizing the existing road network with various traffic management measures and encouraging the use of public transport.

Traffic management measures such as these are good but adequate information is hardly available. Traffic information should be adequate, timely, frequent and spatial before we can model the accident situation of an area. The information should be capable of telling why, when and where to locate command post. The information should show how to deploy Road Safety patrol vehicles to accident scene, how to locate a black spot, how to determine the shortest route to locations and the closeness of spatial features. The information should show the nearest help area, the intersection at which most traffic accidents occur, how close the accident spots are to the freeway exit and which social facility attracts more traffic.

In view of the above, linking geographic location to accident information and socio-economic characteristic of accident victim is vital to decision making. The deaths of persons and serious economic loss caused by road accident demand a continuous attention relative to the spectacular growth in road transportation. Analyzing accident patterns usually involves large volume of data and the database mostly exists in the form of linear record file system, only helpful in placing the analyzed information in tabular forms, missing the spatial distribution of accidents, which is an essential element in analyzing accident locations.

The diverse forms of data generated from traffic (spatial, and aspatial) can best be combined and analyzed with the Geographic Information System (GIS). Unfortunately, this technology is yet to be fully embraced in this part of the world as aid to our planning and decision making process. The study therefore empirically highlights the relevance of GIS as a tool for investigating the causes and patterns of road traffic accidents with a view to developing a spatial decision support system for road traffic management in Abuja Metropolitan Area Council, Nigeria.

## **2. MATERIALS AND METHODS**

### **2.1 The Study Area**

Abuja, the capital of Nigeria came into existence by virtue of the Federal Capital Territory Act, of 1976. It is located in the center of Nigeria in the Federal Capital Territory (FCT). The Federal Capital Territory has a land area of 8,000 square kilometers, while the City proper covers a total land area of 250 square kilometers. The FCT is bounded on the north by Kaduna State, on the west by Niger State, on the east and south-east by Plateau State, and on the south-west by Kogi State. It falls within latitude 7° 25' N and 9° 20' North of the Equator and longitude 5° 45'E and 7° 39'E of the meridian. Abuja is a planned city, and was built mainly in the 1980s. It officially became Nigeria's capital on 12 December 1991, replacing Lagos, the previous capital. The 2006 census estimates the population of the Federal Capital Territory at 778,567.

Abuja's geography is defined by Aso Rock, a 400-metre batholiths left by weathering and erosion. The Presidential Complex, National Assembly, Supreme Court and much of the town extend to the south of the rock. "Aso" means "victorious" in the language of the (now displaced) Asokoro ("the people of victory"). Other sites include the Nigerian National Mosque and the Nigerian National Christian Centre. The city is served by the Nnamdi Azikwe International Airport with Zuma Rock lies nearby. Abuja is known for being the best purpose-built city in Africa as well as being one of the wealthiest and most expensive; however, most population on the semi-developed edges of the city are living in shanty towns to house the capital's civil servants and lower income families.

It has landscape of rolling hills, isolated highlands and gaps with low dissected plains. The South West Area has the lowest elevation where the flood plain of Gurara River is at an elevation of about 70m above sea level. The land rises irregularly from there; eastward we have Bwari, Aso range in the North East and the Idonkasa Range North West of Gwagwalada. There are other isolated inselbergs dotting many parts of the Federal Capital Territory.

Abuja experiences an average daily minimum and maximum temperature of 20.5°C and 30.8°C respectively. This has its minimum in August and September and the highest in January- March. It has a mean rainfall and humidity of about 119.2mm and 58.4% respectively with the highest in August and lowest between November and March respectively [11].

Abuja has six Area Councils namely: Abaji, Kuje, Kwali, Gwagwalada, Bwari and Abuja Municipal. For this study, Abuja Municipal Area Council (AMAC) was selected. AMAC has five Districts namely Maitama, Wuse, Central District, Asokoro, and Garki Fig. 1. Its choice was informed by the fact that this Council Area constitutes the central business district of Abuja in addition to housing all the important government establishments including the Federal Secretariat, Legislative houses, the Central Bank, Federal Ministers' quarters, Legislative quarters and the Presidential Lodge among others.

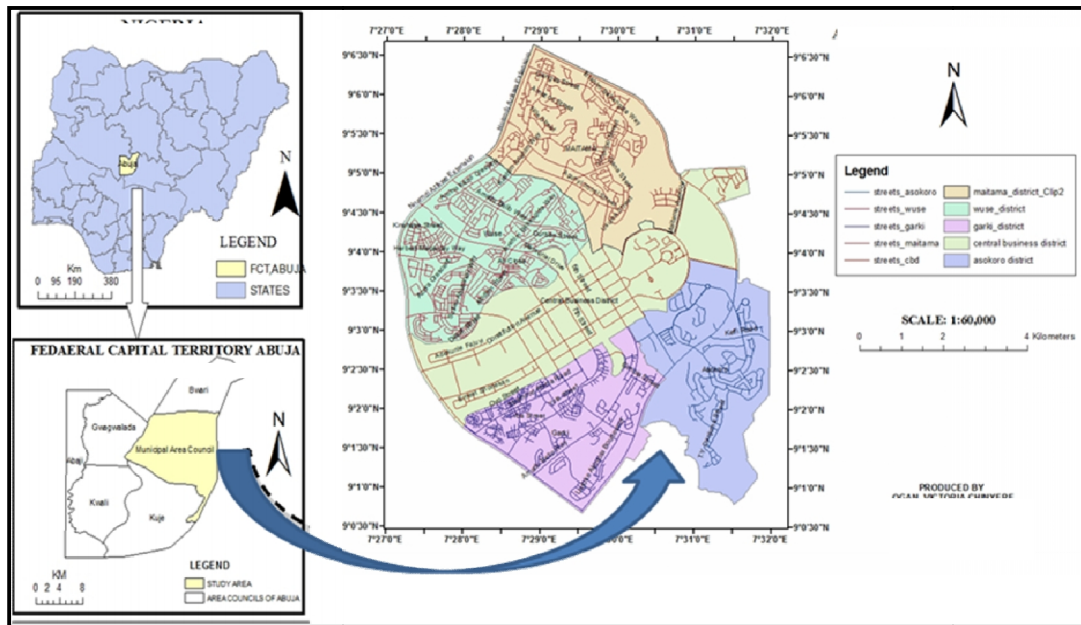


Fig. 1. Study Area Location Map

### 2.1.1 Central district

Abuja's Central District is located between the foot of Aso Rock and into the Three Arms Zone to the southern base of the ring road because it houses the administrative offices of the executive, legislative and judicial arms of the Federal Government. The Central District is the city's principal Business Zone, where practically all parastatals and multinational corporations have their offices located. The National Hospital is also located in the central area. A well known government office in this District is the Ministry of Defense, popularly nicknamed the "Ship House".

### 2.1.2 Garki district

The Garki District is the area in the southwest corner of the city, having the Central District to the north and the Asokoro District to the east. Garki uses a distinctive naming convention of "Area" to refer to parts of Garki. These are designated as Areas 1 to 11. The Abuja Municipal Area Council, which is the local Government administration, has its headquarters in Area 10. Garki is presently the principal business district of Abuja. Numerous buildings of interest are located in this area some of them include the Garki Hospital, Abuja International Conference Centre and the Headquarters of the Nigerian Armed Forces, namely Army Headquarters, Air force Headquarters and Navy Headquarters are all located in the Garki District. The tallest building in this District is the Radio House, which houses the Federal Ministry of Information and Communications, and the Federal Radio Corporation of Nigeria (FRCN). The Nigerian Television Authority (NTA) Stations and Corporate Headquarters are also based in Garki. The Federal Capital Development Authority (FCDA) which oversees and runs the Administration of the Federal Capital Territory has its offices in Area 11, Garki. .

### **2.1.3 Wuse district**

Wuse District is the northwestern part of the city, with the Maitama District to its north and the Central District to its south. The District is numbered Zones 1-8. The Wuse Market is Abuja's principal market. The second most important Post Office in the city is located here. This District also houses the Sheraton Hotel and Towers, the Foreign Affairs Ministry Headquarters and Nigerian Customs Services Headquarters, Road Safety Commission (FRSC), National Agency for Food and Drugs Administration (NAFDAC), Wuse General Hospital, and the Nigerian Tourism Development Corporation.

### **2.1.4 Maitama district**

Maitama District is to the north of the city, with the Wuse and Central Districts lying to its southwest and southeast respectively. This area is home to the top bracket sections of society and business, and has the reputation of being very exclusive and very expensive. Interesting buildings include the Transcorp Hilton Hotel, National Communications Commission Headquarters (NCC), National Universities Commission (NUC), Soil Conservation Complex, and Independent National Electoral Commission (INEC). Maitama District Hospital is another notable building in Maitama.

### **2.1.5 Asokoro district**

The doyen of all the Districts, houses all of the state's lodges/guest houses. The ECOWAS secretariat is a focal point of interest. Asokoro is located to the east of Garki District and south of Central District. It is one of the most exclusive Districts of Abuja and houses virtually all of the federal cabinet ministers; in addition, the Presidential Palace (Aso Rock) is located in Asokoro District. By virtue of this fact, Asokoro is the most secured area of the city.

The relocation of the Federal capital of Nigeria from Lagos to Abuja brought a lot of changes to the pattern and organization of settlements in Abuja. At first, these changes caused outer fringe to inner core movement but the high rent in the Federal Capital City (FCC) has for some time now driven the low and medium income earners back to the satellite towns of FCC. Right now there is inflow of people and vehicles into FCC in the morning and outflow to satellite towns in the evenings. This scenario has far reaching effect on the accident rate along the transit corridors and on the internal circulation in FCC during the work period. The resulting traffic congestion along Wuse, New Market, Area 10, Federal Secretariat and so on deteriorates the environment, increases the accident rate involving pedestrians, causes drivers stress, frustrations, delay and time losses. Though, Nigeria Watch in 2008 on a national level rated Lagos as the most populated city in the country and with highest number of road casualties but Abuja was rated as more dangerous when compared to the number of inhabitants. Nigeria Watch also reported that the probability of having a car accident is much higher in the Federal Capital Territory, Abuja appears twice more dangerous than Lagos in this regard. It is against this backdrop that this study selects the AMAC as the study area with a view to integrating spatial and temporal dimension of road traffic accidents and improving the understanding of traffic and transportation management.

## **2.2 Conceptual Framework**

Man by nature without knowing makes model of all his activities and plan based on this. Models are often monotonous, requiring repetitive task at high speed, and require absolute mechanical accuracy of space-time effect which only the computer can provide. Spatial

planning models have a long tradition in social sciences dating back to Ravenstein [12], while insight into the spatial-temporal nature of it, was reported by Lotka [13]. But the spatial modeling began in the 1950s alongside computer availability. Some models may not be possible today but for the speed and memory of computers.

The principle of geographic information system (GIS) was first conceived in the 1960s and the first (the Canadian Geographic Information System) was implemented in 1964 [14]. The rapid development however is attributed to the rapid reduction in the cost of the hardware and software development, proliferation of data in computer readable format, advances in geographical theory and the practical use of GIS in economic world.

Most studies using GIS have been limited primarily to black spot analyses [15] display site history with a view to showing impact of road design on safety. According to literature, black spots occur on a map when several accidents occur at the same location. It is also possible to use GIS to evaluate the safety benefits of various local counter-measures activities by examining the frequency and spatial distribution of accidents. GIS can be used to identify roads with high exposure to risk by generating disaggregated data with a variable already evaluated with a statistical package. Apart from investigating accident occurrence along specific route, the use of GIS permits analysts to visually inspect the spatial distribution of accidents and interactively query individual site. This research provides opportunity to evaluate incidences along the road and at individual location with GIS.

Functional database management systems are germane in this kind of study and have to be established and maintained. It is necessary to build a database that keeps track of accident because accident database is the building block for accident reduction and prevention. The operation of an accident investigation procedures hinges on the existence of a reliable database and clearly defined technical procedure. The key elements of a geospatial accident database are an accurate location reference, basic information describing the accidents, its victims and the events leading to the accidents. In Nigeria as a typical developing country, there is scarce information about accident phenomena. Most of the accident investigation reports are still stored as paper documents which wear out and become illegible with time, this makes data extraction from such documents cumbersome and futile. So far, there is no integrated database that accounts for accident statistics despite the daily occurrence of accident on our roads. A GIS-based application was chosen as a better alternative to improve the accuracy and timelines in prioritizing accident location in AMAC. The initial advantages are its ability to locate locations quickly and accurately on a map, to support a database with relationships between spatial reference and tabular attributes, and allow integration of user-interface and analytical tools. It is worthy of note to say that an accident database management system has been pinched on the ground of its deficiency in identifying accident-prone location [16]. Thus, the best approach is to integrate GIS and accident database management system to offer more comprehensive management systems which this study adopts to accomplish the purpose of this research work.

### **2.3 Research Methods**

The study utilized both primary and secondary data sources. The primary data sources used include GPS points of accident prone locations and administration of structured questionnaire to elicit accident information from road users, Federal Road Safety Corps (FRSC) and National Union of Road Transport Workers (NURTW) in each District. 200 copies of structured questionnaire with open and close end questions were administered in five Districts namely Maitama, Wuse, Central Area, Asokoro and Garki using a systematic

random technique. Considering the homogenous nature of the research population in these Districts, the sampling size is considered adequate.

The study also utilized secondary data which include high resolution satellite image (Quick bird, 2011) which was obtained from Office of Surveyor General of the Federation (OSGOF); accident records from FRSC between the years 2009 – 2011 and the topographic map of Abuja which served as a base line data. In addition, the road map of the city was obtained from OSGOF. This map assisted in naming the various streets in the study area.

## **2.4 Equipment**

### **2.4.1 Hardware**

The hardware utilized by this study include Toshiba Satellite L500-19X laptop with 500GB of HDD, 4 GB of RAM, 2.10 GH clock-speed, 32-bit Windows 7 Operating System, A4 HP DeskJet Printer and Garmin Handheld Global Positioning System (GPS).

### **2.4.2 Software**

The study used the following software: ARCGIS 9.3 for georeferencing, onscreen digitizing, spatial analysis and processing of the maps; Microsoft Excel 2007 for statistical analysis and Microsoft Word 2007 for report writing in textual format.

### **2.4.3 Data preparation**

Analogue maps with spatial references (coordinate values) such as the topographic and road map Fig. 2 were scanned to enable clarity and better contrast of the scanned map while the Quickbird image in digital format with spatial reference was cross checked and validated.

The scanned maps were geo-referenced in ArcGIS 9.3 ArcMap environment with Root Mean Square (RMS) error of 0.0002 and sub-mapped using a polygon feature marking the area of interest (AOI), the same AOI was used to clip the satellite image. Subsequently the whole raster data was overlaid to check for spatial agreement in geo-referenced process and value.

### **2.4.4 Geospatial data creation, spatial data extraction, coordinate plotting and data editing**

Following the overlaid verification, a personal geo-data base (PGDB) was created in Arc Catalog, a native data structure for storing and managing geographic information. Feature dataset were created in the PGDB and projected. The feature classes created were accident location (point features), road and river (linear features), dam and boundary (polygon features). The spatial data for the project were extracted from the high resolution satellite image and topographic map through on-screen digitizing. Digitizing was done in Arc Map by tracing out features from the background map and image. The re-sampled data (map and image) were added to Arc Map with add button and features of interest were digitized. Data acquired from GPS and secondary data in table format have different preparation in order to make them compatible with the software utilized for the analysis. For the GPS coordinates of points located during field work were arranged in tabular form in Microsoft excel with their attributes while their “X” and “Y” coordinates were converted to decimal degree. The table data was also arranged in Microsoft excel sheet after which they were all imported into



ArcGIS database. GPS readings of accident locations obtained during field survey were plotted to establish their positions on the map. Plotting of GPS readings were carried out with the aid of the editor tool. Absolute latitude (X) and longitude (Y) were plotted directly on the map. Editing was performed after digitizing to trim overshoots and close up under shoots. Finally overlay function was performed; layers were overlaid on one another to check topological relationship among the features. Consequently, query operation was performed to determine the accident hotspots, based on the high frequency of road accidents, in each of the five Districts in AMAC. Further, spatio-temporal trend of accident events over the three years was carried out using the spatial join tool in the overlay function. This process involved the selection of a target feature, join feature and field(s) upon which the join was carried out. Spatial join operation was performed on two years at a time, later on the third year and the preceding year to determine the relationship with respect to location between the years selected.

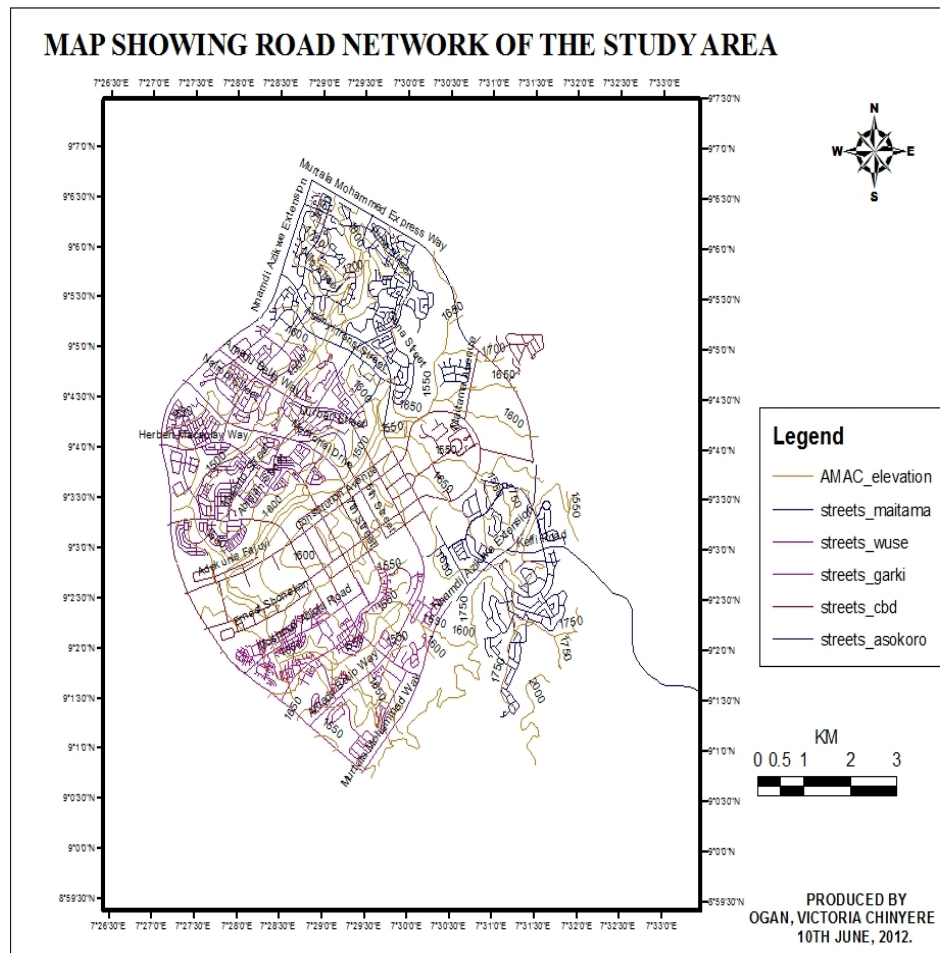


Fig. 2. Road Network of the Study Area

### **2.4.5 Statistical analysis**

Descriptive analysis was carried out on the road accident data obtained from FRSC to facilitate comparison and contributory causes within the three years of study.

## **3. RESULTS AND DISCUSSION**

### **3.1 Results**

#### **3.1.1 Causes of road traffic accidents in AMAC from 2009-2011**

The results of the analysis on the FRSC road accident cases over the three years (2009-2011) and responses from questionnaire administration were shown in Tables 1a, 1b, 1c and 2. Table 1a showed that most of the road accidents reported in 2009 in AMAC was caused by dangerous driving (23.1%). The Table further revealed that brake failure accounted for 13.7%, tyre burst was responsible for 11.1%, over speeding contributed 10.3% and wrong overtaking caused 7.7%. The other causes identified include poor vision brought about 6.8%, loss of control and fatigue recorded 5.1% and 4.3% respectively. From Table 1b, dangerous driving maintained its leading position in 2010 as the most contributory cause of road accidents in AMAC by accounting for 18.8%. The table further showed that 17.4% of the reported cases of road accidents were caused by over speeding while brake failure contributed 15.7%, tyre burst (11.6%), wrong overtaking (10.7%), loss of control (8.3%), fatigue and poor vision 6.6% apiece. However, Table 1c showed that tyre burst became the predominant cause of road accidents in AMAC in 2011 with 19.4%, followed by loss of control (17.6%). Other identified contributory causes include dangerous driving (14.8%), over speeding (12.0%), wrong over taking (11.1%), brake failure (9.3%), fatigue and poor vision 6.5% apiece.

In Table 2, the study further explored the causes of road accidents in the study area. The Table revealed that 50.5% of the respondents attributed the cause of the accidents to human factor. 24.5% respondents considered road factor as an important element of road accident in AMAC. Whilst environmental and vehicle factors were identified by 8.5% and 16.5% respondents respectively. It was further observed from this Table that human factor was largely responsible for accidents in all the Districts in the study area. This was followed by road factor in Asokoro, Garki and CBD. However, vehicle factor also played significant role in road accident in Wuse and Maitama Districts.

The above factors have been found to have contributed to 125 crashes, 423 fatalities and 1,465 injuries in 2009; 127 crashes, 77 fatalities and 793 injuries in 2010; and 124 crashes, 13 fatalities and 443 injuries Table 3. Further analysis showed that the total crash recorded increased by 1.6% in 2010 but dropped by 0.8% in 2011 while fatality decreased significantly by 81.8% in 2010 and further dropped by 96.9% in 2011. The total injury cases was found to have declined by 45.9% in 2010 and further decreased by 69.8% in 2011. However, there were very insignificant decrements in the rate of crashes during the study period. The decline in fatality and injury was largely explained by the strict enforcement of the regulations on compulsory usage of sit belts coupled with other penetrative awareness campaign by FRSC.

**Table 1a. Contributory Causes of Road Traffic Crash in AMAC for the Year 2009**

Districts	Sped	Ddvg	Lsct	Ftge	Pvsn	Brfl	Wovt	Tybu	Ots
Asokoro	2	6	1	1	1	5	1	2	3
Garki	5	5	1	1	2	2	1	2	3
Cbd	1	4	2	1	1	3	2	5	2
Wuse	2	7	2	1	2	4	4	1	5
Maitama	2	5	0	1	2	2	1	3	8
<b>Total = 117(100%)</b>	<b>12 (10.3%)</b>	<b>27 (23.1%)</b>	<b>6 (5.1%)</b>	<b>5 (4.3%)</b>	<b>8 (6.8%)</b>	<b>16 (13.7%)</b>	<b>9 (7.7%)</b>	<b>13 (11.1%)</b>	<b>21 (17.9%)</b>

*SPED: Speed; DDVG: Dangerous Driving; LSCT: Loss of Control; FTGE: Fatigue; PVSAN: Poor Vision; BRFL: Brake Failure; WOVT: Wrong Overtaking; TYBU: Tyre Bust; OTHS: Others, Source: FRSC, 2011*

**Table 1b. Contributory Causes of Road Traffic Crash in AMAC for the Year 2010**

District / Cause	SPED	DDVG	LSCT	FTGE	PVSAN	BRFL	WOVT	TYBU	OTHS
ASOKORO	1	7	1	0	1	9	1	2	1
GARKI	2	10	1	3	2	3	4	2	1
CBD	4	2	3	3	2	4	3	3	1
WUSE	7	2	4	1	1	2	4	3	2
MAITAMA	7	1	1	1	2	1	1	4	1
<b>Total= 121(100%)</b>	<b>21 (17.4%)</b>	<b>22 (18.8%)</b>	<b>10 (8.3%)</b>	<b>8 (6.6%)</b>	<b>8 (6.6%)</b>	<b>19 (15.7%)</b>	<b>13 (10.7%)</b>	<b>14 (11.6%)</b>	<b>6 (5.0%)</b>

*SPED: Speed; DDVG: Dangerous Driving; LSCT: Loss of Control; FTGE: Fatigue; PVSAN: Poor Vision; BRFL: Brake Failure; WOVT: Wrong Overtaking; TYBU: Tyre Bust; OTHS: Others, Source: FRSC, 2011*

**Table 1c. Contributory Causes of Road Traffic Crash in AMAC for the Year 2011**

District / Cause	SPED	DDVG	LSCT	FTQE	PVSAN	BRFL	WOVT	TYBU	OTHS
ASOKORO	0	7	4	0	0	10	3	2	0
GARKI	2	4	3	2	4	0	4	5	0
CBD	1	4	7	1	1	0	1	5	1
WUSE	3	1	4	4	2	0	3	3	2
MAITAMA	7	0	1	0	0	0	1	6	0
<b>Total= 108(100%)</b>	<b>13 (12.0%)</b>	<b>16 (14.8%)</b>	<b>19 (17.6%)</b>	<b>7 (6.5%)</b>	<b>7 (6.5%)</b>	<b>10 (9.3%)</b>	<b>12 (11.1%)</b>	<b>21 (19.4%)</b>	<b>3 (2.8%)</b>

The study further scrutinized the nature of road traffic accident locations within the study period. According to Table 4, crash cases increased by 5% within the built up area in AMAC between 2010 and 2011 while 4% increase in crash cases was recorded along undivided road in the same period. The table further showed that injury cases increased by 2% along divided road between 2010 and 2011. Throughout the study period, it is remarkable that crash, fatality and injury cases declined at road bend. Whilst between 2009 and 2010, more crash and fatality cases took place along straight road with increase of 3% and 2% respectively. The injury case also rose by 1% between 2010 and 2011. At the road intersection, there was an increase of 8% cases of crash between 2009 and 2010, and 1% increase in the injury cases between 2010 and 2011. Further, at bridge points, 2% increase in crash cases between 2010 and 2011, 1% increase in fatality between 2009 and 2010, and 2% increase in injury cases between 2009 and 2011. Along the good roads in the AMAC, crash cases increased by 2% between 2009 and 2010 and further rose by 1% between 2010 and 2011 while the fatality cases jumped up by 4% between 2009 and 2010. Between 2009 and 2010, road traffic crash cases increased by 4% at fair road. Fatality cases of road traffic accidents also shot up by 2% in the same period. Expectedly, the cases of crash and fatality of road traffic accidents at poor road increased by 6% and 4% between 2009 and 2010.

**Table 2. Respondents Perception on Causes of Accident**

District / cause	Cause			
	Human factor	Road factor	Environmental Factor	Vehicle factor
Asokoro	20	10	6	4
Garki	22	9	3	6
Cbd	20	14	4	2
Wuse	16	10	2	13
Maitama	23	6	2	8
<b>Total= 200(100)</b>	<b>101 (50.5%)</b>	<b>49 (24.5%)</b>	<b>17 (8.5%)</b>	<b>33 (16.5%)</b>

Source: Fieldwork, 2012

**Table 3. Road Traffic Accident (RTA) Cases (2009 – 2011)**

RTA / Year	2009	2010	2011	Change between 2009 and 2010	Change between 2009 and 2011
Crash	125	127	124	+2 (1.6%)	-1 (0.8%)
Fatality	423	77	13	-346 (81.8%)	-410 (96.9%)
Injury	1465	793	443	-672 (45.9%)	-1022 (69.8%)

Source: FRSC, 2011

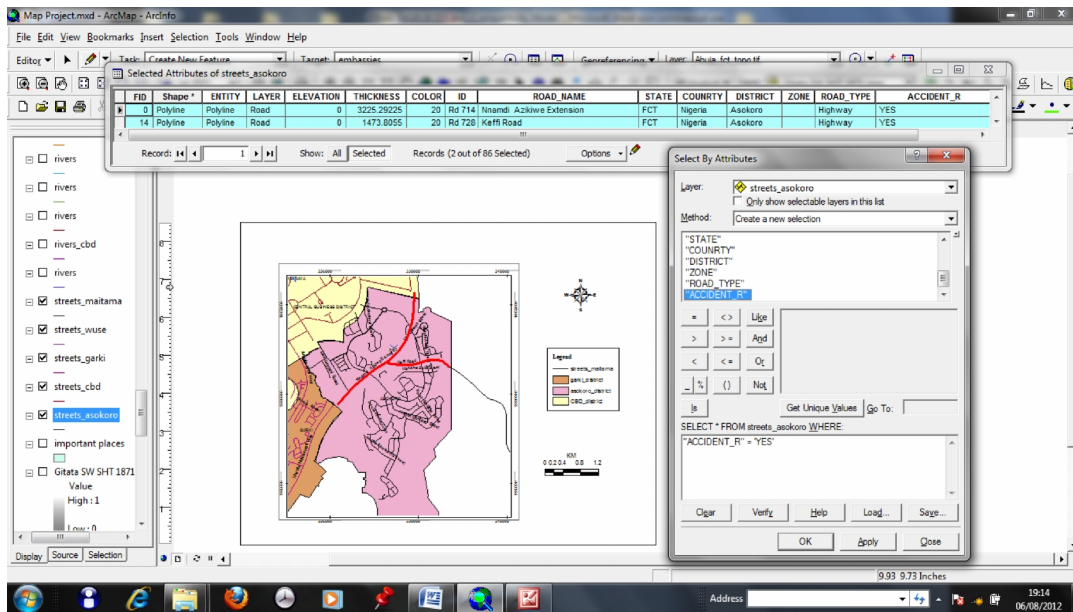
### **3.1.2 Spatial distribution of road accident hot spots in AMAC from 2009-2011**

Based on the number of accident occurrences on a particular spot, the study used the spatial query on the accident layers to show all the accident roads in each District and results were shown in Figs. 3, 4, 5, 6 and 7. According to Fig. 3, the accident hot spots in Asokoro District were Nnamdi Azikwe Extension and Keffi roads.

**Table 4. Comparison based on Crash, Fatality and injury for the period of study**

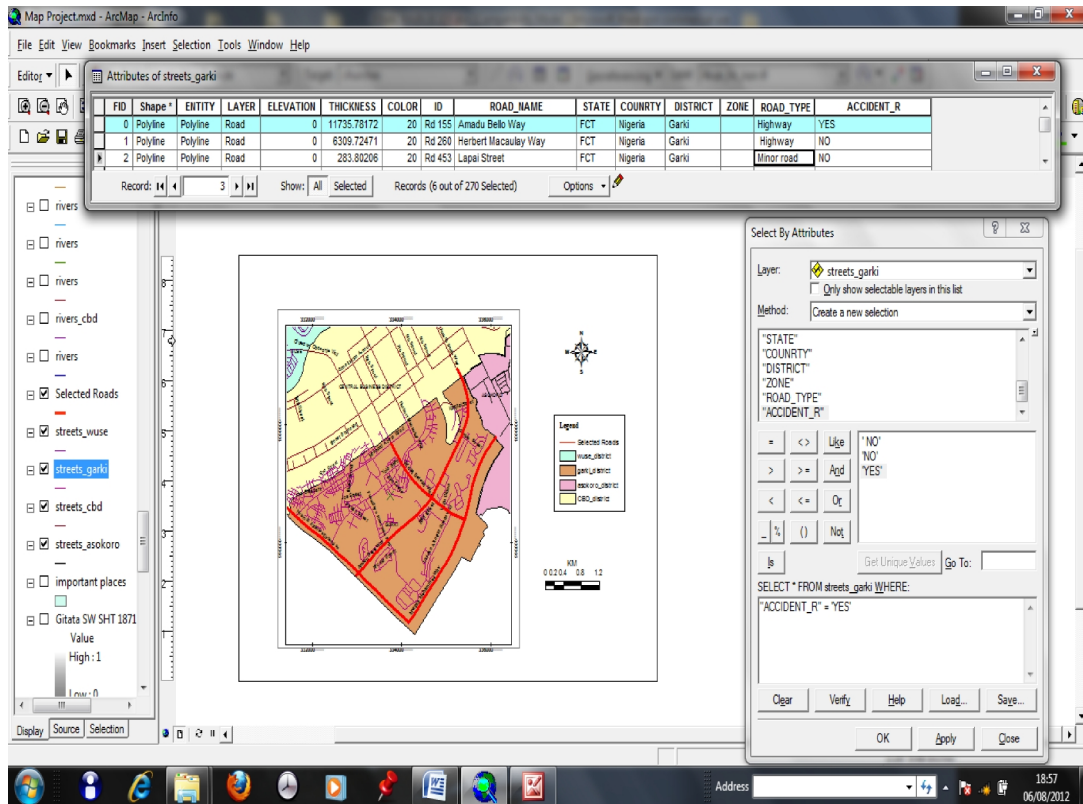
% Change in Case /Location	Crash (2009–2010) % Change 1st	Crash (2010 – 2011) % Change 2 <sup>nd</sup>	Fatality (2009–2010) % Change 1st	Fatality (2010–2011) % Change 2nd	Injury (2009–2010) % Change 1 <sup>st</sup>	Injury (2010–2011) % Change 2nd
BTAR	-3	5	-2	-3	-5	-4
OPAR	1	-1	0	-4	1	-5
DVRD	-2	-1	-1	-3	-1	2
UDRD	-3	4	4	-9	0	1
BEND	0	-3	-12	-2	-6	-9
ITSC	8	-1	-7	0	-11	1
STRD	3	0	2	-6	-1	2
BRGE	-1	2	1	-5	2	2
GDRD	2	1	4	-6	0	-1
FARD	4	-4	2	-6	0	-1
PORD	6	-7	4	-8	0	-2
AVEH	-1	-1	2	-2	1	0
MSGN	7	-7	0	-6	3	-2
MMRK	-1	-1	-3	-4	5	-3
UNKN	-3	9	-4	-3	6	-5

BTAR: Built-Up Area; OPAR: Open Area; DVRD: Divided Road; UDRD: Undivided Road; BEND: Bent Road; ITSC: Intersection Road; STRD: Straight Road; BRGE: Bridge; GDRD: Good Road; FARD: Fair Road; PORD: Poor Road; AVEH: Abandoned Vehicle; MSGN: Missing Sign; MMRK: Missing Mark; UNKN: Unknown, Source: FRSC, 2011



**Fig. 3. Result of query operation on accident roads in Asokoro district**

Fig. 4 also showed the four major roads in Garki District where the accident hotspots were located. The roads were Ahmadu Bello way, Tafawa Balewa Way, Nnamdi Azikiwe Extension and Murtala Mohammed Way.



**Fig. 4. Result of query operation on Accident roads in Garki**

In the Central District (CBD), seven major roads were identified as accident hotspots Fig. 5. These include Ahmadu Bello way, Herbert Macaulay Way, Constitution Avenue, Samuel Ademulegun Avenue, Kur Mohammed Avenue, Ralph Sodeinde Street, and Olusegun Obasanjo Way. Further, in Wuse, the results of query operation performed on the database generated six major roads where the accident hotspots were located Fig. 6. They include Ibrahim Babangida Way, Aguiyi Ironsi Street, Amino Kano Crescent, Ahmadu Bello Way, Nnamdi Azikiwe Extension and Sani Abacha Way. Fig. 7 showed Murtala Mohammed Express Way as the only one major road in Maitama District where Road accident was frequent.

Attempt was made to show the accident hotspots in an aggregate format over the three years of the study. The results presented by Figs. 8, 9 and 10 revealed that there were much, more accident hotspots in 2009 than what obtained in 2010 and 2011. In fact there was a remarkable reduction in the accident hotspots in AMAC in 2011.

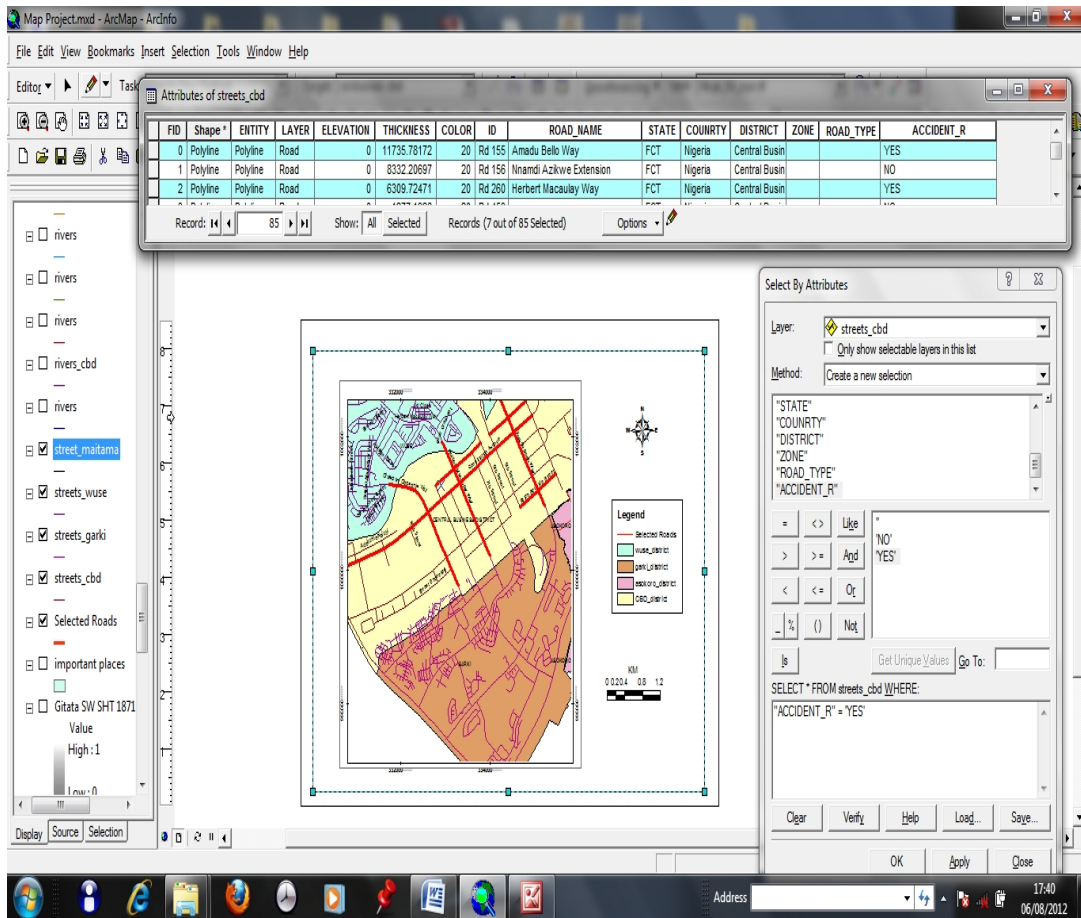


Fig. 5. Result of query operation on Accident roads in CBD

### 3.2 Discussion

#### 3.2.1 Factors Responsible for Road Accidents

Tables 1a, 1b, 1c gave a summary of accident causes as obtained from FRSC records for the period investigated (2009 – 2011). The result shows that non compliance with road traffic rules by the drivers was largely responsible for road accidents during the study period. This is evident in the fact that among the causes of road accidents identified in the study area, dangerous driving tends to be the predominant causes of accident, followed by brake failure, tyre burst, speed, wrong overtaking, poor vision, loss of control and fatigue. The contributions of these causes to road accidents in 2009 are 23.1%, 13.7%, 11.1%, 10.3%, 7.7%, 6.8%, 5.1%, and 4.3% respectively. There was no significant change in the attitude of the road users particularly the drivers to the traffic rules as dangerous driving still remained the highest cause of accident in 2010, followed by over speeding, then brake failure which was also ranked third in 2009. Others include tyre burst that was ranked fourth in 2009, wrong overtaking, loss of control, fatigue and poor vision. Specifically, the contributions of these causes to road accidents in 2010 are 18.8%, 17.4%, 15.7%, 11.6%, 10.7%, 8.3%, 6.6% and 6.6% respectively. Tyre burst accounted for the highest number of road accidents

in AMAC in the year 2011. This is followed by loss of control, then dangerous driving, speed, wrong overtaking, brake failure, poor vision and fatigue. The contributions of each cause to road accidents in 2011 are 19.4%, 17.6%, 14.8%, 12.0%, 11.1%, 9.3%, 6.5%, and 6.5% respectively.

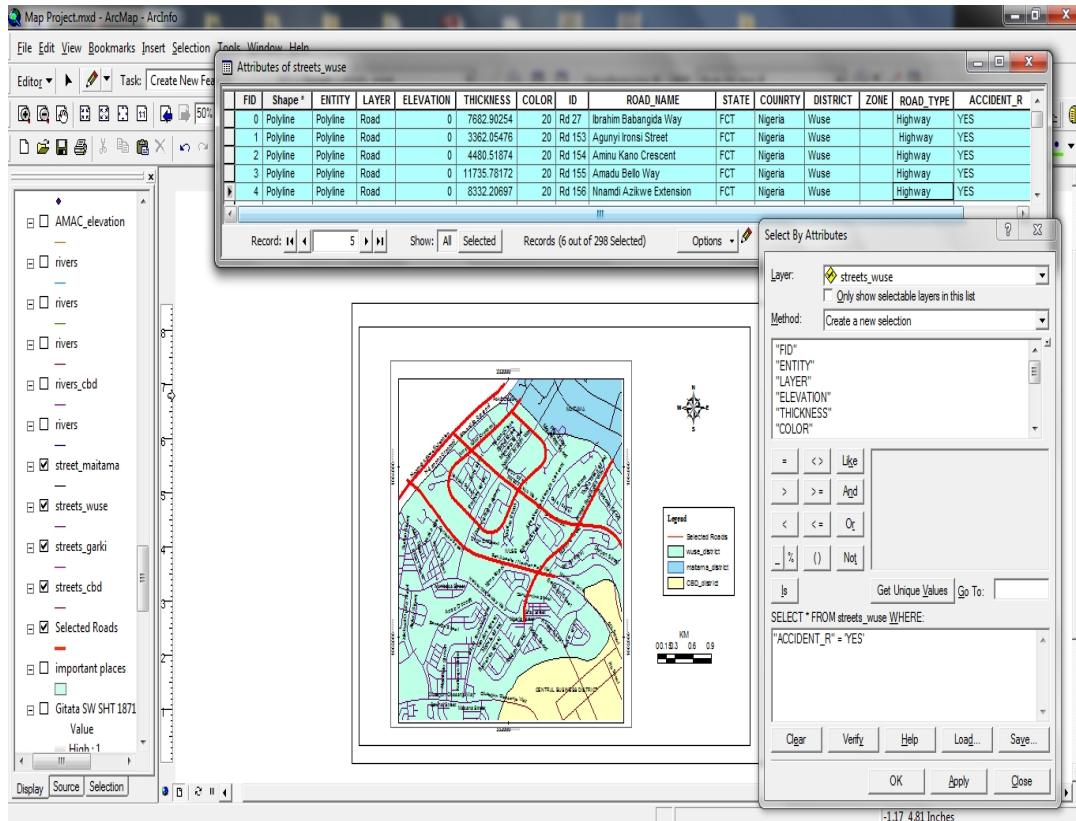


Fig. 6. Result of Query Operation on Accident Roads in Wuse

In Table 2, human factor was found to be the major cause of accident in all the Districts. This human factor includes dangerous driving, wrong overtaking, speed, loss of control and fatigue. This is followed by road factor which is essentially the nature of the road. This agrees with the findings of [17] who reported that a high rate of fatal accidents and a sharp increase in the last ten years of road accidents in Hokkaido, Northern Japan could be attributed to changes in road surface conditions. Other observed causes are vehicle factor (brake failure, tyre burst and abandoned vehicle) and environmental factor involving bad weather condition that often affect visibility thereby causing poor vision to the drivers. These findings are in line with Sasser [3] who expressed the viewpoint that road traffic accident rates are particularly high in the developing countries due to poorly maintained road networks and motor vehicles.

Again, it was observed that dangerous driving which is regarded as human factor was the highest cause of accident for the year 2009 and 2010. However, in 2011, it was vehicle factor.



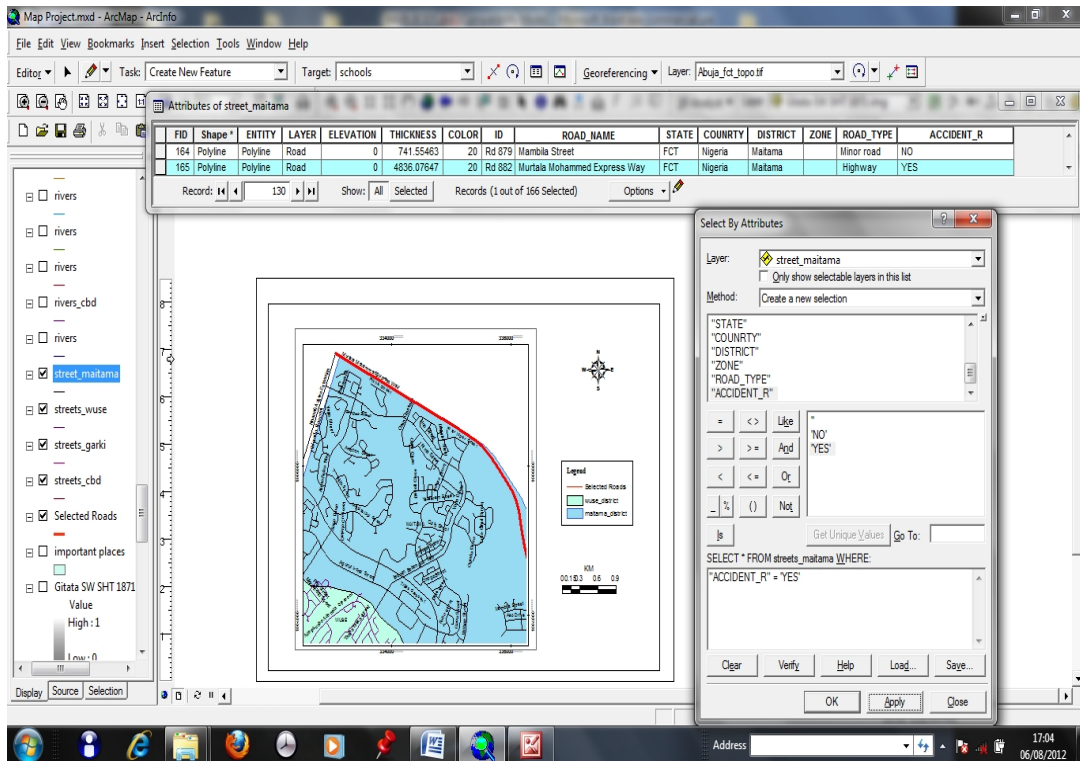


Fig. 7. Result of query operation on Accident roads in Maitama

### 3.2.2 Causes of accident based on nature of location

The nature of location of accident occurrence is discussed below from Table 4.

#### 3.2.2.1 Built-up area

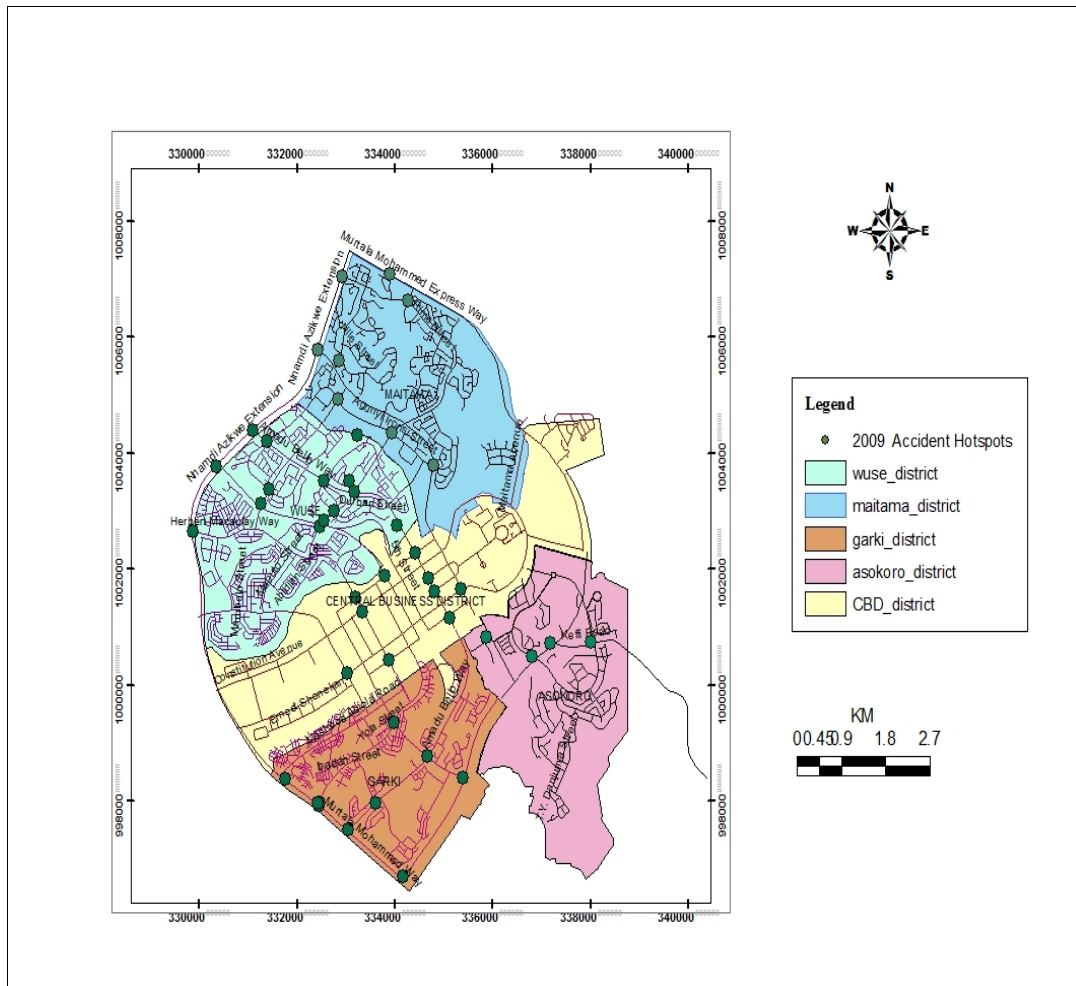
The rate of change in crash cases from 2009-2010 reduced by 3% but increased by 5% from the year 2010-2011. The rate of change in fatality and injury experienced a consistent reduction from the year 2009-2010 and 2010-2011 by 2% and 3% for fatality and 5% and 4% for injury.

#### 3.2.2.2 Open area

For 2009-2010 and 2010-2011, the rate of change in crash cases was 1% increment and 1% reduction respectively. In fatality, no change was recorded from 2009-2010 but from 2010-2011, there was a reduction in fatality rate by 4%. Injury had 1% increment in the first year and 5% reduction in the second year.

#### 3.2.2.3 Divided road

It experienced a reduction all through in crash cases, fatality and the first year in injury, but there was an increase in the second year in injury by 2%.



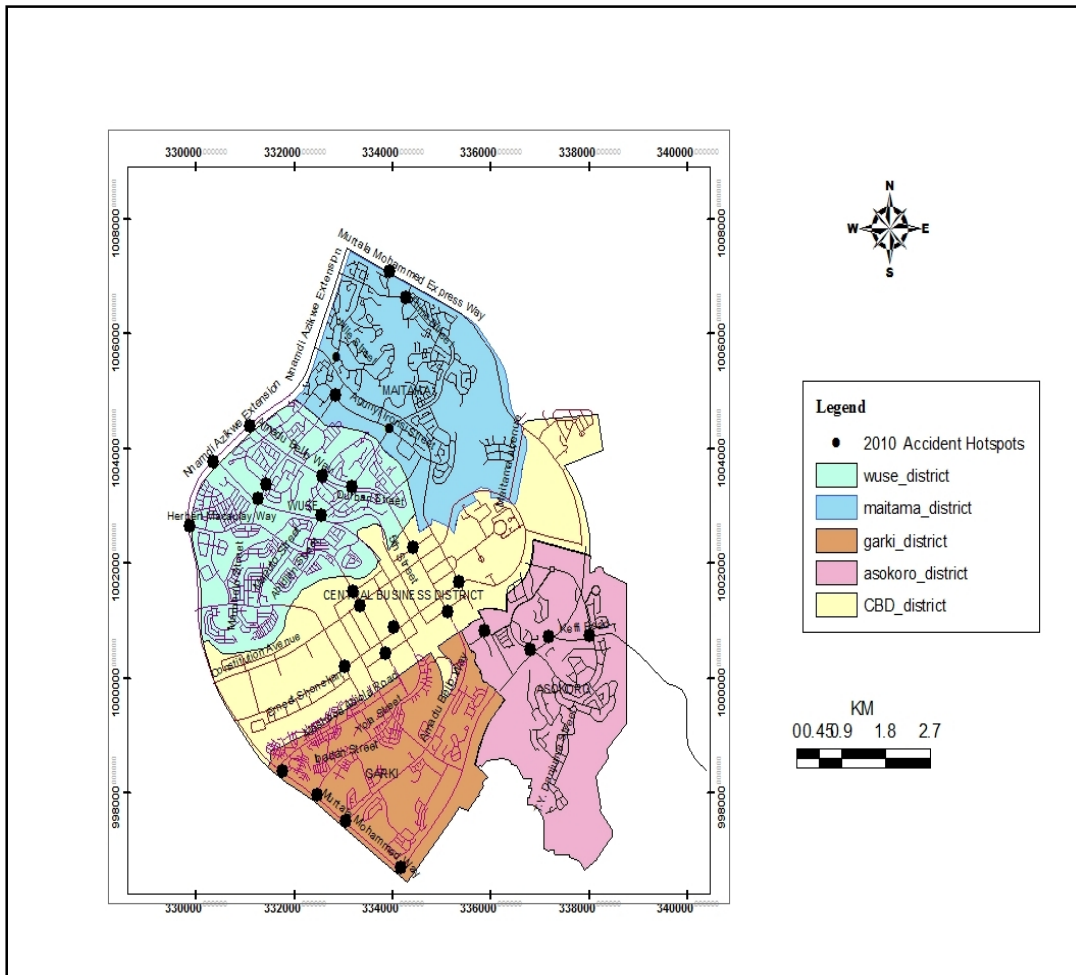
**Fig. 8. 2009 accident hotspots in AMAC**

**3.2.2.4 Undivided road**

In the first and second year, there was 3% reduction and 4% increment in crash cases respectively. For fatality, there was 4% increment and 9% reduction for the first and second year respectively. For injury, there was no change in the first year while 1% increment was recorded in the second year.

**3.2.2.5 Bent road**

There were no changes in crash cases in the first year but the second year experienced a reduction of 3%. For fatality and injury, there was a consistent reduction in both the first and the second year by 12% and 2% for the former and 6% and 9% for the latter.



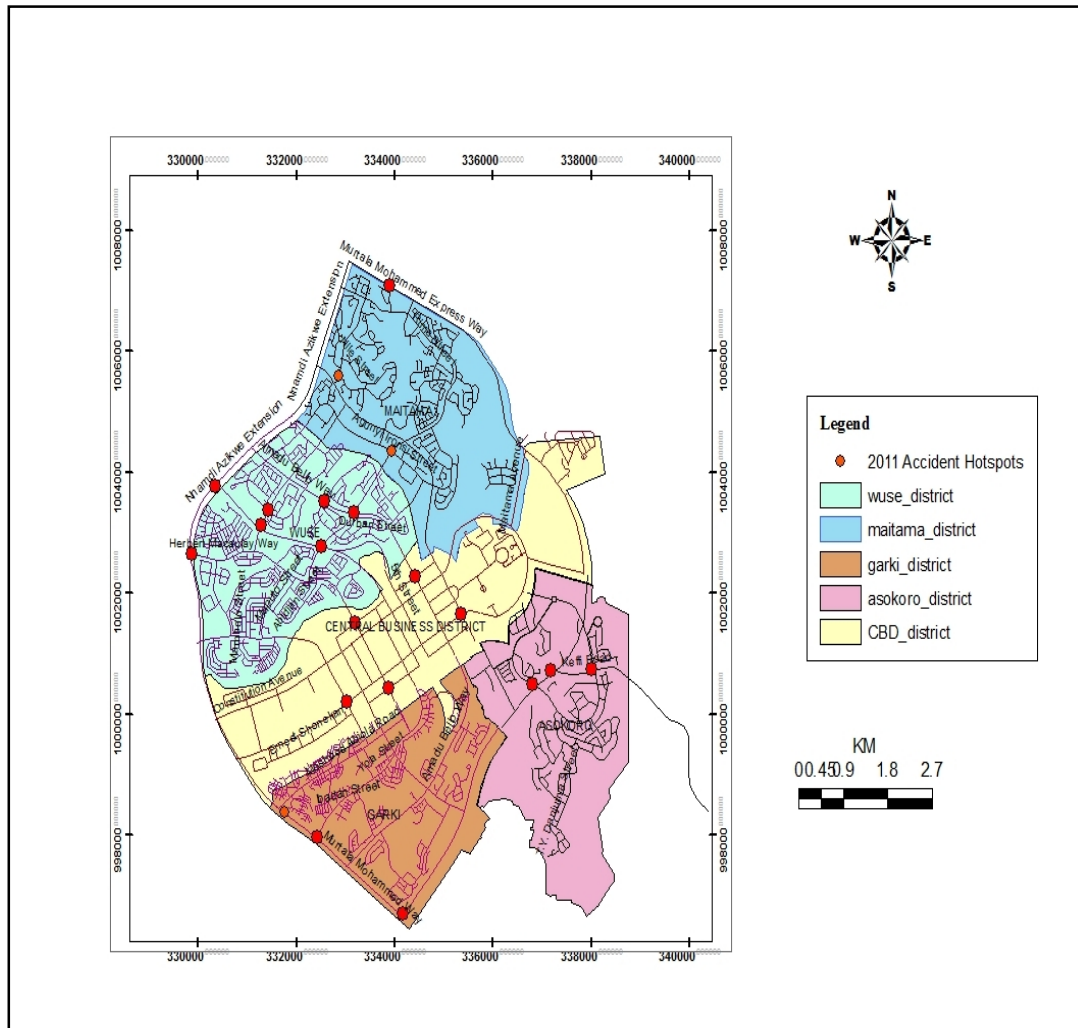
**Fig. 9. 2010 accident hotspots in AMAC**

**3.2.2.6 Intersection**

There was a reduction in the rate of change of crash cases, fatality and injury except for the second year of fatality where there was no change and the second year where 1% increment in injury was recorded.

**3.2.2.7 Straight roads**

3% increment and no change was recorded for the first and second year in crash cases, 2% increment and 6% reduction was recorded for fatalities and 1% reduction and 2% increment was recorded for injury cases on straight roads.



**Fig. 10. 2011 accident hotspots in AMAC**

**3.2.2.8 Bridge**

Road accident on bridge recorded a consistent increase in fatality and injury for the first and second year. Also, crash cases decreased by 1% in the first year but increased in the second year.

**3.2.2.9 Good roads**

On good roads, there was 2% and 1% increment in the first and second year in crash cases, 4% increment and 6% reduction in the first and second year in fatality, there was no change in the first year in injury and in the second year, there was 1% reduction.

#### *3.2.2.10 Fair roads*

Crash cases recorded 4% increment and 4% reduction in the first and second year respectively, fatality cases recorded 2% increment and 6% reduction in the first and second year respectively, while for injury cases, there was no change in the first year and 1% reduction in the second year.

#### *3.2.2.11 Poor roads*

On poor roads, 6% increment and 7% reduction was recorded in crash cases in the first and second year respectively. For fatality, 4% increment and 8% reduction was recorded for the first and second year while no change was recorded in the first year in injury and 2% reduction recorded in the second year.

#### *3.2.2.12 Abandoned vehicle*

For crash cases, -1% was recorded for both first and second year, for fatality cases 2% increment and 2% reduction was recorded for the first and second year while no change was recorded for the second year in injury, 1% increment was recorded in the first year.

#### *3.2.2.13 Missing signs*

7% increment and reduction was recorded for the first and second year in crash cases, no change was recorded for the first year in fatality and for the second year, there was 6% reduction. For injury cases, there was 3% increment and 2% reduction in the first and second year respectively.

#### *3.2.2.14 Missing marks*

This factor experienced a trend of reduction in the first and second year in crash cases, fatality and in the second year in injury but in the first year, there was an increase of 5% in injury.

#### *3.2.2.15 Unknown factors*

In the first and second year in crash cases, there was 3% reduction and 9% increment respectively. For fatality, the rate of change of reduction in the first and second year recorded 4% and 3% respectively. For the first and second year of injury, there was 6% increment and 5% reduction respectively.

### **3.2.3 The black spots**

From Figs. 8, 9 and 10, a total number of 126 accident points were identified for the year 2009 out of which 43 accident hot spots were generated. The numbers of accident points increased to 129 in 2010 but 27 accident points were identified as hotspots. The reduction in the accident hotspots may be attributed to the effective policing of the AMAC by the Federal Road Safety Corps that eventually translates to gradual compliance with traffic rules by the road users. This further shows a decline in accident points as well as hotspots as evident in 2011 during which 18 accidents points were identified as hotspots out of 125 accident spots.

### **3.2.4 Spatio-temporal trend of accident occurrence based on location**

In Asokoro, the hotspots in 2009 and 2010 were mainly as a result of road intersections, but along Keffi road, 3km away from AYA junction (Kugbo), brake failure, over speeding, loss of control, wrong overtaking and tyre burst have emerged as the major causes of accident on this route. This same route has claimed so many lives. People have even attributed the constant occurrence of accident on this route to spiritual influences (as part of other causes). However, in the authors' opinion, the meandering nature of this route as revealed by the topography might have led to incessant brake failure and loss of control during over speeding by drivers.

Most times, especially during peak hours (after close of work around 1500 – 1800 hours), traffic congestion is observed leading to more stationed or broken down vehicles along the road. The situation is further worsened by the urban land uses (such as Police Forces headquarters, POWA International School, Total Filling station, Protea Hotel and Zain office) surrounding Area 11 junction that heightened traffic congestion. However, this junction seized to be an accident hotspot in 2011 because some road traffic officers from police headquarters have constantly been stationed there for enhanced traffic control. Others such as the Water Board junction and Power House junction still remain accident hotspots due to poor and ineffective traffic control light. The presence of traffic officers at these junctions is yet to effectively curb the rate of accident due to the impatient nature of most of the motorists.

In Garki, for 2009, accident was predominant due to increasing nature of road intersections, malfunctioning traffic lights and non compliance with traffic rules. However, a reduction in road accidents was noticed in 2010 which was consequential to provision of more functional traffic light and the stationing of road traffic officials at each road intersection to curb drivers' excesses. This has led to further reduction in accident hotspots. The construction of flyovers and bridges at Apo and Area 3 junctions along Nnamdi Azikiwe express road was a bold effort to reduce accident hotspots. Despite these developments, Apo roundabout and Area 3 junction remain formidable road accident hotspots due to high traffic flow, wrong overtaking, over speeding and lack of concentration. In 2011, speed breakers, road traffic signs and marks were introduced in order to reduce the rate of road accident at Apo roundabout but this led to a little reduction in accident at this particular junction, as motorists still do not observe the road signs and still do not reduce their speed on getting to this junction. In Area 3 junction, over speeding and wrong overtaking remained the major cause of accident in spite of the road traffic signs along the junction.

In the CBD, just as the name implies, is filled with various land uses such as the Federal Secretariat, National Assembly, Nigerian National Petroleum Corporation (NNPC) Towers, Hotels, Banks, Hospitals, Shopping Plazas, Recreational Centres, National Mosque, Ecumenical Centre (National Church) among others. The nature of this District leads to high movement of motorists. It is a District characterized by very good and very straight roads, road intersections and flyovers but having some roads with missing marks and missing signs resulting to several crashes as a result of over speeding and wrong over taking. The presence of traffic light at most of the intersections was not able to curb the rate of accident at some of the junctions due to malfunctioning of the traffic light. These traffic lights are being powered by Power Holding Corporation of Nigeria (PHCN), the main electricity supplier in Nigeria that is noted for its inefficiency.

The rate of accident between 2009 and 2010, reduced a little as a result of road traffic officers at the various road intersections. In 2011, a little reduction was also observed due to more functional traffic light, more road signs and marks and more road traffic officers.

Bullet junction, This-Day-Doom junction, Masalashi junction, Bolingo junction and War College junction by Metro Plaza, remain accident hotspots as a result of malfunctioning traffic light and the absence of road traffic officers especially at War College by Metro Plaza junction. With these poor and inefficient road facilities, most motorists become more impatient to observe the road signs at these junctions, thereby creating room for more crashes as a result of over speeding and wrong overtaking.

Maitama is a District with very good roads, a lot of road signs and marks and more of residential quarters and diplomatic offices. This is a District with very few road intersections. The rate of accident was very high in 2009, due to dangerous driving and over speeding. In 2010, the rate of accident reduced drastically due to the presence of road traffic officers at most intersections. In this District, Mpape junction was still noted to be an accident hotspot in 2011, because of the road curvature, poor road signs and marks, rough surface and narrow lane of the road. The major causes of accident along this route were noted to be dangerous driving, tyre burst, wrong overtaking and brake failure.

Wuse is a District with so many land uses (such as hospitals, club houses, banks, hotels, schools, markets, plazas, recreational gardens, filling stations, Churches, Mosques among others), a lot of road intersections, good road signs and marks, flyovers, but poor functional traffic lights. In 2009, 14 junctions were recorded as accident hotspots due to dangerous driving, brake failure and wrong overtaking which resulted to so many crashes. The number of accident hotspots reduced in 2010 and 2011 to 8 and 7 respectively, due to the gradual compliance of road traffic rules by the motorists. In this District, the major causes of accident along Sani Abacha Way where there are three accident hotspots are over speeding, loss of control, wrong overtaking, tyre burst and fatigue.

#### **4. CONCLUSION**

This study has demonstrated the capability of GIS in identifying accident prone locations in AMAC. The study developed road accident database on which spatial query could be performed to generate different scenarios. The results of query operations on the database could also be provided to police, pedestrians, drivers, and citizens in order to inform them about high-risk road traffic accident locations or locations that have high potential for future road accidents. The maps of road accident hotspots generated could be updated and be useful for planning purposes. The study identified dangerous driving, loss of control, over speeding, tyre burst, rough surface of the road, brake failure and wrong overtaking as the contributory causes of road accident in the study area. The study recommends compulsory educational and awareness programmes for the drivers, provision of functional traffic lights at road intersections, re-engineering of road and defining danger times of high risk locations in AMAC. The study therefore advocates for a uniform accident reporting system that can be used as a working database and feedback mechanism of road traffic accident data that will facilitate modeling accident occurrence with a view to making road accident forecasting possible in Nigeria and in other developing countries.

#### **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

## REFERENCES

1. Yordphol T, Pichai T, Witaya C. GIS Application on road management system for community health promotion. Retrieved 23<sup>rd</sup> November, 2011 from [http://www.rtg.ait.ac.th/abstract/rtg\\_0205.pdf](http://www.rtg.ait.ac.th/abstract/rtg_0205.pdf). 2005.
2. Cole TB. Global road safety crisis remedy sought: 1.2 million killed, 50 million injured annually. JAMA. 2004;291(21):2531–2532.
3. Sasser SVM. Prehospital trauma care systems. World Health Organization, Geneva; 2005.
4. Peden MM. Injury: a leading cause of the global burden of disease”. Department of Injuries and Violence Prevention, Non-communicable Diseases and Mental Health Cluster. World Health Organization, Geneva; 2005.
5. Estochen M, Tim S, Souleyrette R. An assessment of emergency response vehicle pre-deployment using GIS – Identification of high accident density locations”. Proceedings of Transportation Conference. 1998;221–226.
6. Murray CJ, Lopez AD. Regional patterns of disability free life expectancy and disability adjusted life expectancy: global burden of disease study. Lancet. 1997;349:1347-1352.
7. Human Sciences Research Council. The road kill factor. HSRC. 2008;6(4).
8. World Health Organization. “Violence and injury prevention program”. Retrieved 18<sup>th</sup> November, 2011 from [www.who.int/violence\\_injury\\_prevention/en/](http://www.who.int/violence_injury_prevention/en/); 2011.
9. Akpoghomeh OS. Recent trend in Spatio-temporal dimension of RTA in Nigeria. Proceeding in International Conference on Road Safety, Abuja, Nigeria; 1992.
10. Asogwa SE. Road traffic accidents in Nigeria: a review and a reappraisal” Accident Annual Preview. 1992;24:149–155.
11. Balogun SA. Spatio-Temporal analysis of motor vehicle – related accidents in Abuja, Nigeria un-published Ph.D Thesis in Department of Transport Management, Federal University of Technology, Minna, Nigeria; 2005.
12. Ravenstein EG. The laws of migration. Journal of the Royal Statistical Society. 1885;48:167-227.
13. Lotka A. Analytical notes on certain rhythmic relations in organic systems. Proceedings of the U.S. National Academy of Science. 1920;6:410–415.
14. Maguire DJ. Computer in Geography. Longman, London. 1989;175.
15. Ogan V. Spatio-Temporal Analysis of Road Accidents in Abuja Municipal Area Council, Unpublished M.Sc. Thesis in the Department of Remote Sensing & GIS Federal University of Technology, Akure & RECTAS, OAU, Ile-Ife, Nigeria; 2012.
16. Radin UR, Law TH. The development of Road accident Database management System for Road Safety Analysis and Improvement. 2006; Retrieved 25<sup>th</sup> November, 2011 from <http://rakan.1.jkr.gov.my/cjalan/editor/files/dev%20road.pdf>.
17. Hirasawa M, Asano M. Development of traffic accident analysis using GIS. Proceedings of the Eastern Asia Society for Transportation Studies 4. 2003; 1193 – 1198. <http://rakan.1.jkr.gov.my/cjalan/editor/files/dev%20road.pdf>.

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