

GIS-Based Assessment of Public Healthcare Facilities for Improved Service Delivery in Nnewi North LGA of Anambra State

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ARTICLE INFORMATION	ABSTRACT
<p>Article history: Published: October 2026</p> <p>Keywords: Geographic Information Systems Spatial Equity Healthcare Accessibility Health Facility Distribution Geospatial Analysis</p>	<p>The effectiveness of public health interventions is intrinsically tied to the spatial equity and operational readiness of primary healthcare infrastructure. This study utilized Geographic Information System (GIS) techniques to evaluate the distribution and service delivery capacity of public healthcare facilities in Nnewi North Local Government Area, Anambra State. A comprehensive field inventory was conducted across the ten (10) administrative wards of the LGA, capturing spatial coordinates and facility attributes, including service tier, functional status, and human resource capacity. Primary spatial data were acquired through field-based point positioning using handheld GPS receivers to take inventory all 27 public facilities across the 10 administrative wards. This was complemented by attribute data harvesting via structured facility audit checklists to assess staffing and functional tiers. Spatial analysis was executed using Point Pattern Analysis (Nearest Neighbor Index) to determine distribution types and Buffer Analysis to model geographical accessibility. Population-to-provider ratios were calculated using Spatial Join operations, intersecting projected census data with facility capacity attributes to evaluate compliance with World Health Organization (WHO) standards. The results reveal a significant systemic imbalance in health resource allocation. Of the 27 public healthcare facilities identified, 26 functions at the primary level, with only one tertiary institution (Nnamdi Azikiwe University Teaching Hospital). Spatial mapping identified a high concentration of services in specific corridors, notably in Umudim ward II and Nnewichi ward II, which hosts five facilities each, suggesting a lack of strategic spatial planning. The demographic pressure on these facilities is severe; 21 of the 27 facilities exhibit a provider-to-population ratio of 1:10,000, significantly exceeding sustainable limits. Critically, the "personnel-to-facility" gap is acute. Aside from the Teaching Hospital, all other facilities lack resident medical doctors. The workforce is dangerously thin, with only one facility employing at least 10 personnel, while three facilities operate with a minimum of five. Alarming, Okpuno Umuenem Health Post, Umuzumbana PHC, and Umuanyiboku Health Post are manned by only one healthcare staff member each. Only one facility in the entire LGA currently meets the World Health Organization (WHO) recommended physician-to-population ratio. To rectify these spatial and functional disparities, the study proposes a GIS-driven optimization framework involving the strategic allocation of three facilities to underserved zones and the urgent infrastructure and personnel upgrading of seven existing public health care facilities. This research provides a geospatial blueprint for health policy reforms aimed at achieving equitable service delivery in Anambra State.</p>

1. Introduction

Access to quality healthcare is a fundamental human right and a critical determinant of socio-economic development, poverty reduction, and the achievement of the Sustainable Development Goals (particularly SDG 3: Good Health and Well-being). Equitable distribution and efficient delivery of public healthcare services remain central to reducing morbidity, mortality, and the burden of preventable diseases. In developing countries such as Nigeria, however, healthcare systems continue to face significant challenges of spatial inequity, inadequate infrastructure, manpower shortages, and poor accessibility, especially at the primary healthcare level that serves as the first point of contact for the majority of the population. Nigeria operates a three-tier healthcare system comprising primary, secondary, and tertiary facilities. Primary Healthcare Centres (PHCs) and Health Posts are expected to provide essential promotive, preventive, and basic curative services closest to communities. Despite policy frameworks such as the National Health Policy and the National Primary Health Care Development Agency (NPHCDA) minimum standards, many public facilities operate below required thresholds in terms of staffing, equipment, essential drugs, and physical infrastructure. Reports from Anambra State indicate that numerous PHCs function with fewer than five qualified government health workers, inadequate supplies, and structural deficiencies, compelling residents to rely heavily on private providers or informal sources of care. Nnewi North Local Government Area (LGA) in Anambra State presents a particularly relevant context for examining these challenges. The LGA, which comprises the four quarters of Otolu, Uruagu, Umudim, and Nnewichi, is a major industrial and commercial hub often referred to as the "Japan

of Africa” because of its concentration of manufacturing industries, especially in automotive parts and related sectors. With a 2006 census population of 155,443 and a 2022 projected population of approximately 221,500 (and higher recent estimates reflecting continued growth), Nnewi North has a high population density of over 4,000 persons per square kilometre. This rapid urbanisation and industrial expansion place considerable pressure on existing social infrastructure, including healthcare. The LGA hosts the Nnamdi Azikiwe University Teaching Hospital (NAUTH), a major tertiary facility that serves a wide catchment area. However, it lacks a functional public secondary (general) hospital, a gap that has been publicly noted by stakeholders. Public primary healthcare delivery is provided through a network of PHCs and Health Posts managed by the LGA, supplemented by numerous private hospitals, clinics, mission facilities, and informal providers. Previous assessments of child and maternal health services in the LGA’s public PHCs have documented shortages of medical officers and public health nurses, inadequate basic equipment and essential drugs, incomplete records, and overall poor quality of care. Residents frequently face high out-of-pocket costs in private facilities or turn to patent medicine vendors, with implications for equity, financial protection, and health outcomes. Despite the growing application of GIS in healthcare facility assessment in Nigeria, empirical studies specifically focused on Nnewi North LGA remain limited. Given the area’s high population density, industrial character, absence of a public secondary hospital, documented deficiencies in primary facilities, and the presence of a major tertiary institution, a systematic GIS-based assessment is both timely and necessary. Such an assessment can map the spatial distribution of public healthcare facilities, evaluate their accessibility and adequacy relative to population distribution, identify service gaps, and generate actionable spatial intelligence to support planning for improved service delivery.

2. Literature Review

2.1 Overview of the Healthcare System in Sub-Saharan Africa

Recently, the healthcare system in Sub-Saharan Africa has become a focal point among African nations due to the rise of diverse and complex health challenges that coincide with rapid population growth, limited resources, and economic downturns. Resource allocation is particularly challenging and depends heavily on the defined catchment area. In this context, resource-intensive hospital facilities often receive protection from powerful interests, whereas the development of primary healthcare services lags behind (Ejiagha, 2011). In terms of healthcare management and local health information usage, there is a significant limitation imposed by centralized decision-making processes (Oranga, 2010). Additional systemic issues include delays in data flow, failures to report, non-responsiveness, and poor data quality, which are particularly prevalent in Sub-Saharan African nations like Nigeria. For instance, Nigeria’s diverse population characterized by varied ethnic, religious, and socioeconomic backgrounds shapes its health concept and the demand for healthcare services. The primary source of demographic data is the population census, which is conducted only once every decade or more and fails to accurately represent the current population served by healthcare facilities. To combat these issues, several health management strategies have been implemented by governments in the region.

Among these strategies are Nigeria’s third (1975-1980) and fourth (1980-1985) National Development Plans, which aimed at addressing the unequal distribution of medical resources and healthcare personnel across the country (Iyun, 1988). These plans were designed to accelerate health.

2.2 The Policy of the National Health

The National Health Policy and Strategy to Achieve Health for All Nigerians was established in 1988 and has been recognized as a robust framework. However, updates are necessary to align with the evolving health challenges and trends facing the nation. The policy articulates the unified intent of Nigeria’s government and its citizens to establish a comprehensive healthcare system founded on primary healthcare. It outlines the objectives, infrastructure, strategies, and policy directions for Nigeria’s healthcare delivery system. The policy specifies the responsibilities of all three government tiers, including the role of non-governmental actors. Its ultimate aim is to ensure that the entire population has access to primary, secondary, and tertiary healthcare services through an efficient referral system. The need for revision was identified following the 1995 health summit, which highlighted the urgent need for modifications.

In light of this, the Federal Ministry of Health initiated a review of the policy. The Health Sector Reform Change Agents, developed under the Change Agent Programme (CAP) in collaboration with the Federal Government of Nigeria and funded by the UK’s Department for International Development (DFID), utilized their international experience to influence the reform process in Nigeria. They also organized consultations on the revised draft and contributed their findings to the development of a comprehensive health sector reform program initiated in late 2003. A National Consultative Meeting, which included state Health Commissioners and representatives from various stakeholders, was convened to scrutinize the final draft of the revised policy. The feedback gathered during this meeting was instrumental in refining the policy document, ensuring it met the contemporary needs of Nigeria’s health sector.

Abbas et al. (2012) conducted a research study to analyze the spatial distribution of healthcare centers in Chikun Local Government Area of Kaduna State, Nigeria, utilizing Geographic Information System (GIS) techniques to aid in healthcare management planning. The primary source for the study’s data was the administrative map of Chikun LGA, acquired from the council headquarters and used as the base map. Additional attribute data pertaining to healthcare facilities were also collected from the council headquarters. The geographic coordinates of these facilities were gathered on-site using a Global Positioning System (GPS) device.

The study employed various hardware and software tools, including computers and scanners, to facilitate the processing and analysis of the geographic data. The GIS data processing involved digitizing and georeferencing the administrative and natural features within Chikun LGA using ArcGIS 9.2. Features such as rivers and rocks were classified as fine features, while districts and healthcare centers were digitized as point features. These spatial data were organized into layers, and attribute data for each healthcare center were meticulously entered into the attribute table of the respective layer. The coordinates of healthcare centers were first saved in a text file format, which was later imported into the ArcGIS environment for further analysis.

The findings revealed a total of 41 healthcare centers within the study area. An analysis indicated a higher number of private healthcare centers (23, representing 56.1% of the total) compared to public healthcare centers (18, or 43.9%). Spatial analysis depicted in Figures 3.3 and 3.4 highlighted the distribution patterns of these facilities. The public healthcare centers, as shown in Figure 3.3, had significant clustering in the eastern regions of Chikun LGA, particularly in Kujama, Kakau, and Sabon Gaya districts,

with a smaller presence in the southern parts, specifically in Chikun and Gwagwada districts, and no facilities in the northern and western parts of the LGA. Conversely, the private healthcare centers, detailed in Figure 3.4, demonstrated a concentration in the eastern parts of the LGA in districts such as Nasarawa, Kakau, Sabon Tasha, and Kamazou, with fewer facilities in the southern and northwestern parts, in Chikune, Gwagwada, Buruku, and Kasaya districts respectively.

Adewoyin et al (2016) conducted research in Ife East Local Government Area, Osun State, to analyze the spatial distribution and accessibility of primary healthcare centers. The study aimed to delineate the spatial arrangement of healthcare facilities, assess their accessibility, and identify factors contributing to variations in access. The primary data sources for this research included the administrative map of the area, GPS coordinates of healthcare facilities, and information gathered through questionnaires. Geographic Information Systems (GIS) software and Microsoft Excel were utilized to process and analyze the data.

The findings from the study revealed that there were twenty-two primary health centers within the designated area, out of which fourteen were operational while eight were non-functional. A significant insight from the results was that the functional primary health centers were predominantly clustered rather than being evenly distributed across the area, with a higher concentration in urban rather than rural zones. This pattern highlights potential disparities in healthcare accessibility, particularly affecting residents in less urbanized sections of the area. The study recommended an increase in government-owned health facilities and improvements in the distribution and resource allocation across existing facilities to enhance accessibility and effectiveness.

Fanan et al. (2014) conducted a comprehensive examination of the spatial distribution of health facilities across Benue State, utilizing a spatial analysis to address the disparities in public health infrastructure. The study scrutinized the provision of health services across different administrative divisions, focusing on the contrasts between Local Government Areas (LGAs), senatorial zones, and population metrics relative to health facility availability. The findings indicate that while there is an apparent equitable distribution of public health facilities across the three senatorial districts, significant variations persist both within and among LGAs. The study revealed that these discrepancies contribute to issues such as overcrowding and substandard patient care, particularly in rural LGAs where health resources are most scarce. The statistical analysis showed that an R-square value of 0.564 partially explains the relationship between population size and the availability of health facilities. To address these challenges, the study advocates for a more effective health facility management strategy that prioritizes equitable access, enhances facility capabilities, and dynamically adjusts to demographic and health demand shifts across the state.

Ejiagha (2011) study underscores the importance of using GIS for the strategic planning and management of health facilities by identifying not only the geographic distribution of existing health institutions but also the accessibility of these facilities to the general population. Through the GIS analysis, it was possible to identify areas within Enugu Urban that were underserved, thereby providing critical data that could inform future health infrastructure development to ensure a more balanced healthcare provision across the entire urban area.

The use of ArcGIS 9.3 for buffering and network analysis facilitated a detailed examination of accessibility, allowing the researcher to visualize the spatial relationships and connectivity between population centers and healthcare facilities. The results, presented through maps and graphical representations, highlighted the critical need for strategic location planning of health services to improve access in less developed areas of the city, thus promoting better health outcomes for all city residents. This is therefore not good for the people living outside the city because they have to travel fare to access the health facilities.

3. Methodology

The primary data involves direct collection of information on the field, traffic counts, oral interview and GPS observations. The secondary data involves sourcing information from existing records. Such data include Images and street guide maps.

3.1 Data Acquisition

The location data acquired with the use of Survey123. A form was created in survey 123 software for the available types of health facilities such as health centre, Health post, Primary health centre, etc in Nnewi North Local Government Area. The program was chosen for this project due to its ability of holding large amount of data, smartness, accuracy and mobile friendly.

3.2 Database Design

The creation of spatial database adopted for the study is of two phases; the design and construction phase.

The design phase of the database consists of four parts, they are;

The view of reality

The physical design model

Conceptual design model

Logical design model

3.3 Database Design

At the completion of field operations, the data collected were processed to produce the required information in the form specified. The processes include conversion of hard copy records into softcopy, data input, creation of database, georeferencing, digitizing and determination of secondary attributes from the primary ones collected from the field and data integration, etc

3.4 Georeferencing

This is the process of tying a digital map, image or spatial data file to real world geographic coordinates. The georeferencing was performed using four known ground control coordinates obtained at the map grid intersection. The root means square error obtained is 0.0003. a file geodatabase was later created in arc catalog for the storage of all the feature class, such as road, facilities, and junctions identified on the street guide map and the image.

3.5 Digitizing

Digitizing is the process of encoding the geographic features in digital form as x, y coordinates. It was carried out to create spatial data from existing data. Road network and Facilities were manually extracted using onscreen digitizing from Quick bird Image using ArcGIS Pro 3.4 and its extension software. The attribute of the various roads and other features (name, address and type) were rendered into the system manually as the digitizing was in progress.

3.5 Equipment Used

Hardware:

GPS Devices: Handheld GPS receiver (etrax 20 Garmin) for collecting precise coordinates of healthcare facilities and key infrastructure points (e.g., road junctions).

Computers: HP EliteBook laptop with 8GB RAM and GIS-compatible processors for data processing and spatial analysis.

Software:

ArcGIS Pro (version 3.4): For spatial analysis, mapping, and modeling (e.g., network analysis, buffering, location-allocation).

Microsoft Excel: For data organization and preliminary analysis.

Google Earth Pro Desktop: This was used to download google satellite imagery

Microsoft word: This was used for the presentation of the research.

4. Findings

The results obtained from data analysis are presented as graduated symbols, raster surfaces and circles for facilities service areas.

The Geospatial database on healthcare facilities in Nnewi North in UTM Zone 32N projection and WGS 84 Datum and units in meter is shown in table 4.1,

4.1 Table showing 27 healthcare facilities in the Geospatial database in Nnewi North LGA out of the 10 wards in the Local government area highlighting number of physician and total personnel in each facility.

Easting_	Northing	Facility_name	Facility_level	Settlem population	Physician	Total personnel	ward	Address
265575.61	665296.5	Akaboezem PHC	Primary	25,245	0	2	Uruagu II	Ekeson Street
268994.291	661773.947	Inyaba PHC	Primary	25,332	0	4	Umudim I	John White Road
271160.378	666146.099	Umuanuka Health Post	Primary	35,192	0	2	Otolo I	Umuanuka Hall Otolo
270281.145	667025.509	Abubo PHC	Primary	21,768	0	2	Nnewi Ichi II	Mmilikwe road near St Mary catholic church Abubor
269244.75	665776.63	Akaboukwu Health Post	Primary	15,384	0	3	Uruagu III	Nwobi Ugochukwu Road
266306.731	662999.903	Akamili PHC	Primary	15,402	0	4	Umudim II	Obi Umuogo Akamili Umudim
266919.239	669479.289	Edoji PHC	Primary	15,384	0	3	Uruagu III	Inside Edoji Age Grade Hall Uruagu
268144.253	663355.68	Eme Court PHC	Primary	15,402	0	3	Umudim II	Near Ukwu orji or court Eme Umudinkwa
270503.129	662486.127	Ezekwuabor PHC	Primary	20,962	0	6	Otolo III	
269286.665	663290.929	Maternal and Child HC Umudim	Primary	25,332	0	2	Umudim I	Near NPI Office Nnewi
270470.203	662857.918	Mbanagu PHC	Primary	20,962	0	3	Otolo III	
267244.706	666991.461	Ndiezenwankwo PHC	Primary	15,384	0	4	Uruagu III	New Oba Nnewi Road
269211.502	666543.655	Nnamdi Azikiwe University Teaching Hospital	Tertiary	15,384	232	2718	Uruagu III	Along Onitsha Nnewi Old Road by Ibeto Junction
272304.388	663816.671	Obiuno Otolo PHC	Primary	35,192	0	3	Otolo I	Behind Eke Amobi Market OtoloNnewi
268235.986	669034.607	Obiuno Umudim Health Post	Primary	15,402	0	2	Umudim II	Near Obiojukwu Compound umudim
268006.557	666346.881	Obiuruagu PHC	Primary	32,620	0	4	Uruagu I	Inside Obiuruagu Palace Uruagu
269579.905	667532.591	Oduda PHC	Primary	22,254	0	7	Nnewi Ichi I	Inside Obi Oduda by St Peters Plaza Road
269306.182	666349.273	Okpuno Ebenator Health Post	Primary	15,384	0	2	Uruagu III	Obi Iloka Hall Okpuno Ebenator

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270063.22	665630.372	Okpuno Otolu PHC	Primary	35,192	0	3	Otolu I	Igwe Orizu Road Opposite Ikedife Hospital
269245.489	666941.079	Okpuno PHC	Primary	22,254	0	2	Nnewi Ichi I	By Okwuogwugwu Square Nnewichi
270698.67	665825.186	Okpuno Umuenem Health Post	Primary	30,568	0	1	Otolu II	Inside Obi Okpuno Umuenem otolo
269142.395	664607.365	Okpunoegbu PHC	Primary	15,402	0	3	Umudim II	Orizu Palace Okpuno Egbu
266689.531	667801.888	Umuanyiboku Health post	Primary	15,384	0	1	Uruagu III	Near sambros house Umuanyiboku Uruagu
271702.178	665344.308	Umuenem PHC	Primary	30,568	0	4	Otolu II	Opposite St Paul Anglican Church Umuenem Otolu
266951.466	666789.389	Umumejiaku Health Post, Uruagu	Primary	15,384	0	2	Uruagu III	Inside Obi Umumejiaku
271509.45	662983.417	Umuzumbana PHC	Primary	20,962	0	1	Otolu III	Beside Umuzu Mbana Hall otolo
269730.601	664360.665	Uru PHC	Primary	25,332	0	3	Umudim I	Near Obi Uru Palace Uru Umudim

Source: Nigeria Health Facility Registry, 2021

4.2 Healthcare facilities distribution Map

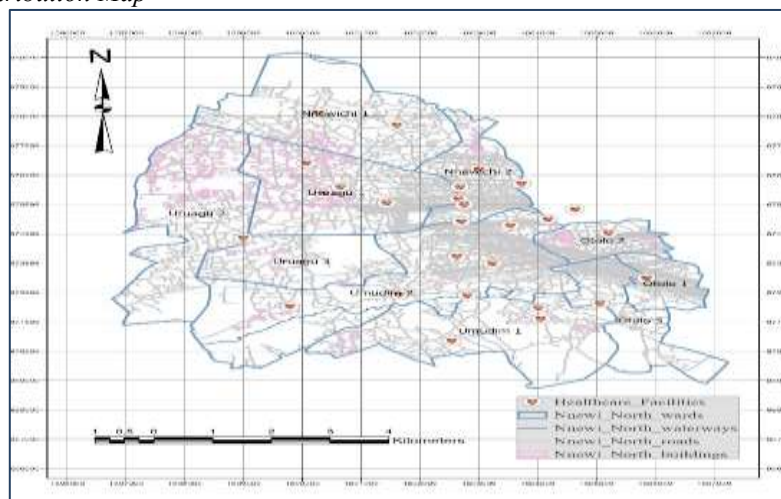


Figure 1: Map showing spatial distribution of healthcare facilities across wards in Nnewi North.

4.3 Population density Map

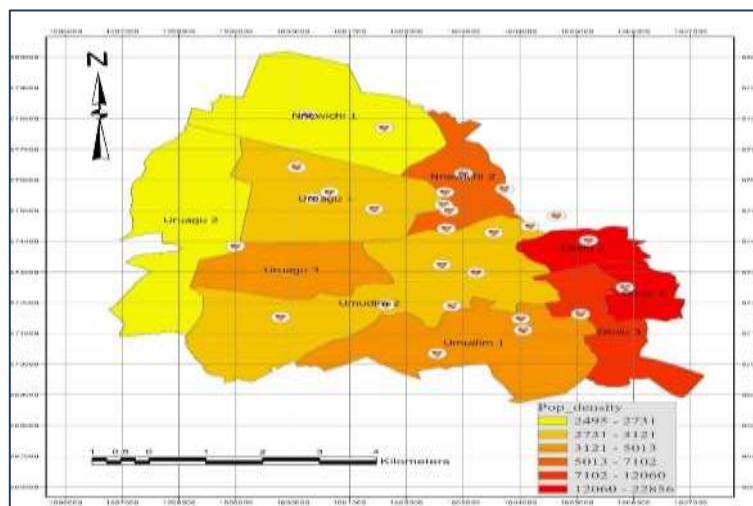


Figure 4.2 Population density map across wards with healthcare facilities location

4.3 Average Nearest Neighbour Analysis.

This analysis determines if the facilities are clustered, dispersed or randomly distributed.

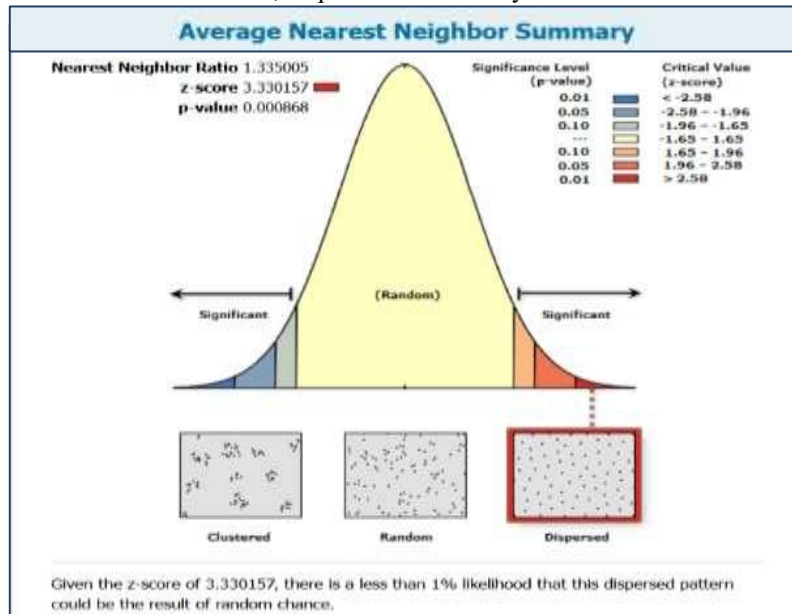


Figure 2: Average Nearest Neighbour Summary.

4.4 Buffer Analysis – Healthcare Facilities distribution gaps

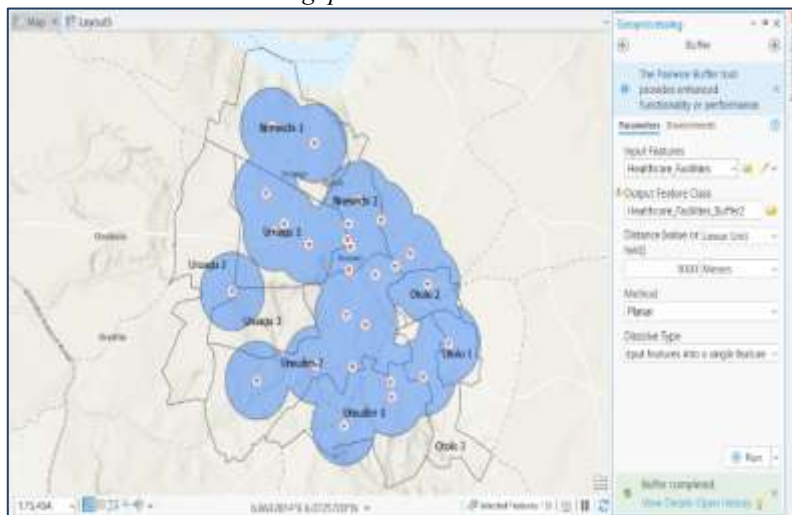


Figure 3: Buffer operation for 1km service area of healthcare facilities in Nnewi North LGA

4.5 Quantitative and qualitative analysis of healthcare distribution across Wards

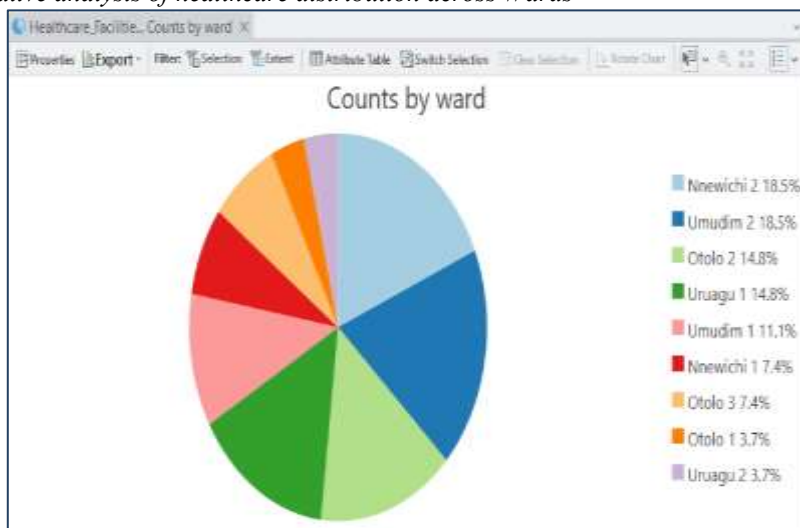


Figure 4: Pie chart showing the percentage of healthcare facilities in each ward in Nnewi North LGA.

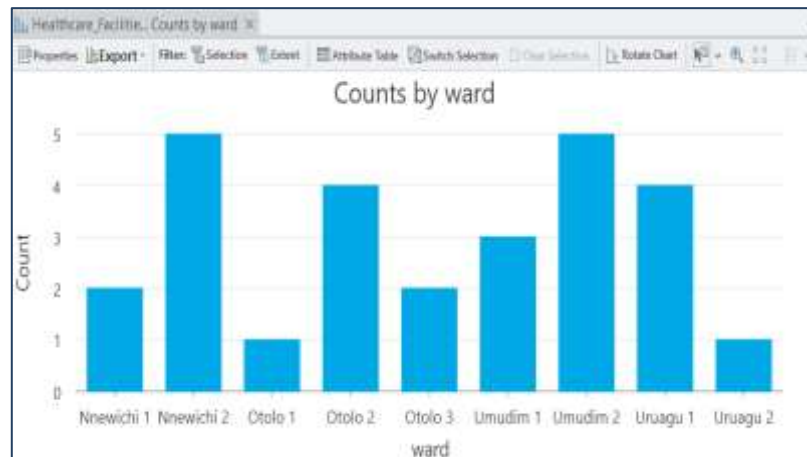


Figure 5: Bar chart showing the percentage of healthcare facilities in each ward in Nnewi North LGA.

5. Conclusion and Recommendations

5.1 Conclusion

This work investigated the distribution of Health Facilities problems using the GIS Approach in Nnewi North LGA, Anambra State, Nigeria. Issues that emerged are as follows;

- Except for Nnamdi Azikiwe University Teaching Hospital, other healthcare facilities do not have a physician.
- A total of 27 healthcare facilities were found to be distributed throughout the study area, with 10 wards.
- Okpuno Umuenem Health Post, Umuzumbana PHC, and Umuaniboku Health Post have only one healthcare personnel. Except for NAUTH, every other healthcare facility in the LGA does not have up to 10 healthcare personnel.
- 1 healthcare facility meets the 10000 population-to-physician ratio standards recommended by WHO.
- There are no public secondary healthcare facilities in the Nnewi LGA.

Geospatial technology as applied in this work demonstrates the spatial distribution of healthcare facilities in the Nnewi North local government area, facility service area, physician-to-population ratio, as well as healthcare facilities deficiency in the study area. The outcome of these various queries and analyses in this work have shown the capabilities of Geospatial technology in solving the lopsidedness in the distribution and management of healthcare facilities in Nnewi North local government area and Nigeria in general.

5.2 Recommendations

This research has shown that healthcare facilities data can be collected and managed using Geospatial technology. The application of Geospatial technology in the mapping and management of healthcare facilities will improve healthcare data collection and management by healthcare administrators. The following are recommended based on the findings:

- Geospatial healthcare information systems should be used more in the management of healthcare facilities within the study area and Nigeria in general.
- More Healthcare facilities should be cited at Uruagu II, Uruagu III and Otolo III wards
- Doctors and especially more nurses should be appointed at the existing primary healthcare centres.
- Working conditions of staff should be improved by effectively equipping this healthcare facilities for improved service delivery.

References

- [1] Abubakar, A., Tanim, R. M., & Samaila, I. (2025). Geospatial analysis of healthcare facilities distribution and accessibility in Igabi LGA, Kaduna State, Nigeria. *Kaduna Journal of Geography*. <https://kadunajournalofgeography.org/index.php/kjg/article/view/101>
- [2] Adesuyi, E. O., et al. (2025). Factors Influencing Primary Healthcare System in the Achievement of Universal Health Coverage in the WHO-AFRO Region: An Integrative Review. *PMC*.
- [3] Abbas A., Idowu I., Abdulqadir, Hussain Z., and Mohammed, N (2014): Mapping the Spatial Distribution of Health Care Facilities of the Millennium Development Goals (MDGs) in Kaduna North and South Local Governments, Kaduna State, Nigeria. *Global Journal of Human-Social Science: B Geography, Geo-Sciences, Environmental Disaster Management*, Volume 14(5).
- [4] Adewoyin, J.E, Ogunyemi. K. H, Muibi, O. Fasote, S.A. Halilu and T. A. Alaga (2016). Spatial Distribution and Accessibility of Primary Health Centre in Ife East Local Government of Osun State, Nigeria. *Journal of Scientific Research & Reports* 9(7): 1-9.
- [5] Akintuyi, A., Otusanya, O., Fashoto, B., & Afolabi, O. (2023). Geospatial analysis of healthcare facilities in Surulere Local Government Area of Lagos state. *Lagos Journal of Geographic Issues*, 3(1), 38–57. <https://ljgi.unilag.edu.ng/article/download/1791/1390/>
- [6] Akinwumi, A. I., et al. (2022). Strong primary care services, an important feature of primary health care: What can Nigeria learn from Israel? *Frontiers in Public Health*.
- [7] Amoah-Nuamah, J., et al. (2023). Analysis of spatial distribution of health care facilities and its effects on access to primary healthcare in rural communities in Kpandai District, Ghana. *Cogent Public Health*, 10(1).
- [8] Bello, I. M., et al. (2023). Modelling geographic accessibility of primary health care facilities in Bauchi Local Government Area. *Academic Research Journal*, 10(1). https://www.texilajournal.com/thumbs/article/Academic_Research_Vol10_Issue1_Article_2.pdf

- [9] Bello, I. M., Musa, K. I., Akpan, G. U., Derrick, C. Y. D., Sallet, F., & Brunda, S. (2023). Modelling geographic accessibility of primary health care facilities in Bauchi Local Government Area. *Academic Research Journal*, 10(1). https://www.texilajournal.com/thumbs/article/Academic_Research_Vol10_Issue1_Article_2.pdf
- [10] Black, M., Ebener, S., Najera Aguilar, P., Vidaurre, M., & El Morjani, Z. (2004). Using GIS to measure physical accessibility to health care. *ESRI Health GIS Conference Proceedings*. <https://proceedings.esri.com/library/userconf/health04/papers/pap3023.pdf>
- [11] Black, M., et al. (2004). Using GIS to measure physical accessibility to health care. *Proceedings of the ESRI Health GIS Conference*.
- [12] Daniel, C. B., Mathew, S., & Saravanan, S. (2021). Network constrained and classified spatial pattern analysis of healthcare facilities and their relationship with the road structure: A case study of Thiruvananthapuram city. *Journal of Urban Management*, 10(1), 48–61. <https://doi.org/10.1016/j.jum.2020.12.003> (PMC7938375)
- [13] Das, M. (2023). Spatial accessibility modeling to healthcare facilities in the case of health shocks of Midnapore municipality, India. *GeoJournal*, 88, 1–20. <https://doi.org/10.1007/s10708-023-10812-5> (PMC9919752)
- [14] Davenhall, W. F. (2012). GIS in health and human services. In *Springer Handbook of Geographic Information* (pp. 689-708). Springer.
- [15] Falchetta, G., et al. (2020). Planning universal accessibility to public health care in sub-Saharan Africa. *Proceedings of the National Academy of Sciences*, 117(50), 31760–31769. <https://doi.org/10.1073/pnas.2009172117>
- [16] Ejiagha I.R. (2011): Locational Analysis of Health Facility in Enugu urban area. An Unpublished MSC thesis submitted to the Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka, Nigeria.
- [17] Fanan, U and Kwaghsende, F (2014). Analysis of the Spatial Distribution of Health Facilities in Benue State, Nigeria. *Public Health Research*, 4(5): 210-218
- [18] Friesen, J., et al. (2025). Differences in walking access to healthcare facilities between formal and informal areas in 19 sub-Saharan African cities. *Communications Medicine*. <https://doi.org/10.1038/s43856-025-00746-5>
- [19] Friesen, J., et al. (2025). Differences in walking access to healthcare facilities between formal and informal areas in 19 sub-Saharan African cities. *Communications Medicine*. <https://doi.org/10.1038/s43856-025-00746-5>
- [20] GRID3. (2024). GRID3 NGA – Health Facilities v2.0. <https://data.grid3.org/maps/GRID3::grid3-nga-health-facilities-v2-0>
- [21] Hassan, M. A. (2024). GIS-based mapping of health infrastructure and access to healthcare services in Taraba State, Nigeria. *Journal of Advanced Science and Optimization Research*, 6(9). <https://ssaapublications.com/index.php/sjasor/article/download/387/357>
- [22] Hassan, M. A. D. O., & Oloyede-Koselu, S. M. (2024). GIS-based mapping of health infrastructure and access to healthcare services in Taraba State. *Journal of Advanced Science and Optimization Research*, 1(5), 1-17.
- [23] Imaobong, U and Ini, U (2014): Assessment of Surface and Ground Water Quality of Uruan in Akwa Ibom State of Nigeria. *Journal of Natural Sciences Research*, 4(6): 20-29
- [24] Ishaq, A. B., et al. (2024). Spatial distribution and accessibility of healthcare facilities in Niger State, Nigeria. *African Journal of Health, Safety and Environment*, 5(2), 26–35. <https://ajhse.org/index.php/ajhse/article/download/506/168>
- [25] Ishaq, A.B., et al. (2024). Spatial distribution and accessibility of healthcare facilities in Niger State, Nigeria. *African Journal of Health, Safety and Environment*, 5(2), 26–35.
- [26] Isma'il, M., Jaro, I. M., & Kim, I. (2014). Analysis of accessibility to healthcare facilities in Giwa and Tofa Local Government Areas of Nigeria: GIS approach. *Journal of Scientific Research and Reports*, 4(3), 1–15. http://www.sdiarticle1.in/prh/JSRR_22/2014/Revised-manuscript_version1_8183.pdf
- [27] Joseph, A. E., & Bantock, P. R. (1982). Measuring potential physical accessibility to general practitioners in rural areas: A method and case study. *Social Science & Medicine*, 16(1), 85-90.
- [28] Kress, D. H., et al. (2016). Assessment of Primary Health Care System Performance in Nigeria: Using the Primary Health Care Performance Indicator Conceptual Framework. *Health Systems & Reform*.
- [29] accessibility to primary care physicians. *Health & Place*, 15(4), 1100-1107.
- [30] Luo, W., & Qi, Y. (2009). An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. *Health & Place*, 15(4), 1100–1107.
- [31] Macharia, P. M., et al. (2025). Putting health facilities on the map: A renewed call to create geolocated, comprehensive, updated, openly licensed dataset of health facilities in sub-Saharan African countries. *BMC Medicine*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11978184/>
- [32] Macharia, P.M., et al. (2025). Putting health facilities on the map: A renewed call to create geolocated, comprehensive, updated, openly licensed dataset of health facilities in sub-Saharan African countries. *BMC Medicine* (or equivalent; PMC11978184).
- [33] Maina, J., et al. (2019). A spatial database of health facilities managed by the public health sector in sub-Saharan Africa. *Scientific Data*, 6, 134. <https://doi.org/10.1038/s41597-019-0142-2>
- [34] Mansour, S. (2016). Spatial analysis of public health facilities in Riyadh Governorate, Saudi Arabia: A GIS-based study to assess geographic variations of service provision and accessibility. *Geocarto International*, 31(7), 799–816. <https://doi.org/10.1080/10095020.2016.1151205>
- [35] McGrail, M. R. (2012). Spatial accessibility of primary health care utilising the two step floating catchment area method. *International Journal of Health Geographics*, 11, 50.
- [36] McGrail, M. R., & Humphreys, J. S. (2009). Measuring spatial accessibility to primary health care services: applying the accessibility score method to the Australian context. *Applied Geography*, 29(4), 533–543.
- [37] geocoded inventory and spatial analysis. *Frontiers in Public Health*, 10, 1002975. <https://doi.org/10.3389/fpubh.2022.1002975>
- [38] National Population Commission, & National Bureau of Statistics. (2022). Demographic statistics bulletin 2022. Federal Republic of Nigeria.

- [39] Nigeria Health Facility Registry from <https://www.hfr.health.gov.ng>
- [40] Nsiah, R. B., et al. (2024). Mapping health disparities: Spatial accessibility to healthcare facilities in a rural district of Ghana using geographic information systems techniques. *American Journal of Health Research*, 12(5), 145–158. <https://doi.org/10.11648/j.ajhr.20241205.11>
- [41] Ogah, P. O., et al. (2024). Primary health care in Nigeria: best practices and quality of care in Nigeria. PMC.
- [42] Oluwayinka, A. E. (2023). Spatial distribution and geographic accessibility to primary healthcare facilities in Oyo State, Nigeria. *Journal of Infectious Diseases and Therapy*. <https://www.walshmedicalmedia.com/open-access/spatial-distribution-and-geographic-accessibility-to-primary-healthcare-facilities-in-oyo-state-nigeria-124877.html>
- [43] Oniyire, F., et al. (2025). Infrastructure, service delivery, and staffing gaps in primary health care facilities in Lagos State, Nigeria: a state-wide assessment. PMC.
- [44] Ossai, E. N., Aigberua, O. D., & Oliha, A. O. (2025). Spatial analysis of educational and healthcare infrastructure in Auchi, Edo State. *HAL Open Science*. <https://hal.science/hal05111274/document>
- [45] Ouma, P. O., et al. (2018). Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: A geocoded inventory and spatial analysis. *The Lancet Global Health*, 6(3), e342–e350.
- [46] Ouma, P.O., et al. (2018). Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: A geocoded inventory and spatial analysis. *The Lancet*
- [47] Parvin, F., et al. (2020). Accessibility and site suitability for healthcare services using GIS-based hybrid decision-making approach: a study in Murshidabad, India. *Spatial Information Research*, 28(4), 427–443.
- [48] Penchansky, R., & Thomas, J. W. (1981). The concept of access: Definition and relationship to consumer satisfaction. *Medical Care*, 19(2), 127–140.
- [49] Coverage Area in Sukhothai Province, Thailand. *International Journal of Geoinformatics*. <https://ijg.journals.publicknowledgeproject.org/index.php/journal/article/view/3449>
- [50] Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46(2), 234–240.
- [51] Wang, F., & Luo, W. (2005). Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health & Place*, 11(2), 131–146.
- [52] Weiss, D.J., et al. (2020). Global maps of travel time to healthcare facilities. *Nature Medicine*, 26, 1835–1838.
- [53] Wong, K. L. M., et al. (2024). Measuring geographic access to emergency obstetric care: A comparison of travel time estimates modelled using Google Maps Directions API and AccessMod in three Nigerian conurbations. *Geospatial Health*, 19(1). <https://doi.org/10.4081/gh.2024.1266>
- [54] World Health Organization. (n.d.). GIS, geospatial solutions for health. WHO GIS Centre for Health.
- [55] Yisa, S. S., et al. (2025). Strengthening primary health care in Nigeria: a means to achieve universal health coverage. PMC.