

Health-Care Facilities Accessibility Analysis Using GIS: A case Study of Uyo Municipal South –Eastern Nigeria

Ike, Felix

Department of Geography and Planning, Abia State University, Uturu, Nigeria

Nweke Esther

Department of Geography and Planning, Abia State University, Uturu, Nigeria

ABSTRACT

As the urban area grows and expands, efficient services such as housing, education, transportation, infrastructure, and healthcare are required. Accessibility to health care facilities is an important vital component of human well-being and the long-term survival of urban life. Spatial disparities occur from the concentration of health facilities in one location. This study used GIS techniques and locally produced data to assess the level of accessibility to health care services in Uyo Urban, Akwa Ibom State, Nigeria. The obtained index from Nearest Neighbour Analysis is roughly 0.74, showing a clustered pattern. The Alpha of the connectedness estimate is roughly 0.5, indicating an average connected network. The Beta Index of 1.9 indicates that Uyo has a high level of connectedness. Furthermore, the Gamma index of 0.6, which equals 60%, demonstrates that the study region is reasonably connected. This indicates that all portions of the study region have a moderate potential for interaction. Seven communities were unable to generate the quickest path to healthcare facilities based on the origin-destination and service areas. Only 14% of the municipalities are within walking distance of the nearest health care services. We propose that the healthcare delivery system, specifically its distribution and accessibility, be reinforced as soon as possible to improve people's health. We believe that the use of GIS as a decision-support tool should be expanded in Uyo L.G.A.'s health policy.

Keywords: Health Care, GIS, Nearest Neighbour, Connectivity Indices

INTRODUCTION

Health is a critical component of human well-being, characterized by physical and mental capacity that is consistent with age, culture, and personal responsibility in meeting life's responsibilities(1–3). Access to health-care facilities and services has long been recognized as critical to the establishment of long-term health-care delivery systems. Accessibility for all socioeconomic classes to basic services such as healthcare facilities has been highlighted as a focus on sustainable urban development and human well-being(4–6).

Access to health-care facilities is not only beneficial to one's quality of life, but it is also necessary for long-term economic and social growth. As a result, health is recognized as a valuable resource in the process of economic development, making health spending a worthwhile investment. Evidence has shown that among poor countries, increase in life expectancy is strongly correlated with increase in productivity and income(7–10). Increased

productivity by individual or group of people in all sectors depends on the health conditions of the labor force, while improved health and quality of life depends to a great extent on the availability of, and accessibility to health care facilities at affordable cost(11).

However, not everyone has reaped the full benefits of total provision because healthcare facility distribution in Nigeria has been marked by significant disparity, as evidenced by their locational pattern of distribution, in which some of these facilities are concentrated in one area at the expense of others. This has prompted governments to demonstrate real commitment to eliminating disparities by doing study on the pattern and accessibility of HCFs in various parts of the world.

The provision and access to health care services are among the most pressing problem in developing countries. Nigeria's is predicted to be over 140 million people, and as the population of Uyo grows, so does the need for adequate and proper health care delivery(12) This has prompted the health sector to focus heavily on the creation of more health care facilities to meet the fast rising population's needs, as well as various studies to investigate the distribution, accessibility, and utilization of health care facilities across the country. The spatial distribution and accessibility of healthcare facilities in Uyo L.G.A. have received little attention. It is against this backdrop that this study is being conducted to obtain a better understanding of the health care distribution pattern and accessibility.

GIS platforms have supported health care planning for a long time by assessing spatial distribution in terms of cost and distance traveled. Most commercial GIS software systems have generic features that give very little interactive and rapid computations on simple geographical distribution. This click-result scenario has been demonstrated to be insufficient for comprehending urban accessibility, especially when it comes to providing information on the economic and modal costs of visits to health-care facilities.

In recent years, improvements to these basic GIS functionalities have been made(13) measured accessibility by employment and different modes of transportation; (14) included transit-based health seeking patterns in their accessibility assessment; and (15) introduced a method for approximating the geographical accessibility to healthcare facilities. Using ground-based observation and secondary data, our paper introduces Service areas and walking time to accessibility of health care facilities in the study area.

MATERIALS AND METHODS

Study Area

The study covered Uyo L.G.A which is the capital city of Akwa Ibom state. It is located between 4° 52'N and 5°07'N and 7° 47'E to 8° 03'E (Figure 1). The rainy season lasts from March to October, with a brief dry period from November to February. The average annual rainfall in the area is 2484 mm, with a mean annual temperature of 27°C. With the exception of the Northern sides, where the 50m deep Ikpa river valley breaks up the monotony, it has a flat landscape of 61 meters above mean sea level (amsl). The town's nearly flat terrain has had a detrimental effect on drainage and physical development.

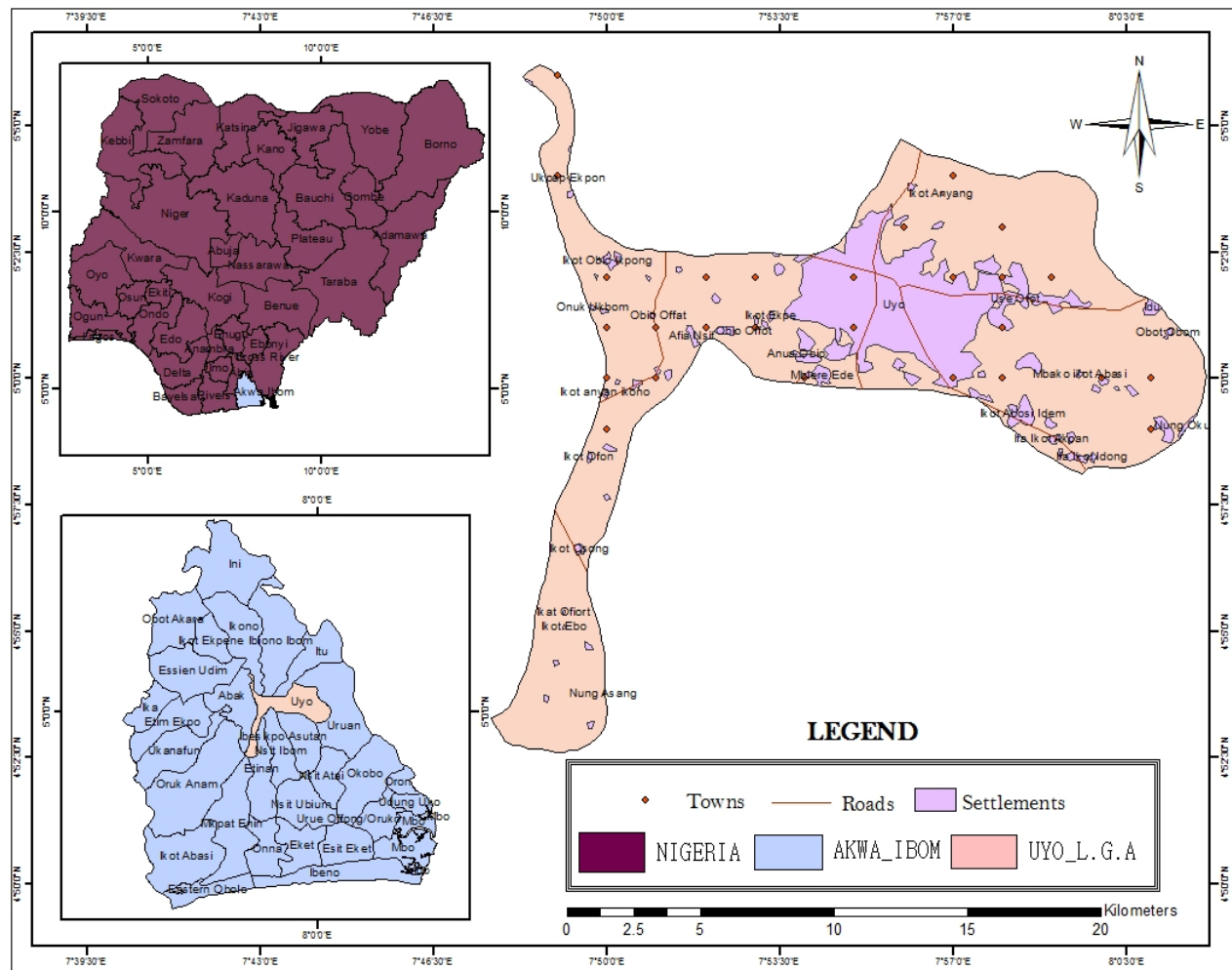


Figure 1: The study area

Data

The Nigerian Geo-Referenced Infrastructure and Demographic Data for Development (GRID3) program (<https://grid3.gov.ng/>) provided the base map, road network, and settlements. The GRID3 products are designed to make high-resolution population, infrastructure, and other reference data in support of national sectoral development priorities, humanitarian initiatives, and the United Nations' Sustainable Development Goals (SDGs). The National Health Insurance Scheme (NIS) provided an updated list of registered and accredited healthcare institutions in the Offot, Etoi, Oku, and Ikono districts of Uyo (Table 1). Their physical coordinates were retrieved using the Global Positioning System (GPS).

Table1: Healthcare facilities in the study area

S/N	Name of Healthcare Facility	Address of the Facility	Ownership	Latitude	Longitude
1	University of Uyo Teaching Hospital	Olusegun Obasanjo way	Government	5.011535278	7.860993333
2	Milestone Specialist Clinic and Maternity	7, old Staduim Rd, Use Ikot Ebios	Private	5.016741667	7.86731
3	Primary Healthcare Centre	Ikot Okubo Offot - 1	Government	5.169869723	7.886238056
4	Unwana Family Hospital and Maternity	16A, Nkemba Street, Uyo.	Private	5.03270333	7.912158611
5	Grace and Mercy Medical Center	Stadium Rd, Nnung Akpan	Private	5.015536667	7.879553333
6	Ibom Specialist Hospital	1, Klinik street, off Nkemba street, Uyo.	Private	5.035041944	7.90783333
7	Ubong Abasi Specialist Clinic	5, Clement Isong street off Abak Rd.	Private	5.025733334	7.913326667
8	St. Luke's Hospital	Anua, Uyo.	Missionary	5.029966945	7.958436389
9	St. Athnesius Hospital	1 Ufeh Street, Off Abak Rd Housing, Uyo.	Private	5.024018333	7.91388
10	Premier Medical Services	3, Hightension Lane, Off Edet Akpan Avenue, Uyo.	Private	5.024053056	7.954268333

11	Sifon Clinic Medical Center	53 Utang Street, Uyo	Private	5.034005278	7.93674
12	Jolad Specilist Clinic and Medical Center	215 Oron Rd, Uyo	Private	5.014735278	7.938970833
13	Majesty Hospital and Eye Clinics	47, Wellington Bassey, Uyo	Private	5.0374	7.32056
14	University of Uyo Medical Center	Ekpa Rd, Uniuyo Town Campus, Uyo	Government	5.038976667	7.926155
15	Mount Olive Clinic and Maternity	8, Ebong street, Ikot Ekpene Rd, Uyo	Private	5.040946389	7.9131555
16	Uwakmfon specialist Clinic and Hospital	55, udo idiokangka Str. Off Urua Udofia, Nwaniba Rd. Uyo	Private	5.02979	7.937403056
17	Primary Healthcare Centre	West Itam 1, Ibiaku Itam	Government	5.05	7.937403056
18	Domingo Specialist Hospital	Plot 9, Unit E, Ben Udo, Off Ewet Housing, Uyo	Private	5.022621667	7.948331944
19	Ekop Specialist Clinic	18F, Ewet Housing Estate	Private	5.013175	7.950663611
20	City Clinic and Infirmary	30, Godwin Abbe Avenue Ewet Housing	Private	5.014523611	7.942036667
21	Federal Staff Clinic	secetariate Complex, Abak Rd, Uyo.	Government	5.019225278	7.8863175
22	Gateway Clinic	Okon Essien Street, Abak Rd, Uyo	Private	5.031931667	7.920065

Advanced Space Technology Application Laboratory (ASTAL), Uyo, provided a topographic map of Akwa Ibom state, as well as Shuttle Rader Topographic Mission (SRTM) satellite images. The Ministry of Mining and Transportation provided the in-vehicle travel time it takes to reach a specific health care institution. In addition, through extensive fieldwork, the time it takes to access the service through public transportation or walking was recorded for all of the districts.

Evaluating the Geographic Distribution of the Health Care Facilities

Nearest Neighbour Analysis (NNA)

The distribution of health facilities in the research area was determined using the Nearest Neighbour Analysis (NNA). The locations of the 22 health-care centers were used to determine whether the spaces are concentrated or evenly distributed.

The NNA formula is as follows: $Rn = \frac{Do}{De} \dots \dots \dots (1)$

Where Rn = description of distribution (NNI), Do =observed distance, De =expected distance

$$Do = \sum D/N \dots \dots \dots (2)$$

$$De = \frac{1}{2\sqrt{N/A}} \dots \dots \dots (3)$$

D =average distance between each point and its nearest neighbour, N =total number of points (healthcare facilities) , A =area under study.

Rn Value ranges from 0 to 2.15: when clustered, $Rn=0$, it is random if $Rn=1.0$ and regular when $Rn=2.15$.

Network Analysis and Connectivity Indices (CI)

Transport network connecting the health care facilities were evaluated by a series of vertices (representing nodes on a network) and a set of edges (representing network linkages). The alpha (eq.4), beta (eq. 5) and gamma Indices are used to represent connectivity (eq. 6).

The alpha index's maximum number of cycles is compared to the integer number of cycles in the distribution of health-care institutions. The higher the alpha index, the better the amenities are connected. The Beta Index is a formula that expresses the relationship between the number of nodes and linkages in a network. The gamma index was used in this study to quantify connectedness between the facilities in terms of the number of observed and probable links.

$$\alpha = \frac{e - v + 1}{2v} - \dots \dots \dots 4$$

$$\beta = \frac{e}{v} \dots \dots \dots 5$$

$$\gamma = \frac{e}{3(v-2)} \dots \dots \dots 6$$

Where 'e' is the number of edges e= number of vertices/edges (arterial roads) and v= number of nodes (junctions).

Origin-destination Cost and service areas

From origin to destination, an OD contains the trip time and distance.

Setting the searching distance is an important element in an origin-destination (OD) cost matrix calculation approach in network-based geographical accessibility analysis (Wu & Tseng, 2018). It also ranks the destinations that each origin connects to in ascending order based on the shortest time or distance to travel from that origin to each destination. From many origins to

multiple destinations, the Analyst can create an origin–destination (OD) cost matrix. The network impedance from each origin to each destination is stored in an OD cost matrix, which is a table. For each origin-destination pair, the optimum network path is found, and the cost is saved in the attribute table of the output lines, which are straight lines.

RESULTS

Health Facility Distribution and Connectivity indices

There are twenty two healthcare facilities in the study location (Figure 2). Nearest neighbour analysis (NNA) was adopted in determining the pattern of the distribution. In the study area, there are twenty-two healthcare facilities (Figure 2). The pattern of the distribution was determined using nearest neighbor analysis (NNA). The NNA's derived index is around 0.74, indicating a clustered pattern. Currently, the distribution pattern shows compaction, indicating that measures to ensure an even distribution of healthcare services in Uyo municipal have not been considered.

In this study, we used ESRI ArcGIS "Model Builder" programming (Esri, Redlands, CA, USA) to compile a list of registered and accredited healthcare institutions in the Offot, Etoi, Oku, and Ikono districts to determine the accessibility level, taking into account, not only road networks as in the O – D cost matrix, but also the land use and slope of the study area. A map layer was generated, as well as a list of disadvantaged settlements, displaying the service area and walking distance to healthcare facilities.

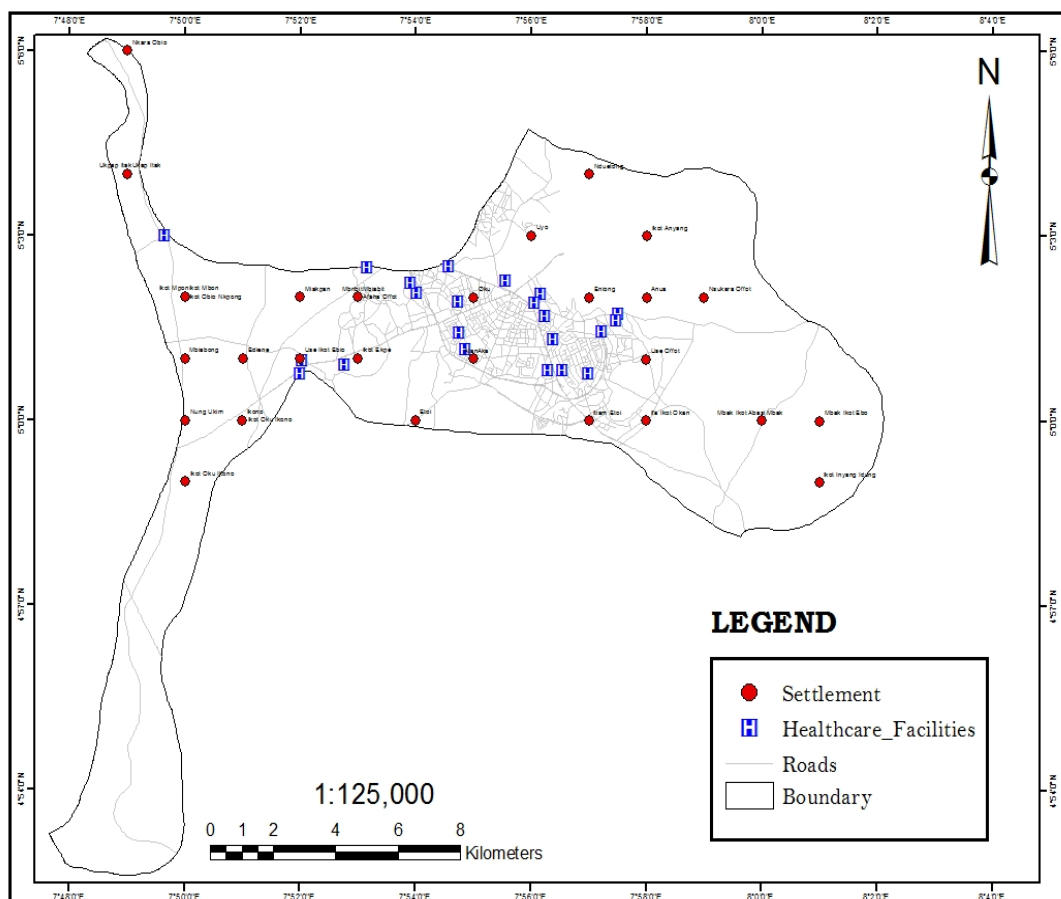


Fig 2: locations of the Healthcare facilities

From the connectivity calculation, the Alpha (α) is approximately 0.5 indicating average connected network. The Beta Index (β) that equals to 1.9 indicating that Uyo has a high connectivity. Also, the Gamma index (γ) is 0.6 which is equal to 60% also confirms the study area is reasonably connected. This shows a moderate potential for interaction with all parts of the study area (Table 2).

Table 2: Showing Connectivity Indices

MEASUREMENT CRITERIA	CONNECTIVITY INDEX (CI)
Alpha (α)	0.46
Beta(β)	1.9
Gamma(γ)	0.6
Mean	0.98

Origin-Destination and service areas

Origin data loaded into the network analyst consisted settlements while the destinations were the healthcare facilities. The distances between origins and destinations are measured as the shortest network distance. By calculating different types of destinations separately, changes in accessibility over time to several healthcare facilities were explored. Figure 3 show that Seven (7) settlements could not generate a shortest path to access the healthcare facilities.

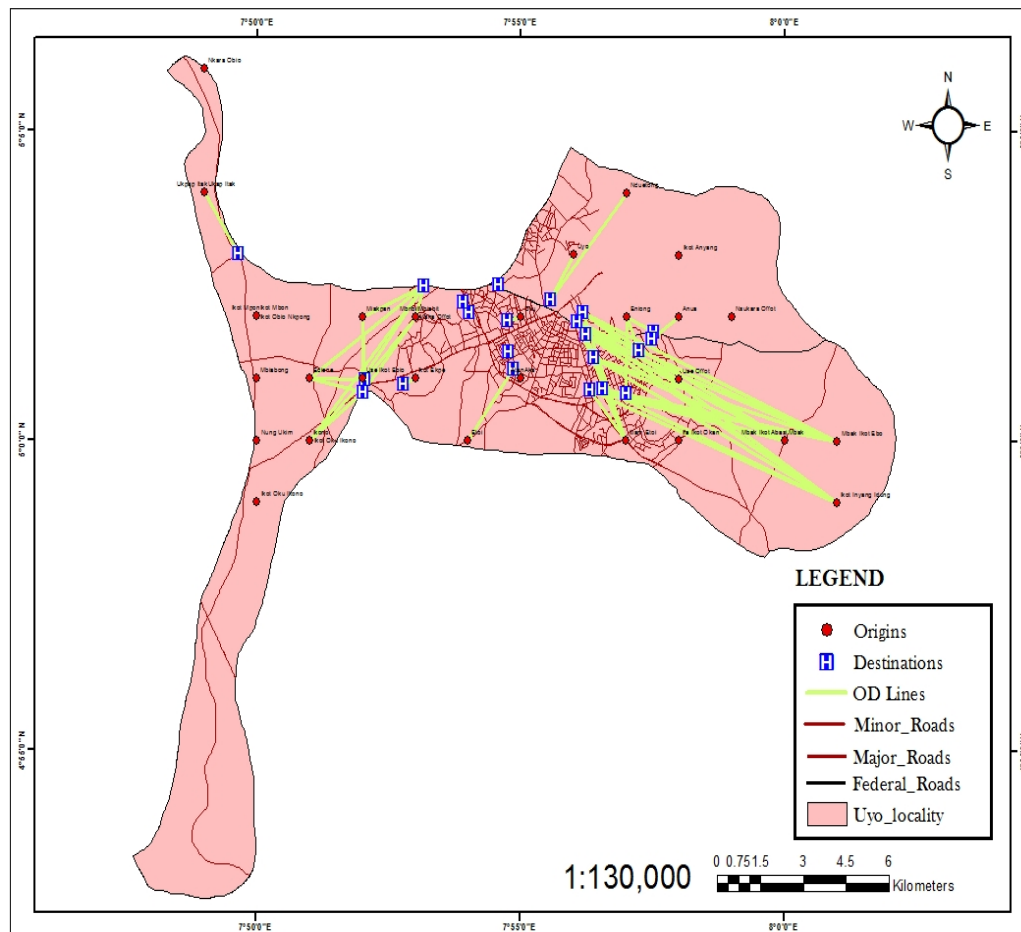


Fig 3: Origins – Destinations Matrices

Figure 4 depicts the service area of travel distance between settlements and healthcare facilities, with breaking values of 400m, 800m, 1200m, 1600m, 2000m, and >2000m. The service area includes 12 settlements that are highly accessible to healthcare facilities, 7 settlements that are least accessible to healthcare facilities, and 6 settlements that are badly accessible to healthcare facilities.

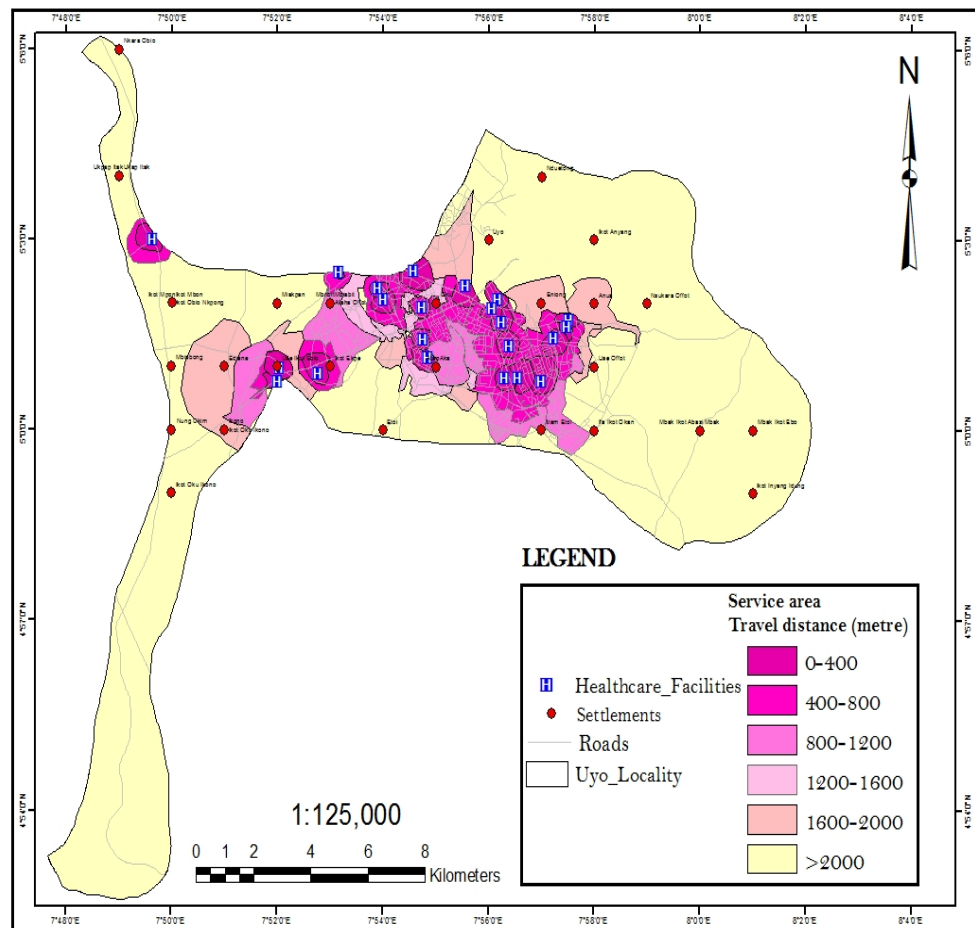


Fig 4: Map showing Service area

Walking Distance/Time

Figure 5 depicts the spatial extents of travel (walking) times of 5m, 10m, and 15m (equal to 400m, 800m, and 1,200m respectively) from healthcare facilities. It is obvious that only a tiny section of the study area in the facilities (i.e., the five towns of Use Ikot Ebio, Oku, Atan Aka, Afaha Offot, and Ikot Ekpe) is within walking distance (1200m, or 15 minutes) of the healthcare facilities. Only 14% of the total towns are within a reasonable walking distance of the nearest health care facilities, as can be observed.

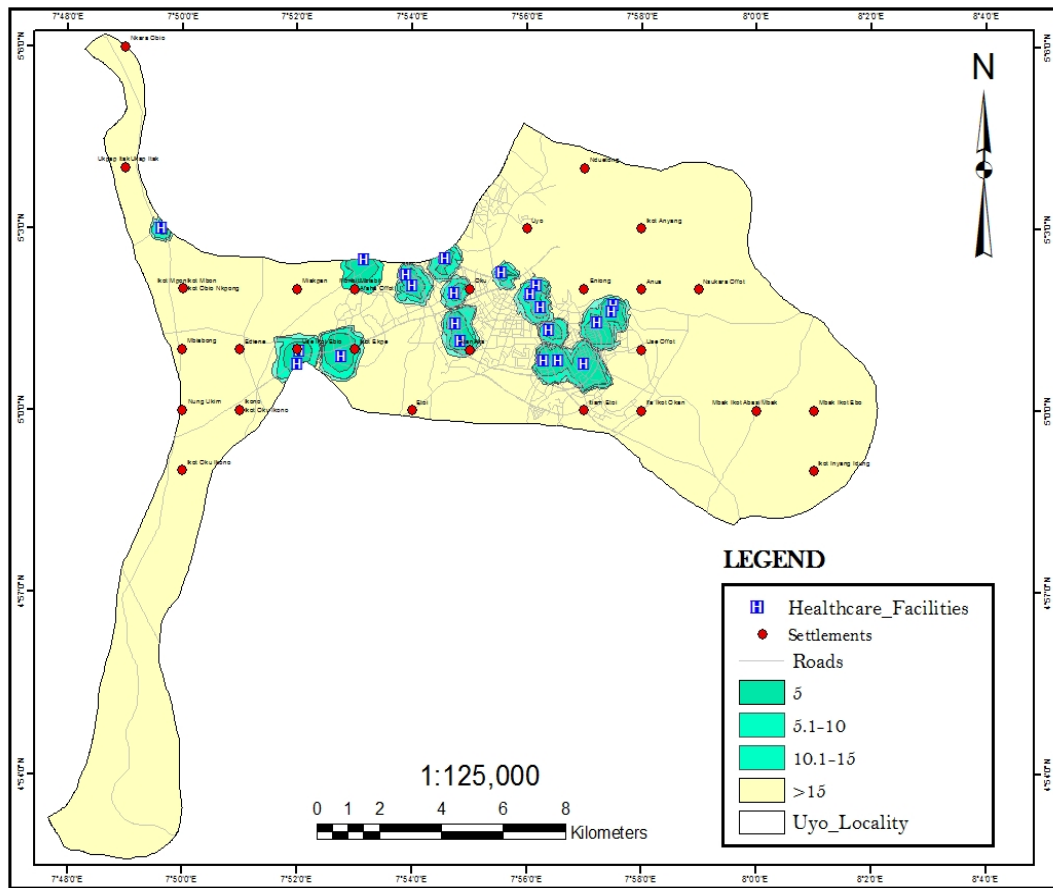


Fig 5: map showing walking travel time

CONCLUSION

Using a GIS-based technique, this study looked at the spatial distribution and accessibility of healthcare services in the Uyo area. The distribution of healthcare facilities in the research area showed a lot of variation. The clustered pattern of health care facilities revealed in this study mostly found in cities in developing nations, such as Thiruvananthapuram, India (16) and Nanjing, China (17). On average, 14% of the population lives within 15 minutes of the nearest health-care institution, whereas over 85% of the population resides beyond walking distance. Anua Offot and Afaha Offot had the shortest travel distances to healthcare services in the study area, according to the research. The longest distance traveled is from Nsukara Offot to St. Luke's Hospital, which is almost 2000 meters.

Because of their inability to access healthcare facilities, eight (8) communities (Nkara Obio, Nkpong, Mbak Ikot Ebo, Nduetong, Mbak Ikot Abasi, Mbiabong, and Nung Ukim) are disadvantaged. Because the survey did not cover the entire state, it is important to emphasize that these disadvantaged villages may obtain their healthcare services from a neighboring local government area. By analyzing and comparing hospital spatial distributions to World Health Organization guidelines(18), the government is in a stronger position to intervene to decrease geographical inequities in healthcare facility distribution. It is necessary to institutionalize GIS in Uyo Local Government Area and Nigeria as a whole in order to fully utilize its potential.

References

1. Adamczyk K, Barr AB, Segrin C. Relationship status and mental and physical health among Polish and American young adults: The role of relationship satisfaction and satisfaction with relationship status. *Appl Psychol Health Well-Being*. 2021;
2. Laporte N, Soenens B, Brenning K, Vansteenkiste M. Adolescents as active managers of their own psychological needs: The role of psychological need crafting in adolescents' mental health. *J Adolesc*. 2021;88:67–83.
3. Lee C-W, Lin L-C, Hung H-C. Art and Cultural Participation and Life Satisfaction in Adults: The Role of Physical Health, Mental Health, and Interpersonal Relationships. *Front Public Health*. 2021;8:1030.
4. Comber AJ, Brunsdon C, Radburn R. A spatial analysis of variations in health access: linking geography, socio-economic status and access perceptions. *Int J Health Geogr*. 2011;10(1):1–11.
5. Delamater PL, Messina JP, Shortridge AM, Grady SC. Measuring geographic access to health care: raster and network-based methods. *Int J Health Geogr*. 2012;11(1):1–18.
6. Mahabir DF, O'Campo P, Lofters A, Shankardass K, Salmon C, Muntaner C. Experiences of everyday racism in Toronto's health care system: a concept mapping study. *Int J Equity Health*. 2021;20(1):1–15.
7. Alhassan GN, Adedoyin FF, Bekun FV, Agabo TJ. Does life expectancy, death rate and public health expenditure matter in sustaining economic growth under COVID-19: Empirical evidence from Nigeria? *J Public Aff*. 2021;21(4):e2302.
8. Aliyu UA, Kolo MA, Chutiyami M. Analysis of distribution, capacity and utilization of public health facilities in Borno, North-Eastern Nigeria. *Pan Afr Med J*. 2020;35.
9. Kawachi I, Kennedy BP. Socioeconomic determinants of health: Health and social cohesion: why care about income inequality? *Bmj*. 1997;314(7086):1037.
10. Koenig J-G. Indicators of urban accessibility: theory and application. *Transportation*. 1980;9(2):145–72.
11. Awoyemi TT, Obayelu OA, Opaluwa HI. Effect of distance on utilization of health care services in rural Kogi State, Nigeria. *J Hum Ecol*. 2011;35(1):1–9.
12. Commission NP. Nigeria demographic and health survey 2013. National Population Commission, ICF International; 2013.
13. AlKheder S, Abdullah W, Al Sayegh H. GIS-based employment availabilities by mode of transport in Kuwait. *Appl Geomat*. 2021;1–15.
14. Du F, Mao L, Wang J, Jin H. Inferring transit-based health seeking patterns from smart card data—A case study in Beijing, China. *Health Place*. 2020;65:102405.
15. Ngowi KA. Measuring Geographical Accessibility to Healthcare Facilities in Peri-Urban dwellers in Mbeya City, Tanzania. *MUST J Res Dev*. 2021;1(5):15–15.
16. Daniel CB, Mathew S, Saravanan S. Network constrained and classified spatial pattern analysis of healthcare facilities and their relationship with the road structure: a case study of Thiruvananthapuram city. *Spat Inf Res*. 2021;1–15.
17. Ni J, Qian T, Xi C, Rui Y, Wang J. Spatial distribution characteristics of healthcare facilities in Nanjing: Network point pattern analysis and correlation analysis. *Int J Environ Res Public Health*. 2016;13(8):833.
18. Organization WH. Social determinants of health. WHO Regional Office for South-East Asia; 2008.