Analyzing Ambulance Service Response Time Using Geospatial Techniques

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Abstract: Emergency medical services play a crucial role in ensuring timely healthcare intervention, particularly in urban and suburban areas. This study employs service area analysis to evaluate the spatial coverage of ambulance services in the Abuja Municipal Area Council (AMAC), Nigeria. Using a 15-minute travel time impedance, service area polygons and coverage lines were generated to assess accessibility. Additionally, population density data was integrated to determine the demographic distribution within the serviceable zones. The findings reveal a concentration of ambulance service providers in the urban core, leaving suburban settlements significantly underserved. The maps and spatial insights derived from this research highlight disparities in emergency medical service distribution, providing valuable information for policymakers and health planners to address gaps and enhance ambulance service accessibility in underserved areas.

Keywords: *Ambulance, Response Time, Geospatial Techniques.*

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I. INTRODUCTION

There is an increasing occurrence of disasters arising from road traffic accidents, ailing patients, domestic accident resulting in several loss of lives. This has attracted a lot of interest on how to address these disasters as emergencies. However, a systematic study of emergency response in disasters (ER) has been ignored (Yi and Shaoze, 2020). The loss of lives can be mitigated and several lives can be saved with an effective emergency medical service system. An emergency medical service system is a system designed with an ultimate goal to save lives (Laura and Maria, 2010). These services include the provision for ambulance services. An ambulance service makes provision for vehicles which are required to respond rapidly to medical emergencies Ethel, et al., (2017). These vehicles essentially have in them first aid medical needs to stabilize patients before reaching the hospital. However, Ethel, et al., (2017) postulates that, in time of an emergency, when there is a call for an ambulance service, a number of factors may affect the response time (how quick an ambulance service can reach the patient). Factors such as the location of emergency services stations, the number of ambulance vehicles available at each station, road conditions and traffic volumes (i.e., a response time threshold) were highlighted. Therefore, the effectiveness of any ambulance service is measured by its response time. Several response times have however been adopted as standards for emergency medical services (EMS). Ian, et al., (2012) explored whether an 8-minutes EMS response time was associated with mortality. Johan, et. al., (2020) adopted a standard of 0 to 6 minutes, 7 to 9 minutes, 10 to 15 minutes, and > 15 to analyze out-of- hospital cardiac arrest survival rate.

Akeem, et al., (2021) identified GIS as a tool to support decision making to mitigate and improve emergency response in road traffic-related emergency management. Geographic information system (GIS) can be used to assess ambulance response performance (Jeremy and Brent, 2000). Ethel, et al., (2017) used a GIS approach to improve placement of stations and allocation of ambulances per station to improve service delivery through reducing the likely response times of ambulance services in an area. Lee, et al., (2021) carried out a study a statewide ambulance coverage incorporating road networks for ambulance travel time, census blocks for population, and backup service coverage using geographic information systems (GIS).

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II. STUDY AREA

Abuja is Nigeria's capital and the country's eighth most populated city. The Federal Capital Territory is in the country's centre (FCT). It serves as the administrative and political capital of Nigeria. Aso Rock, a 400-metre (1,300-foot) rock left by water erosion, defines Abuja's topography. The Abuja Municipal Area Council (AMAC) which was created in 1984, located between latitude 8° 40’ and 9° 20’ north of the equator and longitude 6° 40’ and 7° 40’ east of the Greenwich meridian. AMAC has land area of 1,769 square kilometres, making it the biggest local government area council in the Federal Capital Territory (Ibrahim, 2011). It is one of six area councils that governs the city of Abuja. It is located on the Eastern wing of the Federal Capital Territory. It is bounded on the East by Nasarawa State, on the West, by Kuje area Council, North - West by Gwagwalada and on the North, by Bwari Area Council. In addition to local administration, the city is the headquarters of the Federal Government of Nigeria, as well as the Federal Capital Territory Administration, which oversees the surrounding Federal Capital Territory. The Abuja Municipal Area Council (AMAC), as a local government, is not sovereign, but rather a public institution with the authority to make and implement a restricted range of public policies. It reports to both federal and state authorities.

Abuja Municipal Area Council has 12 wards: City Centre, Garki, Gui,Gwagwa, Gwarinpa, Jiwa, Kabusa, Karshi, Karu, Nyanya, Orozo, and Wuse, (Ajibade, 2021).

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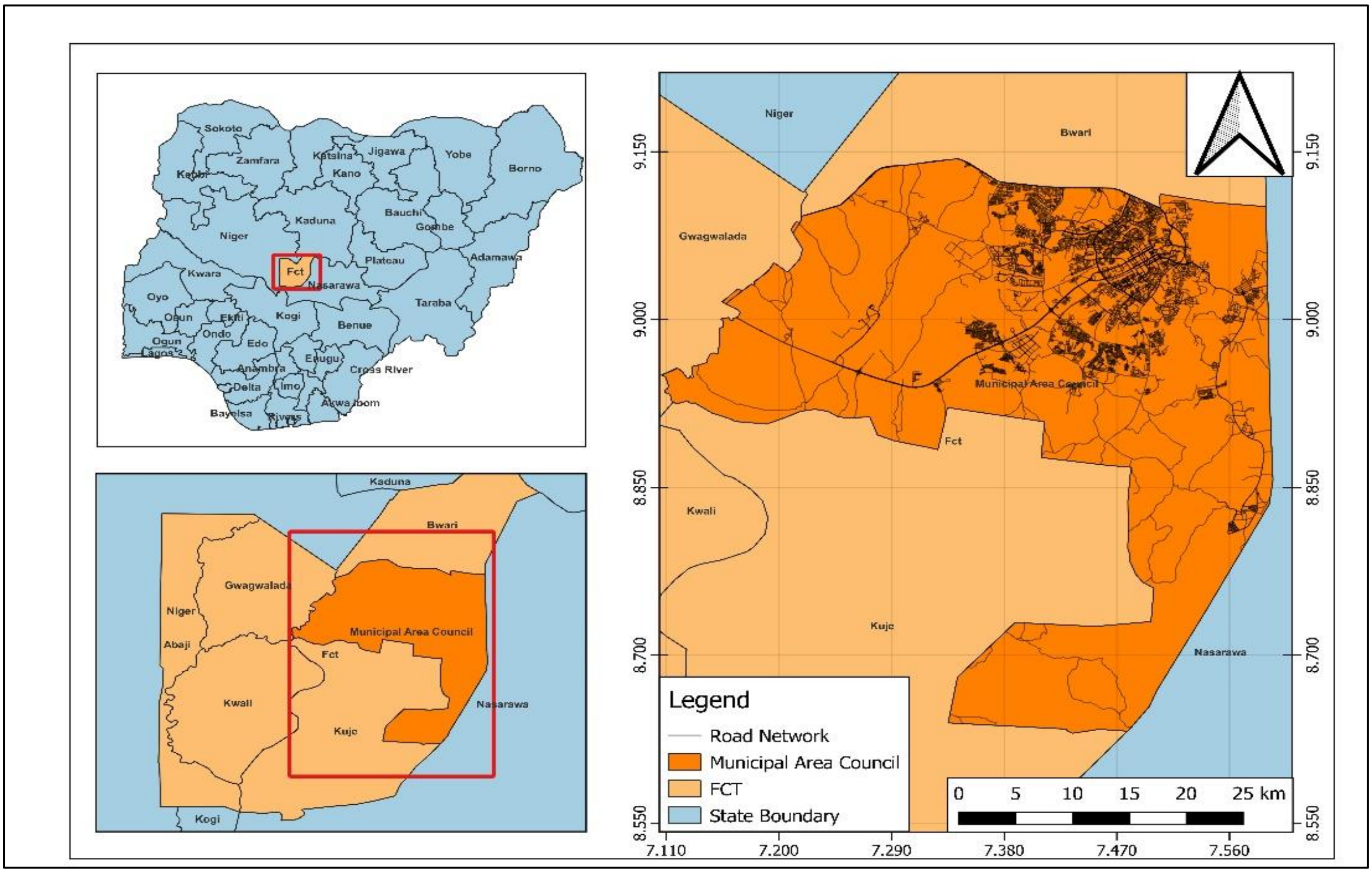

Fig 1: Abuja Municipal Area Council

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III. STATEMENT OF PROBLEM

Ambulance Service is very important in instances of emergency. The goal is to get to the point of demand in good response time so as to stabilize patients with first aid care before transporting them to the hospital where their lives can be saved. The utilization of ambulance services in response to emergency medical cases has been an integral part of healthcare service delivery for a long time in most parts of the world (Swalehea and Aktas, 2016). Emergency response activity relies on transportation networks. Emergency facility location interacts with transportation networks clearly. Yuan, et al,. (2021). Ambulance services utilize road networks every motorist use to get to the point of demand and transport the patients to the hospital. This has made the task of reaching the patient “in good time" to be particularly challenging. Even though most of the emergency hospital ambulances are equipped with paramedics, they are unable to reach the incident site in good response time due to lack of verification of the shortest route and fastest time. A large number of vehicles and road users have resulted in severe transportation delays, lower fuel efficiency, safety risks, and accidents in the traditional system. Khalid, et al. (2021), Inadequate healthcare can also be attributed to uneven spatial distribution of Health Care Facilities in the country. Some areas are more advantageous than others, creating disproportion in service delivery (Eta et al., 2021).

According to the guidelines for the Operation of National Ambulance Services in Nigeria, Nigeria has no formal legal framework for coordination and regulation of ambulance services. This has led to several preventable losses of lives from road traffic incidents, terrorist attacks, natural disasters, civil uprising, domestic violence and other medical complications of childbirth, heart attacks, stroke and acute asthmatic attack. These situations require prompt and professional attention to save lives and improve health indices by reducing mortality and morbidity. These untoward losses can be minimized by deploying intelligent decision system and shortest path algorithms to optimize ambulance travel time to and from accident scene to the nearest hospitals (Ogunwolu et al., 2018).

There is no study yet highlighting the travel time and service area for ambulance service providers within the Abuja Municipal Area Council (AMAC), therefore, it is necessary to analyze recent data and understand the current emergency service performance to aid decision making regarding the locations of ambulance service providers within AMAC. This study presents a GIS approach for determining service area of ambulance service providers in AMAC.

IV. METHODOLOGY

The datasets utilized for this research were mostly obtained from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) portal; road network, recent gridded population estimates and operational ward boundary map of AMAC, the ambulance service providers data was obtained from National Emergency Medical Services and Ambulance Scheme (*NEMSAS*) and Open Street Map (OSM). The Network Analyst extension, Zonal toolset, Zonal Statistics were used to achieve the result.

For this research, the road network dataset was created using the New Network Dataset Tool in ArcGIS Desktop; this is done to aid efficient analysis by creating all the necessary nodes for intersections and connectivity, ensuring that there is no dangles in the road network and the roads do not intersect or overlap with themselves. A network service area is a region that encompasses all accessible streets within a specified impedance, i.e travel time or distance (ESRI, 2021). In order to carry out a Network Analysis, a good road network dataset is required. The road network dataset and the ambulance service providers’ data were analyzed to know the area serviced by the ambulance service providers.

The Zonal toolset was also utilized to analyze the values of the population (raster) within the serviced area polygon and the result reported in to a table, and further summarized to know the total sum of the people serviced within the study area. This was achieved by overlaying the service area polygons on the Population data (raster) and identifying cells in the value raster within the serviced area. The base map of AMAC was downloaded from OpenStreetMap (OSM). OSM can be accessed as an ArcGIS Online Service that provides free read-only access to OpenStreetMap as a base map for GIS work in ESRI products such as ArcGIS Desktop (Ahmed et al., 2017).

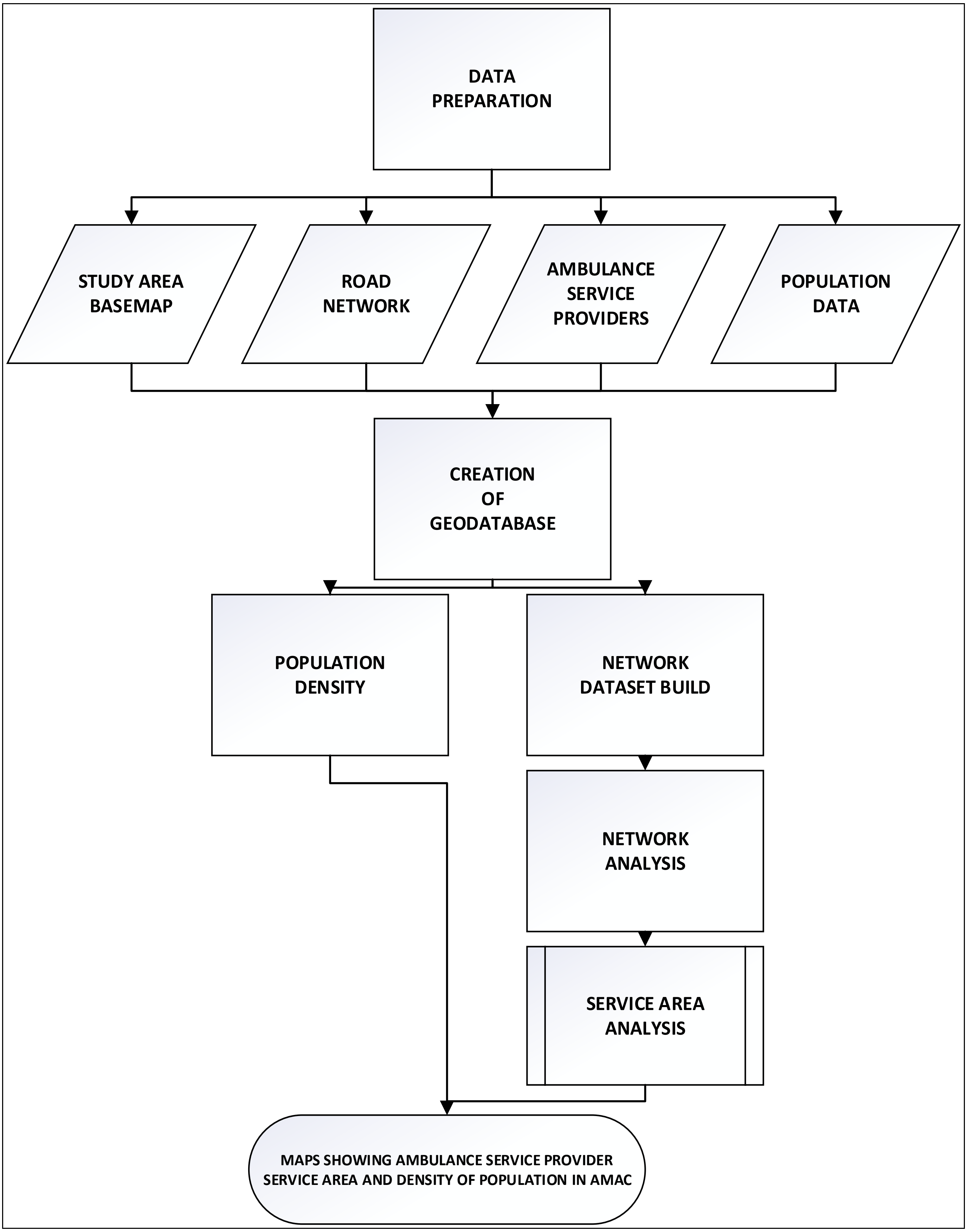

Fig 1: Flowchart Showing Network Analysis Process Flow

V. RESULTS AND DISCUSSION

A. Spatial Distribution of Ambulance Service Providers

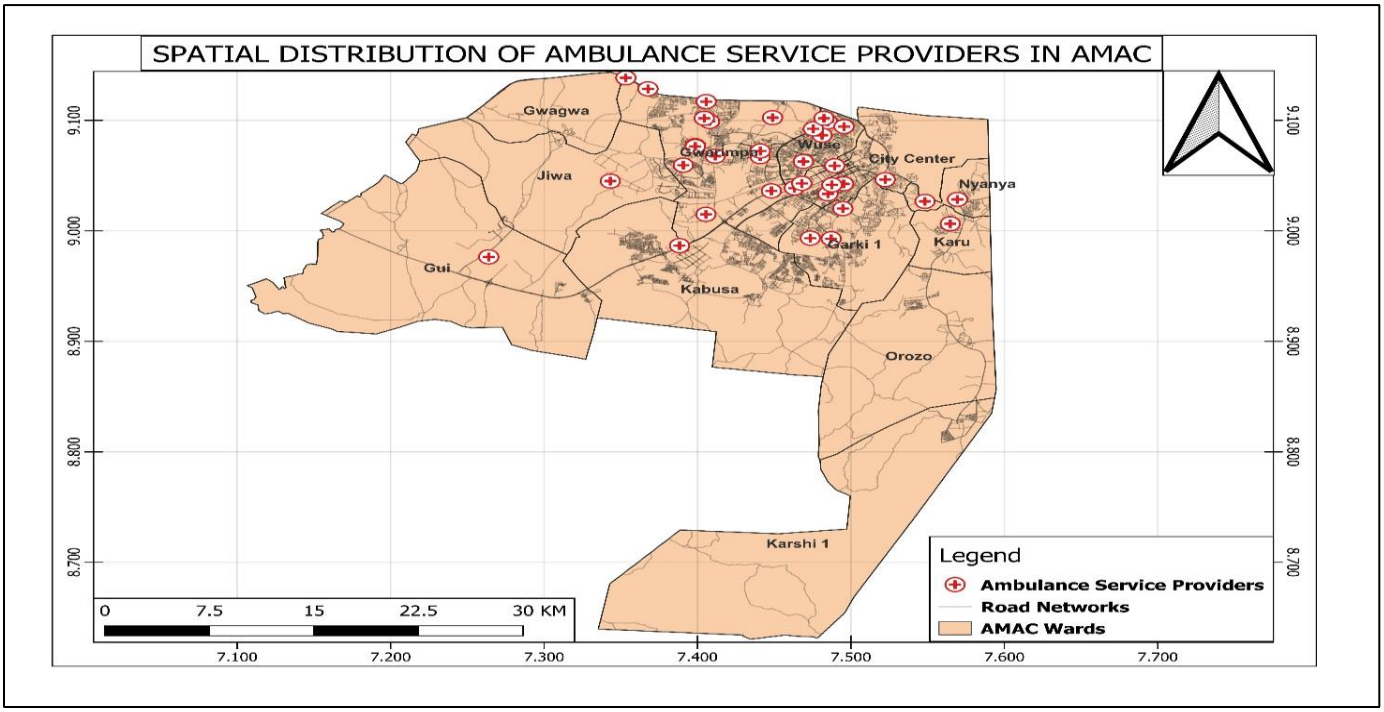

Fig 2: Spatial Distribution of Ambulance Service Providers in AMAC

Figure 2 displays the spatial distribution of the ambulance service providers within the study area to visualize and understand their geographical locations. The data clearly depicts that most of these ambulance service providers are located in the northeastern part of the study area where development is evident, hence, more populated. This may be due to high demand, better facilities (e.g. Road network) or ease of operation in these areas. Out of the thirty-six (36) ambulance service providers in AMAC, eight (8) belongs to the Federal Road Safety Corps. (FRSC) stationed strategically along the highways.

B. Ward Distribution of Ambulance Service Providers in AMAC

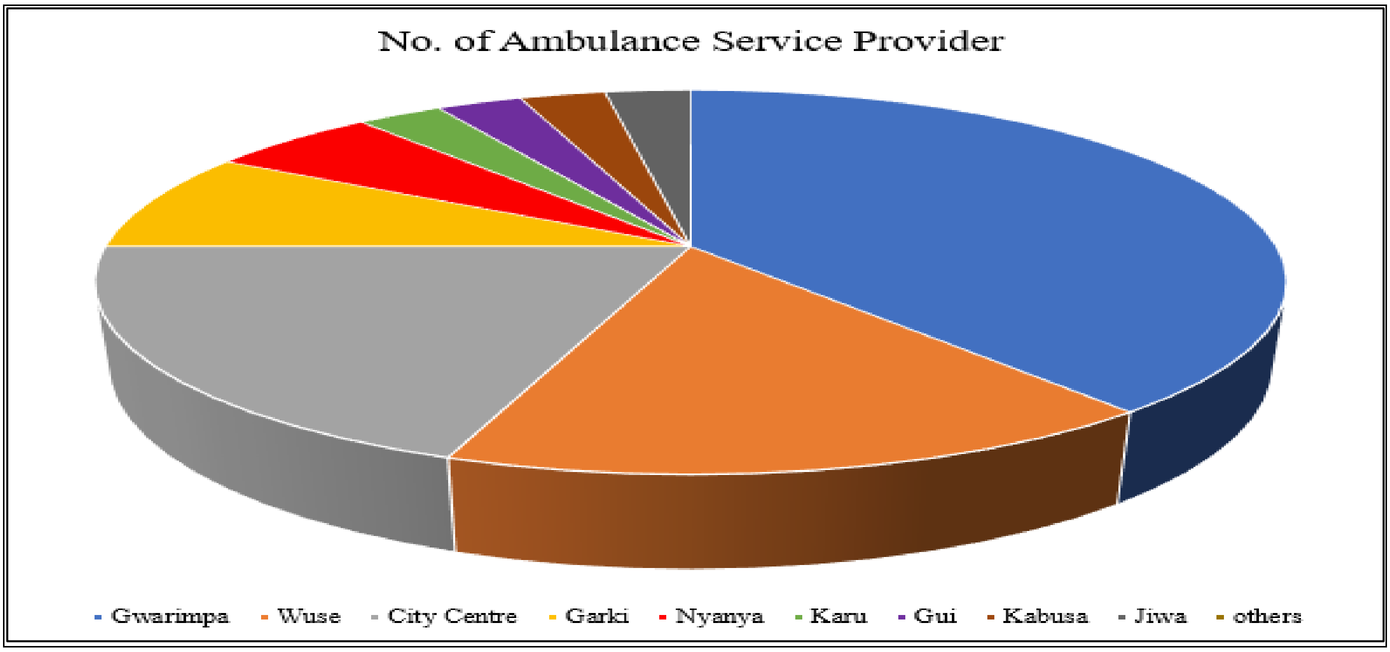

Chart 1: Ambulance Service Providers in AMAC

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Table 1 shows that Gwarimpa has the highest number of ambulance service providers (14), with Karu, Kabusa, Jiwa and Gui having the least (1). However, Orozo, Karshi and Gwagwa do not have any ambulance service provider. This means that people in need of these services would have to wait longer than the specified drive time to be reached by an ambulance service provider.

C. Service Area Polygons within AMAC

The service area polygons represent the extent to which an ambulance service provider can reach people in need of their services within a travel time of 15 minutes via a road network. Rather than using distance to evaluate accessibility to ambulance service providers within AMAC, travel time was used. This study applied 15 minutes travel time to Ambulance service providers within AMAC using the ArcGIS Network Analyst Tool and the Service Areas for every ambulance service provider was generated.

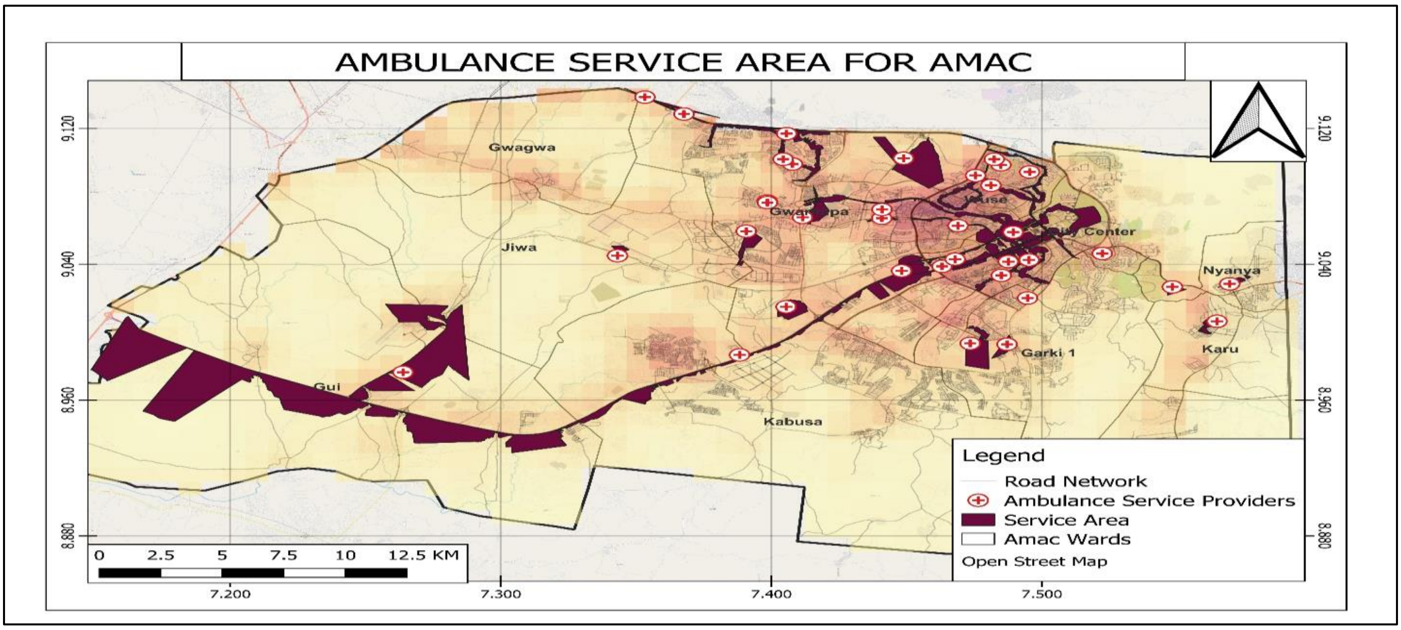

Fig 3: Service Area within AMAC

Figure 3 displays the service area polygons showing the serviceable area for the ambulance service providers and the area not within the polygon cannot be reached at the specified impedance.

D. Population Access to Ambulance Service Providers in AMAC

In order to assess the population that have access to the ambulance service providers, population density of the AMAC area was overlaid to correspond the extent of what each ambulance service provider can cover within the specified travel time.

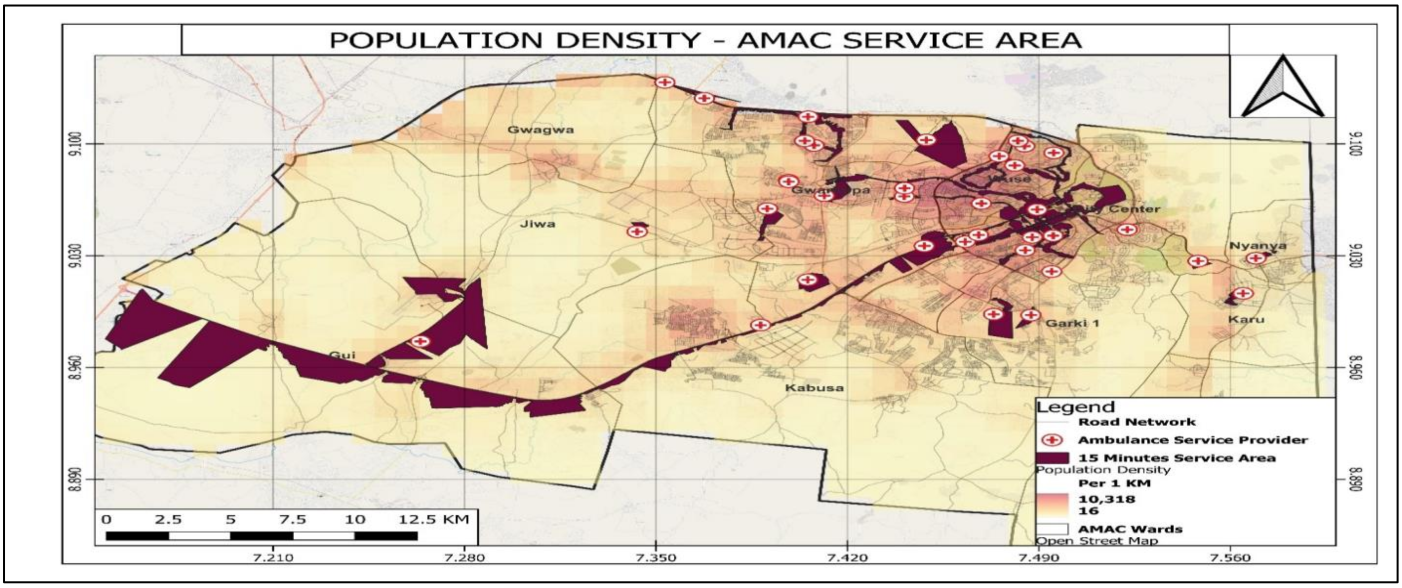

Fig 4: Population Density of AMAC

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Figure 4 presents the population density overlaid for AMAC that falls within the 15 min travel time from ambulance service providers. The population coverage capacity of the ambulance service linked within the specified travel time was estimated to be 263,168 using the zonal statistics tool, which leaves a large area unserved.

VI. CONCLUSION

This research focuses in using service area analysis to determine the service area polygon and lines of coverage for ambulance service providers based on the specified impedance of 15 minutes travel time. In addition, population data was integrated into the service area analysis to display the sum of the population density of AMAC. The result clearly shows that the ambulance service providers area mostly located in the urban part of the city, leaving the suburban settlements underserviced. Maps from this research provide information about ambulance services and availability to residents and may be useful for policy makers and health planners should to prioritize the need for more ambulance service providers in other areas.

RECOMMENDATIONS

This study performed a detailed network analysis with the available ambulance service providers' data and recommends that the FRSC should site more ambulance hubs in areas that are not served. Some places to be considered are Aideyan Osaro Royal Street in Kabusa, Dalhatu Road in Gwagwa, Rabiu Musa Kwankwaso Street in Orozo, Karshi Roundabout – along Karshi Road in Karshi and David Ejofor Street in Apo – Garki due to their high population density. The ambulances need to be more dispersed rather than concentrated, hence, further studies can explore the gab.

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