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The Proximity of Road Traffic Crash Black Spots to Federal Road Safety Commission Zebra Location/Emergency Health Care Facilities in Federal Capital City, Abuja, Nigeria

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Abstract

This research analyzed the proximity of road traffic crash (RTC) Black Spots to Federal Road Safety Commission (FRSC) zebra locations/emergency health care facilities to ascertain the rescue of RTC victims in Federal Capita City (FCC). Geographic Information System (GIS) based location model was applied in the street network analysis to identify RTC black spots that are outside the close reach of FRSC rescue points/health facilities in FCC. Distance was used as impedance factor. Spatial query and buffer analysis were employed to determine accident spots that fall between 2 kms of the health facility and zebra point. Remote Sensing and GIS techniques were applied in proximity analysis using location strategies and interconnected features. The results were presented on road network maps. The result suggests that five (5) additional zebra points would be effective in terms of proximity to RTC in the area and would considerably improve spatial coverage for response times. The areas where quick response and medical facilities are insufficient were identified. Optimal locations for siting zebra points that can effectively service RTC black spots were proposed.

Keywords: proximity analysis, buffering, health facilities, zebra location, RTC, GIS, FCC

1. Introduction

1.1 Background of the Study

In an era of continuous growth in mobility and demand for transportation, safety is an issue of major social concern necessitating search for methods or alternatives that ensure safe, efficient, and faster means of transport (Kepaptsoglou, et al, 2012). This is true in a country like Nigeria, where major cities like Abuja are experiencing continuous growth in terms of population and urban development. Among the three morphological entities that form the city (road network, parcels and buildings), road layout is the most permanent over time (Hanae and Claire, 2021). The cities being the hub of business activities are facing ever-increasing vehicular movement, which results in multifaceted traffic problems such as RTC and peak hours' congestion among others. These situations, particularly emergency situations arising from RTC demand a method that can ensure speedy attention to victims. Immediate medical attention in such circumstances saves valuable human lives. Analysis and modeling research works can be conducted on road networks to analyze their growth mechanisms (Casali & Heinemann, 2019; Jang et al., 2020).

Remote Sensing and Geographic Information Systems (GIS) play a vital role in proximity analysis, transportation and urban planning applications (ESRI, 2007; Sanchez-Mangas, et al, 2010; Pour and Yue, 2012). GIS can be applied to Infrastructure management, fleet/ logistics management, and Transit management as well as provide solutions to traffic congestion (Ojiaka, et al, 2018). Traditional GIS incorporates the aspects of database techniques, data pre-processing and manipulation, spatial analysis and data interpretation, data computation, and data visualization (Mingke and Stefanakis, 2020). This research analyses the proximity of RTC black spots to health facilities in the Federal Capital (FCC) using Geospatial techniques.

The incessant demolition by the Federal Capital Development Authority (FCDA) in a bid to conform to the FCT master plan has resulted to inbound traffic in the morning and outbound traffic in evenings as compared to outer fringe to inner core movement at the initial stage of relocation to Federal Capital Territory (FCT). This peak period movement inundates the traffic landscape with Road Traffic Crash (RTC) along the traffic corridors (Balogun, 2006). Many studies suggest that this problem is common with most cities (Kerekes, 2018; William, et al., 2019; Debashis et al., 2019; Hamid et al., 2020).

The city's rapid growth, increase in the number of vehicles, traffic jams, over speeding and bad driving have resulted to an increase in death toll arising from RTC which is becoming a major source of grief in a number of homes in FCC and Nigeria in general. The problem is been compounded by lack of early emergency response, which can be attributed to inadequate number of emergency health care facilities, inadequate emergency response facilities, and routing problems among others (Pisha, 2002; Ojiaka et al,2018). This increase necessitates the need for developing means of saving the life of RTC victims. According to Sanchez-Mangas, et al, (2010), minimum reduction of medical response time can be statistically associated with an average decrease of the probability of death by one third, both on motorways and conventional roads. Studies follow a similar format of analysis, which consist of collecting incident data pertaining to an 'accident black spots and the distance to the nearest medical facility. However, the spatial distribution of the medical facilities and other first respondents have not always been put into consideration especially in Nigeria where a police/FRSC presence is needed for treatment to be administered to accident victims.

Therefore, this study is embarked upon with a view to identify RTC black spots that are outside the close reach of FRSC rescue points/health facilities within the study area. It attempts answering the question: How far away from RTC black spots are FRSC Zebra points and emergency health care facilities in FCC? It is limited to Federal Capital City. It involved the collection of RTC black spot from FRSC for 2011- 2012 and subsequent identification of the RTC black spots, FRSC zebra points and medical facilities in the study area. Steps were taken to examine coverage distance for emergency response through the use of proximity analysis, with a view to determining measures that can be used to for effective emergency response in FCC.

1.2 GIS Based Location Models

Alade and Adepoju (2010) developed a real time model for road safety and access to emergency service measures using GIS and Remote Sensing through the application of location Based Service (LBs) by obtaining positioning information with spatial and non-spatial database to determine variables as shortest path, closet medical facility, and location-Allocation based on Transportation Network. The result of the model indicates that, the possibility of effective response in real-time can be made attainable

Churches (1997) in Location Modeling and GIS minimized the required number of facilities and EMS regions by using a location set covering model to serve the demand of crashes and emergency incidents. The objective of the model was to provide maximum coverage with a fixed number of facilities. While accessibility is a measurement to represent the number of ambulance locations required to provide service, the ambulance locations establish the population that the ambulance can serve within a response-time criterion. Other studies that adopted a similar methodology include Location science research (Hale and Moberg, 2003), Location-allocation problems in the plane (Beaumont, 1981) and Location analysis: A synthesis and survey (ReVelle, 1987 and Eiselt, 1992)

Lamber (2012) in Proximity Analysis - Location Strategies used interconnected features to determine optimum paths using specific decision rules where the decision rules were based on minimum time or distance. Outcome of the decision rule answered question like, if there has been an accident out of ring road, which is the closest hospital and the shortest route to that hospital for an ambulance. The study concluded that network analysis identifies the closest hospital in terms of distance and also indicates how to go there. The study also indicates that network analysis is commonly used for the analysis of moving resources from one location to another through a set of interconnected features.

Fuller, et al (2002) assigned different weights to risk factors, determined an appropriate location of sign post and other road furniture and produced a map displaying a composite risk of black spots by combining IKONUS digital photograph, digital terrain model of environmentally affected rural roads by means of multi-criteria evaluation (MCE) and Fuzzy sets respectively. Perhaps the limitations of GIS are its over simplification of transport environment which can affect analysis of large network and the inadequate account of 'virtual' relationships.

1.3 Study Area

The Federal Capital City, was designed and structured into four Phases (I-IV) of developments, and located in the northern part of the Federal Capital Territory (FCT) of Nigeria. It became the new administrative centre as development and movement into Abuja started in 1980, after the master plan was completed by International Planning Associates (IPA) in 1979. The entire Federal Capital Territory is located between latitude 8025' and 9025' north of the equator and longitude 6045' and 7024' east of the Greenwich Meridian (Fig 1). The Federal Capital City (FCC) is planned to cover an area of about 250 square kms, while the rest of the Territory of the city region covers about 7,750 square kms. The FCC is currently the administrative Headquarters of the Federal Republic of Nigeria. It is made up of five districts namely: Wuse; Garki; Asokoro; Maitama; and Jabi districts. The FCC is a subset of Abuja Area Municipal Council (AMAC) which constitutes the core area of this study, AMAC is made up of both built-up (planned) and rural (unplanned) areas, AMAC doubles as the headquarters of the federal republic of Nigeria as well as that of the FCT, as it constitutes the economic, financial, trade and administrative center of the territory (Annual Abstract of statistics, 2009). The bulk of Federal institutions, ministries, and embassies are located within the confines of the FCC. Due to the slow pace of road reconstruction, many inhabitants of Abuja spend hours in traffic trying to get to work each day. About 75 percent of residents reside in the outskirts of the main city where all economic activities are located (Wikipedia, 2013). The Federal Capital Territory, Abuja has 13 government hospitals, spread across the 6 area councils, namely, General hospitals, AMAC located in Nyanya, Abaji, Gwagwalada, Kwali, Kuje and Bwari, including those located in the federal capital city. They include: Wuse General Hospital, Maitama General Hospital, Asokoro General Hospital, National Hospital, Gwarimpa General Hospital and of course Gwagwalada Teaching Hospital, as well as Federal Staff hospital, airport road Jabi.

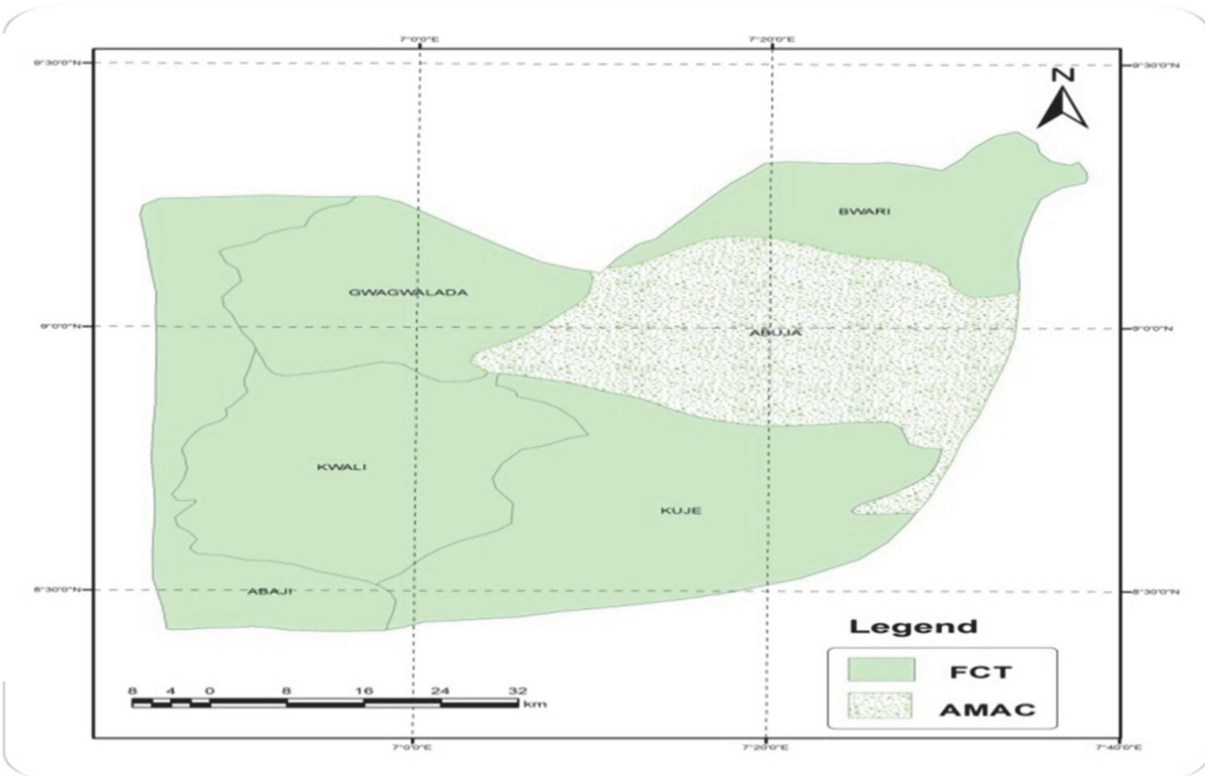

Figure 1. FCT and AMAC

Source: NASRDA, 2012

2. Methods

2.1 Data Source and Data Acquisition

The study combined both spatial and attribute data (acquired from both primary and secondary sources) in a GIS environment using ArcGIS 10.0 and then subjected this to spatial query. A site survey of the study area was carried out to obtain the coordinates of RTC black spots and zebra points collected from FRSC as well as hospital locations with the use of a GPS Map 76S Mark (GARMIN) for validation. This instrument was used to locate and pick coordinates in (Universal Transverse Mercator (UTM) usually in meters) of data in the study area. The secondary data include data obtained via satellites and other cartographic devices and agencies. Hence the data comprises of the following information; source, description and types as summarized in table 1.

Table 1. Summary of Data Sources

Data Type	Description	Source	Year
Nigerian Sat II Imagery	5metres multi spectral	NASRDA	2013
Blackspots and coordinates	Area of high Accident occurrence	FRSC /Field work	2011/2012
Zebra point and coordinates	Road Safety emergency rescue centers	FRSC /Field work	2012
Emergency health care facilities and coordinates	Emergency health care facilities within FCC	FRSC/Field work	2013
Road network	Digitized from the satellite Imagery	Field work	2013

Figure 2 is Nigerian Sat II 2013 multispectral imagery (5m multispectral and 2.5m Panchromatic) of FCC obtained from the National Space Research and Development Agency, (NASRDA). List of 16 possible emergency health care facilities were obtained from FRSC which are: National Hospital, Garki General Hospital, Asokoro General Hospital, Wuse General Hospital, Gwarimpa General Hospital, Zankli Medical Centre, Lifeway Medical Centre, Fereprod Medical Centre, Winners Medical Centre, Ruz Medical Centre, State House Clinic, Amana Medical Centre, Abuja Clinic, Arewa Specialist Hospital, Sauki Private Hospital and Maitama General Hospital. A total of seventy (70) RTC black spots obtained from FRSC and Five Zebra points locations obtained from FRSC in the study area are: Area 10 Old Parade Ground; Federal Secretariat by National Assembly; City Gate; Gwarinpa by Kubuwa Express and Kugbo under bridge.

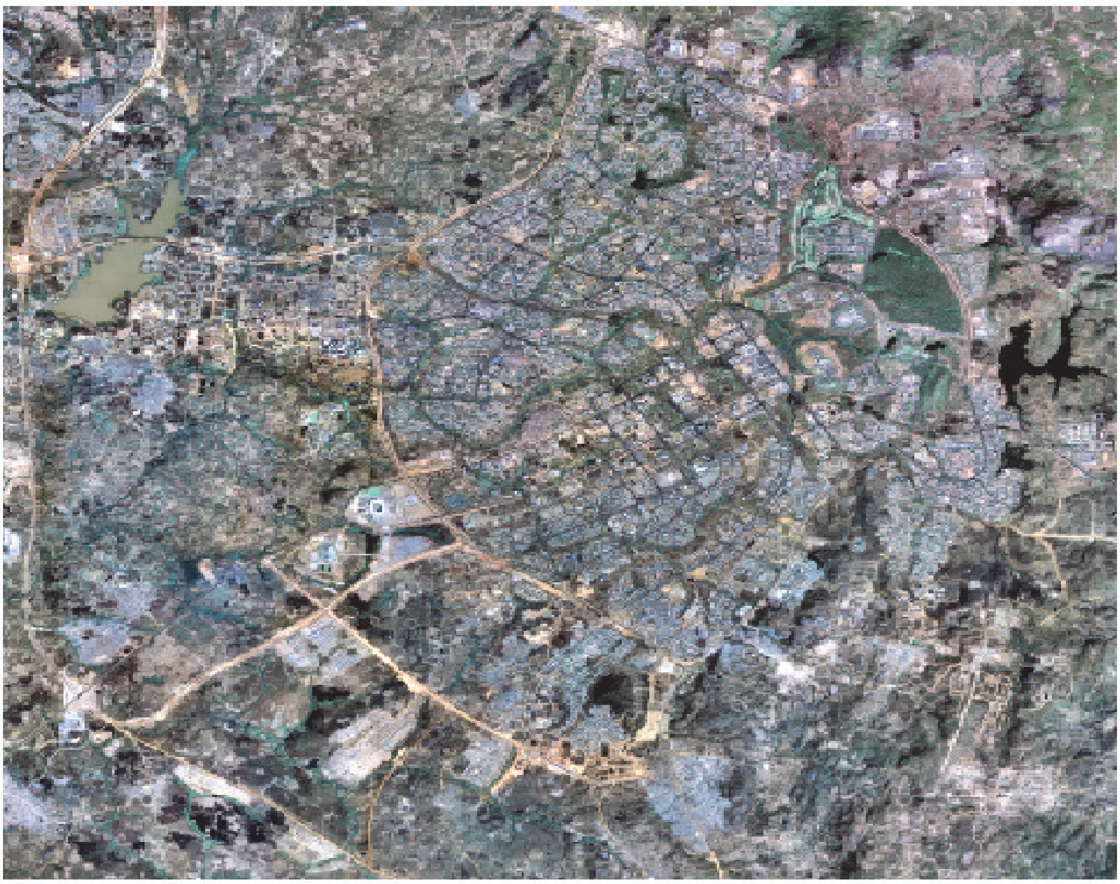

Figure 2. Nigerian Sat II Image of FCC

Source: NASRDA, 2013

2.2 Image Interpretation Technique

The Arc GIS 10.0 software developed by Environmental Scientific Research Institute was used to display Nigeria Sat II imagery in three bands (Red, Green and Blue). The software was employed to combine the three bands to produce a true colour image of the study area (multispectral band) which enhanced the ability to visualize, identify and extract features from the imagery.

2.3 Data Projection and Geo-referencing

The Nigerian Sat II, 2013 multispectral imagery covering the study area was projected to WGS 1984, Universal Transverse Mercator, Datum 100 Minna–Nigeria, Zone 32P via the data frame property of the software. The imagery was georeferenced by the collection of the X and Y coordinates of T- junctions (roads) and identifiable buildings via the use of Garmin global positioning System device during the field work (ground truthing exercise). The points collected where then used to geo-reference the image. At the end of the geo-referencing, an image clipping operation was performed using the Arc GIS 10.0 software in the arc toolbox to extract the area of interest. This was done to obtain a rectified map and to aid the visibility of the features to be digitized which include road network of the study area.

2.4 On-Screen Digitizing

The digitizing process of converted geographical features from raster map into vector format, hence a personal geo-database for each feature of interest were created in the Arc Catalogue of the ArcGIS software. The features created are shown in the table 2 below and they were projected to WGS 1984, Universal Transverse Mercator, Datum 100 Minna–Nigeria Zone and later imported into the ArcMap environment as shape files (.shp).

Table 2. Feature Types

S/NO	Data	Feature Type
1.	Roads	Line
2.	Some Built-up Areas	Polygon
3.	Rivers	Line
4.	District	Polygon
5.	Water body/Lakes	Polygon

2.5 Data Base Creation, Feature Integration and Overlay

The creation of database was carried out after geo-referencing in Arc-Catalog, after which feature dataset and feature classes were fashioned out, they include; FCT Roads, Rivers, Built-up area, Water body, river channels, FCT Boundary, and the various Districts. Four Layers were extracted from the satellite imagery via a digitization operation, hence the layers digitized include: FCT roads, river channels, FCT Boundary, and the various Districts (Maitama, Wuse, Central Area, Asokoro, Garki, and Jabi) respectively as shown in the figure 2. The roads include: B/4 city gate, 3 Arm zone, Sagari/Fikko/Area II, A Bello/Benue pla, Shagari/Fed sec, H Macau/Mailam/war coll, Abator/M muhmd, T Balew/Area 7, N mkt/zon 1, Wusezo 5/Ibro, H Macau/z-6/NEPA, Sherato/M drive, Kubwa exp, zone2/Obasanjo, karmo, Life camp, Durumi/Kado etc. This was followed by feature integration and overlay to create a visual picture of the transportation network in FCC

2.6 Geospatial Analysis

The basic spatial analysis employed for this work was done in ArcMap environment.

2.6.1 The Arc Map Applications

In Arc Map, the study was able to create maps from different layers of spatial data, choose colors and symbols, query attributes, analyze spatial relationships, and design map layouts. The Arc Map interface contains a list (or table of contents) of the layers in the map, a display area for viewing the map, and menus and tools for working with the map. In Arc Toolbox, tools were used to convert spatial data from one format to another as well as to change the map projection of data.

2.6.2 Proximity Analysis

This was achieved via the process of queries and buffering techniques hence coordinates of the health facilities were mapped on the layer then a circumference buffer of about 2km was performed to identify the RTC black spots that fall within the region and as well to determine the sufficiency of the available facilities.

2.6.3 Buffering Operation

This geo-processing operation was used to determine the distances of features from each other within a defined area. Hence buffer analysis was employed to determine accident spots that fall between 2 kms of the health facility and zebra point.

3. Results

3.1 Feature Integration

The Zebra points, Black spots and Hospital coordinates obtained during the field work and from the Federal road safety commission was first recorded into the Microsoft excel document. It was then converted to the .csv file delimited format and subsequently imported into the ArcGIS software as longitude and latitude coordinates. Then it was converted to an event file and tied to the coordinate system of the data frame property and finally exported into the map layer

3.2 Overlay of Field Features on the Satellite Imagery.

During data collection, coordinates of identified RTC black spots and their respective addresses were obtained, a total of seventy (70) point (Figure 3) were located and plotted on the base map for the study area. Furthermore, the black spots representation indicates that RTC occur mostly at intersecting roads or junctions of major roads in the Federal Capital City. These major roads are dual carriage ways with triple lanes that accommodate three vehicles each with traffic grid at junctions or intersections especially at round about. Reckless driving and over speeding by motorist on these roads especially during pick and in-bound as well as out bound hours was observed during the field work.

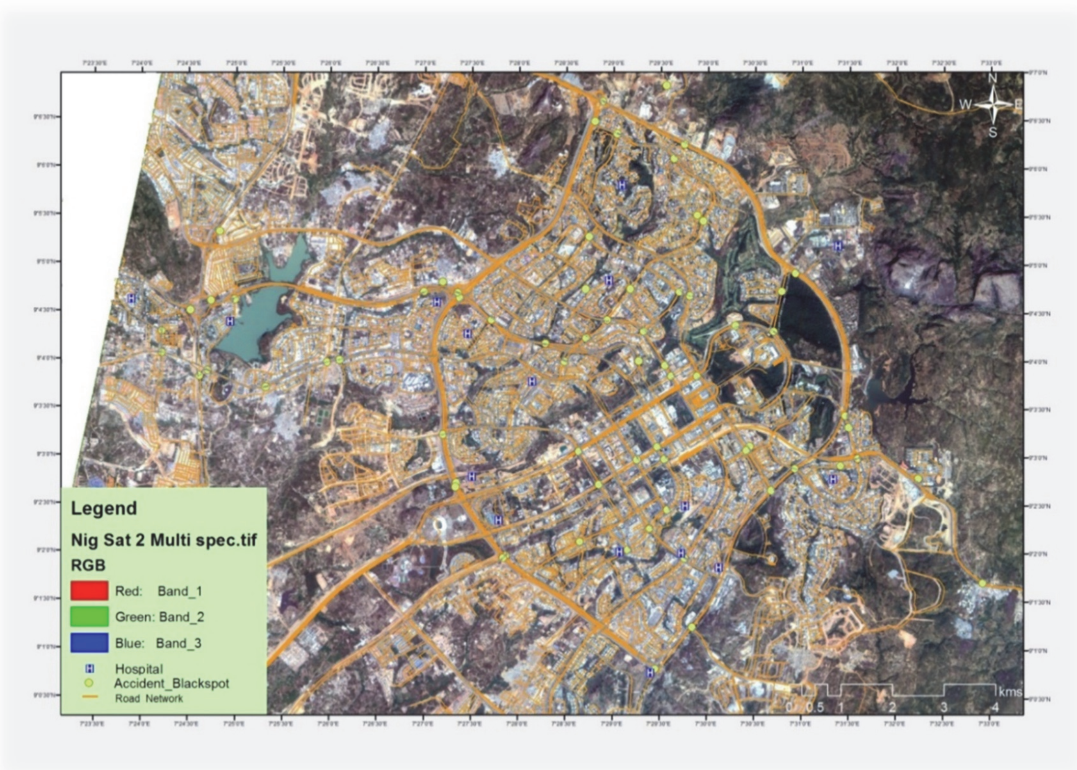

Figure 3. Overlay of Satellite Imagery and Spatial Features

3.3 Proximity of RTC Black Spots to FRSC Ambulance/Health facilities

In order to determine the sufficiency of the existing hospitals and FRSC zebra points rescue team to service the study area in terms of RTC, query analysis was embarked upon to ascertain the proximity of existing Hospital and FRSC zebra point rescue team to RTC black spots

3.3.1 Distance from Black Spots to Emergency Health Care Facilities

To ascertain the coverage of emergency health facilities in relation to RTC black spots, data query on a 2km distance from black spots to Emergency health care facilities was generated for the six General Hospitals (Figure 4) and all identified hospitals (Figure 5) in the study area. The query results displayed indicate that almost all black spots in CBD, Garki, Wuse and part of Asokoro district are within the 2km distance (represented in blue) from the General Hospitals. However, about one-third of the black spots in Maitama and Jabi districts are outside the 2km distance (represented in red) from the general hospitals. Also, figure 6 displays a 2km distance from RTC black spots to all identified FRSC certified Health care centres (both General and Private Hospitals) that have the capability to attend to RTC victims in the study area. More so, the services could be improved upon if all the hospitals with adequate facilities within FCC are mandated to immediately attend to accident victims.

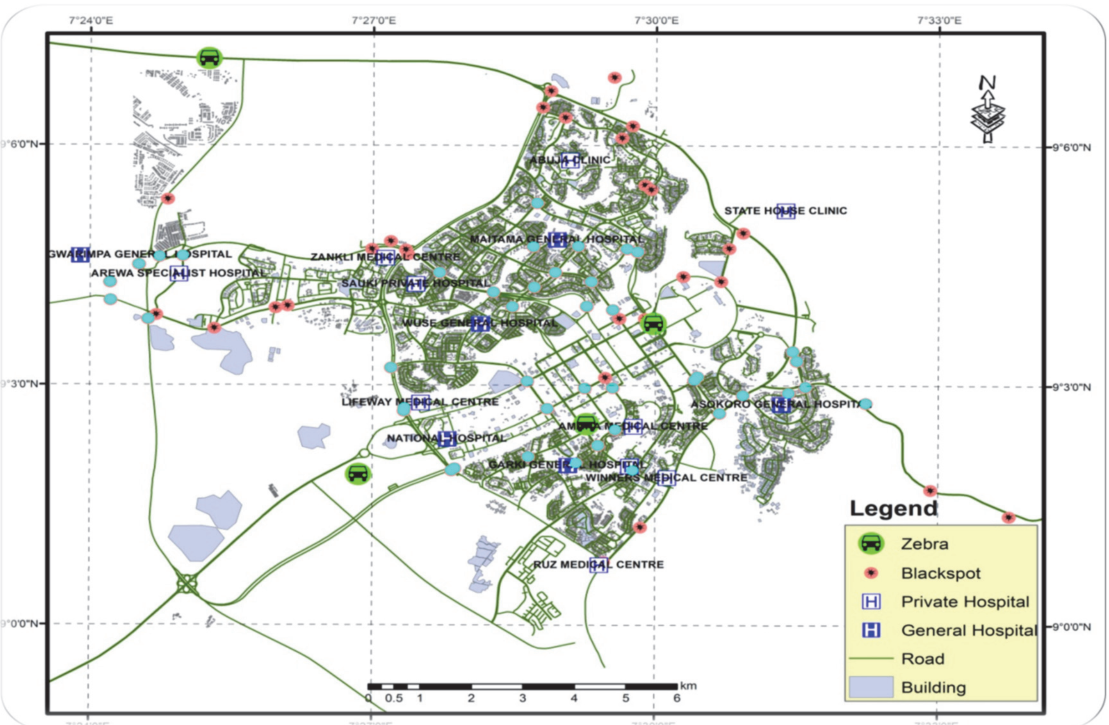

Figure 4. 2 km Query Operation of General Hospital and RTC Black Spots

Figure 5. 2 km Query Operation of Hospital and RTC Black Spots

3.4 Buffer Operation

3.4.1 Creation of 2km Buffer to General Hospitals

Buffer analysis was employed to map the identified RTC black spots in the study area that fall within the distances of two kilometers (2km) from the general hospitals (Figure 6). The result of the buffer zones created indicate that general hospitals which are assumed to be adequately equipped in the study are fairly sufficient to service RTC victims within sufficient time and efficient coverage of rescue operation.

3.4.2 Distance from FRSC Zebra Points to Black Spot

Figure 7 displays Black spots that fall within 2km distance from zebra points. Whereas the majority of RTC are accessible by the FRSC rescue team in CBD and Garki, there are areas in Wuse, Maitama, Asokoro and Jabi districts that fall outside the 2km response target by FRSC. Consequently, to achieve sufficient and effective coverage of RTC black spots, there is the need for the creation of more zebra points by FRSC.

3.4.3 Site Selection for Siting of Additional Zebra Point

The selection was done through a query in Arc Map, using 2km accessibility distance from the nearest black spots taking into consideration areas that have less coverage and major road networks at an average speed of 60km/hour. The results as shown in figure 8 suggests that five (5) additional zebra points would be effective in terms of proximity to RTC in the area and population and would considerably improve spatial coverage for response times. Proposed optimal locations for siting zebra points that can effectively service RTC black spots in (AMAC) Phase I of the FCT as shown in figure 9 include:

i. Murtala Mohammed Way and Kubwa Road in Maitama district

ii. Sani Abacha Way and Life camp roundabout in Jabi district

iii. Nnamdi Azikiwe Way in Wuse district

iv. Cairo Road in Maitama district and

v. AYA roundabout in Asokoro district.

3.4.4 Existing and Possible Zebra Point

A 2km buffer was created for the existing zebra points and possible (represented in Purple background) zebra points to show their proximity to RTC black spots. Figure 10 gives a visual picture of the spatial network of road traffic crash black spots and FRSC Zebra location/Emergency health care facilities that will exist in Federal Capital City when the new zebra points are created. This reveals the nature and quality of rescue operation that will exist in the area should the additional rescue points be created.

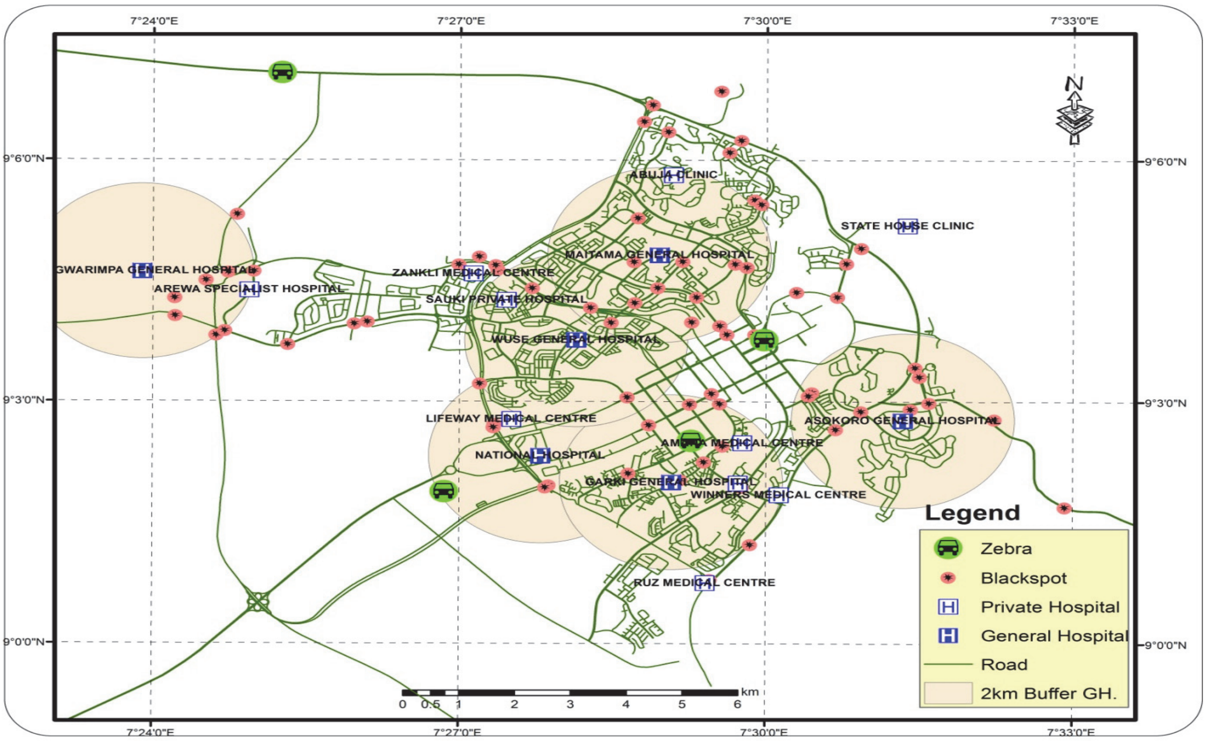

Figure 6. 2km Buffer of Hospital Facilities to RTC Black Spots

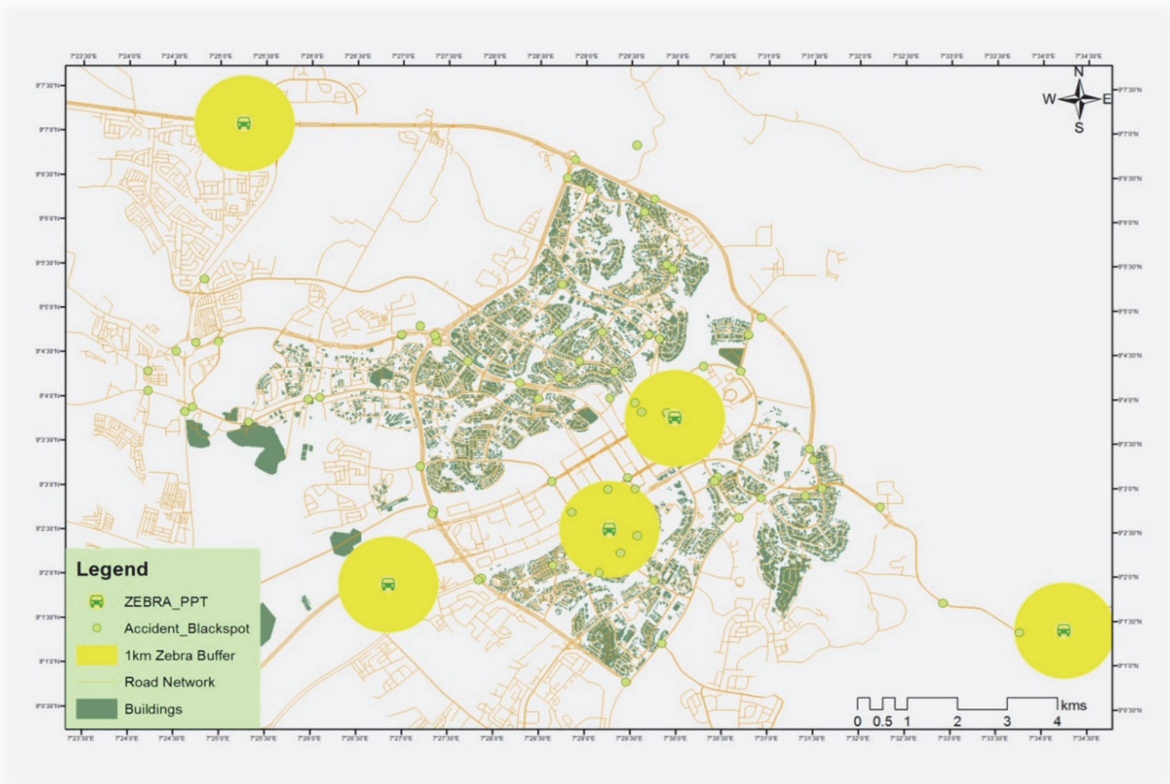

Figure 7. 2km Buffer of the Zebra Points and RTC Black Spots

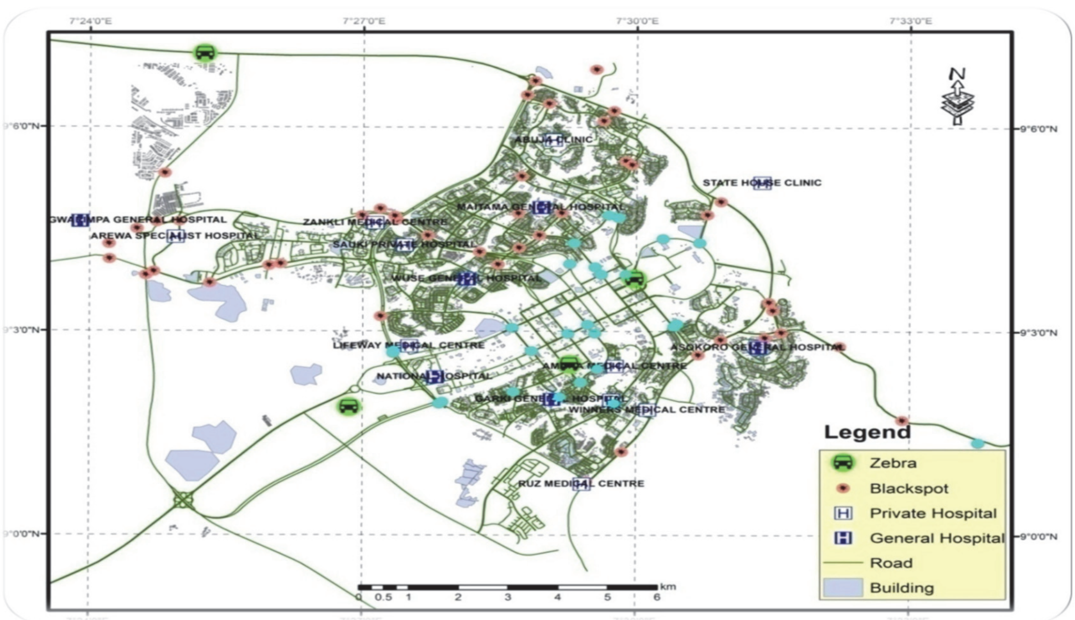

Figure 8. Query of 2km Distances from Zebra Point to RTC Black Spot

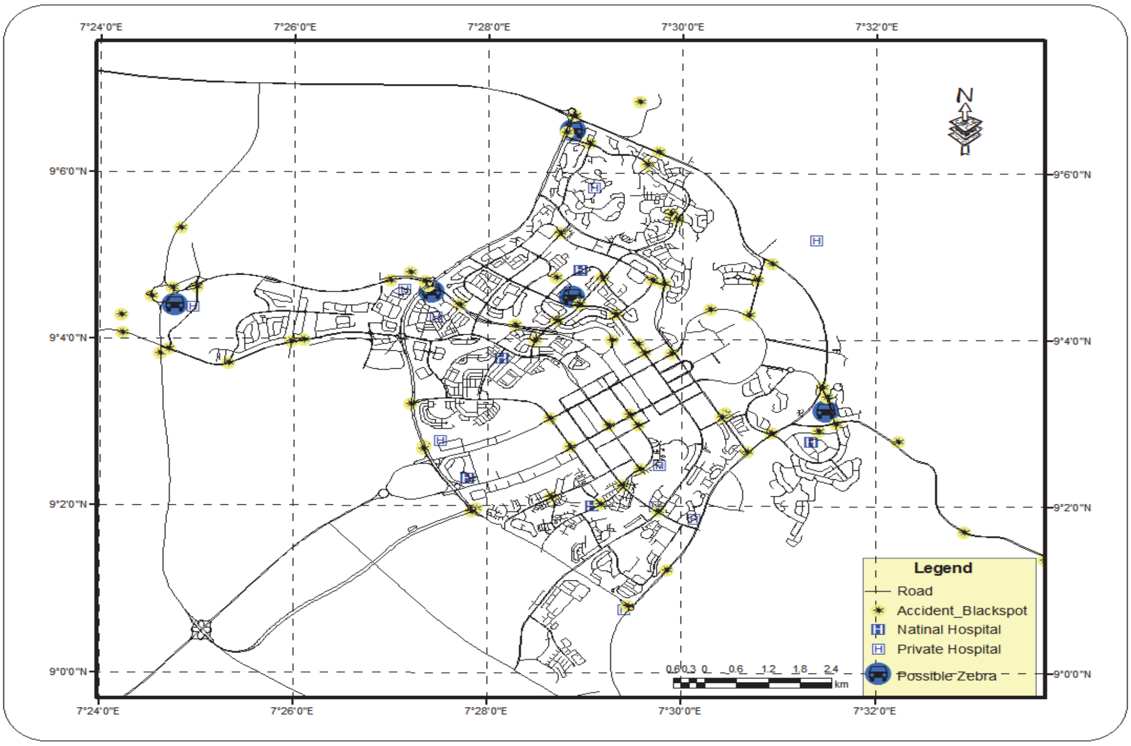

Figure 9. Possible Zebra Point Location

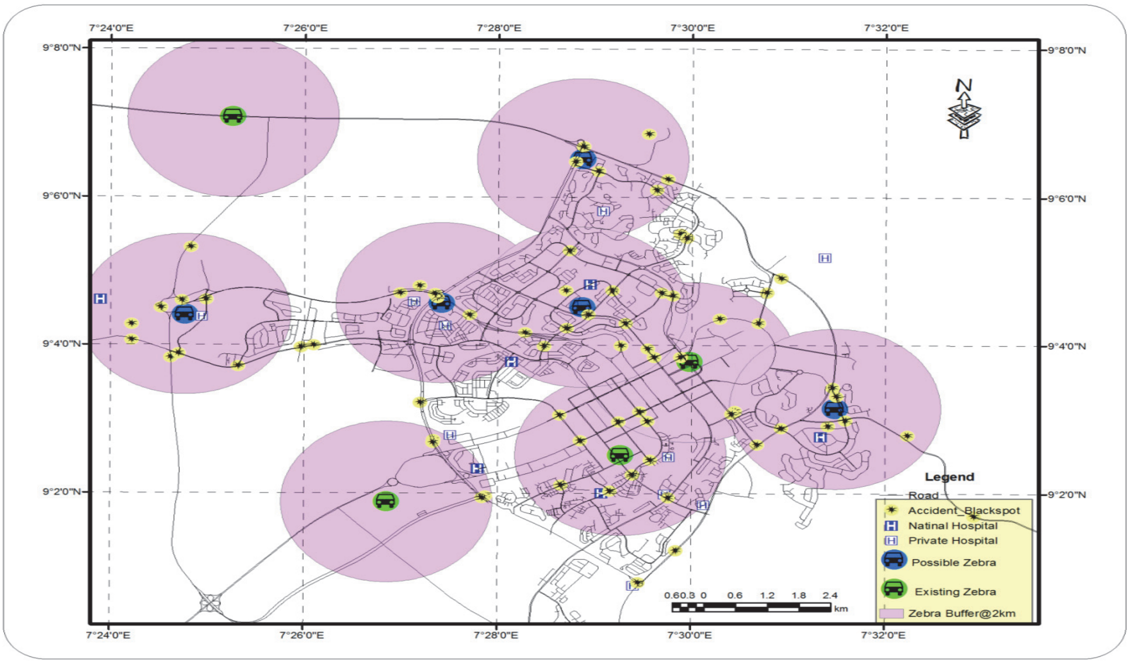

Figure 10. Existing and Possible Zebra Point

4. Discussion

Knowledge of the proximity of road traffic crash black Spots to FRSC zebra locations/emergency health care facilities is resourceful for the rescue of RTC victims in Federal Capita City. Proximity analysis is highly efficient in solving transport network problems. It has high potentiality in analyzing the closest facility and service areas in a transport network. In many cases, where time is considered as impedance factor, it has been seen that the shortest route in terms of time doesn't always mean the shortest one in terms of distance. This study therefore, considered distance as impedance factor, both for assessing the spatial relationship between RTC black spots and health care facilities as well as that between the former and FRSC zebra points. Buffering and spatial query operations were conducted using 2km distance to assess the spatial interaction in Federal Capital City.

The black spots representation indicates that RTC occur mostly at intersecting roads or junctions of major roads in the Federal Capital City. Proximity analysis indicates that the farther the distance, the higher the number of emergency health facilities that can be accessed from RTC blacks spots and the higher the number of RTC black spots that can be covered by FRSC vehicles from the various zebra points. That is, distance is of importance in terms of coverage of RTC black spots rescue operations by action agencies and conveyance of RTC victims to emergency health facilities. This implies that access to RTC black spots and emergency health facilities increases as the distance increases. The road network also expands creating alternative routes to RTC black spots.

The query results indicate that RTC black spots in FCC can be effectively serviced by the already existing health care facilities although about one-third of the RTC black spots in Maitama and Jabi districts are outside the 2km distance from the general hospitals, but they could be serviced by other hospitals. Whereas the majority of RTC black spots are accessible by the FRSC rescue team in CBD and Garki, there are areas in Wuse, Maitama, Asokoro and Jabi districts that fall outside the 2km response target. Although the study implies that most accidents occur within the radius of 2km of general emergency health care facilities, it however, concludes that FRSC emergency response units are insufficient. The results suggest that five (5) additional zebra points would be effective in terms of proximity to RTC in the area and would considerably improve spatial coverage for response times. Optimal locations for siting zebra points that can effectively service RTC black spots in (AMAC) Phase I of the FCT were proposed.

The study further offers a creative and realistic graphical presentation of the RTC black spots where FRSC rescue zebra points and emergency health care facilities in the study area were overlaid using GIS software program (ArcGIS 10.0) to provide stakeholders with a better understanding of the RTC accessibility to emergency facilities. It further analyzed proximity of FRSC zebra points to black spots and from the black spots to health centers using a 2km distance in order to establish the coverage of existing emergence health centers and rescue vehicles.

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