Geospatial Analysis of Road Traffic Accidents and Emergency Response Optimization in Kano Metropolis, Nigeria

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Abstract

Background

Increase in occurrence of road traffic accidents in Kano metropolis have resulted into continuous loss of lives, injuries and increased people's exposure to risk. This study examined road traffic accidents emergency response within Kano metropolis with a view to enhancing its efficiency through establishing communication and synergy between Emergency Healthcare Facilities (EHCF), ambulances and accident hotspots.

Methods

GPS surveying was conducted to obtain the location and attributes of the major EHCF, accident hotspots along the junctions of the highways and the 2 existing ambulances at Kano State Fire Service and Federal Road Safety Corp head offices (KSFS and FRSC). Road traffic data (vector format) was digitized from Worldview 3 satellite image (2018, 30cm spatial resolution) from which two major road classes were identified (highways and minor roads) along with their speed limits of 50km/hr and 30km/hr respectively. Time distances were determined based on length and speed limits. Nearest Neighbor and Network analysis (closest facility, shortest route and location-allocation) analyses were conducted.

Results

The result revealed a variation in the distribution patterns of EHCH, ambulances and accident spots. Closest ambulance facility analysis shows that it takes the FRSC ambulance about 9.41 minutes to reach to accident spot 18 (Maiduguri Road, after NNPC), and 7.52 minutes to travel to AKTH as the closest EHCF. On the other hand, it takes the same ambulance about 3 times the time taken to spot 18 and 4 times the time taken to AKTH to reach to Court road incident spot (spot 16) and IRPH as the closest EHCF. This signifies greater chances of death of almost all victims across the metropolis due to inability to provide CPS within the first 4 minutes before reaching to the hospital. However, in case of Pediatric emergencies, the analysis of closest EHCF from accident spots revealed that it takes less than one minute to travel from accident spots 13, 14 and 15 to IRPH as the closest Pediatric EHCF. Equally, similar time is taken to travel from incident spots 20 and 23 to Sir Sunusi and MMS hospitals respectively. Location-allocation analysis identified eight new locations based on maximum of 4 minutes impedance cutoff from all directions towards the incidents spots.

Conclusion

It is concluded that the prevailing road traffic accident emergency response system within the metropolis is inefficient. Therefore, more ambulances should be strategically positioned to fasten emergency response.

1. Introduction
Road traffic accidents worldwide have become a major threat to public safety and health because it is responsible for disabling and injuring about 50 million people across all age groups and gender per year (Khorasani-Zavareh et al., 2012; McIlroy et al., 2019; WHO, 2018 and Naboureh et al., 2019). According to World Health Organization (WHO, 2015 and 2018; ITF 2017; Khanh et al., 2019), about 1.35 million people died worldwide due to road traffic accidents in 2016, which is equivalent to about 3,700 persons every day in addition to the injured ones. Presently, injuries as a result of road traffic crashes are considered as one of the main reason for death (eight leading cause of death across all age groups) and the leading cause for death of younger generation within the age of 5–29 years old (WHO, 2015 and WHO, 2018). The economic costs attributed with road crashes range from 2% to 5% of each country’s Gross Domestic Product (WHO, 2018). Countries of the Global South especially the less developed countries of South-Asia, Africa and Latin America often bears the greatest burden. Although these countries have only 50% of the world’s vehicles, 90% of the world’s fatalities due to roads crashes occur in these countries (WHO, 2015). In south Asia, riders of two and three wheelers represent the majority of the fatalities (43%) recoded in the region (ESCAP, 2010; WHO, 2018). In Thailand and Myanmar for example, the rate of fatalities related to motorcycles accounted for about 24.3 per 100,000 and 12.9 per 100,000 respectively. Unfortunately, in south Asia, Africa and Nigeria, these major categories of road users remain neglected when road systems are designed.

In Nigeria, according to the Second Quarter Report of the National Bureau of Statistics (Q2 NBS, 2018), about 2,608 road crashes occurred and speed violation is reported as the major cause which accounted for 50.65% of the total road crashes reported. This is followed by bursting of tyre and dangerous driving, both accounted for 8.59% and 8.40% of the total road crashes recorded respectively. A total of 8,437 Nigerians got injured out of which 7,946 (94%) are adults while the remaining 491 Nigerians (representing 6%) are children. On the basis of gender, about 6,415 injured are males (representing 76%) and 2,022 (24%) were females. Similarly, a total of 1,331 Nigerians got killed out of which 1,257 (representing 94%) are adults, while the remaining 74 (6%) are children. On the other hand, 1,047 male Nigerians (representing 79%) and 284 (21%) female got killed respectively. Kano state within which the metropolis is located in the second quarter of 2018 have experienced about 115 road crashes out of which 28 are fatal, 85 are major and only 2 are minor (Q2 NBS, 2018). However, about 763 people were involved out of which 47 were killed and over 700 injured. Sixty one (61) of the crashes were as a result of speed limit violation, 10 due to worn-out tyres, 7 each as a result of brake failure and dangerous driving respectively. Other causes includes sign light violation (5), sleeping on steering (2), bad roads (2) and dangerous overtaking among others.

Pre-hospital emergency medical services and ambulance transportation services plays a significant role in handling and decreasing the effect of road traffic accidents (Bahadori et al., 2010 and Kepaptsoglou et al., 2011). These services helps in saving lives, trauma care and assisting people in serious need of assistance at the right time (Li et al., 2015). Ambulance transportation service seems quite simple but in actual circumstance, it is very difficult especially during peak hours (Ganeshkumar, 2010). Optimum utilization of time after road traffic accident is a key measure of effectiveness of ambulance emergency service and also a determinant of life lost and casualty (Kassaw and Asefa, 2020). According to World
Health Organization (WHO, 2011) due to inefficient ambulance transportation service, about 3,500 people lost their lives on daily basis and tens of millions are injured every year. More than 85% of these casualties occur in low and middle income countries (Kassaw and Asefa, 2020). This global crisis led to the development of two specific targets in the United Nation's Sustainable Development Goals. The first target is 3.6 which required that by 2020, halve the number of global deaths and injuries from road traffic accidents should be reduced. The second target (11.2) stated that by 2030, there should be access to safe, affordable, accessible and sustainable transport system for all, improving road safety, notable by expanding public transport with special attention to the needs of those in vulnerable conditions, women, children, persons with disabilities, and elderly people. However, despite some progress observed in some parts of the world, these targets particularly 3.6 are still far from being achieved.

The benefit of rapid response to traffic accidents and treatment of victims is increasingly being recognized as an important contributory factor to decreasing severity of long-term injuries and life loss. Recent studies indicate that improved medical response and associated technology are an important contributory factor to decrease in the severity of long-term injuries. It is recognized that time is a crucial factor in dealing with medical emergencies resulting from road traffic accidents. If proper first aid is given, road accident victims have a greater chance of survival and a reduction in the severity of their injuries (Moore, 2002). Many studies have been conducted worldwide using various approaches and methodologies to solve the problems associated to the occurrence of road traffic accidents, causes, consequences, and its emergency response towards achieving the SDG, for example; Huang & Pan, 2007; Anderson 2009; Durduran, 2010; Lloyd 2010; Polat & Durduran 2011; Plug, Xia, and Caulfield 2011; Shekhar et al. 2011; Han, Pei, and Kamber, 2011; Plug, Xia, and Caulfield 2011; Dai, 2012; MOT, 2012; Ponnaluri, 2012; Dai 2012; Mirbagheri 2013; Çela, Shiode & Lipovac 2013; Yang, Lu, & Wu, 2013; Xie and Yan 2013; Mohaymany, Shahri, and Mirbagheri 2013; Timmermans et al., 2015; Xuan 2015; Choudhary, Ohri, and Kumar 2015; Qiu, Xu, and Bao 2016; Harirforoush and Bellalite 2016; Satria & Castro, 2016; Sandhu et al. 2016; Corazza et al., 2017; Harirforoush 2017; Aghajani et al., 2017; Dereli & Erdogan 2017; Shafabakhsh, Famili & Bahadori 2017; Hegyi, Borsos, and Koren 2017; Amorim, Ferreira & Couto, 2017; Dereli and Erdogan, 2017; Vemulapalli et al. 2017; Phong, 2018; Iyanda, 2019; Chung, 2019; Fisa et al., 2019; Shi and Pun-Cheng 2019; Hayidso, Gemeda & Abraham 2019; Kassaw and Asefa, 2020; Dumka & Sah 2020; Jiang, Yuen & Lee 2020; Outay, Mengash, & Adnan 2020; Kmet & Kvet 2021; Al-Aamri et al., 2021. Studies in Nigeria includes Adekunle, 2010; Ohakwe and Iwueze 2011; Augustus, 2012; Saleh, 2014; Adebayo, 2015; Oluwasegun, 2015 and Osayomi, & Areola, 2015 among others.

Therefore, since accidents are inevitable, however, mitigating its impacts can be achieved through systematically analyzing the accidents using appropriate solutions such as traffic control equipment, better design of roads, traffic regulation enforcement and most fundamentally provisions for efficient emergency response and optimum access to emergency healthcare facility. However, the task of making effective solutions to the impact of road traffic accidents warrants analysis of spatial patterns of traffic accidents hotspots which can be achieved through the application of geospatial technology (Cheng and Washington, 2008). Therefore, this study examined the spatial distribution of road traffic accident
hotspots and model (using network analysis) accessibility of ambulances to incident spots and then to the closest healthcare facilities in order to minimize fatalities and optimize emergency response to road traffic accidents. This was achieved through mapping accident hotspots, ambulances and emergency healthcare facilities including orthopedic, general hospitals, specialist hospitals, and pediatric hospitals. Closest facility analysis was conducted to show the optimum emergency routes for safe and sustainable living within Kano metropolis.

2. Study Area

Kano metropolis is located between longitudes 8° 25’ E to 8° 40’ E and latitude 11° 50’ N and 12° 10’ N. The metropolis comprises of eight (8) local government areas (Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni) and parts of Kumbotso and Ungogo (Maigari, 2016). The metropolis covers a total area of about 499 km², with an urban area of about 137 km² (Figure 1)

Kano metropolis is one of the fastest growing urban centers (both economically and with regards to population) in the West African sub-continent. It is the most populous area in the northern Nigeria, and next to Lagos state and Ibadan (Barau, 2005). Kano metropolis with the projected population of about 4,331,790 (NPC, 2013) by 2018 has in few decades undergone drastic transformation and growth. The accompanying increase in intensities of human activities is reaching towards intolerable limits making proper management of the outcomes of such activities impossible resulting in degraded environment (Barau et al., 2015), and however increase in risk to various disasters and road traffic accidents. Economic activities involving trade and manufacturing in Kano can be traced as far back as before 1900 when the Kano empire was subjugated by the force of British colonialism and the region was incorporated into the world capitalist economy. The state is the most eminent commercial and industrial (cottage, commerce, agriculture and industries) centre in the whole of the Northern Nigeria during the precolonial times and the state's influence extended to neighboring countries including Niger Republic, Chad and Benin Republic. Later, after 1945, there was rapid growth of modern industries such as the Bompai industrial estate.

Kano metropolis, like the rest of the world, is exposed to a wide range of natural or human induced disasters. While some of these disasters are rapid, others are slow-onset, all resulting in loss of lives, property and degradation of environment. These disasters occur in form of flooding, epidemics, dam failure, building collapse, accidents (road and air crashes), bomb explosion, communal clash, fire disaster (residential, commercial and industrial landuses), air crashes, among others. The metropolis having thousands of registered and unregistered automobiles including tricycles and motorcycles, is losing many lives, and others injured each year due to traffic road accidents. The majority of these accidents result from human errors and other factors including rapid population growth coupled with rapid increase in the number of vehicles, traffic jams, lack of road signs, bad roads, violation of road regulations, absence of footpaths and unsafe roads for people to walk or to cross among others (Q2 NBS, 2018).

3. Materials And Methods
This section describes the various data types, materials/instruments, procedure and methods used for data collection, analysis methods and results presentation. The methodology is summarized and presented in Figure 2.

### 2.2 Data Types and Sources

The study employed the use of quantitative and geospatial data which were obtained from both primary and secondary sources. The quantitative data in the form of latitudinal locations of all the existing emergency healthcare facilities and major road traffic accident spots (junctions along the highways) within the metropolis was obtained through GPS surveying and the use of Google Earth Pro version. Additionally, similar data of the two ambulances (i.e. Federal Road Safety Corps HQ and Kano State Fire Service HQ) were obtained through same method to enable distance and time travel calculation for determining best (shortest) emergency response routes in relation to the distribution patterns of the accident spots and emergency healthcare facilities. Very High Spatial Resolution Satellite Image (World View 3 data with 30cm spatial resolution) captured in 2018 was obtained from the KanGIS department and used for visualization, and on screen digitization of road network data (in vector format) based on topological relationships. More than 10,000 road network data of various types was digitized along with attributes of lengths (km), distance travel (minutes) and speed limits for network analyses.

### 2.3 Data Collection Methods, Instruments and Procedure

The data collection methods used include GPS surveying, accident record consultation (from FRSC and KSFS), on-screen data capture and field observation. GPS surveying was used to obtain locational attributes of healthcare facilities, ambulance spots, and road traffic crash incidents locations. This is to enable spatial analysis to understand the spatial relationships between them. Major incident spots were determined based on accident frequency within the selected junctions along the highways of the metropolis. Field observation was also employed especially at most of the highway junctions to understand some of the causes for frequency of accidents and the emergency response activities. Onscreen digitization in the GIS environment (ArcGIS 10.2) was conducted to capture vector shapefiles of the road network within the metropolis based on topological regulations and attributes (Figure 3). Two classes of roads were identified (Highway and residential), and speed limits of 50km/hr and 30km/hr respectively were assigned to each. The length of each road was computed from the attribute table and the time and physical distances (in minutes and kilometers) were determined respectively. The instruments for the data collection used includes Global Positioning System (GPS) Garmin 86i and Google Earth Pro application were used for capturing the absolute locations of healthcare facilities, ambulances (FRSC and KSFS) and accident spots. Field notes and accident records were used for recording the observed causes of accidents and identifying accidents hotspots respectively.

### 2.3 Method of Data Analysis

Various methods of analysis were employed to understand the distribution pattern of road traffic accidents, emergency healthcare facilities, ambulances and in addition, modeling (based on time and
physical distance) the emergency response to such accidents. Nearest Neighbor Analysis (NNA) was conducted using ArcGIS 10.2 software to determine the distribution pattern of emergency healthcare facilities, road traffic accident incidents spots and ambulances. The analysis calculates the nearest neighbor index based on the average distance from each emergency healthcare facility and incident point to its nearest neighboring location. The procedure involves importing the latitude and longitude attributes of all emergency healthcare facilities on one hand and that of the incidents locations on the other. In order to determine the time and physical distances from ambulance locations to the incident spots, shortest routes analysis was conducted using the defined network data set to determine the best and shortest routes from the ambulance location to the various incident spots within the metropolis. The results of physical (in Km) and time (minutes) distances of routes were computed. Thirdly, Network Analysis and specifically Shortest route and Closest Facility Analyses were conducted to determine the shortest travel distance of ambulances to incident locations and from incident locations to the closest emergency healthcare facilities. This analysis was used to measure the travel distance (in km and minutes) between ambulance locations and incidents spots on one hand and incident spots to healthcare facilities. This was to determines the best routes for emergency response. In finding the closest ambulance to incident spots and emergency healthcare facilities from the incident spots, 1 closest facility (i.e ambulance and EHCF) was specified to be identified from all directions of travel from the incidents location. The analysis displays the the best route (depending on specifications) from ambulance location to incident spots and incidents spots to the closest healthcare facilities reporting their travel distances in km and minutes. When finding the closest facility, no specific defined cutoff distance travel was assigned, however, the search for the closest facility was throughout the metropolis. In describing the restriction attributes during developing the network datasets, there is only one restriction attribute which is no violation of road regulations (i.e one-way). Finally, after identifying the travel distances, location-allocation analysis using the Network Analyst tool was conducted to identify new locations to position more ambulances especially along the highway to enable optimum coverage. Maximum impedance cut-off of 4 minutes was assigned to clearly define the extents of coverage of all the ambulances (including the 2 existing and the 8 new locations identified).

4. Results

4.1 Distribution Pattern of Emergency Healthcare Facilities and Road Traffic Accidents Spots

The distribution pattern of emergency Healthcare facilities and that of the accident spots significantly varies in that the EHCF within the metropolis are dispersely distributed with Nearest Neighbor Ratio (NNR) of 1.42 and z-score value of 2.94. This distribution pattern is influenced by the nature of services rendered and the existing service coverage especially within the population clusters in the area (Figure 4). The accident spots were found to be randomly distributed (with NNR 1.0) throughout the metropolis, and the pattern is influenced by the network pattern and distribution of junctions along the highways. Since the distribution patterns of the EHCF and that of the accidents spots are not similar, an there is strong relationship between the two, there is then the need to examine the synergy (if any) among them or
otherwise. This is especially with respect to influencing the ability to achieve efficient emergency response throughout the metropolis.

4.2 Shortest Route analysis for Ambulance Emergency Response to Accident Spots

The role of ambulances in road traffic accidents emergency response cannot be overemphasized. Examining the distribution patterns of the ambulances in relation to accident spots and EHCF is very important in achieving efficiency in the response system. The result of analysis (Figure 5) depicts the closest routes from the 2 ambulance locations to all the identified accident hotspots within the metropolis. The result ranked the routes based on time and physical distances (in minutes and km) to the incident spots (Table 1). This to enable determining the travel distances from the ambulance locations to the incident spots before traveling from the spots to the closest EHCF. From Table 1, Facility ID 1 and 2 refers to the Kano State Fire Service (KSFS) and the Federal Road Safety Corps (FRSC) Ambulances respectively.

From Figure 5, it was found that, KSFS ambulance will travel for about 15 minutes to reach to incident spot 1 along Gwarzo road, and about 6.54 minutes (Table 2) for transporting the victims to IWGH which is the closest EHCF (excluding the time taken at the scene for possibly first aid). Similarly, it will take FRSC ambulance about 9.41 minutes to reach to accident spot 18 (Maiduguri Road, after NNPC), and 7.52 minutes to travel to AKTH as the closest EHCF. On the other hand, it takes the same ambulance about 3 times the time taken to spot 18 and 4 times the time taken to AKTH to reach to Court road incident spot (spot 16) and IRPH as the closest EHCF. This by implication signifies that there are variations in the time taken for responding to accidents, and in most cases its takes longer time beyond the recommended standards by NFPA (2010) and ESRI, (2007) before victims reached to the hospital. According to ESRI, (2007), if a victim has a heart attack after an accident, and cardiopulmonary resuscitation (CPR) is started within four minutes, the victim's chances of leaving the hospital alive are almost four times greater than if the victim did not receive CPR until after four minutes. In comparism to these standards, the result shows that about 90% of the accidents spots within the metropolis are accessed long after the recommended 4 minutes travel distances. In most cases, it takes up to 3 times or more than the recommended time before emergency personnel reaches to the incident spots. This result into increase in the chances for death after accidents because CPR are usually given sometimes more than 10 minutes after the occurrence of the accidents. This therefore warrants the need for redistribution of and location of more ambulances in some strategic locations to enable efficient and optimum coverage throughout the metropolis.

Table 1: Distance Ranking for Ambulance Response to Road Traffic Accidents
| FID | Facility ID | Incident ID | Incident Spot Name                                      | Time (Mins) | Distance (km) |
|-----|-------------|-------------|--------------------------------------------------------|-------------|---------------|
| 0   | 1           | 1           | BUK, Opp. Danbare Junction                             | 15.06       | 12.56         |
| 1   | 1           | 2           | Rimin Gata, Hijra Filling Station                      | 13.87       | 11.56         |
| 2   | 1           | 3           | Rimin Gata, Ring Road                                  | 13.04       | 10.87         |
| 3   | 1           | 4           | Sabuwar Tasha, Rijiyar Zaki                            | 12          | 10            |
| 4   | 1           | 5           | Kabuga, along BUK Road (Old Campus)                    | 7.57        | 6.31          |
| 5   | 1           | 6           | Dorayi, along Sheikh Jaafar Road                       | 7.88        | 6.57          |
| 6   | 1           | 7           | BUK Road, Opp. Legal                                  | 5.85        | 4.88          |
| 7   | 1           | 8           | Hauren Shanu, Kofar Nai’isa                            | 4.39        | 3.66          |
| 8   | 1           | 9           | Dan Agundi, Opp. Filin Mahaha                          | 3.46        | 2.88          |
| 9   | 1           | 10          | Along Sharada Road                                    | 2.94        | 2.45          |
| 10  | 1           | 11          | Sharada Industrial Area Junction                       | 4.81        | 4.01          |
| 11  | 1           | 12          | Sharada, Junction                                    | 8.49        | 7.08          |
| 12  | 2           | 13          | Zoo Road, Gandun Albasa                               | 2.78        | 2.32          |
| 13  | 2           | 14          | Zoo Road, Titin Dankura                               | 3.19        | 2.66          |
| 14  | 1           | 15          | Zoo Road, Total                                       | 3.39        | 2.83          |
| 15  | 2           | 16          | Court Road                                            | 2.34        | 1.95          |
| 16  | 2           | 17          | Naibawa                                               | 7.4         | 6.17          |
| 17  | 2           | 18          | Maiduguri Road, after NNPC                            | 9.41        | 7.84          |
| 18  | 1           | 19          | Kofar Ruwa after Kofar Dawanau                         | 8.56        | 7.14          |
| 19  | 2           | 20          | Yankaba by Sir Sunusi Hospital                         | 8.8         | 7.34          |
| 20  | 2           | 21          | Hadejia, Road                                         | 7.49        | 6.24          |
| 21  | 2           | 22          | Hadejia Road, 2                                       | 7.18        | 5.99          |
| 22  | 1           | 23          | Kofar Mata                                            | 1.86        | 1.55          |
| 23  | 1           | 24          | Mandawari                                             | 3.12        | 2.6           |
| 24  | 1           | 25          | Gidan Sarki Junction                                  | 2.69        | 2.25          |

4.3 Closest Emergency Healthcare Facilities from Accidents Spots
Apart from time taken for ambulance travel to incident spot, there is also additional time spent on travelling from the incident spot to the closest healthcare facilities. The results in Figure 6 and Table 2 depicts these relationships. Travel distance from incident spots to the closest EHCF is also a determinant for survival of victims when accidents occur. From Table 2, it is evident that, it takes less than one minute to travel from accident spots 13, 14 and 15 to IRPH as the closest EHCF. Equally, similar time is taken to travel from incident spots 20 and 23 to Sir Sunusi and MMS hospitals respectively. However, the longest distances travel from all incident spots to the closest EHCF is from Sharada Junction (spot 12) to IWGH which takes about 8.27 minutes, followed by spot 18 (Maiduguri road, NNPC) to AKTH which takes about 7.52 minutes. However, about 70% of the travel distances falls within the 0-4 minutes travel distance as recommended by NFPA (2010) and ESRI, (2007).

Table 2: Distance Ranking from Road Traffic Accidents Spots to the Closest EHCF
| S/N | IncidentID | FacilityID | Accident Spots and Hospitals                                      | Time (Minutes) | Distance (Km) |
|-----|------------|------------|------------------------------------------------------------------|----------------|---------------|
| 1   | 1          | 9          | BUK, Opp. Danbare Junction - IWG Hospital                         | 6.54           | 5.06          |
| 2   | 2          | 9          | Rimin Gata, Hijra Filling Station - IWG Hospital                  | 5.34           | 4.06          |
| 3   | 3          | 9          | Rimin Gata, Ring Road - IWG Hospital                              | 4.52           | 3.37          |
| 4   | 4          | 9          | Sabuwar Tasha, Rijiyar Zaki - IWG Hospital                        | 3.47           | 2.5           |
| 5   | 5          | 9          | Kabuga, along BUK Road (Old Campus) - IWG Hospital                | 3.7            | 2.69          |
| 6   | 6          | 9          | Dorayi, along Sheikh Jaafar Road - IWG Hospital                   | 4.48           | 2.44          |
| 7   | 7          | 10         | BUK Road, Opp. Legal - ABP Hospital                               | 4.39           | 3.66          |
| 8   | 8          | 10         | Hauren Shanu, Kofar Nai’isa - ABP Hospital                        | 2.94           | 2.45          |
| 9   | 9          | 10         | Dan Agundi, Opp. Filin Mahaha - ABP Hospital                      | 2              | 1.67          |
| 10  | 10         | 10         | Along Sharada Road - ABP Hospital                                 | 3.46           | 2.22          |
| 11  | 11         | 10         | Sharada Industrial Area Junction - ABP Hospital                   | 5.32           | 3.78          |
| 12  | 12         | 9          | Sharada, Junction - IWG Hospital                                  | 8.27           | 5.34          |
| 13  | 13         | 13         | Zoo Road, Gandun Albasa - IRP Hospital                            | 0.26           | 0.22          |
| 14  | 14         | 13         | Zoo Road, Titin Dankura - IRP Hospital                            | 0.15           | 0.12          |
| 15  | 15         | 13         | Zoo Road, Total - IRP Hospital                                    | 0.49           | 0.41          |
| 16  | 16         | 13         | Court Road - IRP Hospital                                         | 1.76           | 1.47          |
| 17  | 17         | 1          | Naibawa - AKTH Hospital                                           | 4.35           | 3.63          |
| 18  | 18         | 1          | Maiduguri Road, after NNPC - AKTH Hospital                       | 7.52           | 6.27          |
| 19  | 19         | 12         | Kofar Ruwa after Kofar Dawanau - NO Hospital, Dala               | 2.48           | 1.58          |
| 20  | 20         | 3          | Yankaba by Sir Sunusi Hospital - SMS Hospital                     | 0.53           | 0.44          |
| 21  | 21         | 3          | Hadejia, Road - SMS Hospital                                      | 1.85           | 1.54          |
| 22  | 22         | 3          | Hadejia Road, 2 - SMS Hospital                                    | 2.15           | 1.79          |
4.3.1 Closest Orthopedic Emergency Healthcare Facilities from all Accidents Spots

In case of orthopedic related emergencies, the results showing the best routes from all incident spots to the only National Orthopedic Hospital revealed that the closest incident spot is Kofar Dawanau junction with a travel distance of about 1.58km which is equivalent to 2.48 minutes (Figure 7 and Table 3).

However, the longest distance to the orthopedic hospital throughout the metropolis is from Maiduguri Road (after NNPC) which takes an approximate 16 minutes travel distance, which is equivalent to about 13km distance (excluding the travel distance from ambulance location to the incident spots). This signifies tendencies of suffocating of the casualty before arriving to the hospital. Only the accident spots at Mandawari and Gidan Sarki junctions falls within the recommended standards by NFPA (2010) and ESRI, (2007) which emphasizes higher chances of survival if response and CPR is done for victims with heart attack within 4 minutes.

Table 3: Travel Distances (Time and Physical) from all Accident Spots to National Orthopedic Hospital Dala
| SN | Incident ID | Accident Spots to NOH, Dala                                      | Time (Minutes) | Distance (Km) | Proximity Ranking |
|----|-------------|-----------------------------------------------------------------|----------------|---------------|-------------------|
| 1  | 19          | Kofar Dawanau - NOH, Dala                                      | 2.48           | 1.58          | 1                 |
| 2  | 24          | Mandawari - NOH, Dala                                          | 4.35           | 3.63          | 2                 |
| 3  | 25          | Gidan Sarki Junction - NOH, Dala                                | 4.38           | 3.65          | 3                 |
| 4  | 23          | Kofar Mata - NOH, Dala                                         | 5.12           | 4.27          | 4                 |
| 5  | 9           | Dan Agundi, Opp. Filin Mahaha - NOH, Dala                     | 6.41           | 5.34          | 5                 |
| 6  | 7           | BUK Road, Opp. Legal - NOH, Dala                               | 6.75           | 5.63          | 6                 |
| 7  | 8           | Hauren Shanu, Kofar Nai’isa - NOH, Dala                       | 7              | 5.83          | 7                 |
| 8  | 5           | Kabuga, along BUK Road (Old Campus) - NOH, Dala                | 7.04           | 5.87          | 8                 |
| 9  | 11          | Sharada Industrial Area Junction - NOH, Dala                   | 8.45           | 7.04          | 9                 |
| 10 | 10          | Dorayi, along Sheikh Jaafar Road - NOH, Dala                   | 8.67           | 7.15          | 10                |
| 11 | 6           | Along Sharada Road - NOH, Dala                                 | 8.65           | 7.21          | 11                |
| 12 | 16          | Court Road - NOH, Dala                                         | 9.06           | 7.55          | 12                |
| 13 | 15          | Zoo Road, Total - NOH, Dala                                    | 9.37           | 7.82          | 13                |
| 14 | 13          | Zoo Road, Gandun Albasa - NOH, Dala                            | 9.45           | 7.88          | 14                |
| 15 | 14          | Zoo Road, Titin Dankura - NOH, Dala                            | 9.72           | 8.1           | 15                |
| 16 | 22          | Hadejia Road, 2 - NOH, Dala                                    | 10.72          | 8.93          | 16                |
| 17 | 4           | Sabuwar Tasha, Rijiyar Zaki - NOH, Dala                       | 10.99          | 9.16          | 17                |
| 18 | 21          | Hadejia, Road - NOH, Dala                                      | 11.02          | 9.19          | 18                |
| 19 | 3           | Rimin Gata, Ring Road - NOH, Dala                              | 12.03          | 10.03         | 19                |
| 20 | 12          | Sharada, Junction - NOH, Dala                                  | 12.14          | 10.12         | 20                |
| 21 | 20          | Yankaba by Sir Sunusi Hospital - NOH, Dala                     | 12.33          | 10.28         | 21                |
| 22 | 2           | Rimin Gata, Hijra Filling Station - NOH, Dala                  | 12.86          | 10.72         | 22                |
| 23 | 1           | BUK, Opp. Danbare Junction - NOH, Dala                         | 14.05          | 11.71         | 23                |
Table 4: Travel Distances (Time and Physical) from all Accident Spots to the Pediatric Hospitals

| Accident Spot                                      | Time (in minutes) | Distance (in kilometers) | Nearest Hospital |
|----------------------------------------------------|-------------------|--------------------------|------------------|
| Naibawa - NOH, Dala                               | 14.11             | 11.77                    | 24               |
| Maiduguri Road, after NNPC - NOH, Dala            | 15.75             | 13.13                    | 25               |

### 4.3.2 Closest Pediatric Emergency Healthcare Facilities from all Accidents Spots

Results of pediatric related casualties revealed the best routes to the two prominent pediatric hospitals (i.e. Asiya Bayero and Isiaka Rabiu Pediatric Hospital). Figure 8 revealed that about 85% of the accident spots are closer to Asiya Bayero Pediatric Hospital than Isiaka Rabiu Hospital.

However, the shortest distance travel observed were from the junctions at Zoo Road Dan Kura street, Gandun Albasa and Total with corresponding travel distance of 0.15, 0.26 and 0.49 minutes respectively (Table 4). This excludes the travel distances from ambulance location to the incident spot. On the other hand, the shortest distance travels (in minutes) to Asiya Bayero Pediatric Hospital is from the junctions at Gidan Sarki (0.92), Dan Agundi (2), Kofar Mata (2.48) and Kofar Naisa (2.94). It is important to note that these distance are within the recommended standards and signifying greater chances of pediatric survival in cases of accidents if ambulance travel distances are also within 2 minutes drive. However, the real picture on ground depicts longer ambulance travel to incident spots than from incident spots to closest EHCF.

Table 4: Travel Distances (Time and Physical) from all Accident Spots to the Pediatric Hospitals
| SN | IncidentID | Accident Spots and Hospitals | Time (Minutes) | Distance (Km) |
|----|------------|------------------------------|---------------|--------------|
| 1  | 1          | BUK, Opp. Danbare Junction - ABP Hospital | 13.29 | 11.08 |
| 2  | 2          | Rimin Gata, Hijra Filling Station - ABP Hospital | 12.09 | 10.08 |
| 3  | 3          | Rimin Gata, Ring Road - ABP Hospital | 11.26 | 9.39 |
| 4  | 4          | Sabuwar Tasha, Rijiyar Zaki - ABP Hospital | 10.22 | 8.52 |
| 5  | 5          | Kabuga, along BUK Road (Old Campus) - ABP Hospital | 6.11 | 5.1 |
| 6  | 6          | Dorayi, along Sheikh Jaafar Road - ABP Hospital | 6.42 | 5.35 |
| 7  | 7          | BUK Road, Opp. Legal - ABP Hospital | 4.39 | 3.66 |
| 8  | 8          | Hauren Shanu, Kofar Nai’isa - ABP Hospital | 2.94 | 2.45 |
| 9  | 9          | Dan Agundi, Opp. Filin Mahaha - ABP Hospital | 2 | 1.67 |
| 10 | 10         | Along Sharada Road - ABP Hospital | 3.46 | 2.22 |
| 11 | 11         | Sharada Industrial Area Junction - ABP Hospital | 5.32 | 3.78 |
| 12 | 12         | Sharada, Junction - ABP Hospital | 9.01 | 6.85 |
| 13 | 13         | Zoo Road, Gandun Albasa - IRP Hospital | 0.26 | 0.22 |
| 14 | 14         | Zoo Road, Titin Dankura - IRP Hospital | 0.15 | 0.12 |
| 15 | 15         | Zoo Road, Total - IRP Hospital | 0.49 | 0.41 |
| 16 | 16         | Court Road - IRP Hospital | 1.76 | 1.47 |
| 17 | 17         | Naibawa - IRP Hospital | 7.22 | 5.54 |
| 18 | 18         | Maiduguri Road, after NNPC - IRP Hospital | 10.52 | 8.68 |
| 19 | 19         | Kofar Ruwa after Kofar Dawanau - ABP Hospital | 7.55 | 6.29 |
| 20 | 20         | Yankaba by Sir Sunusi Hospital - ABP Hospital | 10.63 | 8.86 |
| 21 | 21         | Hadejia, Road - ABP Hospital | 9.31 | 7.76 |
| 22 | 22         | Hadejia Road, 2 - ABP Hospital | 9.01 | 7.51 |
| 23 | 23         | Kofar Mata - ABP Hospital | 2.48 | 2.07 |
| 24 | 25         | Mandawari - ABP Hospital | 1.34 | 1.12 |
| 25 | 25         | Gidan Sarki Junction - ABP Hospital | 0.92 | 0.76 |

The longest distance travel to pediatric hospital is from Danbare junction (opp BUK, new site) and Rimin Gata (opp Hijra filling station) to ABP which takes about 13.29 and 12.09 minutes plus ambulance
distance travel of about 15.06 and 13.87 minutes (Table 1) respectively.

4.4 Location-allocation of Ambulances for Optimum Emergency Coverage within Kano Metropolis

In order to propose suitable locations for positioning more ambulances for optimum coverage, the service coverage of the existing ambulances was determined based on maximum impedance coverage of 4 minutes (Figure 9). The result shows that only accident spots 12, 13 and 15 can be reached from FRSC within the stipulated distance travel. On the other hand, the KSFS ambulance can reach to accident spots 8, 9, 14, 22, 23 and 24. However, all other accident locations cannot be reached within the required travel distance by the two existing ambulances. This therefore necessitated the need for location-allocation analysis to propose new places to locate ambulances for optimum coverage.

Figure 10 depicts the proposed locations for ambulances along the major highways within the metropolis. Eight new locations were identified (Table 5) based on maximum of 4 minutes impedance cutoff from all directions towards the incidents spots. The results depict that only accident spots 10 and 11 (all within Sharada) could not be reached by any of the ambulances within 4 minutes.

Table 5: New Ambulance locations and Accident Spots Served

The results in Table 5 show that with the new ambulances, all accident spots can be reached within or even less than the stipulated standard of 4 minutes to enable CPR.
| SN | Name                          | Facility ID | Accident Spots | Travel Time (Minutes) | Distance (km) |
|----|-------------------------------|-------------|----------------|-----------------------|---------------|
| 1  | KSFS                          | 1           | 9              | 2.94                  | 2.45          |
| 2  | KSFS                          | 1           | 14             | 3.39                  | 2.83          |
| 3  | FRSC                          | 2           | 12             | 2.78                  | 2.32          |
| 4  | FRSC                          | 2           | 13             | 3.19                  | 2.66          |
| 5  | BUK New Campus                | 3           | 0              | 0.45                  | 0.38          |
| 6  | BUK New Campus                | 3           | 1              | 0.74                  | 0.62          |
| 7  | BUK New Campus                | 3           | 2              | 1.57                  | 1.31          |
| 8  | BUK New Campus                | 3           | 3              | 2.62                  | 2.18          |
| 9  | Sa’adatu Rimi College         | 4           | 16             | 3.48                  | 2.90          |
| 10 | NNPC Roundabout               | 5           | 17             | 0.74                  | 0.61          |
| 11 | Hadejia Rd, Roundabout        | 6           | 19             | 0.59                  | 0.49          |
| 12 | Hadejia Rd, Roundabout        | 6           | 20             | 0.72                  | 0.60          |
| 13 | Hadejia Rd, Roundabout        | 6           | 21             | 1.03                  | 0.86          |
| 14 | Katsina Rd, Barracks          | 7           | 18             | 1.40                  | 1.17          |
| 15 | Emir's Central Mosque         | 8           | 8              | 2.54                  | 2.12          |
| 16 | Emir's Central Mosque         | 8           | 22             | 1.50                  | 1.25          |
| 17 | Emir's Central Mosque         | 8           | 23             | 0.49                  | 0.40          |
| 18 | Emir's Central Mosque         | 8           | 24             | 0.06                  | 0.05          |
| 19 | Sheikh Ja’afar Rd             | 9           | 4              | 1.56                  | 1.30          |
| 20 | Sheikh Ja’afar Rd             | 9           | 5              | 2.64                  | 2.20          |
| 21 | Sheikh Ja’afar Rd             | 9           | 6              | 2.33                  | 1.94          |
| 22 | Sheikh Ja’afar Rd             | 9           | 7              | 2.91                  | 2.43          |
| 23 | Gadan Lado                    | 10          | 15             | 2.27                  | 1.62          |

5. Discussion
The distribution of ambulances for emergency response and EHCF in most cities of the world is usually based on many factors including the nature and state of the city, population density and distribution, landuse pattern, emergency response demand, risk pattern among others. The major factors for each city depends on the peculiarity of that city. However, in many cities of Africa, Kano metropolis inclusive, these response facilities are haphazardly distributed irrespective of any of the factors mentioned above. The most disturbing issue is most of the emergency response facilities are inadequate (where available) and totally lacking in most of the cities. Kano metropolis today with the population of about 4,331,790 and experiencing not less than 50 road traffic accidents on daily basis (KSFS, 2021) posses only 2 active emergency response ambulances (i.e KSFS and FRSC ambulances) which is grossly inadequate.

Talking about emergency response in cases of accidents in the metropolis, for example it takes the KSFS ambulance about 13-15 minutes to reach to accident spots 1, 2 and 3 before finally moving to the closest EHCF (Table 1). Similarly, it takes the FRSC ambulance 7-9 minutes to reach to accident spots 18, 20 and 21. This clearly shows greater chances of death of affected people before the ambulance reaches to most of the incident spots especially those who will require CPR within the first 4 minutes after the accident. Additionally, the travel distance from incident spots to the closest EHCF is also a serious issue of concern. This is because there is the need for some additional 4-6 minutes travel distance before the casualty is conveyed to the hospital (Table 2).

In cases of orthopedic and pediatric emergencies, similar challenges prevails within the metropolis. For example, in situations of complicated orthopedic and or pediatric related emergencies, it takes additional 10-15 minutes to reach to NOH or ABP from accident spots 1-4, 12, 17, 18, 20 and 21 (Table 3). This generally shows the level of inefficiency of the prevailing emergency response system within Kano metropolis. Challenges including that of inadequacy of ambulances and lack of synergy in terms of the distribution and proximity to EHCF and and accident hotspots. As a result, the need for more ambulances at strategic locations to enable optimum and efficient response coverage throughout the metropolis becomes necessary.

6. Conclusion And Recommendation

Road traffic accidents which has been and is still responsible for loss of several lives and properties are inevitable in Kano Metropolis especially due to population growth and density of traffic flow especially along the highways connecting the state with the neighbouring states. The prevailing road traffic accident emergency response system within the metropolis is inefficient due to many factors among which is inadequacy of ambulances at various locations. Based on the findings, the following are recommended:

1. More ambulances should be positioned especially along the highways and in proximity to accident spots in order to fasten emergency response so as to save more lives of the affected victims.
2. There is the need for enforcement of traffic regulations and placing of traffic signs along the roads to enable full compliance by drivers.
3. Pedestrians and drivers should be enlighten on when and how to cross the road when necessary and turn along the U-turns respectively.
4. Over-head pedestrian bridges should be constructed at major junctions to reduce people’s exposure to road traffic accidents.

**Abbreviations**

EHCF  Emergency Healthcare Facilities
KSFS  Kano State Fire Service
FRSC  Federal Road Safety Corp
CPR  Cardiopulmonary Resuscitation
IGW  Imam Wali General Hospital
ABP  Asia Bayero Pediatric Hospital
IRP  Isiaka Rabiu Pediatric Hospital
AKTH  Aminu Kano Teaching Hospital
NOH  National Orthopedic Hospital
SMS  Sir Muhammad Sunusi Hospital
MMS  Murtala Muhammad Specialist Hospital

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**Figures**
Figure 1

Kano Metropolis
**Figure 2**

Methodological Flowchart
Figure 3

Network Data and Attributes
Figure 4

Distribution of Healthcare Facilities and Road Traffic Accident Spots
Figure 5

Ambulance Best Routes to Accident Spots
Figure 6

Closest Emergency Healthcare Facilities from Accident Spots
Figure 7

Routes from all Accident Spots to National Orthopedic Hospital Dala
Figure 8

Routes from all Accident Spots to Pediatric Hospitals
Figure 9

Four Minutes Distance to Accident Spots by KSFS and FRSC Ambulances
Figure 10

Location-allocation of Ambulances for Optimum Coverage within Kano Metropolis