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

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Abstract

Increased occurrence of road traffic crashes in Kano metropolis has resulted in a steady loss of lives, injuries, and increased people's risk exposure. This study looked into the emergency response to road traffic crashes in Kano, with a view to improving efficiency by developing linkages and synergy between Emergency Healthcare Facilities (EHCF), ambulances, and crash hotspots. The geographical location and attributes of the major EHCF, crash hotspots along highway intersections, and the two existent ambulances at the Kano State Fire Service (KSFS) and Federal Road Safety Corp head offices (FRSC) were obtained using GPS surveying. Road traffic network data (vector format) was digitized from satellite image, from which two major road classes (highways and minor roads) were identified, as well as their respective speed limits. The length and speed constraints were used to calculate time distances. Nearest Neighbor and Network (closest facility, shortest route, and location-allocation) analyses were carried out. The results demonstrated that EHCF, ambulances, and crash places have different distribution patterns with almost no linkages. Closest ambulance facility analysis revealed the FRSC ambulance takes 9.41 minutes to arrive to crash spot 18 (Maiduguri Road, following NNPC) and 7.52 minutes to arrive at AKTH, the nearest EHCF. Comparatively, getting to Court road incident scene (spot 16) and IRPH as the closest EHCF takes about 3 times the time it takes to get to spot 18 and 4 times the time it takes to get to AKTH. This means that practically almost all victims in the city suffocate before reaching to the hospital. This signifies that, in cases of demand for CPR at the incident scene, there are higher likelihood of dying as it is expected to be provided within the first four minutes after the crash. Based on a maximum of 4 minutes impedance cutoff from all directions towards the occurrences areas, location-allocation analysis found eight new locations to maximize coverage and improve efficiency. It is concluded that current road traffic crash emergency response system has been determined to be ineffective. As a result, more ambulances should be strategically placed to improve emergency response times.

1. Introduction

Road traffic crashes have become a huge menace to public safety and health around the world, crippling and injuring approximately 50 million people every year of all ages and genders (Khorasani-Zavareh *et al.*, 2012; McIlroy *et al.*, 2019; WHO, 2018 and Naboureh *et al.*, 2019). Approximately 1.35 million people died in road traffic crashes worldwide in 2016, which equates to about 3,700 deaths per day (WHO, 2015 and 2018; ITF 2017; Khanh *et al.*, 2019). Currently, injuries resulting from traffic collisions are one of the leading causes of death (the eighth leading cause of death across all age groups) and the leading cause of death among the younger generation (5–29 years old) (WHO, 2015 and WHO, 2018). The Global South, particularly the less developed countries of Southeast Asia, Africa, and Latin America, bear the brunt of the load. Despite having only 50% of the world's vehicles, these countries account for 90% of the world's road deaths (WHO, 2015). Riders of two and three wheeled vehicles account for the majority of fatalities (43%) in south Asia (ESCAP, 2010; WHO, 2018). Motorcycle-related fatalities accounted for around 24.3 per 100,000 in Thailand and 12.9 per 100,000 in Myanmar, respectively. Unfortunately, when road

networks are developed in South Asia, Africa, and Nigeria, these primary categories of road users are ignored.

According to the National Bureau of Statistics' Second Quarter Report (Q2 NBS, 2018), roughly 2,608 road crashes occurred in Nigeria, with speeding being the leading cause, accounting for 50.65% of all reported road crashes. The bursting of a tyre and risky driving came in second and third, accounting for 8.59% and 8.40% of all road crashes, respectively. A total of 8,437 Nigerians were injured, with 7,946 (94%) of them being adults and 491 (6%), being children. According to gender, 6,415 men (76%) and 2,022 women (24%) were injured. Similarly, a total of 1,331 Nigerians were slain, with 1,257 (94%) of them being adults and 74 (6%) being children. On the other hand, 1,047 male Nigerians (representing 79%) and 284 female Nigerians (representing 21%) were killed. In the second quarter of 2018, Kano state, where the metropolis is located, experienced roughly 115 reported traffic crashes, of which 28 were deadly, 85 were major, and only two were minor (Q2 NBS, 2018). However, 763 people were involved, with 47 died and more than 700 injured. Sixty-one (61) of the crashes were caused by speeding, ten by worn-out tyres, and seven each by brake failure and risky driving. Sign light violations (5), napping on the steering wheel (2), bad roads (2), and risky overtaking are among the other causes.

Pre-hospital emergency medical care and ambulance transportation services play an important role in dealing with and minimizing the consequences of traffic crashes (Bahadori et al., 2010 and Kepaptsoglou et al., 2011). These services aid in the saving of lives, trauma care, and supporting people who are in desperate need of help at the proper time (Li et al., 2015). Although ambulance transportation appears to be straightforward, it is really challenging in practice, particularly during peak hours (Ganeshkumar, 2010). The best use of time following a road traffic crash is a crucial indicator of ambulance emergency service efficacy, as well as a determinant of the number of lives lost and casualties (Kassaw and Asefa, 2020). According to the World Health Organization (WHO, 2011), around 3,500 people die every day as a result of poor ambulance transportation, and tens of millions are injured every year. More than 85% of the victims are from low- and middle-income nations (Kassaw and Asefa, 2020). The United Nations' Sustainable Development Goals include two specific aims as a result of the global crisis. The first goal is 3.6, which calls for halving the number of global deaths and injuries caused by road traffic crashes by 2020. The second target (11.2) stated that by 2030, everyone should have access to a safe, affordable, accessible, and sustainable transportation system, with a focus on improving road safety, particularly for those in vulnerable situations such as women, children, people with disabilities, and the elderly. Despite considerable progress in some regions of the world, these aims, particularly target 3.6, are still distant from being met.

Rapid reaction to traffic crashes and victim treatment is increasingly being acknowledged as a key contributory element in reducing the severity of long-term injuries and death. According to recent studies, improved medical response and accompanying technology have a key role in reducing the severity of long-term injuries. It is widely acknowledged that when dealing with medical emergencies originating from traffic crashes, time is of the essence. Road crash victims have a better chance of survival and a reduction in the severity of their injuries if they receive competent first assistance (Moore, 2002). Many studies have been conducted around the world using various approaches and methodologies to solve problems related to the occurrence of road traffic crashes, their causes, consequences, and emergency response in order to achieve the SDG, such as 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; Han, Pei, and Kamber, 2011; Han, Pei, and Kamber, 2011; Han, Pei, and Kamber, 2011; Han, Pei, Dai, 2012; MOT, 2012; Ponnaluri, 2012; Dai, 2012; Mirbagheri, 2013; ela, Shiode, and 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, Gameda & 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. Nigerian research involves Among them are Adekunle (2010), Ohakwe and Iwueze (2011), Augustus (2012), Saleh (2014), Adebayo (2015), Oluwasegun (2015), and Osayomi and Areola (2015).

Because crashes are unavoidable, mitigating their consequences can be accomplished by systematically analyzing them and implementing appropriate solutions such as traffic control equipment, better road design, traffic regulation enforcement, and, most importantly, provisions for efficient emergency response and optimum access to emergency healthcare facilities. The task of developing efficient remedies to the impact of road traffic crashes, on the other hand, necessitates an examination of spatial patterns of traffic crash hotspots, which can be accomplished using geospatial technology (Cheng and Washington, 2008). As a result, this research looked at the spatial distribution of road traffic crash hotspots and used network analysis to model ambulance accessibility to incident spots and then to the nearest healthcare facilities in order to reduce fatalities and improve emergency response to road traffic crashes. Crash hotspots, ambulances, and emergency healthcare facilities such as orthopedic, general, specialized, and pediatric hospitals were all mapped to achieve this. Closest facility analysis was then conducted to show the optimum emergency routes for safe and sustainable living within Kano metropolis.

2. Study Area

Kano is situated between the longitudes of 8° 25' E and 8° 40' E, and the latitudes of 11° 50' N and 12° 10' N. Eight (8) local government areas (Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni) and parts of Kumbotso and Ungoggo make up the city (Maigari, 2016). The metropolis has a total size of around 499 km², with a 137 km² urban area (Figure 1).

Kano metropolis is one of the fastest expanding urban hubs in the West African sub-continent, both economically and in terms of population. It is the most populous region in northern Nigeria (Barau, 2005). Kano city, with a projected population of 4, 331, 790 people by 2018 (NPC, 2013), has witnessed significant development and growth in recent decades. The accompanying increase in human activity intensities is approaching intolerable limits, making proper management of the outcomes of such activities impossible, resulting in a degraded environment (Barau et al., 2015), as well as an increased risk of various disasters and road traffic crashes (Yunus and Falola, 2022). Trade and manufacturing activities in Kano may be traced all the way back to before 1900, when the Kano empire was subjugated by British colonization and the region was absorbed into the global capitalist economy. During precolonial times, the state was the most important commercial and industrial (cottage, commerce, agriculture, and industries) center in Northern Nigeria, and its influence extended to neighboring countries such as Niger Republic, Chad, and Benin Republic. After 1945, modern enterprises, such as the Bompai industrial park, grew at a rapid pace.

Kano, like the rest of the world, is vulnerable to a variety of natural and man-made disasters all of them resulting in the loss of life, property, and environmental destruction. Flooding, diseases, dam failure, building collapse, crashes (road and air crashes), bomb explosions, communal clashes, fire catastrophes (residential, commercial, and industrial landuses), and air crashes are only some of the disasters that occur. Every year, thousands of people are killed and injured in traffic road crashes in the city. The majority of these crashes are caused by human error and other factors such as rapid population growth combined with a rapid increase in the number of vehicles, traffic jams, lack of road signs, bad roads, violations of road regulations, lack of footpaths, and unsafe roads for people to walk or cross, to name a few (Q2 NBS, 2018).

3. Materials And Methods

This section covers data types, materials/instruments used, data gathering procedures and methodologies, analysis methods, and results presentation. Figure 2 summarizes and presents the process.

3.1 Data Types and Sources

Quantitative and geospatial data were used in the study, which came from both primary and secondary sources. Through GPS surveying, quantitative data in the form of latitudinal locations of all existing emergency healthcare facilities and major road traffic crash spots (junctions along highways) within the

metropolis was obtained. Additionally, similar data from two ambulances (Federal Road Safety Corps HQ and Kano State Fire Service HQ) was obtained using the same method in order to calculate distance and time travel for determining the best (shortest) emergency response routes in relation to the distribution patterns of crash spots and emergency healthcare facilities. The KanGIS department provided a Very High Spatial Resolution Satellite Image (World View 3 data with 30cm spatial resolution), which was used for visualization and on-screen digitization of road network data (in vector format) based on topological relationships. For network evaluations, more than 10,000 connected road network data of various sorts was digitized, together with variables such as lengths (km), distance traveled (minutes), and speed limits.

3.2 Data Collection Methods, Instruments and Procedure

GPS surveying, crash record consultation (from FRSC and KSFS), on-screen data capture, and field observation were all employed to acquire data. The locational features of healthcare facilities, ambulance stops, and road traffic crash occurrences were obtained using GPS surveying (Garmin 86i). This is so that spatial analysis can figure out how they are related spatially. Crash frequency within the specified junctions along the metropolis' highways was used to determine major incident areas. Field observation was also used, particularly at most highway intersections, to gain a better understanding of some of the factors that contribute to the high frequency of crashes and the emergency response actions. Onscreen digitization in the ArcGIS 10.8 GIS environment was used to collect vector shapefiles of the metropolis's road network based on topological regulations and properties (Figure 3). Two types of highways were categorized (highway and residential) based on this study, each with a speed limit of 50-70 km/hr and 30-50 km/hr, respectively. The length of each route was established as well as the time and physical distances in minutes and kilometers respectively. For recording the observed causes of crashes and identifying crash hotspots, field notes and crash data were used.

3.3 Data Analysis Techniques

To better understand the distribution pattern of road traffic crashes, emergency healthcare facilities, and ambulances, various methods of analysis were used, as well as modeling (based on time and physical distance) the emergency response to such crashes. The Nearest Neighbor Analysis (NNA) was used to determine the distribution pattern of emergency healthcare facilities, road traffic crash incident places, and ambulances using ArcGIS 10.2 software. The nearest neighbor index is calculated using the average distance between each emergency healthcare facility and incident spot and the closest neighboring location. On the one hand, the technique entails importing the latitude and longitude properties of all emergency healthcare facilities, and on the other, the incident locations. Network Analysis (shortest and closest route) was used to establish the best and shortest travel distance of ambulances to incident locations and from incident locations to the closest emergency healthcare facilities, as well as the shortest route and closest facility within the metropolis. This is to enable determining the time and

physical distances (in minutes and kilometer) from ambulance locations to incident spots and as well from the incident spots to the EHCF. The analysis shows the optimum route (based on requirements) from an ambulance site to an incident scene, and from an incident spot to the nearest healthcare facility, with journey distances in kilometers and minutes reported. There was no set cutoff distance for determining the closest facility; however, the search for the closest facility was conducted across the metropolis. There is only one restriction attribute when describing the restriction attributes during the development of network datasets, which is no infringement of road regulations (i.e one-way). Finally, after identifying the trip bottlenecks, a location-allocation study was performed to find new places where more ambulances may be stationed, particularly along the highway, to provide optimal coverage. Maximum impedance cut-off of 4 minutes was assigned to clearly define the extents of coverage of all the ambulances (existing and the proposed).

4. Results

4.1 Emergency Healthcare Facility and Road Traffic Crash Spot Distribution Pattern

The distribution pattern of emergency Healthcare facilities and that of the crash places considerably vary in that the EHCF inside the metropolis are dispersedly distributed with Nearest Neighbor Ratio (NNR) of 1.42 and z-score value of 2.94. This distribution pattern is determined by the nature of services supplied and the existing service coverage specifically within the population clusters in the area (Figure 4). The crash places were found to be randomly distributed (with NNR 1.0) throughout the city, and the pattern is impacted by the network pattern and distribution of junctions along the highways. The ambulances were found to be dispersedly distributes. Since the distribution patterns of the ambulances, EHCF and those of the crashes sites are not identical, and there is a significant need for interaction between them, there is therefore the necessity to evaluate the synergy (if any) among them or otherwise. This is especially with respect to influencing the ability to deliver efficient emergency response throughout the metropolis.

4.2 Shortest Routes of Ambulances for Emergency Response to Crash Spots

The role of ambulances in road traffic crashes emergency response cannot be overemphasized. Examining the distribution patterns of the ambulances in relation to crash places and EHCF is very significant in achieving efficiency in the response system. The outcome of study (Figure 5) illustrates the closest paths from the 2 ambulance locations to all the identified crash 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.

Table 1: Distance Ranking for Ambulance Response to Road Traffic Crashes

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	Sabuwari 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

From Figure 5, it was found that, KSFS ambulance travels 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 and CPR where necessary). Similarly, it takes FRSC ambulance about 9.41 minutes to reach to crash spot 18 (Maiduguri Road, after NNPC), and 7.52 minutes to travel to AKTH as the closest EHCF. Furthermore, 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 time variations and extensive delays in responding to crashes. Victims can easily die in the process especially if a cardiopulmonary resuscitation (CPR) is required which should be provided within four minutes after the incidence before victims reached to the hospital (NFPA, 2010 and ESRI, 2007).

In comparison to these standards, the result shows that about 90% of the crashes spots within the metropolis are accessed long after the recommended 4 minutes travel distances (if CPR is required). In

most cases, it takes up to 3 times or more than the minimum recommended time before emergency personnel reaches to the incident spots. This results into increase in the chances for death after crashes especially if CPR is required. 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.

4.3 Accessibility to the Closest Emergency Healthcare Facilities from Crashes 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 depict these relationships. Travel distance from event areas to the closest EHCF is also a consideration for survival of victims when crashes occur.

Table 2: Ranking of Distances from Road Traffic Crash Spots to the Nearest EHCF

S/N	IncidentID	FacilityID	Crash 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
23	23	2	Kofar Mata - MMS Hospital	0.66	0.55
24	24	2	Mandawari - MMS Hospital	1.33	1.11
25	25	2	Gidan Sarki Junction - MMS Hospital	0.91	0.75

From Table 2, it is obvious that, it takes less than one minute to go from crash places 13, 14 and 15 to IRPH as the closest EHCF. Traveling from incident areas 20 and 23 to Sir Sunusi and MMS hospitals takes about the same amount of time. However, the longest distance traveled from all incident places to

the closest EHCF is 8.27 minutes which is from Sharada Junction (spot 12) to IWGH, followed by 7.52 minutes from spot 18 (Maiduguri road, NNPC) to AKTH. However, over 70% of trip routes fall within the recommended 0-4 minute journey distance (if CPR is required).

4.3.1 Accessibility to Nearest Orthopedic Emergency Healthcare Facilities from all Crash Locations

In the event of an orthopedic emergency, the best routes from all incident spots to the only National Orthopedic Hospital revealed that the closest incident spot is Kofar Dawanau junction, which is about 1.58km away and takes 2.48 minutes to travel (Figure 7 and Table 3).

However, the longest distance to the orthopedic hospital in the city is from Maiduguri Road (after NNPC), which takes around 16 minutes to cover a distance of about 13 kilometers (excluding the travel distance from ambulance location to the incident spots). This denotes the casualty's proclivity for suffocating before arriving at the hospital. Only the crash sites at Mandawari and Gidan Sarki crossroads meet the suggested standards, which highlight a higher likelihood of survival if response and CPR (if required) are performed within 4 minutes.

Table 3: Travel Distances (Time and Physical) to National Orthopedic Hospital Dala from all Crash Spots

SN	Incident ID	Crash 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
24	17	Naibawa - NOH, Dala	14.11	11.77	24
25	18	Maiduguri Road, after NNPC - NOH, Dala	15.75	13.13	25

4.3.2 Accessibility to Pediatric Emergency Healthcare Facilities from all Crash Locations

The optimal paths to two famous pediatric hospitals were discovered as a result of pediatric-related casualties (i.e Asiya Bayero and Isiaka Rabiou Pediatric Hospital). Figure 8 shows that Asiya Bayero Pediatric Hospital is around 85% closer to the crash sites than Isiaka Rabiou Hospital.

However, the shortest distance traveled was between the intersections of Zoo Road Dan Kura Street, Gandun Albasa Street, and Total, which took 0.15, 0.26, and 0.49 minutes, respectively (Table 4). This does not include travel kilometers from the ambulance to the incident site. The shortest distance to Asiya Bayero Pediatric Hospital (in minutes) is from the intersections of Gidan Sarki (0.92), Dan Agundi (2), Kofar Mata (2.48), and Kofar Naisa (2.94). It's worth noting that these distances are within prescribed guidelines, implying that if ambulance travel lengths are likewise within a 2-minute drive, there's a better probability of pediatric survival in the event of an crash. However, the reality on the ground shows that ambulance travel time to incident locations is longer than journey time from incident locations to the next EHCF.

Table 4: Travel Distances (Time and Physical) to Pediatric Hospitals from All Crash Spots

SN	IncidentID	Crash 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	Sabuwari 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		Gidan Sarki Junction - ABP Hospital	0.92	0.76

The longest distances to pediatric hospitals are from Danbare junction (opposite BUK, newsite) and Rimin Gata (opposite Hijra filling station), which take approximately 13.29 and 12.09 minutes, respectively, plus ambulance distance travel of approximately 15.06 and 13.87 minutes (Table 1).

4.4 Ambulance Location Allocation for Maximum Emergency Coverage in Kano Metropolis

The service coverage of existing ambulances was determined based on maximum impedance coverage of 4 minutes in order to propose ideal places for putting more ambulances for optimum coverage (Figure

9). Only crash areas 12, 13, and 15 can be reached within the specified travel distance from FRSC, according to the results. The KSFS ambulance, on the other hand, can go to crash areas 8, 9, 14, 22, 23, and 24. However, the two existing ambulances, on the other hand, are unable to reach all other crash sites within the mandated travel distance. As a result, a location-allocation study was required to propose new locations for ambulances to be stationed for optimal coverage.

The suggested sites for ambulances along the major routes within the metropolis are depicted in Figure 10. Based on a maximum of four minutes impedance cutoff from all directions towards the occurrences areas, eight new locations were found (Table 5). Only crash places 10 and 11 (both within Sharada) were not reached by any of the ambulances within 4 minutes, according to the results.

Table 5: Ambulance Service Locations and Crash Sites

SN	Name	Facility ID	Crash 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
SN	Name	Facility ID	Crash Spots	Travel Time (Minutes)	Distance (km)
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

Table 5 indicates that with the new ambulances, all crash places can be reached in less than the minimum standard of four minutes, allowing for immediate CPR when needed.

5. Discussion

In most cities around the world, the distribution of ambulances for emergency response and EHCF is usually based on a number of factors, including the city's nature and state, population density and distribution, landuse pattern, emergency response demand, and risk pattern, among others. The most important variables for any city are determined by its unique characteristics. However, in many African towns, including Kano, these response facilities are placed randomly, regardless of any of the conditions described above. This results into extensive delays before victims reached to the hospital. This supports the findings of Ashiagbor, *et al.* (2020) and Ouma, *et al.* (2018). The most concerning issue is that most emergency response facilities are insufficient (where they exist) or non-existent in most parts of the metropolis. With a population of 4, 331, 790 people and at least 50 road traffic incidents per day (KSFS, 2021), Kano metropolitan has only two active emergency response ambulances (KSFS and FRSC ambulances), which is woefully inadequate.

When it comes to emergency response in the event of a crash in the city, the KSFS ambulance, for example, takes about 13-15 minutes to reach crash spots 1, 2, and 3 before transferring to the next EHCF (Table 1). Similarly, the FRSC ambulance takes 7-9 minutes to arrive at crash locations 18, 20, and 21. This clearly reveals that impacted people have a higher likelihood of dying before an ambulance arrives at most event sites, particularly those who will require CPR within the first four minutes following the crash. In addition, the travel distance between incident sites and the nearest EHCF is a major source of worry. This is because the casualty must travel for an extra 4-6 minutes before being transported to the hospital (Table 2). This contradicts the findings of Kassaw and Asefa (2020) in Arada Sub-City, Addis Ababa, Ethiopia, who found that it takes between 1 and 2 minutes to get to hospitals in an emergency. Similar issues exist in the city when it comes to orthopedic and pediatric emergencies. For example, it takes an extra 10-15 minutes to go to NOH or ABP from crash spots 1-4, 12, 17, 18, 20, and 21 in the event of a complicated orthopedic or pediatric emergency (Table 3). This demonstrates the inefficiency of the current emergency response system in Kano. The inadequacy of ambulances, as well as a lack of synergy in terms of distribution and closeness to EHCF and crash hotspots, are all challenges experienced in emergency response. This finding contrasted with that of Oruonye, Dimas, and Ahmed (2021).

6. Conclusion And Recommendation

Road traffic crash, which has resulted in injuring and losing of several lives and properties, is unavoidable in Kano Metropolis, owing to population growth and the density of traffic flow, particularly along the state's highways connecting it to neighboring states. The city's current road traffic crash emergency response system is ineffective due to a number of factors, one of which being a lack of ambulances at various places. Following are some suggestions based on the findings:

- 1. More ambulances should be stationed, particularly along highways and near crash sites, to speed up emergency response and save more lives of those who have been injured.
- 2. To ensure full compliance by drivers, traffic regulations must be enforced and traffic signs must be placed along the highways.
- 3. Pedestrians and drivers should be informed about when and how to cross the road and turn around U-turns, respectively.
- 4. At key intersections, overhead pedestrian bridges should be built to decrease people's exposure to road traffic crashes.

Abbreviations

EHCF	Emergency Healthcare Facilities
KSFS	Kano State Fire Service
FRSC	Federal Road Safety Corp
CPR	Cardiopulmonary Resuscitation
IGW	Imam Wali General Hospital
ABP	Asiya Bayero Pediatric Hospital
IRP	Isiaka Rabiou 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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Author's Contribution

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Emergency Healthcare Facility data capture, ambulance location and mapping by Dr. Ishaq A.A

Figures

Figure 1

Kano Metropolis

Figure 2

Methodological Flowchart

Figure 3

Network Data and Attributes

Figure 4

Distribution of Healthcare Facilities and Road Traffic Crash Spots

Figure 5

Ambulance Best Routes to Crash Spots

Figure 6

Nearest Emergency Medical Services from Crash Locations

Figure 7

Routes to National Orthopedic Hospital Dala from all crash sites

Figure 8

Routes to Pediatric Hospitals from all Crash Locations

Figure 9

KSFS and FRSC Ambulances' Distance to Crash Spots in Four Minutes

Figure 10

Ambulance Location Allocation for Maximum Coverage in Kano Metropolis