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GIS analysis of the spatial distribution of public infrastructure in Calabar metropolis, Cross River State, Nigeria

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Abstract

Geographic Information System (GIS) is a very important system which can be used in data collection, entry, development, management and analysis of spatial information. *It has the ability to record, store, query, update and retrieve at will when necessary in all infrastructure related information in a database.* The study is aimed at assessing the inventory of public infrastructure in Calabar metropolis, Cross River State using GIS techniques. The method of data collection were obtained from the field using a handheld Global Positioning (GPS) receiver, public infrastructure datasets were obtained from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID^3). The data obtained from the portal include; school, health facilities, road, administrative boundary shapefile, water point, fire stations, police, settlement and markets. The coordinates obtained from the field were collated in EXCEL spread sheet and transformed to Universal Transverse Mercator (UTM) coordinate system. They were used to plot the digital Map in ArcGIS 10.8. The finding of the study revealed that public schools covered 51.93% of the study area, while fire station and heath care centers covered 12.9% and 61.03% respectively in the study area. The result also revealed that most of the infrastructures are located mostly in the southern part of the study area because of the high concentration of socio-economic and political activities. The study has established the capability of GIS in creating a Geodatabase for assessing the public infrastructure inventory within the study area. It is, therefore, recommended that Geospatial techniques be adopted for proper planning and development of public infrastructure and management system for easy management and control of its facilities.

Keywords: GIS; Calabar; Geodatabase; Infrastructure; Map

1. Introduction

According to Ajayi (2025), 2024 was a transformative year for Nigeria's infrastructure sector as the government launched ambitious projects to improve connectivity, drive economic growth, and strengthen long-term development. These initiatives mark a crucial step towards closing the infrastructure gap and building a more resilient economy and, by extension, achieving the Sustainable Development Goals (Willoughby, 2004). Conceptually, infrastructures are basic physical systems of a business or nation. Although these systems tend to be high-cost investments; they are, however, vital to a country's economic development and prosperity. According to the World Bank (1994), infrastructure is the umbrella term for any activities referred to as "social overhead capital" and characterized by peculiar technical and economic features. They are fundamental facilities and systems serving a country, city, or other area, including the services and facilities necessary for its economy to function e.g. public and private physical assets such as roads, bridges, railways, harbors, pipelines, airports, tunnels, etc. However, since the late 1980s, several researches examining the

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correlation between sufficient infrastructures and socio-economic growth and development have been recorded. The general consensus is achieved around the idea that basic infrastructure facilities are essential features related to socio-economic buoyancy and performance despite the fact that the magnitude and the causality are well noted (Torrisi, 2009a; 2009b). Likewise, studies integrating sophisticated GIS mapping technologies in studying surface configurations (topography), hydro-geological resources, urban structural development and other socio-economic problems feature all over the world (Bello, Aisabokhale & Sufiyan, 2025; Njikam *et al.,* 2024; Ekele *et al.,* 2024; Bello & Ortese, 2023; WHO, 2004).

All the infrastructure facilities that are meant for the use of the general public, such as roads, telecommunication, railways, water supply, public parks, schools, and universities, can be commonly grouped under a single term – "Public Infrastructure" (Bello, Aisabokhale & Sufiyan, 2025; Bello & Ikhuoria, 2015; Agenor & Moreno, 2006). These essential systems and facilities aids in the continuous, seamless and smooth flow of an economy. These can be described as fundamental facilities that are served to citizens of the country and also helped in a thriving economy. Infrastructure enhances the living standards of society by providing essential commodities and services to sustain a good life. The level of such investment done by a country defines the development level of that economy. The integration of smart infrastructure such as smart road networks for conducive human use has been well articulated in recent studies (Bello, Usman & Abubakar, 2022).

Researches have shown that investment in infrastructure has tremendous positive impact on a country's economic growth and development (Adenikinju, 2005). Different government policies in Nigeria have led to infrastructure decay which then culminates into poor and erratic power supply, inefficient telecommunication, poor urban and rural road networks; hence, resulting in a near stagnant economic performance (Bureau of Public Enterprises (BPE), 2003; Edame & Effiong, 2013). The importance of, and the need for, investment in infrastructure and other public goods as a way of increasing urban and rural productivity and national economic growth and development has become an important subject of renewed attention in most developing countries. As a result of the inadequacy of empirical studies on the trend of public expenditure on infrastructure and economic growth, coupled with the nature of investment in infrastructure on the overall development of any nation's economy, there is the need to understudy the spatial distribution and efficiency of available infrastructure in a given geographic space (Bello & Dogara, 2025). This also finds expression in the road infrastructure in Calabar metropolis in Cross Rivers State, Nigeria. This has become very important in view of the endless benefits derivable from infrastructural development; especially that which is based on smart - internet of things (IoT) and e-governance system (Bello, Usman & Abubakar, 2022).

Furthermore, Public infrastructures are needed for the growth and well-being of a community or a society (Agenor & Moreno, 2006). Among the main challenges facing urban centers like Calabar metropolis is how to provide adequate level of public infrastructure and services for the growing urban population. This has become expedient in view of the fact that Calabar is characterized by inadequate transport system, water and power supply, communication networks, and other infrastructural services. Intricately, multifaceted infrastructure problems are attributed to weak urban planning, inefficient urban management and ignorance of service consumers by the local authorities (Frischmann, 2005). In fact, it has been observed over the years that there has been a kind of disparity in the distribution of infrastructures in Calabar (Uche & Onyebuchi, 2011), a situation whereby some facilities are located more in an area where, in most cases, they are not needed. Whereas, there are some areas where these facilities are not available at all and are really needed. Studies reveal that inequality in the distribution of infrastructure is obvious in primary and secondary schools, as well as health facilities in the sense that people have to travel long distances to get to these facilities which, in itself, is a problem due to the fact that they can't access the facilities easily (Dogara & Bello, 2025). It is pertinent, therefore, to investigate the spatial inventory of public infrastructure in Calabar metropolis in order to understand how they are distributed and utilized using the Geographic Information System approach.

Geographic Information System (GIS) is a mapping technology with the capability to capture, store, retrieve, analyze and create georeferenced spatial visualization (Bello, 2025; Bello & Ojigi, 2013). Its application areas includes assessing urban built area conditions and social networks which have proved to be essential in creating a sustainable planning tool (strategy) and for designing a development that fit both constructions and social needs within specified site (Su, 2003). Professionally, the success of planners in combating chronic urban problems is largely determined by their ability to utilize effective tools and planning support systems that allow them to make informed decisions based on actionable intelligence. Nowadays, urban planners make use of GIS in a variety of applications because it provides the necessary planning platform for visualization, modelling, analysis and making spatial relationship (Mitchell, 2005). Therefore, the aim of this study is to carryout a GIS-based inventory and mapping of Public infrastructure in Calabar, Cross River State, in South-South region of Nigeria. The specific objectives are to (i) identify and map the public infrastructure in Calabar, and (ii) examine the pattern of distribution of public infrastructure in the study area.

2. Materials and Method

2.1. The study Area

Calabar (also referred to as Callabar, Calabari, Calbari, Cali and Kalabar), the capital city of Cross River State (Falola & Warnock, 2007) is located on a fan-shaped alluvial formation of the Niger Delta region, south-south of Nigeria (Figure 1). Generally, Cross River State is located within latitudes 4^0 15'N and 7^0 00' N and longitudes 7^0 15'E and 9^0 30' E. Cross Rivers State is made up of 18 LGAs. Calabar, the state capital, formerly called Akwa Akpa, derives its name from the cross river which transcends along the state and empty into the Atlantic Ocean. Calabar is a port city in southern Nigeria, near the Cameroon border. It sits on a hill near the Calabar River and the Cross River delta. British colonial architecture fills the city's older sections, including Henshaw Town, Duke Town and the waterfront area. Dating from the 19th century, Duke Town Cathedral is one of Nigeria's oldest churches in Calabar. Thus, Calabar was once described as the tourism capital of Nigeria, especially due to several initiatives implemented during the administration of Donald Duke as the Governor of Cross River State (1999–2007). The city became the cleanest and most environmentally friendly city in Nigeria (Ofose, 2016), thus giving rise to clamour for improved facilities.

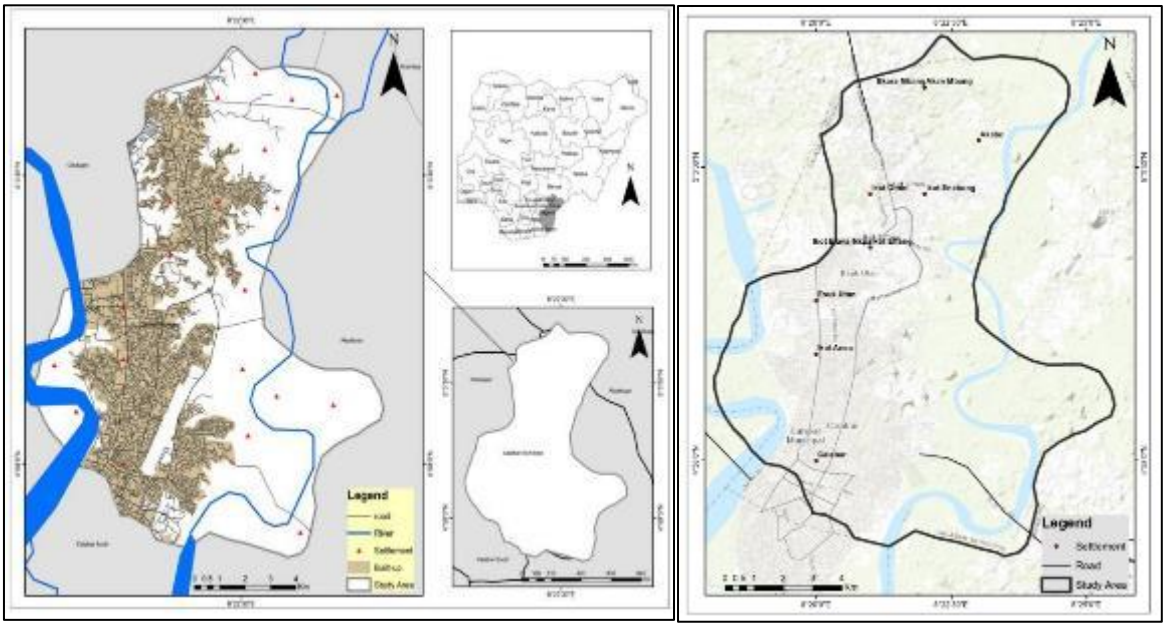

Figure 1 Location of Calabar Metropolis, Cross River State, Nigeria

Administratively, the Calabar metropolis is divided into Calabar Municipal and Calabar South Local Government Areas. It has an area of 406 square kilometres (157 sq mi) and, based on the 2006 census, a population of 371,022 (Ering, Ottong & Akpan, 2010). Both LGAs together had an estimated population of 571,500 in 2022. It is characterized by fast growth in population, economic activities and urbanization just like Lagos State and most coastal cities of the world. A good assessment of available public infrastructure in achieving socio-economic development and growth of the port city made this study a novel one (Agbaje, Bello & Ojo, 2017).

3. Methodology

In order to achieve the aim and objectives of this study, the public infrastructure datasets were obtained from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) web platform (www.grid3.gov.ng). The GRID3 is part of a bigger global initiative which aims to improve access to data for decision making in all participating countries. The data obtained from the portal include; schools, health facilities, roads, administrative boundary shapefile, water points, fire stations, police stations, settlements and markets. The data were downloaded in vector, csv format. Field-based ground-truthing was carried out to validate the positional attributes of the identified infrastructure using a Garmin GPSMAP 79s Handheld Global Positioning System (GPS) receiver.

The datasets collected were analyzed to meet the set objectives as follows:

- To map the spatial coverage of the facilities, the data on the public infrastructure obtained from the GRID3 portal were plotted on the administrative boundary of the study area using ArcGIS 10.8 mapping software. It was cartographically visualized as maps.
- To examine the pattern of distribution of public infrastructures in Calabar metropolis, the ArcGIS 10.8 Geo-statistical analyst tool of "Average Nearest Neighbour (ANN)" was used to determine if the data will exhibit a cluster, random or disperse pattern of distribution. In essence, the ANN examines the distances from each point and the closest point to it, and then compares it to expected values for a random sample of points from a CSR (complete spatial randomness) pattern (Mitchell, 2005).

Also, the ANN index, calculated as the ratio of observed to expected mean distances, is used to compare the degree of clustering or dispersion between different datasets or features in a fixed study area.

$$\text{ANN} = \frac{\text{DO}}{DE} \quad \text{.....(Eqn. 1)}$$

Where DO is the observed mean distance between each feature and its nearest neighbor:

$$\text{DO} = \frac{(\sum_{i=1}^{n} di)}{n} \quad \text{..... (Eqn. 2)}$$

And DE is the expected mean distance for the features given in a random pattern:

$$\text{DE} = \frac{0.5}{\sqrt{n/A}} \quad \text{..... (Eqn. 3)}$$

In the above equation, *di* equals the distance between feature *i* and its nearest neighboring feature, *n* corresponds to the total number of features and *A* is the area of a minimum enclosing rectangle around all features or its user specified area value (Mitchel, 2005).

The Average Nearest Neighbor (ANN) result, or its ratio, provides insight into the spatial distribution of points, indicating whether they tend to cluster, disperse, or exhibit a random pattern. An index (ratio) less than 1 suggests clustering, while an index greater than 1 indicates dispersion.

3.1. Interpreting the ANN Results

- *Clustered Pattern* (Index < 1): The points are more likely to be found close together than would be expected if they were randomly distributed. This could be due to factors like shared resources, similar characteristics, or attraction to specific locations.
- *Dispersed Pattern* (Index > 1): The points are relatively evenly spaced out across the study area. This could be due to factors like competition for resources, avoidance of certain areas, or random spatial processes.
- *Random Patter*n (Index ≈ 1): The points are distributed in a way that is consistent with a hypothetical random distribution. The pattern doesn't deviate significantly from what would be expected by chance

4. Results and Discussions

4.1. Identification and mapping of public infrastructure in Calabar

Figure 2 reveals that most of the public infrastructure are located mostly in the southern part of Calabar. Public schools, water points and health facilities are more in the south than there are in the northern part of the study area.

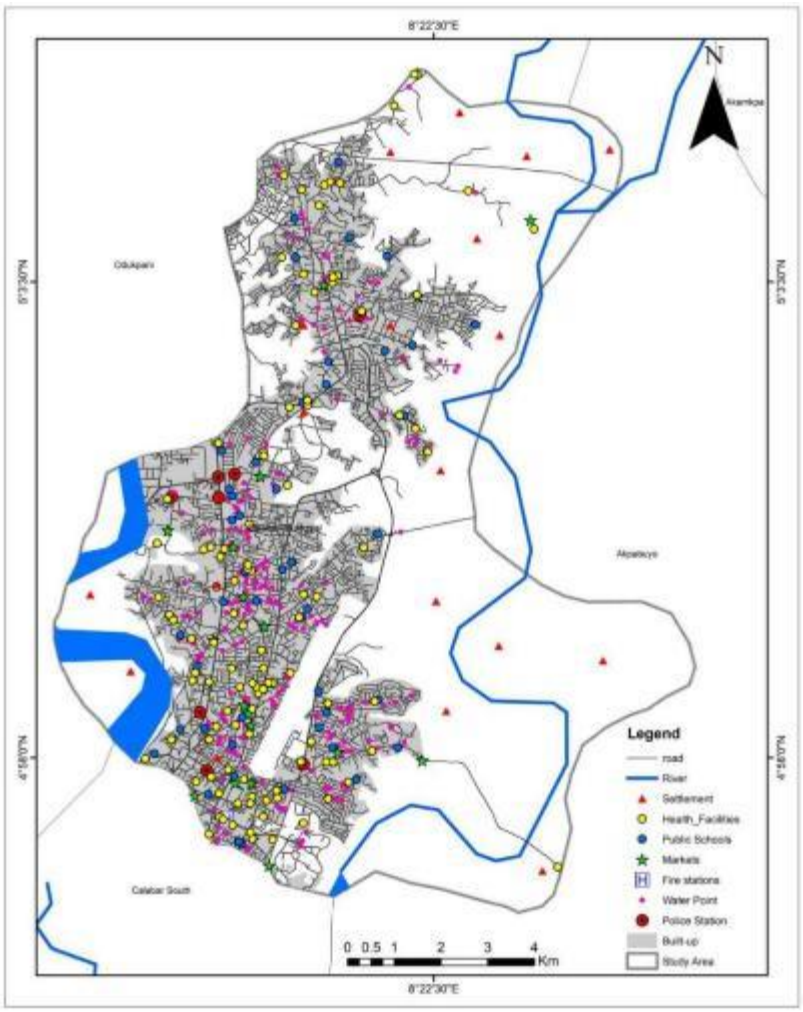

Figure 2 Public Infrastructure in Calabar Metropolis

This is because of the high level of government activities which attract high level of socio-economic services and agglomeration of people; thereby making it a dense area of choice for businesses. It is important to reiterate in this study that Public infrastructure are structures that are essential for security, safety and social well-being of the people of in Calabar. Thus, the inventory of these public infrastructure that renders services are necessary in understanding the type and number of facilities that exist and where they are located for the purpose of decision making in terms of plannings and management.

4.2. Distribution Pattern of Public Infrastructure in Calabar

4.2.1. Schools and Police Stations

Figure 3 shows the geographic distribution of public schools and police Stations in Calabar. The public schools include government owned primary and secondary schools. The results from the Average Nearest Neighbor (ANN) analysis revealed that the location of schools exhibited a random pattern of spatial distribution. Thus, with a Z-Score of 1.168918, result indicates that schools are randomly located in every accessible parts of the study area (Figure 3). Therefore, no part of the study is deficient in terms of geographic access to schools. Few Police Stations are within strategic junctions along major roads. There are lots of under-served areas in Calabar. They are grossly inadequate; hence, the need for more police stations or outposts to handle the rising insecurity challenges in the City and beyond.

It is important to reiterate that Public Infrastructure is the set of facilities and systems that serve a country, city, or other area, and encompasses the services and facilities necessary for its economy, households and firms to function. Thus, schools and polices stations are major facilities and systems of knowledge and security in Calabar. They have become the backbone of socio-economic development and safer society; hence. the need to have clear inventory and map to help in future planning, and resource utilization and management for sustainable living in Calabar.

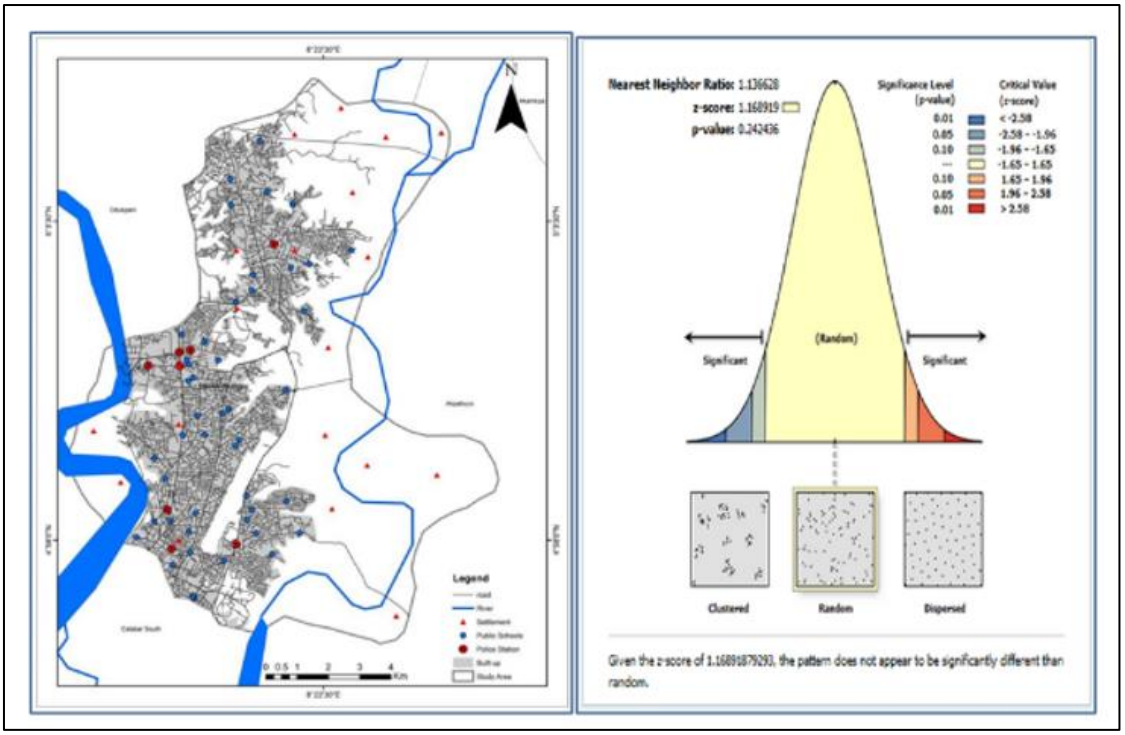

Figure 3 Location of Schools (Left), Random ANN Distribution Pattern of Schools (Right)

4.2.2. Health facilities

Figure 4 shows the spatial distribution and the Random ANN statistical pattern results of healthcare centers in the study area. The results from the Average Nearest Neighbor (ANN) analysis shows that the pattern of distribution of health care centers is random just like the schools which means there are underlying factors behind this kind of pattern of distribution. It could be that of ensuring accessibility of health care centers to the people (Figure 4).

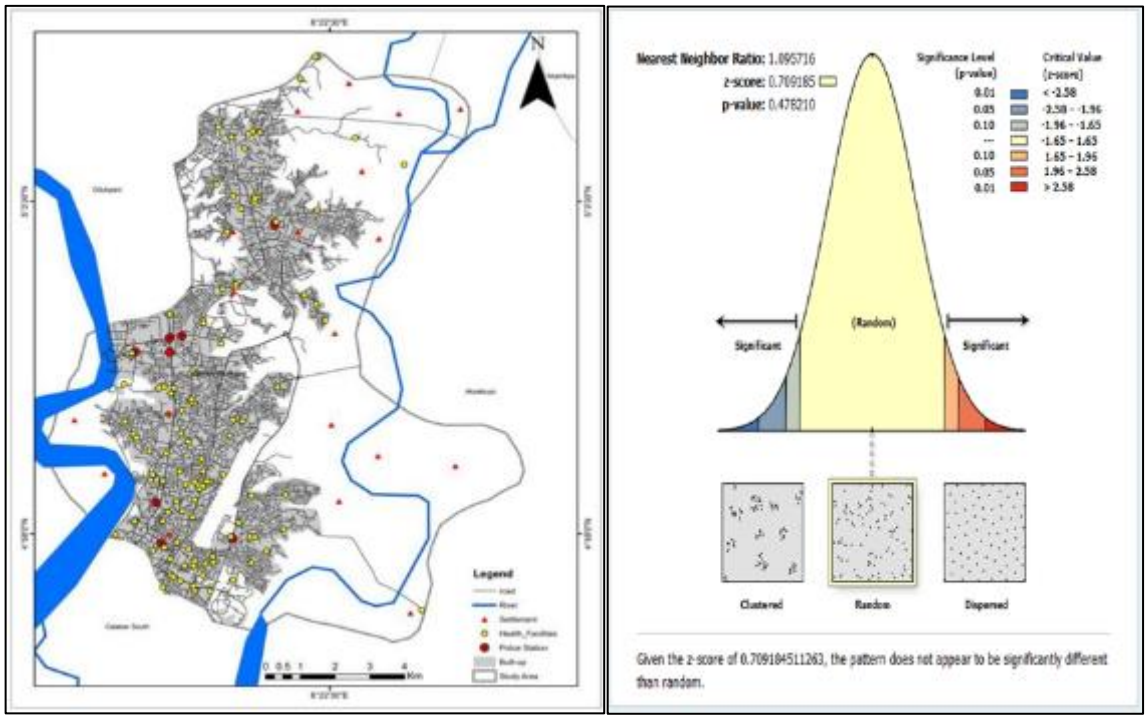

Figure 4 Distribution of Health Centers (left), Random ANN Pattern of HealthCare Centers (Right)

The healthcare facilities in this case include hospitals and clinics that are owned by the state government and private individuals but utilized by the public. It is important to reiterate that the location of health facilities is known to influence its utilization and efficiency, as proximity to them do influence the decision to seek and receive healthcare services (Bello & Dogara, 2015). GIS mapping of these facilities is inevitable (Njuguna, 2010). Likewise, being a port city and the same time a capital city of high level of tourism, one can understand why there is the need for accessible healthcare facilities. In fact, the health of the people does not only contribute to better quality of life but is also essential for sustained economic, political and social development of the people because a healthy people is a wealthy people.

4.2.3. Market

Figure 5 shows the spatial distribution of markets in the study area. Markets are essential for people to transact businesses (i.e. for buying, selling and exchange of goods and services). The study reveals that the markets are more in the southern part of the city. The study also revealed that with a Z-Score of 4.608346, there is a <1% likelihood that the dispersed pattern of markets in Calabar could be the result of random chance.

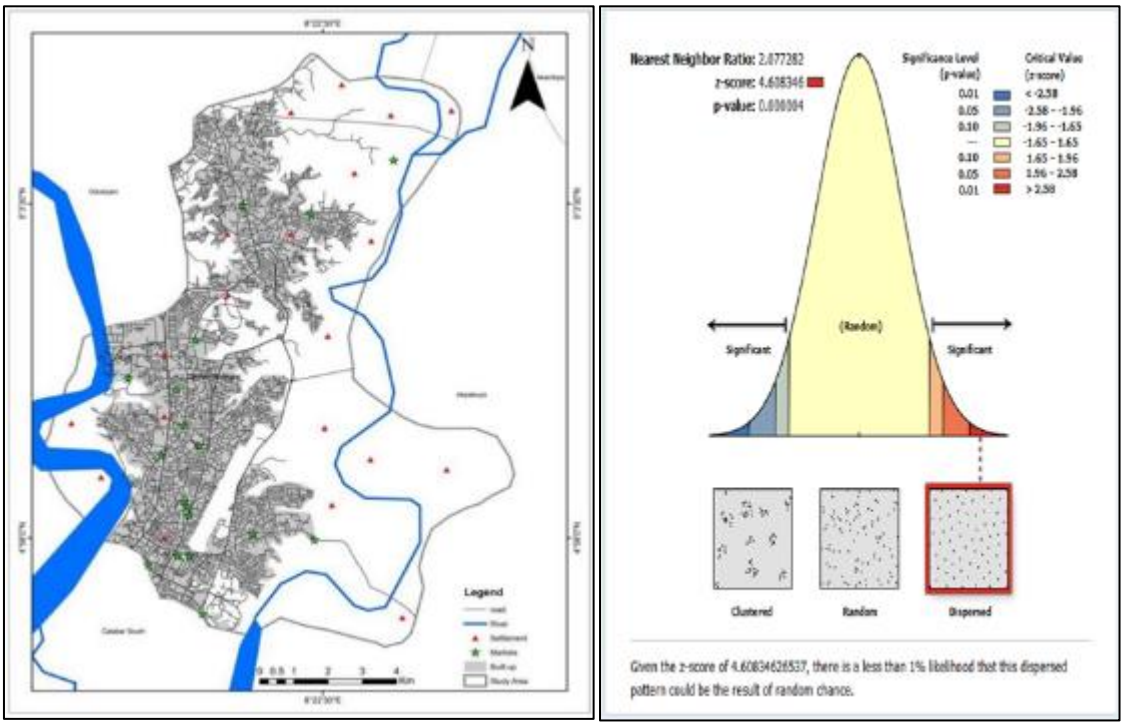

Figure 5 Spatial Distribution of Markets (left), Dispersed ANN statistics of Markets (Right)

The dispersed pattern of the distribution of market in the study is due to the fact that the markets are owned by government and their locations were determined by the decision of the government. The study further shows that a number of informal markets such as stores are on the increase. Most of them are privately owned. They render services such as sales of clothing, bags, shoes, eateries, building materials, to mention but a few. It is expected as there is increase in population and most of the government markets are not enough to provide space for everyone. Thus, most residential land uses are being converted to mixed use; for which markets of various forms are more. There is the need for more standard large markets in Calabar metropolis in order to avert urban blight orchestrated by illegal and unorganized localization of markets.

4.2.4. Water points

Figure 6 illustrates the distribution of water points in Calabar metropolis. Conceptually, a water point is a system that provides water via piping or other constructed conveyances to the public for human consumption. The results from the ANN statistical analysis indicate a dispersed pattern of spatial distribution. The study shows that the distribution pattern of the water points in the study area is not due to random chance. Thus, with a Z-Score of 5.850672, there is a <1% likelihood that the dispersed pattern of water points in Calabar could be the result of random chance.

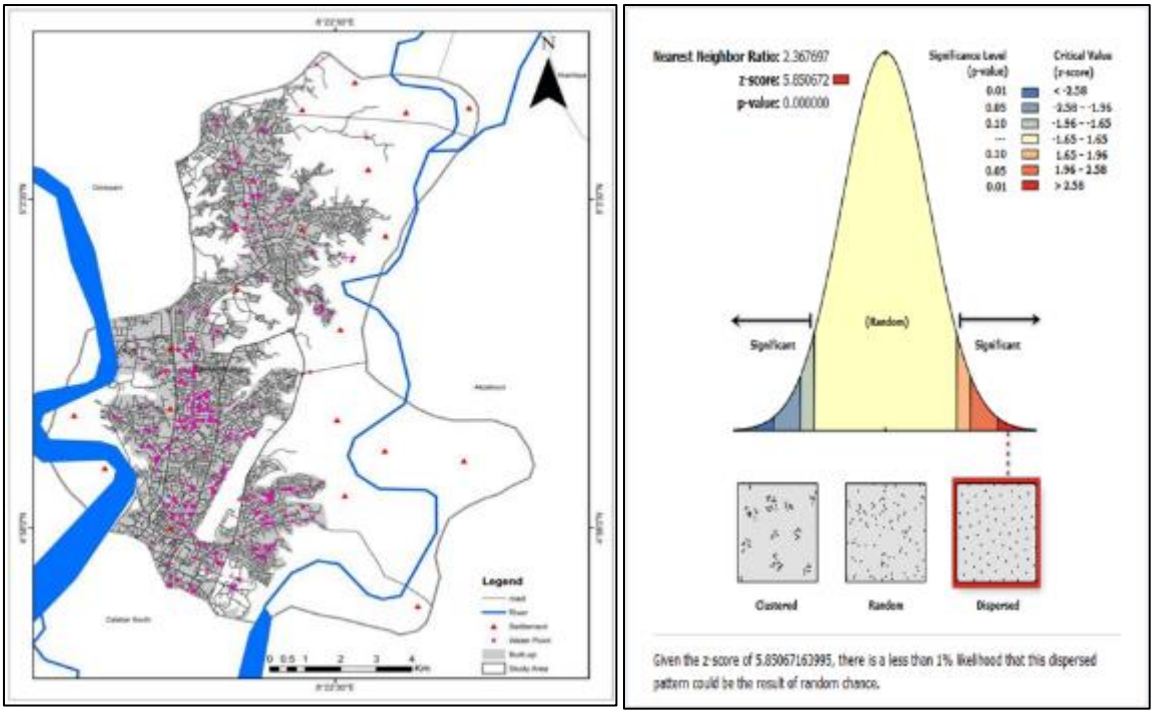

Figure 6 Distribution of water points in Calabar

4.2.5. Emergency service (Fire Station)

Figure 7 shows the spatial distribution of the fire station in Calabar. The study indicates that since there is just one fire station, no pattern of distribution was identified, despite being in the South-Western part of the Metropolis. This location is skewed because it is not in the centre of the metropolis which means that more time is required for the fire service personnel to reach the Eastern and northern parts of the metropolis. There, is therefore, the need to have more fire stations constructed across the study area for ease of reach and response to emergencies without delay.

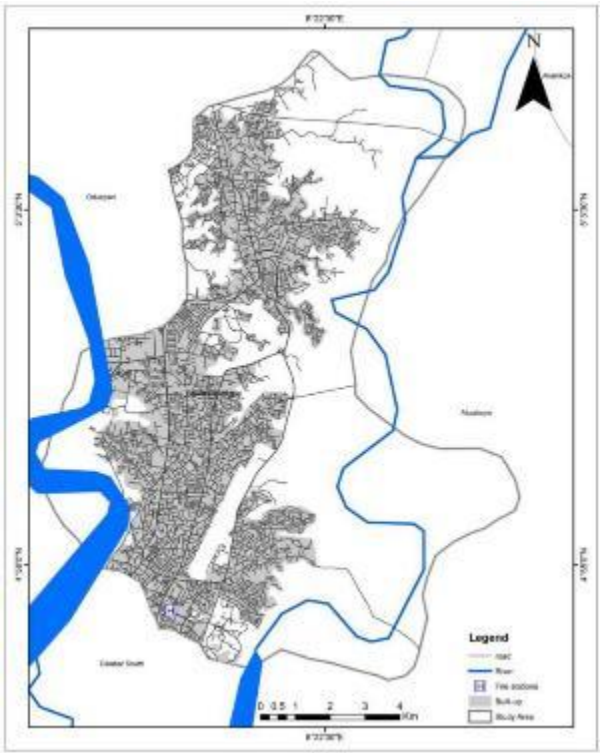

Figure 7 Fire station in the study area

5. Conclusion and Recommendations

This study highlights the usefulness of GIS in inventorying and mapping public infrastructure in Calabar, Cross River State, Nigeria. Result of the geospatial analysis carried out revealed that health and school infrastructure were randomly distributed while markets and water points shows a disperse distribution pattern. Furthermore, public schools achieved 51.93% coverage of the study area while health care facilities achieved 61.03% coverage. The fire service can covers an area of 12.9% which is grossly inadequate. Most parts of the study area revealed that the waterpoint have 15.34% coverage. Findings from this study indicates that most part of Calabar are completely without basic infrastructure, thereby making life and living standard unbearable especially for residents living in the outskirt of the city. This study, therefore, recommends the provision of more public infrastructure to areas completely without any of the basic infrastructure examined in this study. It is important to also note that Infrastructure requires large investments to enable productivity in an economy, hence the government should as a matter of urgency invest heavily on public infrastructure in the city and, by extension, in the entire state. As Nigeria continues its push for infrastructure modernization, the outlook for 2025 remains promising. Thus, increased collaboration between the government and private sector investors is expected to drive further innovation and efficiency in infrastructure development. The focus should be on sustainable energy projects, smart city initiatives, and enhanced digital infrastructure to support Nigeria's growing economy as corroborated in previous studies of smart infrastructure.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest and no fund was provided for this study.

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