Journal of Geoscience and Environment Protection, 2023, 11, 121-134
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

The Spatial Patterns of Road Traffic Crash Black Spots and Emergency Facilities in Federal Capital City

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How to cite this paper: Jibril, M. S., Aule, D. S., & Garba, B. D. (2023). The Spatial Patterns of Road Traffic Crash Black Spots and Emergency Facilities in Federal Capital City. *Journal of Geoscience and Environment Protection, 11,* 121-134.
https://doi.org/10.4236/gep.2023.112008

Received: June 12, 2022
Accepted: February 25, 2023
Published: February 28, 2023

Abstract

This study aimed at determining the spatial patterns of Road Traffic Crash (RTC) black spots, Federal Road Safety Commission (FRSC) zebra points and emergency health care facilities in Federal Capital City (FCC). The aim was to provide stakeholders with information that will aid their understanding of accident prone locations and accessible rescue possibilities for accident victims on the roads in FCT. GPS Map 76S Mark (GARMIN) was used to locate and pick coordinates of data in the study area. A total of 16 possible emergency health care facilities, seventy (70) RTC black spots and Five Zebra point locations were obtained from FRSC. ArcGIS 10.0 was used to compute the data by plotting the coordinates to produce maps of the spatial relationship and to carry out Nearest Neighbour Analysis (NNA). The result was further used to determine the spatial patterns of RTC black spots as well as patterns of the emergency facilities. Generally, the result shows that the spatial trend is turning towards dispersion. However, there is less than 1% likelihood that the dispersed patterns could be the result of random chance. It was recommended that, the Federal Road Safety Commission should be staffed with trained professionals that can be responsible for accident data surveillance and analysis using geospatial techniques.

Keywords

Accident, Black Spot, Emergency, Pattern, Spatial, Zebra Point

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, Karlaftis, & Mintsis, 2013; Aule, Jibril, Garba, & Adewuyi, 2022). This is also true in a country like Nigeria, where cities are experiencing continuous growth in terms of population and built-up areas (Hanae & Claire, 2021; Aule, Jibril, Garba, & Adewuyi, 2022). 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 (Maqboo, Sethi, & Singh, 2019; Monia, 2021; Yunus & Abdulkarim, 2022; Aule, Jibril, Garba, & Adewuyi, 2022). These situations, particularly emergency situations arising from RTC demand a method that can ensure speedy attention to victims (Gebretensay & Juremalani, 2018; Thakare, Shete, & Bijwe, 2021; Dinesh, Sujesh, & Kumar, 2021; Aule, Jibril, Garba, & Adewuyi, 2022). Remote Sensing and Geographic Information Systems (GIS) play a vital role in proximity analysis, transportation and urban planning applications (Sánchez-Mangas, García-Ferrrer, De Juan, & Arroyo, 2010; Olawole, Arilesere, & Aguda, 2015; Jibril & Aule, 2020). The potentials of GIS technology in database design and creation has been demonstrated and found to be more efficient than the manual approach (Aliyu, Shahidah, & Aliyu, 2013; Leni, Gladwin, Jency, Sreelakshmi, & Vishnu, 2018; Yunus & Abdulkarim, 2022). Scholars have demonstrated the ability of GIS to display locational information of geo-based schools and other institutions together with useful attribute data (Aliyu, Shahidah, & Aliyu, 2013; Akpan & Njoku, 2013; Makadi, Abbas, Sati, & Dankaka, 2019; Qaddumi, 2020; Aule, Jibril, & Adewuyi, 2021). In FCC, vehicular movements are increasing with increasing traffic problems and consequent need for control measures. Thus geospatial techniques find application in handling traffic crash challenges.

Consequently, this research focuses on spatial patterns of RTC black spots, FRSC zebra locations and emergency health care facilities in the Federal Capital City (FCC) using Geospatial techniques. The problem of time travel can be addressed if emergency health care facilities are spatially distributed which can be achieved through the combination of spatial and non-spatial data to derive meaningful information (Pasha, 2006). 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. Against this backdrop, this study assessed spatial distribution of RTC black spots and Zebra points as well as emergency health care facilities in FCC through the application of geospatial techniques so as to determine the pattern of distribution of RTC black spots, FRSC zebra points and emergency health care facilities in FCC. The study involved the collection of RTC black spot from FRSC for 2011-2012 and subsequent identification of coordinates of the RTC black spots, zebra points and medical facilities in the study area. These coordinates were further plotted and queried, using Nearest

Neighbor Analysis to determine whether they are systematic, clustered or uniform.

1.2. Conceptual Framework

The study utilizes the concepts of GPS, GIS, Remote Sensing and Conventional Methods in order to identify RTC black spots in the FCC and analyze the pattern of distribution of RTC black spots, FRSC zebra points and emergency health care facilities as well as establish the time of travel from the RTC black spots to emergency health care facilities and converts the results to useful data to determine the sufficiency of exiting emergency health care facilities and rescue facilities in servicing RTC victims within the study area.

1.3. Spatial Models

These models got their spatial dimension from zonal structure in which it is assumed that all attributes are uniformly distributed throughout space as the spatial interaction between zones are established via networks, linked only to the centroids of the zone, however, it does not take the topological relationship of places into account. Whereas, in transport system, junctions and roads have topological relationship as junctions and links are better described by their neighbors. The shape and often the size of roads also follow the topography or the terrain of the area and portend unique risk which is spatial in nature. In fact, RTC is modified and often magnified by topological factors *i.e.* heterogeneous landscape and land-use (indiscriminate parking or location of shops along the road). The topological relationship of two road junctions or cities for that matter can best be appreciated if viewed from above (sky) as provided by remotely sensed Image. Remote sensing provides a bird's eye view or Synoptic image of ground situation. An aerial view of congested spots have shown that vehicles actually occupy a small portion of road (<40%) with the remaining lost to traffic indiscipline *i.e.* wrong parking (Godwin, 1989). Zonal models are straitjackets, and are not amenable to dis-aggregation of data. These limitations led to serious methodological difficulties such as the "modifiable areas unit problem" and problems of spatial interpolation between incompatible zones (Openshaw, 1984; Flowerdew & Openshaw, 1987; Fotheringham & Wong, 1991; Goodchild, Anselin, & Diechmann, 1993; Fisher & Langford, 1995). Hazard and RTC in particular do not recognize Political boundary, yet the data that are generated in order to effectively mitigate disaster are administered within politically defined boundaries (Environmental Systems Research Institute, 2000). These boundary conditions are difficult to map and virtually impossible to model without the use of Geographical Information system (GIS) and remote sensing.

The foregoing discussion shows that models amenable to micro data are needed (Wegener & Spiekermann, 1996). GIS is capable of coping with the monotony, repetitiveness, speed and accuracy required by the multistage, spatio-temporal and multi temporal data. In addition to these, the GIS are capable of handling the issue of randomness associated with traffic data.

2. Materials and Methods

The entire Federal Capital Territory is located between latitude 8˚25'N and 9˚25'N north of the equator and longitude 6˚45'E and 7˚24'E of the Greenwich Meridian (**Figure 1**). The FCC, which constitutes the study Area, is located on

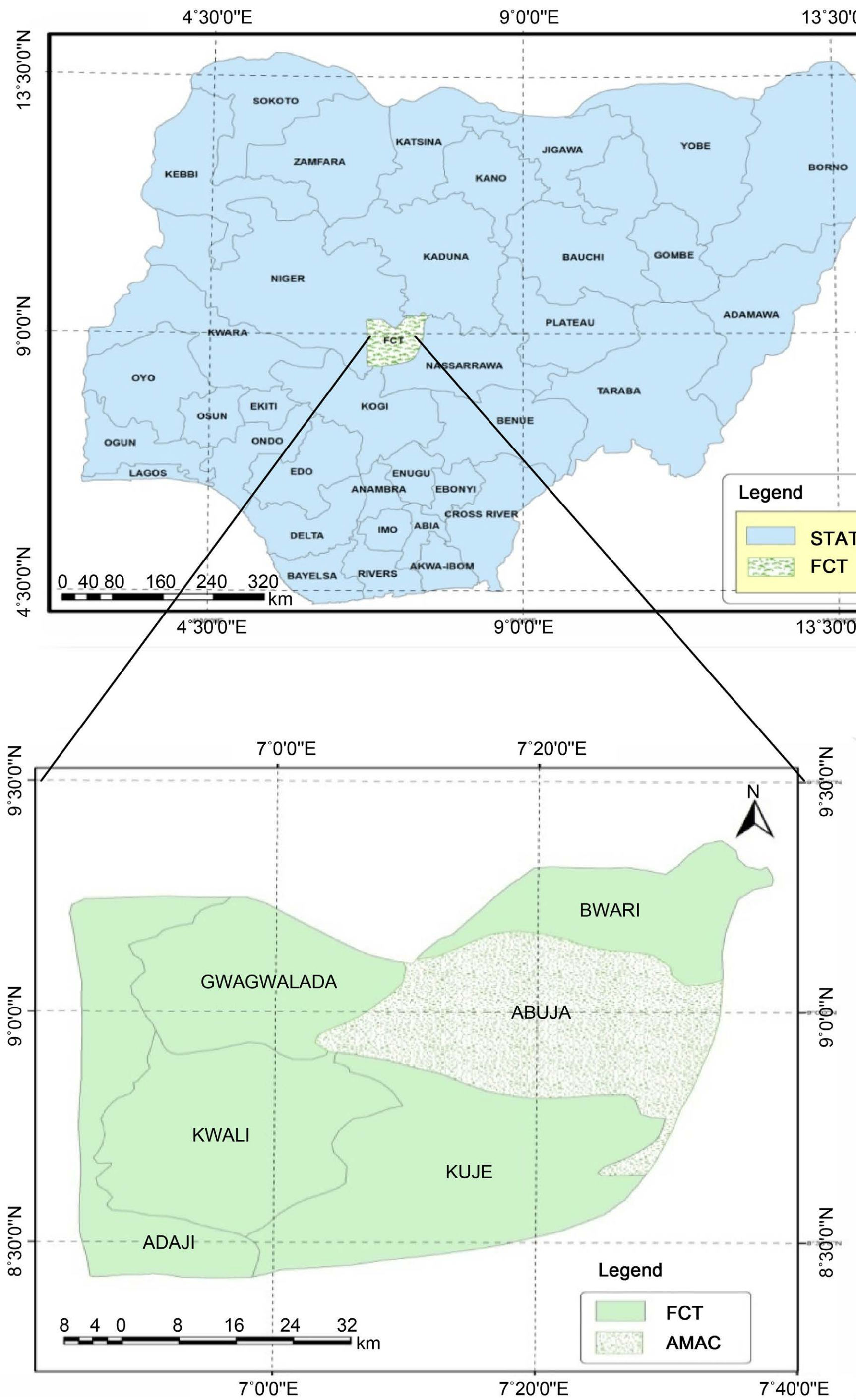

Figure 1. Nigeria showing FCT. Source: NASRDA, 2012.

the eastern wing of the territory with a land mass of 1200 km^2. The FCT has a warm climate all year round with an average annual temperature of 27.3˚C. It is relatively humid with an annual average rainfall of 1200 mm (Adakayi, 2000). From 1980 to date, the changes in urban land use(s) and surface cover have been on the increase due to massive social, economic and construction activities in the designated areas of the FCC. However, the natives of Abuja which FCC, is a subset, are chiefly subsistence farmers (Federal Capital Devlopment Authority, 2013). 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 data used for this study were obtained from primary sources. 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. Hence the data comprises of black spots, zebra points, emergency health care facilities and their respective coordinates. A total of 16 possible emergency health care facilities, seventy (70) RTC black spots and Five Zebra point locations were obtained from FRSC. Black spots are areas of high accident occurrence, zebra points are road safety emergency centers while emergency health care facilities are the hospitals found within the FCC.

Pattern analysis was conducted to determine the spatial spread of RTC black spots and emergency facilities. This was computed in ArcGIS 10.0 by plotting the coordinates of the RTC black spots, medical facilities and Zebra points to produce maps of the spatial relationship between them. ArcGIS 10.0 was also used to carry out Nearest Neighbour Analysis (NNA). The result of NNA was further used to determine the spatial patterns of RTC black spots as well as patterns of the emergency facilities.

Nearest neighbor analysis examines the distances between each point and the closest point to it (Euclidean distances). Hence, it describes the distribution of points according to their spacing. The Nearest neighbor index measures the degree of spatial dispersion in the distribution based on the minimum inter-feature distances. It is based on the distance between adjacent point features, such that the distance between point's features in a clustered pattern will be smaller than in a scattered (uniform) distribution with random falling between the two. The equation for the nearest neighbor is computed in ArcGIS through the following steps

$$\text{Nearest Neighbor Index}(\text{NNI}) = \text{d}(\text{NN})/\text{d}(\text{ran}) \quad (1)$$

Source: ArcGIS Resource.

where, $\text{d}(\text{NN})$ is observed Nearest Neighbor distance;

$\text{d}(\text{ran})$ is mean random distance.

The values of NNI fall in between two theoretical extremes, 0 and 2.1491. When all the points in a pattern fall at the same location, the pattern represents the theoretical extreme of spatial concentration, in this case, Ad = 0 and NNI = 0.

The more closely the points are clustered together, the closer to 0 NNI will be, since the average nearest neighbor distance decreases. The closer NNI gets to 1, the more randomly spaced the points are. The value of NNI approaches 2.1491 for perfectly uniformly spaced or dispersed points. Hence, the closer NNI is to 2.1491, the more uniformly spaced or dispersed the data are.

The result of the analysis was displayed graphically. This was subsequently analyzed to determine the pattern of distribution of the RTC black spots, FRSC zebra points and Emergency healthcare facilities.

3. Results and Discussion

This section presents and discusses the results of the spatial distribution of RTC black spots, emergency health care facilities and FRSC zebra points. The spatial data of RTC black spots is presented in **Table 1**. **Table 2** shows the spatial data of emergency health care facilities while **Table 3** captures the spatial data of the FRSC zebra points. The spatial relationship between the RTC black spots and FRSC zebra locations is expressed in **Figure 2**, while **Figure 3** presents the relationship between the spatial distribution of RTC black spots and emergency health care facilities found in the study area.

Spatial Patterns of RTC Black Pots and Emergency Facilities

Nearest Neighbor Analysis was conducted for emergency health care facilities, RTC black spots and FRSC zebra points in ArcMap from the plotted coordinates so as to establish their pattern of distribution. Results of the analysis are shown in **Figures 4-6** respectively. In **Figure 4**, Nearest Neighbour Ratio is 290.7, Z-score is 2217.2 and P-value is 0.01. The z-score value implies that, there is less than 1% likelihood that this dispersed pattern could be the result of random chance. Likewise, a dispersed pattern of the RTC black spots is observed. However, the Z-Score of 3030.03, P value of 0.01 and Nearest Neighbor Ratio of 187.65 imply that, there is less than 1% likelihood that this dispersed pattern could be the result of random chance. The situation does not differ for Zebra point locations where the Nearest Neighbor Ratio of 577.5, z-score value of 2466. 4 and p-value of 0.01 are arrived at. It means that, there is less than 1% likelihood that this dispersed pattern could be the result of random chance.

Figures 4-6 indicate the significance level of the analysis for emergency facilities' locations, RTC black spots. A dispersed pattern of distribution appears evident in each case. Recalling that, the nearest neighbor index is expressed as the ratio of the observed distance divided by the expected distance, it is statistically evident that the trend is toward dispersion since the index for each of the three variables is greater than 1. This means that spatial variation exists in the incident

Table 1. Spatial coordinates of RTC crash black spots.

S/N	Address	Northing	Easing	S/N	Address	Northing	Easting
1	Maitama Avenue	1,003,114	336,422	36	Lake Chad Crescent	1,005,340	334,947
2	Aso Drive	1,003,875	336,584	37	NamadiAzikiwe Expressway	1,005,235	335,068
3	Murtala Mohammed Express	1,004,230	336,854	38	NamadiAzikiwe Expressway	1,000,219	330,265
4	Yakubu Gowon Cresent	1,001,497	337,812	39	NamadiAzikiwe Expressway	1,000,145	330,252
5	Queen Idia Street	1,001,273	337,889	40	NamadiAzikiwe Expressway	998,818	331,236
6	A Y A Roundabout	1,000,677	338,058	41	Apo Roundabout	998,770	331,173
7	Yakubu Gowon Crescent	1,000,535	337,728	42	OlusegunObasanjo Way	996,657	334,124
8	Murtala Mohammed Expres…	1,000,486	336,841	43	OlusegunObasanjo Way	1,000,824	332,650
9	Murtala Mohammed Expres…	1,000,297	339,226	44	MoshoodAbiola Road	1,000,190	333,037
10	Murtala Mohammed Expres…	998,292	340,483	45	TafawaBalewa Way	999,084	332,667
11	Murtala Mohammed Expres…	997,682	342,009	46	TafawaBalewa Way	1,003,929	332,778
12	Yakubu Gowon Cresent	1,000,076	336,386	47	TafawaBalewa Way	998,932	333,597
13	Yakubu Gowon Cresent	1,024,492	336,526	48	Mohammed Buhari Way	999,341	334,021
14	ShehuShagari Way	1,000,919	335,961	49	MurtalaMohammed Express	997,452	334,845
15	ShehuShagari Way	1,000,841	335,902	50	Mohammed Buhari Way	998,761	334,697
16	Circular Road	1,003,227	335,690	51	TafawaBalewa Way	999,337	334,022
17	Constitution Avenue	1,002,261	334,943	52	TafawaBalewa Way	999,702	334,358
18	SaniAbacha Way	1,002,264	334,442	53	TafawaBalewa Way	1,000,668	334,309
19	SaniAbacha Way	1,002,550	333,811	54	Independence Avenue	1,000,904	334,164
20	Ahmadu Bello Way	1,002,465	334,318	55	Independence Avenue	1,000,659	333,769
21	Ibrahim Babangida Way	1,002,993	332,789	56	AdemolaAdetokunbo	1,003,935	333,651
22	SaniAbacha Way	1,002,883	331,998	57	Ahmadu Bello Way	1,003,332	333,199
23	SaniAbacha Way	1,002,543	332,366	58	AdemolaAdetokunbo	1,003,799	334,803
24	SaniAbacha Way	1,003,334	330,954	59	AdemolaAdetokunbo	1,003,872	334,595
25	NnamdiAzikiwe Expressway	1,003,760	330,338	60	Ahmadu Bello Way	1,003,117	333,901
26	ShehuYaradua Way	1,003,864	330,299	61	Ibrahim Babangida Way	1,003,334	333,201
27	ShehuYaradua Way	1,004,061	330,008	62	Aminu Kano Crescent	1,004,932	332,852
28	Murtala Mohammed Expres	1,003,880	329,641	63	AdemolaAdetokunbo	1,002,278	325,288
29	NnamdiAzikiwe Expressway	1,001,146	330,008	64	ObafemiAwolowo Way	1,002,378	325,446
30	Ibrahim Babangida Way	1,007,517	333,122	65	Life Camp Junction	1,002,721	324,558
31	Ibrahim Babangida Way	1,007,139	332,964	66	Gwarimpa Junction	1,003,536	325,113
32	EseOke Street	1,006,901	333,399	67	ObafemiAwolowo Way	1,003,717	325,512
33	Osun Crescent	1,007,827	334,355	68	Gwarimpa Junction	1,005,038	325,676
34	Murtala Mohammed Express	1,006,428	334,501	69	ObafemiAwolowo Way	1,002,063	326,571
35	Limpopo Street	1,006,702	334,708	70	ObafemiAwolowo Way	1,007,832	324,576

Source: Field work 2013.

Table 2. Spatial coordinates of hospital locations.

S/N	Hospital	Northing	Easting
1	National Hospital	999,499	331,093
2	Garki General Hospital	998,886	333,436
3	Asokoro General Hospi	1,000,283	337,589
4	Wuse General Hospital	1,000,215	331,739
5	Maitama General Hospital	1,001,019	333,074
6	Qwarimpa General Hospital	1,003,745	323,969
7	Zankli Medical Centre	1,003,678	329,901
8	Lifeway medical centre	1,000,335	330,575
9	Fereprod Medical Centre	998,858	334,632
10	Winners Medical Centre	998,590	335,365
11	Ruz medical Centre	996,587	334,038
12	State House Clinic	1,004,746	337,681
13	Amana medical Centre	999,778	334,714
14	Abuja Clinic	1,005,918	333,488
15	Arewa Specialist Hospital	1,003,311	325,884
16	Sauki Private Hospital	1,003,072	330,492

Source: Field work 2013.

Table 3. Spatial coordinates of zebra point ambulance location.

S/No	Zebra point	Northing	Easting
1	Area 10 Old Parade Ground	999,834	333,796
2	Federal Secretrait by National Assembly	1,002,146	335,110
3	City Gate	998,685	329,366
4	Gwarinpa by Kubuwa Express	1,008,279	326,481
5	Kugbo, Under Bridge	997,728	342,911

Source: Field work 2013.

of road traffic accident in the study area. However, the results reveal that, there is less than 1% likelihood that the dispersed patterns could be the result of random chance. Comparatively, a random spatial pattern of emergency facilities and the RTC black spot is revealed. This result is similar to the findings of Yunus & Abdulkarim (2022) who found a random pattern of distribution of emergency facilities and the crash places in Kano metropolis. Whereas a considerable varying relationship exists between the crash places and emergency facilities in Kano metropolis, the relationship is similar for the emergency facilities and the RTC black spots in FCC, where the random pattern is generally turning towards dispersion. A pattern of distribution perceived to have resulted from different

Figure 2. The spatial distribution of RTC black spots and zebra points.

factors, including the distances from emergency response units to the accident scenes. This also corroborates the findings of Yunus & Abdulkarim (2022) in their study of road traffic crashes and emergency response optimization: a geospatial analysis using closest facility and location-allocation methods. The RTC crash black spots have an index of more than 1, implying a randomly distributed pattern which is impacted by the network pattern and distribution of junctions along the highways. The zebra locations were found to be randomly distributed with the likelihood for dispersion. In agreement with Yunus & Abdulkarim (2022) the distribution patterns of the zebra points, Emegency Health Care Facilities and those of the RTC crash black spots are not identical, and there is a significant need for interaction between them, there is therefore the necessity

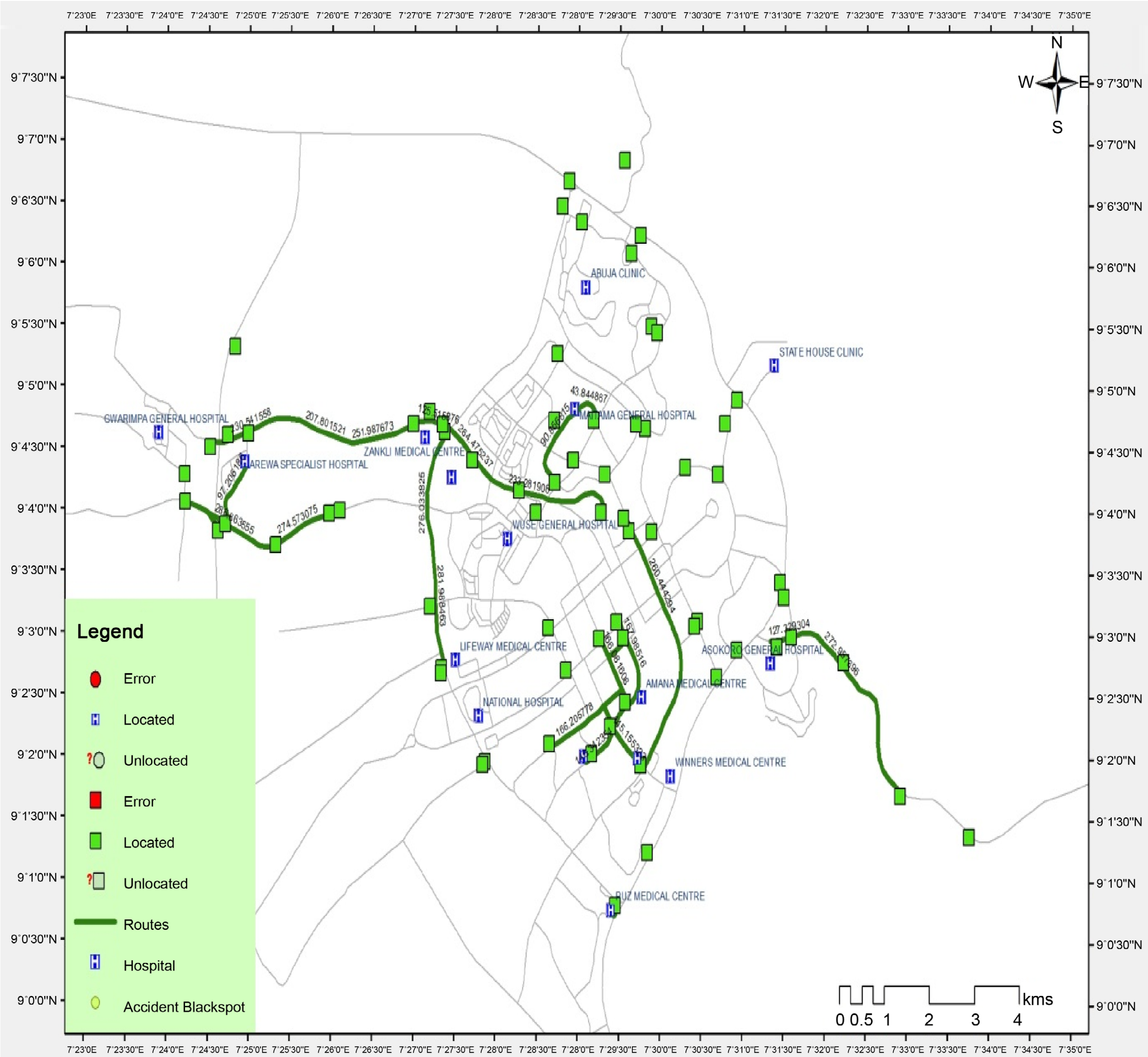

Figure 3. The spatial distribution of RTC black spots and Hospitals Locations.

to evaluate the synergy (if any) among them or otherwise. This is important especially for influencing the ability to deliver efficient emergency response throughout the FCC. This relationship clearly indicates that proportionately, the spatial interaction between these parameters is lopsided. There are incidences of inadequate distribution of zebra points in relation to emergency health care facilities and RTC black spots.

4. Conclusion

This study focuses on Spatial Analysis of Road Traffic Crash black spots in relation to Emergency Facilities in FCC using geo-spatial techniques in order to identify RTC black spots, the spatial distribution of existing health care centers and FRSC zebra point with a view to determining their spatial patterns and their

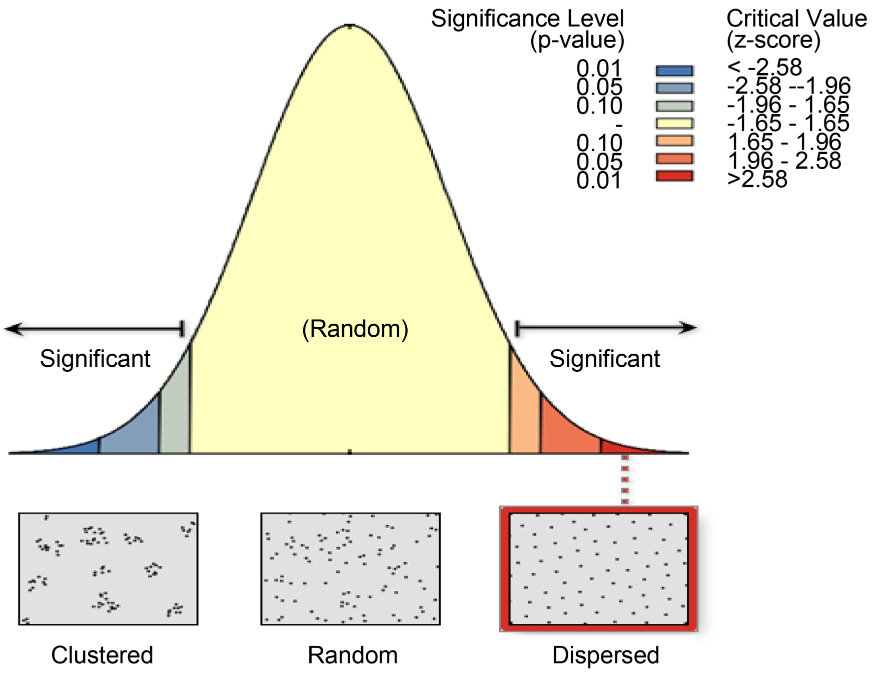

Figure 4. Average nearest neighborhood of hospital.

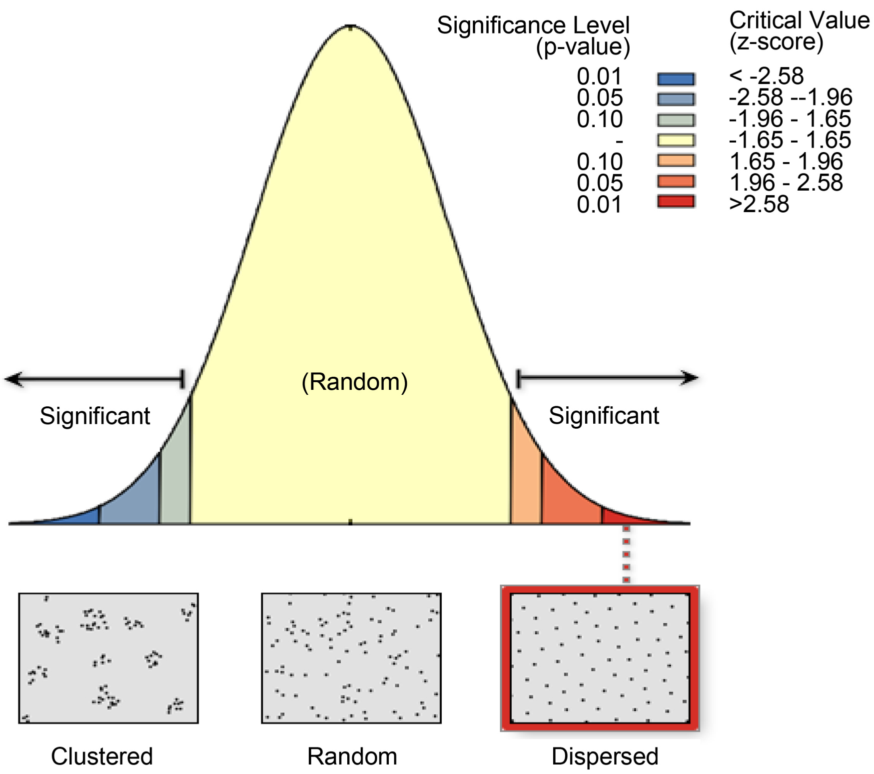

Figure 5. Average nearest neighbor of RTC black spot.

implications for response and medical attention to victims. The research demonstrated importance of GIS and Remote Sensing in carrying out analysis of the spatial patterns of RTC black spots and emergency health centers as well as

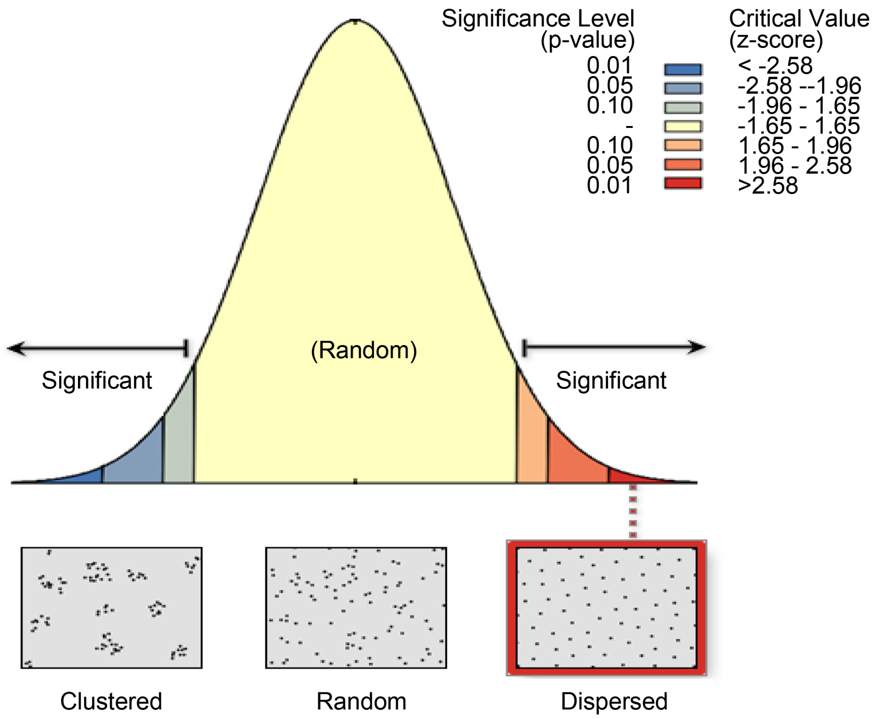

Figure 6. Nearest neighbor analysis of zebra point.

optimization of routes in carrying accident victims by FRSC response team. It has developed a foundation for the analysis and presentation of the RTC emergency situation in the Federal Capital City using geospatial technique.

Consequently, the following limitations are outlined with recommendations for subsequent research to be undertaken.

1) Real time data could be employed to model accident potentials of black spots and proximity to emergency facility rather than using RTC data that were obtained from FRSC Achieves.

2) Evaluation of adjacent land use and other structural design characteristics can be conducted to further analyze delay in travel time as regard to rescue RTC operation.

3) Further analysis of the RTC in relation to emergency response can be embarked upon for the entire FCT using an Excel spreadsheet and presentation of the situation with the application of the ArcGIS Desktop or another GIS software program with similar or advanced capabilities.

4) The identification of service quality indicators pertinent to evaluating the impact of FRSC rescues service interventions on a national scale is also necessary.

5. Recommendations

In view of the foregoing, it is therefore recommended that, the Federal Road Safety Commission should be staffed with trained professionals that can be responsible for accident data surveillance and analysis using geospatial techniques.

Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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