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SPATIAL INTELLIGENCE IN URBAN HEALTH: A GIS-BASED ANALYSIS OF HEALTHCARE FACILITY DISTRIBUTION IN UYO, NIGERIA

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ABSTRACT

This study employed Geographic Information Systems (GIS) techniques to map and evaluate the inventory and spatial distribution of Healthcare Facilities (HCF) in Uyo Capital City, Nigeria. Utilizing handheld Global Positioning System (GPS) devices for field data collection and ArcGIS 10.8 for spatial analysis, the research identified a total of 64 healthcare facilities within the study area. An inventory analysis revealed a significant structural imbalance: 14 facilities (22.6%) are categorized as Primary Health Care (PHC), 49 (76.6%) as Secondary facilities—predominantly privately owned—and only one (1.6%) as a Tertiary facility. The spatial pattern of distribution was assessed using Nearest Neighbour Analysis, yielding a Nearest Neighbour Ratio of 0.603357 and a highly significant z-score of -5.926470 ($p < 0.01$). These statistics confirm a significantly clustered distribution pattern, concentrated primarily within the city center (Eniong, Oku, Uyo, and Aka regions) while leaving the suburban fringes underserved. Furthermore, the study evaluated accessibility based on the World Health Organization (WHO) standard walking distance of 4km. The findings indicate that while central urban residents enjoy high proximity, peripheral communities such as Ikot Udo Ibiono and Mbiakong Uruan suffer from locational disadvantage and increased travel burdens. This "Inverse Care Law" manifestation suggests that private-sector dominance has driven facilities toward high-population density areas at the expense of equitable spatial coverage. The study concludes that the current distribution is uneven and inadequate for the city's projected growth. It recommends the strategic siting of new public PHCs in identified "blind spots" and the use of GIS-driven suitability modeling by the Ministry of Health to ensure that healthcare delivery transitions from a clustered luxury to a spatially accessible right for all citizens.

KEYWORDS: Geographic Information Systems (GIS) based techniques, Health Care Facilities (HCF), Spatial Distribution, Nearest Neighbour Analysis, Uyo Capital City, Nigeria

1. INTRODUCTION

Health is necessary for people to be able to enjoy and appreciate all other aspects of life, it is a key to community wellbeing and to personal welfare (Gerard 2015). The health of a population of a country through the availability of health care facilities are important concerns for developing countries and access to health care is a significant factor that contributes to a healthy population. In most developing countries, the number of new cases of disease related to health risks has increased over time, partly due to rising population, and increased poverty incidence, access to healthcare is very vital. Healthcare is among the most important services provided by the government of both developed and developing nations of the world, as the productivity level of one is dependent on its state of health and a significant proportion of the nation's resources is devoted to health. (WHO, 1978).

Healthcare is a major concern for policy makers globally. Thus, adequate and effective distribution of health care facilities contributes immensely to health care service provision and needs of the people (Ujoh and Kwagbsende, 2014). According to Effiong (2010), public healthcare is regarded as the basic form of health services, as it provides the least expensive source of medical treatment to the greater population of people resident in any given area. People use healthcare services to diagnose, cure or ameliorate diseases and also obtain information about their health status and prognosis. According to Onyekerhoraye and Dudu (2017), Healthcare needs to differ in time and space. As a matter of fact, he also Opined that there is need for healthcare services in space; consequently, in organizing healthcare provision, it is essential to understanding the usage given that having physical access to health facilities is important in determining the accessibility of healthcare facilities by the people.

Nigeria today is confronted with unplanned and uneven distribution of health facilities; this calls for serious national concern. Additionally, planning the location of health facilities as well as the travel distance to access healthcare services has been a major concern to urban planners over the years. For example, the (World Health Reports, 2006) gave Nigerian governments expenditure on health as a percentage of the nation's Gross Domestic Product (GDP) for year 2001, 2002, and 2003 as 5.3 percent, 5 percent, and 4.7 percent respectively. This is to show the fact that Nigerian government healthcare expenditures are not only significant in absolute terms but also relative to the Gross Domestic Product.

Nigeria with the projected population of about 200million is in need of improved and sophisticated healthcare services to render good services to people. Alabi (2011), observed that, there is a problem of coordination due to the sharing of

responsibilities among the three tiers of government, with the structure affecting the managerial decision and financing, which in turn affects the operation of healthcare facilities in terms of service provision and medical inputs.

The performance of these institutions in the health care sector must be assessed if health and development goals will be met. In a bid to show a quick and good response to the need for improvement in the health of her populace, Nigeria had accrued three out of the eight points agenda of the Millenium Development Goals to health issues. These are reduction of child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases (USAID, 2005). Poverty and other socio-economic factors contribute to poor accessibility to healthcare facilities which in turn may cause anger, hostility, stress, anxiety and frustration to patients and their families causing distraction to supposed health-staff giving directions (Sadek and Ahmed 2015).

Travel and transportation due to distance from health facilities may pose significant access factor and adversely impact on their uses. The main drivers of accessibility to healthcare in Nigeria are the limited healthcare and low personal mobility (Kemfon Ekpo, 2016). Healthcare provision in Nigeria is the responsibility of the three tiers of government, the Local, State, and Federal Government, which handles the Primary, Secondary, and Tertiary health facilities services. The Federal government's role is mostly limited to coordinating the affairs of the University Teaching Hospitals and Federal Medical Centers (Tertiary healthcare) while the State government manages the various general hospitals and the local government focuses on dispensaries (Secondary healthcare). The local Government focus on Primary HealthCare (PHC) which are regulated by the federal government through the National Primary Healthcare Development Agency (NPHCDA, 2018). Understanding the spatial distribution of health facilities would inform appropriate policy implementation in the health sector. To achieve this, the following specific objectives are pursued: to carry out inventory of the different healthcare facilities in the study area as well as examining the spatial distribution of healthcare facilities in the study area.

2. LITERATURE REVIEW

The classification and evaluation of healthcare facilities represent a critical juncture between administrative bureaucracy and functional service delivery, as evidenced by the divergent findings of Tarek et al. (2015) and Ayuba and Wash (2016). While Tarek et al. developed a sophisticated energy performance benchmark in Australia by categorizing facilities into six distinct typologies—including patient type, level of care, and management—Ayuba and Wash's study in Bukuru, Plateau State, revealed a more precarious reality. Despite employing similar mapping techniques, the Nigerian study highlighted a severe infrastructural imbalance, where nineteen out of twenty-one facilities were privately owned and only one attained tertiary status. This disparity suggests that while developed contexts focus on optimizing the internal efficiency and energy performance of health centers, developing regions are still grappling with the fundamental challenges of public ownership and the sheer scarcity of high-level medical infrastructure.

The spatial distribution of these facilities further complicates the "Inverse Care Law," a phenomenon explored by Yemi et al. (2018) and Alebachew et al. (2014) through the lens of rapid urbanization. In Ibadan, Yemi et al. observed a catastrophic decline in hospital density, where the number of facilities dropped by nearly 50% even as the population grew by 12% over a fifteen-year period. This demographic-infrastructural mismatch shifted the hospital-to-population ratio from 1:1,000 to 1:2,600, effectively diluting the quality of urban health coverage. By utilizing QGIS and quintile breaks, Alebachew and colleagues were able to visualize these disparities across geopolitical zones, demonstrating that the ratio of public to private facilities is not merely a statistical curiosity but a spatial indicator of where the state has retreated from its social contract with the citizenry.

Furthermore, the actual patterns of these distributions—whether random, clustered, or dispersed—dictate the everyday accessibility of healthcare for the average resident. Abdulahi et al. (2022) used Nearest Neighbor Analysis (NNA) to find that private hospitals in Northern Taraba are distributed randomly, indicating a lack of centralized planning or strategic zoning. This randomness is echoed by the work of Ujoh and Felix (2014), who argue that the relationship between population density and infrastructure remains weak in most developing nations, leaving the private sector to fill the void in an uncoordinated fashion. When facilities are not strategically placed, they fail to meet the World Health Organization (WHO) standards for coverage, regardless of how many clinics are present in a given neighborhood.

The human cost of these spatial inefficiencies is most visible in the travel distances required for basic care, as highlighted by the research of Kwaku (2008), Adetunji (2013), and Umar (2016). In rural and peri-urban areas, the uneven distribution of hospitals forces residents to travel distances far exceeding the WHO-recommended 4km limit, often leading to a total reliance on traditional medical practices. Umar's network analysis in Kano State quantified this struggle, showing that while some lucky communities reside within 0.5km of a facility, others are isolated by over 5km of geographical barriers. As Micheal (2011) suggests, even when facilities appear to be clustered, the lack of "randomness" can actually signify a concentration of services in elite enclaves, leaving the wider population in a state of insignificant accessibility. Therefore, the maintenance of public health in cities like Uyo requires more than just building new structures; it necessitates a GIS-driven, strategic relocation and upgrading of existing facilities to ensure that healthcare is a reachable right rather than a distant luxury.

2.1 CONCEPTUAL FRAMEWORK

2.1.1 ANDERSEN'S BEHAVIORAL MODEL

Andersen's Behavioral Model of Healthcare facilities was developed by Ronald Andersen in 1986. And was revised in 1973, 1995, 2000, and 2001. He Used a well-known and frequently applied model of access to care.

Andersen's model serves as a framework for large scale studies and incorporates a comprehensive and wide array of determinants. Determinants include demographic factors (age and gender), social structure (education, occupation, ethnicity, and other factors measuring status in the community, as well as coping and the health of the physical environment), and health beliefs 37 (attitudes, values, and knowledge that might influence perceptions of need and use of healthcare facilities).

The Model serves as a tool for the study of a broad set of determinants, both modifiable and not modifiable. A number of variations of the Andersen model have evolved over the years, but all subscribe to the same fundamental characteristics (Goldsmith 2002). The Andersen model was built on the basis of quantitative national health surveys and offers a broad framework for the analysis of data from large datasets.

Anderson's behavioral model for health services utilization provides a theoretical structure to understand access and utilization of health service, and to recognize the factors that impact a person's decision to use or not use existing health services (Andersen 1995). This behavioral model predicts that a sequence of predisposing, enabling, and need factors influence person's utilization of health service (Andersen 1995). As stated by the model, predisposing factors are social and demographic structures. Enabling factors assist people to use services (e.g., resource availability). For instance, income, access to free services, and the availability of those services. Factors such as need motivate people to use the service. For example, disease conditions, illness, or physical conditions.

Andersen model put his effort into building a model that determines conditions that assist or impede health care services utilization by the people. (Andersen et. at.,1973)

2.1.2 GRAVITY MODEL

The gravity model is based on Isaac newton law of gravitation. It is a mathematical formula so it cannot rely on something like cultural output because this is unquantifiable. It instead relies on population size and distance. The model holds that the interaction between two places can be determined by the product of the population of both places, divided by the square of their distance from one another.

The primary implication of this model is that distance is not the only determining factor in the interaction between two cities. The potential model (or gravity model) reflects spatial competitions between facility suppliers and demanders, including the competition between facility suppliers for demanders and the competition between demanders for limited resources (Cheng and lian 2018).

The gravity model is complete in concept and more flexible in use than other methods. It follows Newton's law of universal gravitation. It is a widely applied method in studying spatial interactions. This model supposes that residents' spatial accessibility to medical services decreases with the increase of distance to nearby medical facilities.

3. MATERIALS AND METHODS

3.1 STUDY AREA

The study is conducted in Uyo capital city, of Nigeria, which is the capital city of Akwa Ibom state north-east senatorial zone. It is located between Latitude 4˚ 52'N and 5˚07'N and Longitude 7˚ 47'E to 8˚ 03'E of Akwa Ibom State. Uyo Capital City is made up of Uyo urban and bounded in the north with Ikono, Itu and Ibiono Ibom Local Government Area, In the East it is bounded with Uruan LGA, in the West it is bounded with Abak LGA, in the south it is bounded with Ibesikpo Asutan and Nsit Ibom Local Government Area. The city covers an area of about 214.32square kilometers. It is a collecting station of palm oil and kernels, it is also a local trade center (yam, cassava, palm produce) for an area inhabited mainly by Ibibio people. The town has brewery.

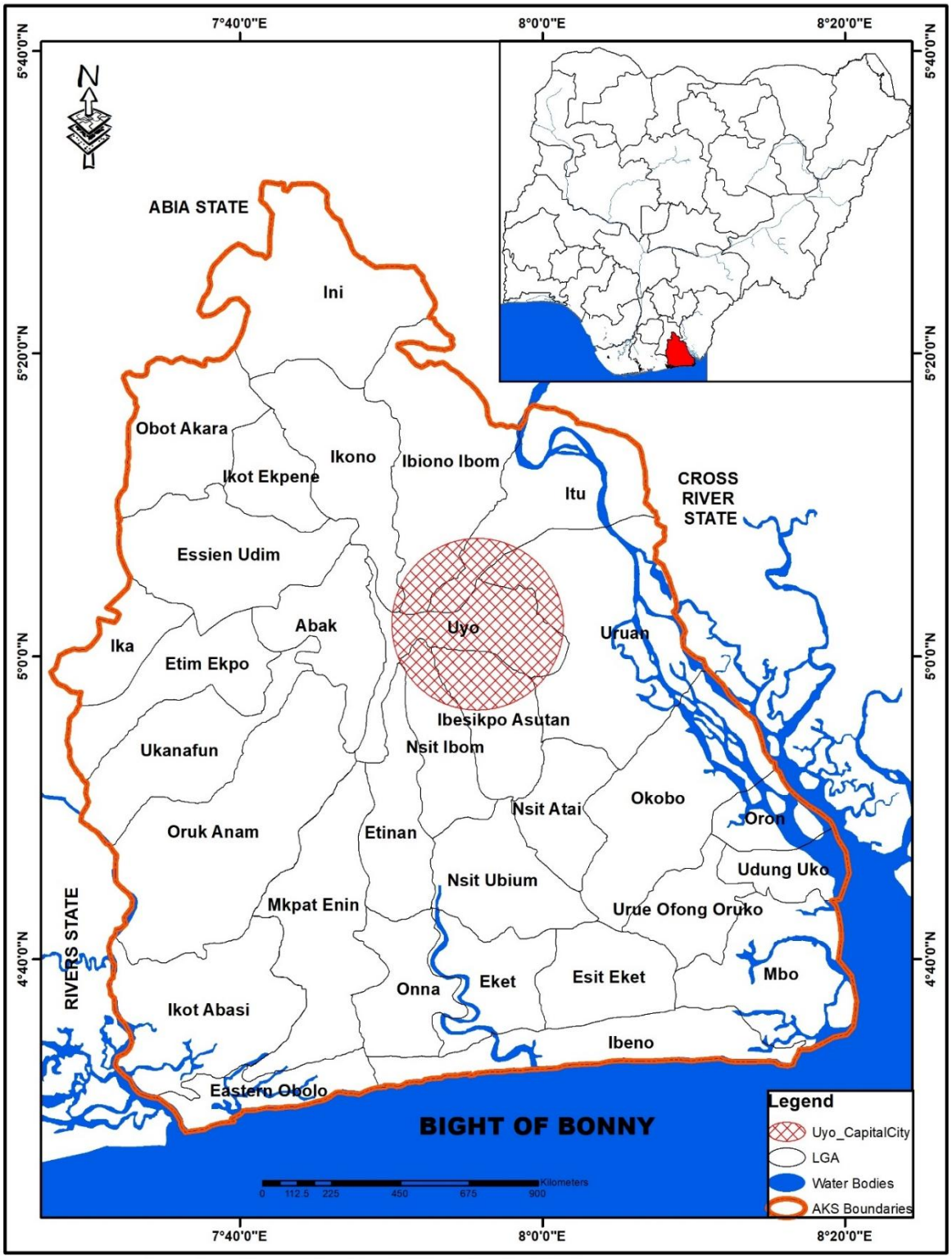


Figure 1: Map of Akwa Ibom State showing the study area.

(**Source:** Field data 2026)

3.2 METHODS

The research methodology for this study follows a structured geospatial framework designed to process both spatial and non-spatial data to evaluate healthcare accessibility in Uyo Capital City. The study area, located in the north-east senatorial zone of Akwa Ibom State, covers approximately 214.32 square kilometers and is bounded by several local government areas, including Itu, Ibiono Ibom, and Uruan. To accurately capture the healthcare landscape, a comprehensive field survey was conducted using a handheld Global Positioning System (GPS) device to acquire the precise geographic coordinates of all existing facilities. This primary spatial data was complemented by secondary attribute data obtained from the Akwa Ibom

State Ministry of Health and the Hospital Management Board, which provided details on facility names, addresses, and classifications.

Data processing involved the integration of these datasets into a Geographic Information System (GIS) environment using ArcGIS 10.8. The administrative map of Uyo, sourced from the Ministry of Lands and Survey, served as the base map for georeferencing and spatial alignment. The inventory of healthcare facilities was categorized into primary, secondary, and tertiary levels to reflect the three-tier structure of the Nigerian health system. By linking the attribute data—such as ownership and service type—to the GPS locations, a functional spatial database was created, allowing for a multifaceted evaluation of the city's medical infrastructure.

The analytical phase of the methodology employed both descriptive statistics and spatial econometrics to determine the efficiency of the healthcare distribution. Frequency tables and percentages were used to summarize the categories and ownership patterns, while Nearest Neighbor Analysis (NNA) was used to identify the level of randomness or clustering in the distribution. This statistical technique calculates a Nearest Neighbor Ratio by comparing the observed mean distance between facilities to the expected mean distance. Furthermore, the study utilized Euclidean distance and network analysis to assess accessibility, specifically testing the distribution against the World Health Organization (WHO) standard of a 4km maximum travel distance for primary care.

To conclude the methodological process, suitability analysis was conducted to identify optimal sites for future healthcare interventions. This involved a multi-criteria evaluation that considered current facility density, population demand, and existing "blind spots" in the urban fabric. This integrated GIS approach ensures that the findings are not merely descriptive but provide a prescriptive tool for urban planners and health administrators. By identifying where the supply of healthcare fails to meet the spatial demand of the population, the methodology provides a data-driven foundation for proffering solutions to the medical challenges faced by the residents of Uyo.

4. RESULTS AND FINDINGS

The distribution of healthcare facilities within the study area. The **(Figure 4.1)** shows the distribution of health care facilities within Uyo Capital City of Nigeria. Basically, the categorization of health care facilities was based on the three categories of healthcare facilities, which includes: primary, secondary and tertiary health care facilities. And all these three categories of health care facilities existed in the study area.

Table 1: Categories of Health Care Facilities in the study area

Category	Frequency	Percentage%
Primary	14	22.6%
Secondary	49	76.6%
Tertiary	1	1.6%
Total	64	100

(**Source:** Field data 2026)

The result shows that a total of 62 health care facilities were distributed across the study area. The Primary health care (PHC) facilities were 14 while the Secondary health care facilities were 49, and the Tertiary health care facility was 1. This implies that the Primary health care facilities constitute about 22.6%, secondary health care facilities constitute about 76.6% which is predominantly private exist is in the study area, and this could be attributed to be the first point of contact to obtain health care services, it was also observed that Tertiary health care facility constitute about 1.6% in the study area.

Based on the ownership shown in **(Table 4.1)**, it indicated that, only 22.6% of primary health care facilities in the study area which is very small as larger percentage of people believe they can only benefit from government own health care facility than the private because of the affordability, and which could have attributed as the first point of contact to obtain health care services.

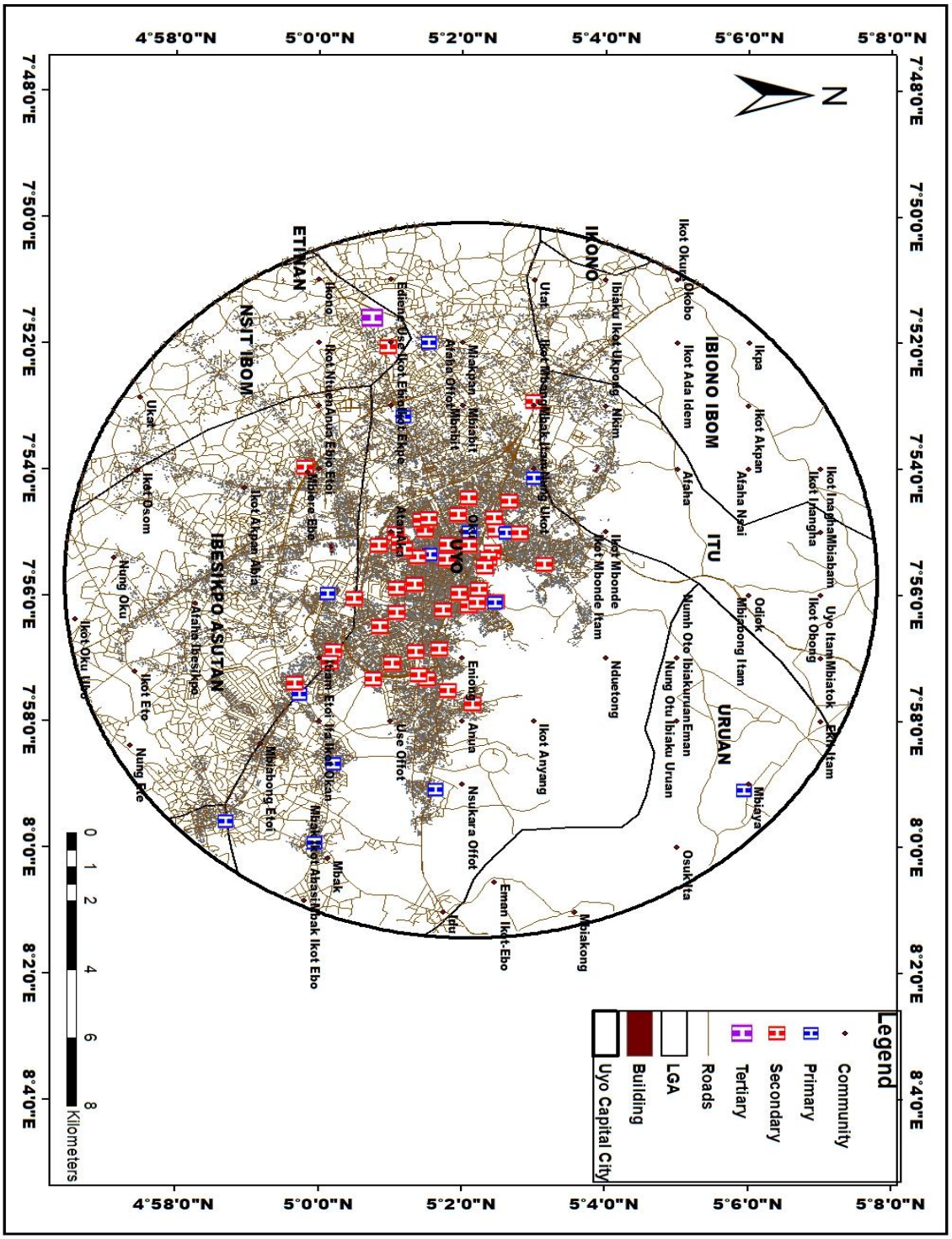


Figure 2: Map showing inventory of Health care Facilities distribution in Uyo Capital City.

(**Source:** Field data 2024)

The above map **(Fig 4.1)** showed the coverage area of health care facilities that handle the medical services within the study area. the primary health care facilities, the secondary health care facilities which is mostly private. However, only one tertiary health care facility was found within the study area. **(Fig.4.1).**

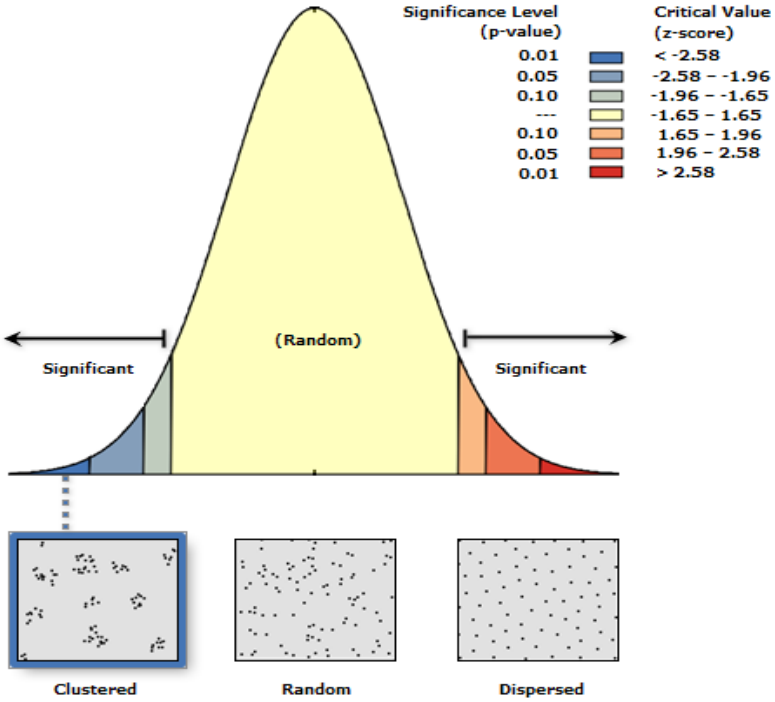
In determining the spatial distribution of health care facilities in Uyo Capital City. The Nearest Neighbor Analysis of the Sixty- two (64) health care facilities found in the study area determine the level of randomness to these health care facilities using ArcGIS 10.8 software shown that the facilities are clustered. Which indicated that the health facilities within the study

area were unevenly distributed. This could be attributed to the ownership of the health care facilities (private) establishing the health care facilities around where the population is large, which happen to be at the city center of Uyo capital city.

Nearest Neighbor Ratio: 0.603357

z-score: -5.926470

p-value: 0.000000



Observed Mean Distance:	716.3898 Meters
Expected Mean Distance:	1187.3407 Meters
Nearest Neighbor Ratio:	0.603357
z-score:	-5.926470
p-value:	0.000000

Average Nearest Neighbor Summary

Input Feature Class:	Health facilities
Distance Method:	EUCLIDEAN
Study Area:	343985796.811000

Dataset Information

Figure 3: Average Nearest Neighbor Summary

(Source: Field data 2024)

From the result of the analysis presented, it indicates that the Nearest Neighbour Ratio for the spatial pattern of health care facilities in Uyo Capital City is 0.603357 with critical value (z-score) of -5.9226470 at 0.00 level of significance (p-value). From the Summary of Nearest Neighbour Statistics, Observed Mean Distance: 716.3898 Meters, Expected Mean Distance: 1187.3407 Meters Nearest Neighbor Ratio: 0.603357 z-score: -5.926470 p-value: 0.00. For Spatial Distribution Pattern of Health Care Facilities in Uyo Capital City, the z-score usually returns a range of values between -2.58 to 2.58; therefore, a negative z-score less than -2.58 indicates a significant clustering at 0.01 probability level. A range of scores between both -2.58 to -1.96 at 0.05 significant levels and -1.96 to -1.65 at 0.10 probability level shows clustered pattern. A range of z-scores between -1.65 to 1.65 indicates a random distribution. Again, if the z-score lies between both 1.65 to 1.96 at 0.10 significance level and 1.96 to 2.58 at 0.05 probabilities level then it is obvious that there is tendency towards a regular pattern. Therefore, since the z-score is approximately -5.926470 which is less than the standard critical value of 2.58, from the emerging result this affirms that the distribution pattern of Health Care facilities in the study area is significantly clustered. This therefore indicate that most of the health care facilities are situated close to each other at a particular region.

4.1 DISCUSSION OF FINDINGS

The evaluation of healthcare facilities in Uyo Capital City reveals a complex spatial narrative defined by structural imbalances and significant geographical disparities. A primary finding of this research is the extreme disparity in the levels of care available to the populace. The inventory analysis identified that Secondary Health Care facilities dominate the landscape, accounting for 76.6% of the total 64 facilities, while Primary Health Care (PHC) facilities constitute only 22.6%. This is a significant departure from the ideal public health pyramid, which dictates that PHCs should be the most numerous and widely dispersed to serve as the first point of contact. This structural leaning toward secondary care—predominantly driven by the private sector—suggests that healthcare in Uyo is increasingly commodified, potentially marginalizing low-income residents who rely on subsidized public primary care.

The spatial distribution pattern, as determined by the Nearest Neighbor Analysis, further underscores these inequities. The resulting Nearest Neighbor Ratio of 0.603357 and a highly significant z-score of -5.926470 confirm that healthcare facilities in Uyo are significantly clustered. This clustering is concentrated within the urban core and high-density neighborhoods such as Eniong, Oku, Uyo, and Aka. While clustering might offer a concentration of specialized services, in the context of Uyo, it indicates an "urban bias" where facilities are sited based on market profitability and existing infrastructure rather than equitable geographical access. This finding aligns with the global "Inverse Care Law," where those with the greatest need for healthcare—often residing in the less-developed urban fringes—have the least access to it.

Accessibility remains a critical challenge, as evidenced by the travel distances observed during the field survey. The findings show that while central communities enjoy proximity well within the World Health Organization (WHO) 4km walking distance standard, peripheral areas such as Ikot Udo Ibiono, Akon Itam, and Mbiakong Uruan exist in "medical blind spots." For residents in these suburban stretches, the distance to the nearest facility acts as a significant barrier to utilization, increasing the likelihood of health complications due to delayed treatment. This spatial gap reinforces the need for a transition from unplanned, private-led growth to a GIS-driven strategic placement of public facilities.

Ultimately, the results of this study illustrate that Uyo is experiencing a state of "Economic and Spatial Scarcity" in healthcare. The reliance on a clustered, private-dominated secondary sector has created a landscape where supply does not meet the demand of the urban poor and those in the city's outskirts. These findings provide a data-driven indictment of current health planning and highlight the urgent need for policy interventions that prioritize the establishment of Primary Health Care centers in underserved regions. By utilizing the suitability analysis provided in this research, urban planners can move toward a more balanced distribution that ensures healthcare is accessible to all residents, regardless of their location within the capital city.

5. CONCLUSION

The geospatial evaluation of healthcare facilities in Uyo Capital City provides a critical diagnostic of the city's current medical infrastructure and its alignment with public health goals. The study established that while Uyo possesses a relatively high number of facilities, the structural distribution is heavily skewed toward the secondary sector, which accounts for over 76% of the total inventory. This imbalance is compounded by a significant trust in private-sector dominance, leaving the public primary healthcare system—intended to be the bedrock of community wellness—underrepresented and overstretched. The findings confirm that the "Inverse Care Law" is active within the city, as the availability of medical care is not dictated by communal need, but by urban density and market proximity.

Spatial analysis through the Nearest Neighbor technique mathematically confirmed a significantly clustered pattern (Rn = 0.603), proving that the healthcare landscape is characterized by geographical inequity. The concentration of facilities within the urban core of Uyo LGA leaves the burgeoning suburban populations in peripheral areas like Ibiono Ibom and Itu in a state of "medical invisibility." For these residents, the distance to the nearest facility often exceeds the WHO-recommended 4km threshold, transforming a basic human right into a logistical and financial burden. This clustering suggests that the current growth of healthcare infrastructure in Uyo is unplanned and reactive, rather than strategic and inclusive.

Ultimately, this research highlights that the integration of Geographic Information Systems (GIS) is no longer a luxury but a necessity for sustainable urban health planning. By mapping the relationship between supply and demand, this study has

identified specific "blind spots" where the intervention of the Ministry of Health is most urgently required. To achieve the goals of Universal Health Coverage, Uyo must move beyond mere inventory collection toward a paradigm of "Spatial Intelligence," where new facilities are sited based on accessibility, demographic demand, and geographical equity. Only through such data-driven planning can the city ensure that its healthcare system evolves into a resilient and reachable safety net for all its inhabitants.

5.1 RECOMMENDATIONS

Having carried out this research, the following recommendations have been outlined which may be useful in assisting the ministry of health and the government body at large in planning the further distribution of facilities and improving the efficiency of the already existing ones.

i. The government should prioritize the establishment of new Primary Health Care (PHC) centers in underserved suburban communities such as Ikot Udo Ibiono, Akon Itam, and Mbiakong Uruan. Relieving the pressure on the urban core by decentralizing facilities will directly combat the "medical blind spots" identified in this study and ensure that the most vulnerable populations have a first point of contact within the WHO-recommended 4km radius.
ii. The Ministry of Health and Hospital Management Board should transition away from ad-hoc siting of facilities toward a data-driven approach.
iii. To enhance Suitability Modeling, future healthcare projects must be preceded by GIS suitability analysis that considers population density, existing facility proximity, and road network connectivity. Policy should restrict the over-concentration of private clinics in the city center through zoning regulations, encouraging the private sector to expand into growing suburban regions.
iv. Given that over 76% of the healthcare landscape in Uyo is secondary and predominantly private, the state should develop a framework to subsidize or integrate these private facilities into a public safety net. This could involve expanding National Health Insurance Scheme (NHIS) coverage to a wider range of private clinics in underserved areas to make them affordable for the poor and also ensuring that private secondary clinics meet specific primary care mandates to fill the gap where public PHCs are currently absent.
v. Since travel distance is a major barrier in the outskirts, improving the road network leading to clustered urban hospitals is essential. Furthermore, the government should invest in Mobile Health Units or "medical emergency outposts" in communities with low accessibility. These units can provide immediate maternal and infant care, serving as a bridge until permanent structures are built.
vi. The state should establish a permanent Geospatial Health Database that is updated annually. By making this data open to researchers and planners, the city can perform real-time "spatial intelligent audits" to ensure that as Uyo expands, its healthcare footprint expands with it, preventing the recurrence of the current clustered imbalance.

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