

Spatial Analysis of Effects of Road Traffic Accident Hotspots Using High-Resolution Satellite Imagery and Statistical Analysis in Owerri Metropolis, Imo State, Nigeria.

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Abstract

Background: One of the key features for the economic growth and development of a country is the level of its road transportation system. Road safety movement of goods and people from within and outside a locality is of great importance to the well-being of the people. With increasing number of vehicles every day and the nature of the road, road safety has become a major concern in Owerri metropolis due to the alarming nature of road traffic accidents. The traffic accidents are predictable and can be avoided by improving preventions. This paper is aimed at identifying the causes and effects of road traffic accident hotspots using high resolution satellite imagery and statistical analysis in Owerri Metropolis, Imo State, Nigeria.

Materials and Methods: In order to study the pattern of accidents in the Metropolis, several different spatial and non-spatial datasets were collected through social surveys/questionnaires and ground trothing; then processed using GIS approach and analyzed using spatial queries and statistical analysis. The non-spatial data used were obtained from the records from the Federal Road Safety Commission and Police between 2016 to 2017. Infoterra satellite imagery with 0.5m resolution and ArcGIS 10.3 were used for the analysis.

Results: Map of the accident hotspots was produced showing the most dangerous spot, which is the IMSU junction roundabout. Result revealed that the causes of the accidents were grouped into 3; the human, vehicular and road factor of which the human factor recorded highest with 44.23% and 47.75% for 2016 and 2017 respectively. The effect of RTA was evident in RTD, Major injury, Minor injury and property damage. Amongst these, the RTD was recorded highest with 61.13% and 60.85% in 2016 and 2017 respectively.

Conclusion: The study recommends provision of quality roads, repair of bad roads, provisions of functional traffic lights, defining danger times of high risk locations in Owerri and constant orientation of drivers on the importance of safe driving. The results can be effectively used by various agencies for adopting better planning and management strategies for improved traffic conditions as well as accident reduction and enhancing socio-economic growth and development of the state.

Key Word: Road Transportation, Road Traffic Accident, Accident Hotspots, Spatial query, GIS and Satellite Imagery.

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I. 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 (Abdul and Ansa, 2012). 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 commonly 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 Nigeria, one of the unavoidable negative consequences is the occurrence road accidents. Road traffic accidents (RTA) and the associated injuries are a major cause of death in developing countries. RTA prevention and mitigation should therefore be accorded greater attention to reduce the increasing human loss and injury (Rukewe et al, 2014). 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 (Rune and Truls, 2004).

Road accidents appear to occur regularly at some flash points such as where there are sharp bends, potholes and at bad sections of the highways (Atubi, 2009a). The nation's economy has been degraded due to the large rate of road traffic accidents (Bolade, 1991). Places or spots that are prone to road accidents or where road accidents are more concentrated on a road network is denoted as hotspots, high-hazard, hazardous or blackspots (Reshina and Sheikh, 2012). This often contributes to worsen the severity of a road accident (Gregory and Jarrett, 1994). Road traffic safety refers to the methods or measures used to prevent road users from being killed or seriously injured. Typical road users include pedestrians, cyclists, motorists, vehicle passengers, Truck, Trailer drivers, horse riders and passengers, on road public transport (mainly buses).

Causes of Road Traffic Accidents

According to Centre for Advanced Spatial Analysis, 2013, Road traffic accidents are caused by the following 3 factors;

- a. **Human factor:** This include the age of the driver or victim, gender of the victim; over speeding, drunken driving, red light jumping, avoiding safety gears like seat belts & helmets, dangerous driving, dangerous overtaking, loss of control, stationary vehicles, obstruction, sleeping on steering, route violation, light/sign violation, drugs/alcohol misuse, use of phone, talking and driving,
- b. **Vehicular factor:** This includes the general factors of climate and environment, lightning conditions of roads, time of accident i.e. day or night, pavement conditions etc. it leads to distraction to driver, tyre burst, faulty engine, brakes, etc.
- c. **Road and environmental factor:** This includes the type of junction or intersection, then horizontal slope, curves, Improper designing of road; bad roads, etc. present on the road due to the faults of which accidents may occur.

There is no enough data in the relationship between road characteristics and road traffic accident severity in Owerri Metropolis, Imo State. However, according to the Federal Road Safety Commission (FRSC) report, the death rate due to car accidents is significantly increasing among pedestrians and passengers due to bad road from time to time in Owerri Metropolis, Imo State. The high traffic volume in Owerri metropolis 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 for sustainable economic development in the state. The application of Geographic Information System (GIS) technology will reduce the causes and effect of road traffic accidents in Owerri Metropolis. It is a tool revealing what is otherwise invisible in geographical information, it can be used to assist road traffic accident hotspots to understand the geographical distribution of accident hotspots, Identify hotspot accident concentrated areas, identify the accident causes and facilitate deployment decision making in the State.

Statement of Problem

Nigeria has recorded a high statistics on Road traffic accidents as a serious and growing problem with absolute fatality rate and casualty figure. In Nigeria, accident occurrence and related deaths are with increase in population and number of vehicles. In Nigeria, studies have indicated that better facilities in terms of good quality and standardized roads have been accompanied by increasing number of accidents (Atubi and Onokala, 2009). According to Atubi (2012), in 1976 there were 53,897 road traffic accidents resulting in 7,717 deaths. Although in 1981, the magnitude reduced to 5,114 accidents, but the fatality increased to 10,236 which mean that there was an average of 96 accidents and 28 deaths for everyday of that year (Ogunsanya, 1991) as cited in Atubi (2012). It has come to the agreement that road traffic accident has an alarming increase in the world's record due to different factors such as over speeding, impatience, refusal to allow traffic rules, reckless driving, improper designing of road, etc. Researchers suggested ways to reduce road traffic accident like road signs and symbols, traffic lights, and also traffic control officers have been stationed at every point/bus-stop to control and minimize road traffic accident but the problem have not been solved permanently. The number of people that die on a daily bases in Owerri Metropolis is really alarming. Some victims sustain serious injuries like brain loss, amputation of the leg and arms etc., while others loss their cars and properties.

In Owerri Metropolis, GIS has not yet been used as an obligatory tool within the police force and the Federal Road Safety Corps. Records of accident incidents with the Police force and Federal Road Safety Corps within Owerri, Imo State are still in analogue format, in different books which could be lost, damaged, torn or even burnt. Making retrieval, accessing, updating, editing, manipulation and integration of information very difficult and sometimes impossible. This is due to high cost of GIS tools, ignorance to the GIS technology and lack of GIS experts in the police force. The law enforcement really needs Information Management especially Location Information because it deals with data collection and it makes information management a lot easier.

With the use of Geographic information system (GIS), the problem of road traffic accident will be minimized which will improve and enhance the socio-economic development of the state and country Nigeria.

Aim and objectives

This paper is aimed at identifying the causes and effects of road traffic accident hotspots using high resolution satellite imagery and statistical analysis in Owerri Metropolis, Imo State, Nigeria. The following objectives will enable the aim to be achieved;

- a. Determination of the road traffic accident hotspots in the study area.
- b. To determine the major factors that contributed to the occurrence of road traffic accidents in Owerri Metropolis.
- c. To analyze the effects of the road accidents within the study area.
- d. To analyze the frequency of occurrence road accident hotspots.
- e. To produce a spatial database of road traffic accident hotspot of the study area.
- f. To use the spatial capabilities of GIS to analyze accident hotspot by query, buffer, etc.

Significance of Study

When considering GIS in road traffic accidents, an obvious question is whether GIS is simply a better, more precise and flexible spatial analysis tool for representing accident analysis. Improving data analysis using geographic information system (GIS) can;

- a. Prevent loss of lives.
- b. Prevent loss of properties.
- c. Minimize road traffic accident.
- d. Make people's mind to be at rest.
- e. Help to get record of happenings on the road.

II. Material and Methods

Study Area

The study area is within Owerri Metropolis Imo state, Nigeria. Owerri Metropolis lies between Latitude $05^{\circ}25'57''$ North of the equator and Longitude $07^{\circ}01'04''$ East of the Green-wish Meridian. Its' headquarter is in the city of Owerri. It has an area of 175,395 according to the census, with a 460 postal code. This is shown in Fig 1

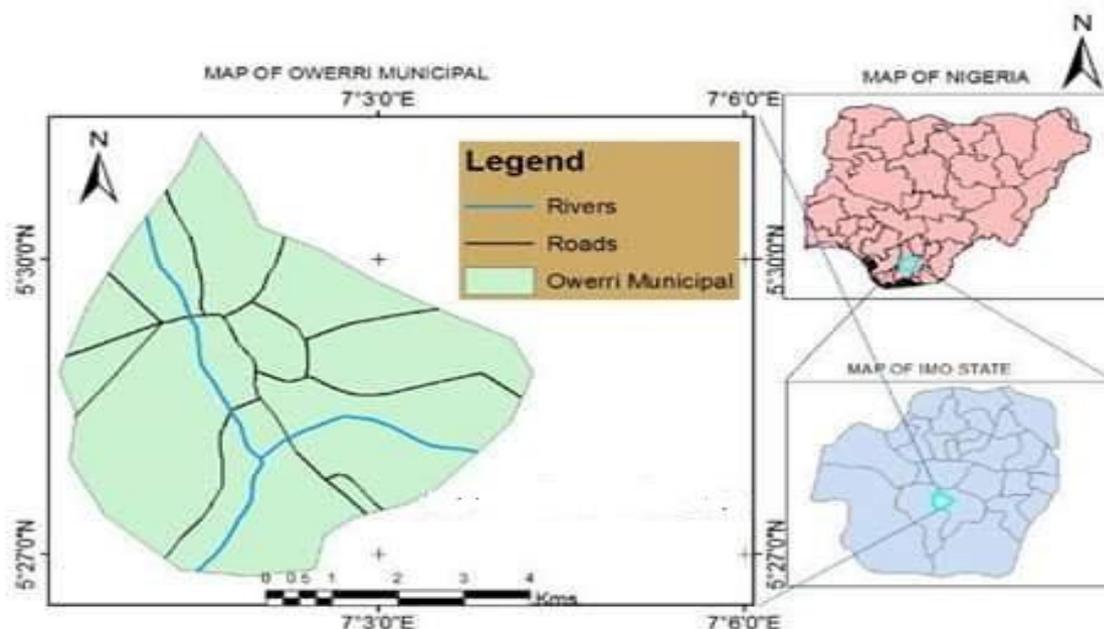


Fig 1: Administrative map of Nigeria, Imo State and Owerri Municipal and Map.

Sources of Data

The data was sourced from two major sources; **Primary and Secondary**. The primary data includes field data that was collected with the use of Global Positioning System (GPS). The GPS survey was carried out all over the accident hotspot location of the roads. Google Earth spatial resolution and Infoterra satellite imagery

with 0.5m spatial resolution were used to extract the map and from the map, the route was gotten. The bulk of attributes for the database was obtained from Federal Road Safety Commission and Police State Sector Command Owerri, Imo State. The secondary data such as Administrative map of Nigeria, Imo State and Owerri Municipal were obtained from the Ministry of Lands, Survey and Urban Planning Owerri Imo State. Other vital information about the study area were obtained from textbooks, journals, documentaries etc.

Data used

Accident records obtained from Federal Road Safety Commission and Police Station from January 2016 to December 2017 include the following;

- a. Name of road involved.
- b. State of road
- c. Type of road
- d. Date of accident
- e. Time of occurrence of accident
- f. Location/hotspot of accident
- g. Coordinates of accident hotspots
- h. Number of vehicles involved
- i. Types of vehicles involved
- j. Severity of accident (fatal, major, minor or car damage)
- k. Causes of accident
- l. Number of people involved in the accident
- m. Sex of the persons involved in the accident.

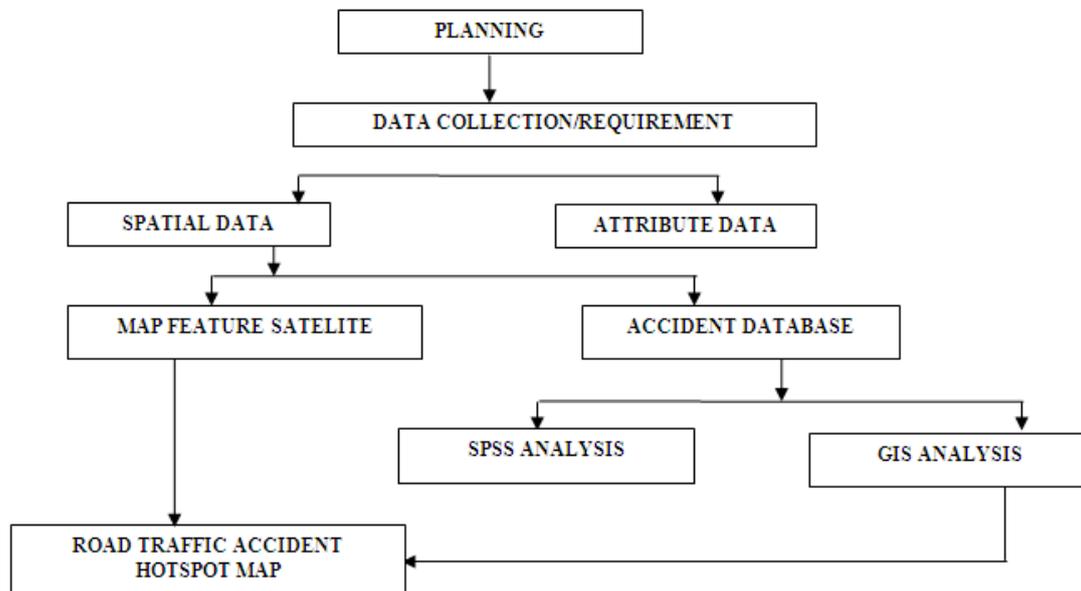


Fig 2: Flowchart of Methodology

Data Conversion

This is the scanning, geo referencing, and digitizing of the analogue map. This stage involves the conversion of the topographic map of Owerri Municipal Council which was originally in analogue format into a computer based format using the AO Scanner device. The scanned topographic map was exported into the Arc Map environment for geo- referencing using the Arc GIS 10.3 software. Geo-referencing allows the map to be properly viewed, queried, and analyzed with other geographical data. This was done by using the coordinate system of the map. Digitizing was done by tracing out all the required features/layers which were carried out and saved. Then, representing the features with symbols such as points, line and polygon. Vector data creation (road map) fix at digitization. The Google earth interface covering the study area was imported in the ArcGIS 10.3 environment using the Arc 2 earth extension tool features such as the study route, junctions, U-turns, intersecting road was digitized using the Editor tool.

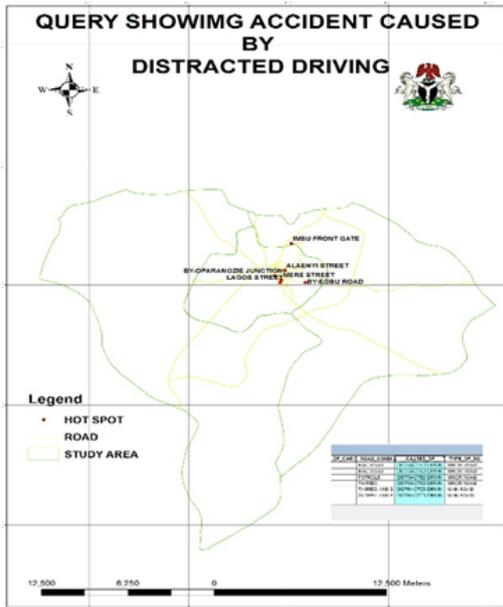


Fig 5: Query result of road traffic accidents caused by distracted driving in 2017

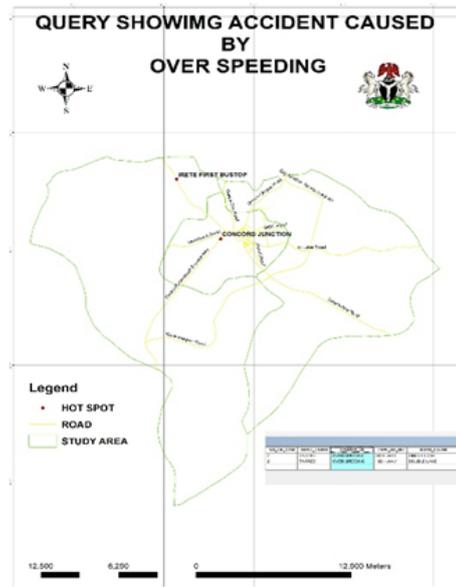


Fig 6: Query result of road traffic accidents caused by over speeding in 2016.

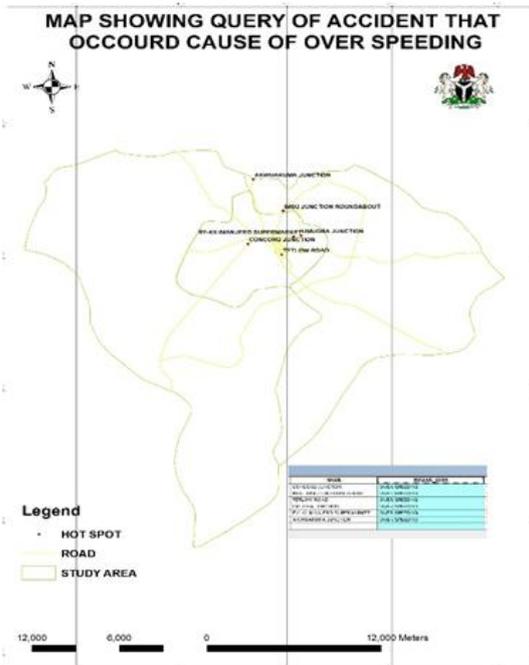


Fig 7: Query result of road traffic accidents caused by over speeding in 2017

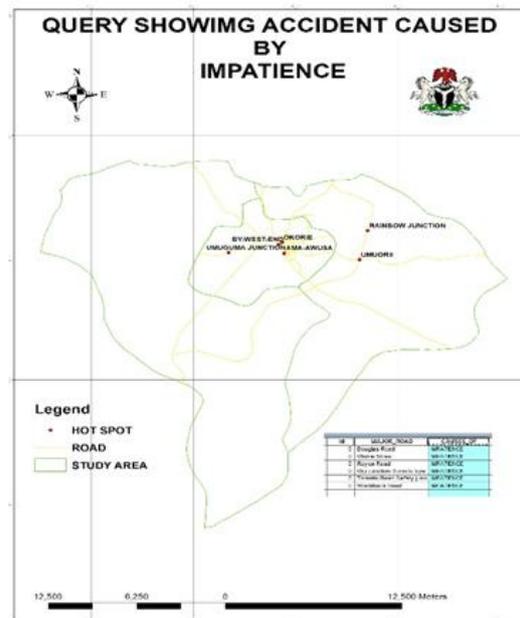


Fig 8: Query result of road traffic accidents caused by impatience in 2016

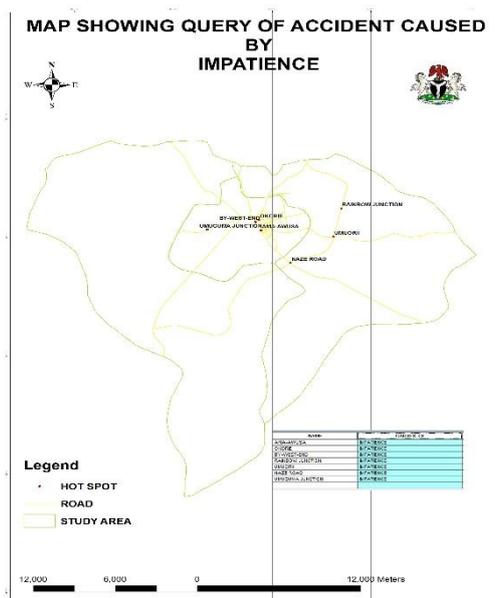


Fig 9: Query result of road traffic accidents caused by impatience in 2017

Fig 3, is a query result that showed the road traffic accident hotspots in Owerri Metropolis, Imo State. The result revealed that there are about 41 road accident hotspots within the study area. Each of the hotspots have their peculiar causes, number of incidents, severity of accidents, and nature of road at the time of accident and so on. The result also revealed that IMSU junction roundabout is the most hazardous hotspot.

The query result from Fig 4 revealed that in 2016 about 6 road traffic accidents were caused by distraction on the drivers which could either be talking while driving, eating, laughing and so on. The incidents happened on tarred roads, bad roads, tarred and potholed roads and tarred and sloppy roads respectively.

The query result from Fig 5 revealed that in 2017 about 9 road traffic accidents were caused by distraction on the drivers which could either be talking while driving, eating, laughing and so on. The incidents happened on tarred roads, bad roads, tarred and potholed roads and tarred and sloppy roads respectively. The hotspots are IMSU back gate, Onumiri street, Onumonu street, Mere street, IMSU front gate, Oparanozie street, Lagos street, Alaenyi and Egbu road.

Fig 6 revealed that only 2 road accidents were caused by over-speeding in 2016. This is also a human factor which occurred on tarred high-ways of both single and double lanes. Over-speeding is usually due to none application of speed limits controls and reckless driving. When a car is Over-speeding, it will be uncontrollable when there is a sudden intersection of an unforeseen force thereby leading to road accidents.

Fig 7 showed that in 2017 about 6 road accidents were caused by over-speeding. During rainy season, when the road is slippery, over-speeding incurs accidents that leads to death, serious injuries and car damages. Over-speeding is caused by lack of speed limit gadgets and brake failure. This is both human and vehicular factors.

In 2016, the Fig 8 revealed that out of the 41 road accident hotspots, about 6 accidents were caused by impatience. Driving requires high level of focus, calmness and articulation. Without which road traffic accident that will lead to RTD, RTI or car damage will be the resultant end.

In 2016, the Fig 9 revealed that out of the 41 road accident hotspots, about 7 accidents were caused by impatience. Patience, focus and calmness in driving tends to prevent RTA, RTD and RTI.

Statistical Results

Statistical analysis performed on the road accident records obtained from questionnaires from Federal Road Safety Commission and Police Station revealed many causes of road traffic accidents which are grouped into 3 major factors, they are the Human Factor, the vehicular factor and the road factor. The sources of these 3 factors of road traffic accidents are shown in Chart 1, Chart 2 and Chart 3 below

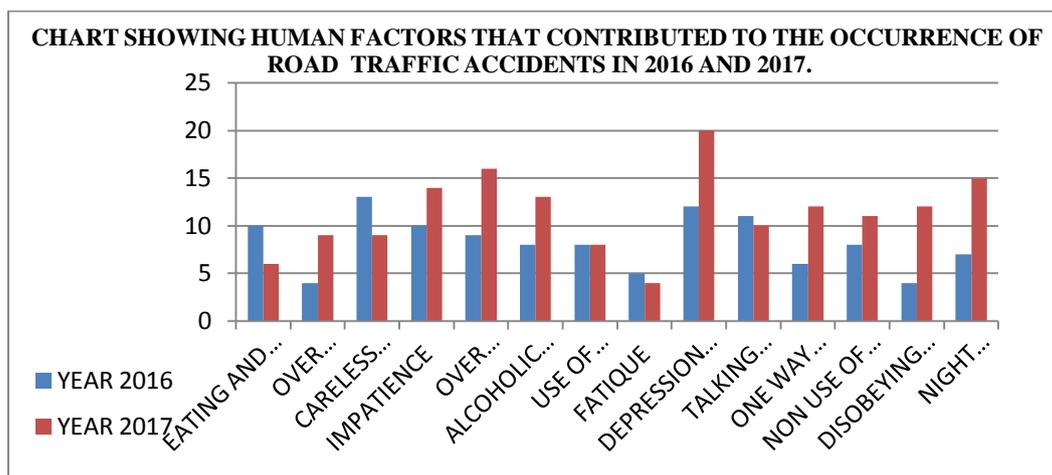


Chart 1: Human Factors that contributed to the occurrence of Road Traffic Accidents in 2016 and 2017

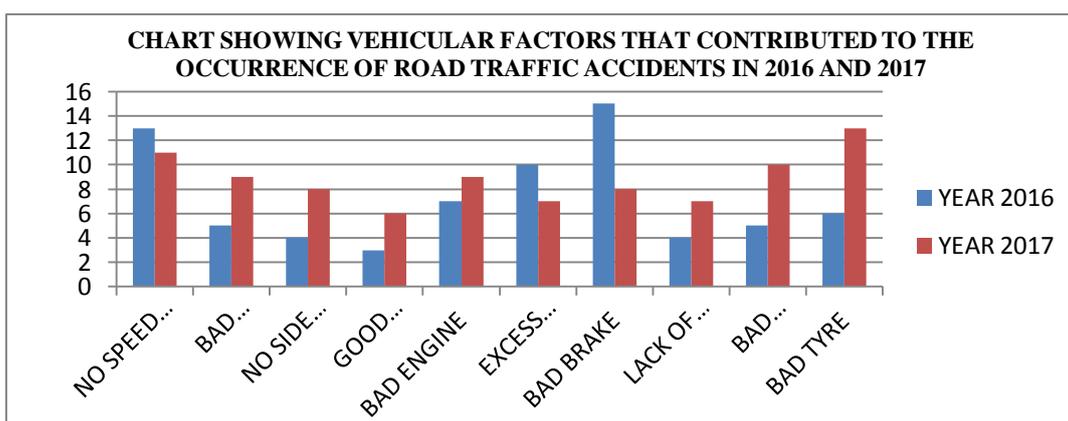


Chart 2: Road Factors that contributed to the occurrence of Road Traffic Accidents in 2016 and 2017.

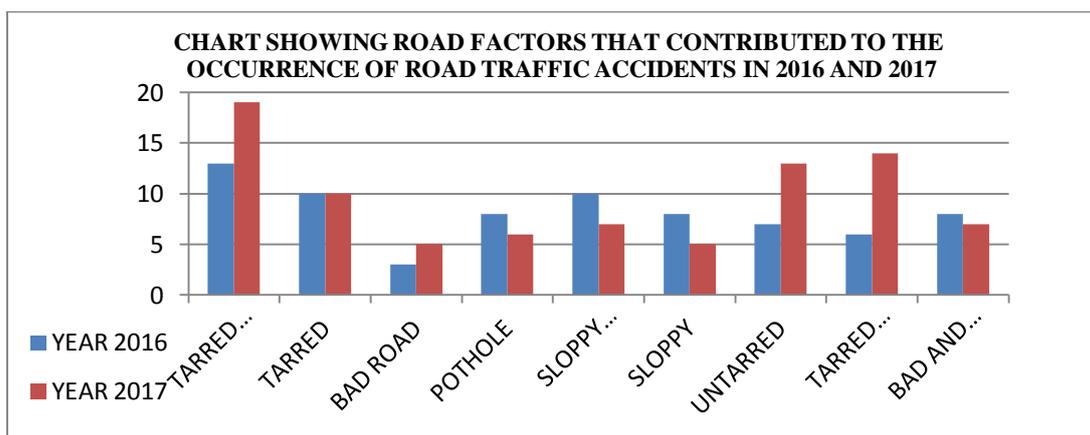


Chart 3: Road Factors that contributed to the occurrence of Road Traffic Accidents in 2016 and 2017.

In Chart 1, the highest Human Factor that caused of RTA that led to RTD, RTI and Car damage is Depression and Careless Driving = 20, followed by Over Speeding = 16, Night Driving = 15, Impatience = 14, Alcoholic Influence = 13, One-Way Driving = 12, Disobeying Traffic Rules = 12, Non Use of Helmet and Impatience = 11, Talking and Driving = 10, Over Speeding and Night Driving = 9, Careless Driving = 9, Use of Phones = 8, Eating and Driving = 6, and lastly is Fatigue = 4.

Chart 2 revealed the Vehicular factor that caused RTA, RTD, RTI and Car damage. The highest vehicular factor is Bad Tyre that recorded 13, then No Speed Limit = 11, Bad Wiper Blade = 10, Bad Vehicle Lights = 9, Bad Engine = 9, No Side Mirror = 8, Bad Brake = 8, Excess Carrying Capacity = 7, Lack of Maintenance = 7, the least vehicular factor is Good vehicle that recorded 6.

Chart 3 revealed that the highest Road factor that caused RTA that led to RTD, Major and Minor injuries is Tared and Pothole = 19, followed by Tarred and Sloppy = 14, Untarred = 13, Tarred = 10, Sloppy and Pothole = 7, Bad and Pothole = 7, Pothole = 6, Bad Road = 5, the least road factor is Sloppy road that recorded 5

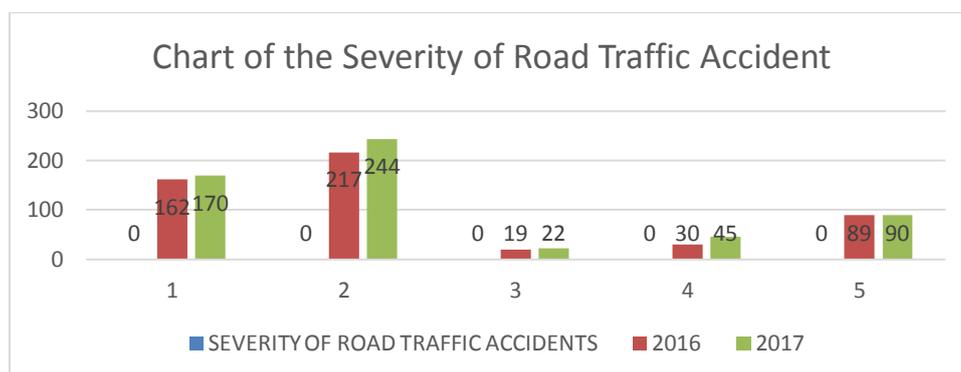


Chart 4: Severity of Road Traffic Accident for 2016 and 2017.

The Chart 4 showed the rate of Road Traffic Accidents, Fatality rate/Road Traffic Death, Major injury rate, Minor injury rate and Property damage. The Chart further showed the ratio of results for 2016: 2017 as RTA = 162 : 170, Fatality/RTD = 217 : 244, Major injury = 19 : 22, Minor injury = 30: 45 and Property damage = 89 : 90.

IV. Findings

The findings made on this paper are as follows:

1. The locations of the road traffic accident hotspots were spatially mapped as shown in Fig 3.
2. The hazardous or most dangerous hotspot within the study area is the IMSU junction roundabout.
3. The causes of the Road Traffic Accidents in the Metropolis were grouped into 3:
 - i. Human factors such as Depression and Careless Driving, Over Speeding, Night Driving, Impatience, Alcoholic Influence, One-Way Driving, Disobeying Traffic Rules, Non Use of Helmet and Impatience, Talking and Driving, Over Speeding and Night Driving, Careless Driving, Use of Phones, Eating and Driving and Fatigue.
 - ii. Vehicular factors such as Bad Tyre, No Speed Limit, Bad Wiper Blade, Bad Vehicle Lights, Bad Engine, No Side Mirror, Bad Brake, Excess Carrying Capacity, Lack of Maintenance and Good vehicle.
 - iii. Road factors such as Tarred and Pothole, Tarred and Sloppy, Untarred, Tarred, Sloppy and Pothole, Bad and Pothole, Pothole, Bad Road and Sloppy road.
4. Among the 3 factors that led to the occurrence of RTA, Human factor was analysed to be the highest cause of RTA for both 2016 and 2017. The percentage ratio of the Human factor: Vehicular factor : Road factor for 2016 and 2017 is shown in Table 1

Table 1: Percentage ratio of the Factors of RTA

Factors of RTA	% ratio for 2016	% ratio for 2017
Human factor	44.23%	47.75%
Vehicular factor	27.69%	26.43%
Road factor	28.08%	25.82%

5. The effect of the road traffic accident was shown in Chart 4, Severity of Road Traffic Accident. Which is Fatality or Road Traffic Death (RTD), Major injury, Minor injury and Property damage in the Metropolis. The result showed that Fatality rate was higher than the other effects and it is shown in Table

Table 2: Percentage ratio of the effects of RTA

Effects of RTA	% ratio for 2016	% ratio for 2017
Fatality/ Road Traffic Death	61.13%	60.85%
Major Injury	5.35%	5.49%
Minor injury	8.45%	11.22%
Property damage	25.07%	22.44%

V. Recommendations

- i. Owerri Metropolis, Imo State should be provided with good quality roads and the bad ones should be maintained frequently to avoid RTA when conveying people and goods from one location to the other.
- ii. Owerri people should be made to know the importance of Safe-Landing in road safety. It is better to be late than being late. Being too in a hurry, carelessness and lack of focus has landed many people into road accident, death and more.
- iii. The hazardous spots of the roads should be repaired and should be made known to the people of Owerri so that they will be more careful so as to avoid accidents that might lead to death, severe injuries like loss of arm, legs, brain damage, blindness etc.
- iv. Speed limit control/gadgets should be made compulsory. Every vehicle found without speed limit gadgets should be penalized.
- v. There should be strict adherence and enforcement of road safety measures and rules on road users and drivers. Do not drive while eating”, “Do not drive when tired or sleepy”, “Do not drive when you are depressed”, “Do not drive while on drugs”, “Do not drive without seat belt”, “Do not talk while driving” and so on. Defaulters should be heavily penalized and punished.
- vi. Vehicles must be checked properly before driving and all form of malfunctioning on any part of the vehicle should be worked on. This will prevent accident occurrence.
- vii. It is important to adopt GIS technology to produce reliable and up to date information on road accident data for the benefit of road users, Government agencies, researchers and decision making.

VI. Conclusion

GIS remains a very powerful tool for effective decision making, the application of GIS and Remote Sensing in the identification of the causes and effects of road traffic accident hotspots in Owerri Metropolis, Imo State, Nigeria will improve the spatial capabilities to analyze accident hotspot, identify their causes and effects and predict future occurrence of Road Traffic Accidents that will help to minimize the rate of Road Traffic Accidents occurrence and enhance the socio-economic development of Owerri Metropolis, Imo State, Nigeria.

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