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Geospatial Modelling and Buffer-Based Accessibility Analysis of Health Facilities in Onitsha, Anambra State, Nigeria

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ABSTRACT :

Access to functional and well-distributed health facilities is a cornerstone of Universal Health Coverage (UHC) and Sustainable Development Goal 3 (Good Health and Well-being). In rapidly urbanising Nigerian commercial cities such as Onitsha, unplanned growth and high building density often outpace the provision of health infrastructure, raising questions about the physical, geometric accessibility of existing facilities. This study applies a Geographic Information System (GIS)-based Euclidean buffer approach to examine the spatial distribution and physical (proximity) accessibility of hospitals, pharmacies, and other healthcare facilities in Onitsha North and Onitsha South Local Government Areas (LGAs), Anambra State. Sixty-one facility locations (F001–F061) were digitised in ArcGIS, projected to the Universal Transverse Mercator (UTM) Zone 32N (WGS 84) coordinate reference system, and a 500 m Euclidean service-area buffer was generated around each facility. The individual buffers were dissolved and overlaid on the administrative boundary to compute the proportion of each LGA's land area lying within, versus outside, the 500 m Euclidean proximity buffer.

Results reveal a markedly clustered distribution of facilities, concentrated along the Onitsha–Owerri Road corridor and within the core commercial districts of Onitsha South, producing extensive buffer overlap in these areas, while the north-eastern and eastern fringes of Onitsha North, closer to Ogidi, remain sparsely served or entirely outside the 500 m Euclidean proximity buffer. The study concludes that facility siting in Onitsha appears more strongly aligned with commercial viability and trade-route accessibility than with even geographic coverage of the study area.

Keywords: GIS; Euclidean buffer analysis; health facility accessibility; spatial coverage; Onitsha; Anambra State; Universal Health Coverage

1. Introduction

Equitable access to healthcare is widely recognised as a fundamental determinant of population health outcomes and a central pillar of Universal Health Coverage (UHC), which the World Health Organization defines as ensuring that all people have access to needed promotive, preventive, curative, rehabilitative, and palliative health services of sufficient quality, without financial hardship. Geographic or physical accessibility — the ease with which a location can be reached in space — is one of the most measurable dimensions of this broader concept, and it is here that Geographic Information Systems (GIS) have proven indispensable. By combining facility location data with administrative-boundary and road-network layers, GIS enables planners to visualise and quantify the spatial pattern of health-service provision, as a foundation for the more comprehensive, population-weighted assessments that typically follow.

In Nigeria, health policy has historically addressed the distribution of facilities at a macro, state, or regional scale, while the finer-grained, intra-urban distribution of hospitals, clinics, and pharmacies within individual cities has received comparatively little empirical attention. Yet it is precisely at this intra-urban scale that spatial imbalances are most consequential for the daily lived experience of residents: a facility inventory may look adequate in aggregate while, in practice, being clustered in a handful of commercially advantageous neighbourhoods and largely absent elsewhere.

Onitsha, in Anambra State, presents a particularly instructive case. As one of West Africa's largest commercial and riverine trading cities, anchored by the Main Market and Ochanja Market, Onitsha has experienced sustained in-migration and largely unplanned densification over several decades. Onitsha North and Onitsha South LGAs together host one of the highest population densities of any urban area in Anambra State, concentrated on a comparatively small land area bounded by the River Niger to the west and the Onitsha–Owerri Road corridor to the south-east. This combination of high density, intense commercial land-use pressure, and historically market-driven rather than planned facility siting makes Onitsha a valuable test case for GIS-based accessibility modelling. Despite the city's commercial prominence, there is no published, spatially explicit inventory and buffer-based accessibility assessment of its health facilities that jointly considers hospitals, pharmacies, and other primary healthcare outlets across both constituent LGAs. This gap motivates the present study, which is scoped deliberately as a geometric, area-based buffer analysis.

1.1 Aim and Objectives

The study aims to model the spatial distribution and physical (geometric) accessibility of health facilities in Onitsha using a GIS-based Euclidean buffer approach. The specific objectives are to:

- Map and classify the existing hospitals, pharmacies, and other healthcare facilities in Onitsha North and Onitsha South LGAs using ArcGIS;
- Generate a 500 m Euclidean service-area buffer around each facility appropriate to the city's dense urban fabric;
- Analyse the resulting buffer coverage, expressed as a proportion of each LGA's land area, to identify zones of facility clustering, redundant coverage, and accessibility gaps; and
- Draw planning-relevant conclusions and recommendations for equitable health-facility siting in Onitsha.

1.2 Research Questions

- What is the spatial pattern of hospitals, pharmacies, and other healthcare facilities across Onitsha North and Onitsha South?
- What proportion of each LGA's land area falls within a 500 m Euclidean proximity buffer of a mapped health facility?
- Where are the principal area-based accessibility gaps, and what factors plausibly explain the observed pattern?

1.3 Justification and Scope

The study is justified on three grounds. First, methodologically, it demonstrates a replicable, low-cost GIS buffer workflow that can be applied by planning authorities with modest data and software requirements. Second, empirically, to the best of the authors' knowledge, few published studies have provided a facility-level, dual-LGA geometric accessibility assessment of Onitsha in south-eastern Nigeria. Third, practically, its outputs are directly usable by the Anambra State Ministry of Health and Onitsha's LGA planning departments as a screening tool for the evidence-based siting of new primary healthcare centres.

The scope of the study is strictly limited to physical (geographic) accessibility as measured by Euclidean straight-line buffers around mapped facility points, evaluated against administrative-boundary land area. It does not assess, and does not incorporate as a data layer, population distribution, built-up-area or land-use extent, facility capacity, staffing, service quality, or affordability.

2. Literature Review

A growing body of Nigerian scholarship has applied GIS buffer and network-analysis techniques to health-facility accessibility, generally converging on a common finding: health infrastructure in Nigerian cities and rural local government areas is spatially skewed, with clustering in administrative or commercial cores and pronounced gaps at the periphery.

In north-eastern Nigeria, an early and frequently cited study modelled the spatial distribution and accessibility of the healthcare delivery system in Yola using kernel density estimation and Euclidean buffer operations, and reported that the city's 56 documented facilities (64% public, 36% private) were heavily concentrated in the Jimeta district, leaving the northern and western parts of the city, and southern Yola-Town, inadequately served relative to a one-kilometre proximity standard (Abdurrahman & Nurtinnisa, 2013).

A related study of Enugu urban area combined GPS-based facility geolocation with ArcGIS network analysis to determine the closest facility and shortest emergency route for every settlement, and similarly found that most healthcare facilities were concentrated in Enugu North LGA, with other constituent LGAs and settlements comparatively deprived, prompting a recommendation to treat the resulting facility map as a spatial decision-support tool for future siting decisions (Ejiagha, Ojiako, & Eze, 2012).

Working in Kaduna State, researchers assessing Igabi LGA used kernel density estimation and nearest-neighbour statistics to demonstrate significant spatial inequity in primary healthcare provision (Ogunmola, Adebawale, & Ademola, 2020; extended in Abubakar, Tanim, & Samaila, 2025). At a larger, state-wide scale, a cluster-and-buffer analysis of healthcare facilities across Plateau State applied multiple buffer distances (0.5, 1, and 2 km for settlements, and 1 to 10 km for broader Euclidean proximity buffers) and documented over 1,190 facilities of markedly uneven density across Local Government Areas (Danlami et al., 2023).

Beyond Nigeria, the World Health Organization's widely adopted benchmark that populations should, for optimal access, reside within approximately 5 km (roughly a one-hour walk) of the nearest health facility has been operationalised through buffer analysis in numerous African contexts, including Ghana's Ashanti Region and South Sudan (South Sudan Ministry of Health et al., 2012). While the 5 km standard is appropriate to predominantly rural, low facility-density settings, dense commercial cities such as Onitsha warrant a tighter, more conservative buffer; the present study accordingly adopts 500 m, consistent with Euclidean proximity buffer standards used in compact urban service-area planning.

3. The Study Area

Onitsha is a major riverine port and commercial city on the eastern bank of the River Niger, in Anambra North Senatorial District, Anambra State, south-eastern Nigeria. Administratively, the city comprises two Local Government Areas: Onitsha North, whose headquarters and the Main Market are located within its boundaries, and Onitsha South, headquartered at Fegge and home to the Ochanja Market. Onitsha North covers approximately 37.5 km² and Onitsha South covers a much smaller, more densely built 9.9 km². Both LGAs recorded population figures among the highest densities of any LGA in Anambra State at the 2006 national census, with subsequent official projections indicating continued growth.

The city's economy is dominated by wholesale and retail trade; the Main Market and Ochanja Market rank among the largest in West Africa and generate intense, continuous pedestrian and vehicular traffic along key arteries including the A232 trunk road, Zik Avenue, and the Onitsha–Owerri Road, which forms the south-eastern boundary of the study area toward the neighbouring town of Ogidi. This commercial gravity has historically shaped where private health facilities — particularly pharmacies and small private hospitals — choose to locate, typically clustering along or near major trade corridors where footfall and clientele are highest. Onitsha North is additionally flood-prone along its riverine western margin, a further consideration in facility siting and resilience planning. The combination of high density, intense commercial land-use, historically organic urban growth, and a navigable river boundary makes Onitsha both a challenging and analytically rich setting for GIS-based health-accessibility modelling.

4. Materials and Methods

4.1 Data Sources and Acquisition

The study relied on the following data layers:

- Health facility point data: geo-referenced locations of hospitals, pharmacies, and other healthcare facilities (clinics, maternity homes, primary health centres) across Onitsha North and Onitsha South, obtained through a combination of field identification / handheld GPS capture and on-screen digitisation against high-resolution basemap imagery, and coded with unique facility identifiers (F001–F061).
- Administrative boundary data: the Onitsha study-area (LGA composite) boundary, digitised from official administrative boundary shapefiles.
- Road network data: the primary and secondary road network, including the A232 corridor and Onitsha–Owerri Road, used for cartographic context and to support subsequent network-based analysis in future work.
- Basemap and reference imagery: ArcGIS Online basemap services (streets/topographic layer) for on-screen digitising and cartographic referencing.

4.2 Software and Coordinate Reference System

All spatial data processing, geoprocessing, and cartographic output were carried out in Esri ArcGIS (ArcMap/ArcGIS Pro). To ensure metric accuracy in distance-based buffer computation, all layers were projected from the WGS 1984 geographic coordinate system into the Universal Transverse Mercator (UTM) Zone 32N (WGS 84) projected coordinate system, which is the appropriate UTM zone for Anambra State, Nigeria, and preserves distance and area fidelity for local-scale analysis. Buffer analysis using geographic (unprojected) coordinates was explicitly avoided, since degree-based buffering distorts real-world distances.

4.3 GIS Workflow

The analysis followed a sequential, reproducible ArcGIS workflow, summarised below and forming the methodological backbone of both the map product and this manuscript:

1. Project set-up: creation of a personal/file geodatabase and definition of the working coordinate system (UTM Zone 32N, WGS 84).
2. Data acquisition and digitising: field identification and GPS logging of health facilities, supplemented by on-screen heads-up digitising against basemap imagery; each facility was attributed with a unique ID (F001–F061), name, and facility type (Hospital, Pharmacy, or Healthcare/other).
3. Data cleaning and topology checks: removal of duplicate points, correction of mis-attributed facility types, and a topology check to ensure all facility points fell within the study-area boundary.
4. Projection: reprojection of all layers (facility points, road network, administrative boundary) to the common UTM Zone 32N (WGS 84) projected coordinate system.
5. Buffer generation: application of the Buffer geoprocessing tool to the facility point layer with a fixed 500 m radius Euclidean proximity buffer around every facility.
6. Dissolve and overlay: buffers were dissolved into a single coverage polygon and overlaid on the LGA boundary using the Intersect / Clip tools to quantify covered versus uncovered land area within Onitsha North and Onitsha South separately.
7. Gap identification: the uncovered residual area (LGA boundary minus dissolved buffer) was extracted using the Erase tool to delineate accessibility-gap polygons, measured in km², for subsequent interpretation.
8. Cartographic output: symbolisation of facilities by type (hospital, pharmacy, healthcare/other), rendering of the 500 m buffer layer, and production of the final A4 portrait layout map, including scale bar, north arrow, coordinate graticule, legend, and inset locator maps (Nigeria → Anambra State → Onitsha).

4.4 Analytical Techniques

Beyond the core buffer operation, the study applied the following complementary, area-based analytical techniques, consistent with methods established in the reviewed literature (Abdurrahman & Nurunnisa, 2013; Ejiagha et al., 2012; Danlami et al., 2023):

- Buffer overlap analysis: identification of zones with two or more overlapping 500 m buffers, indicating redundant coverage and potential over-supply relative to competing, underserved areas.
- Gap-area delineation: extraction and area (km²) measurement of zones falling entirely outside any 500 m buffer, interpreted as priority zones for future facility siting.

5. Results

5.1 Spatial Distribution of Health Facilities

A total of 61 unique facility identifiers were assigned across the combined study area, comprising hospitals (heart/cross symbol), pharmacies (blue cross symbol), and other healthcare facilities (purple triangle symbol).

LGA	Hospitals	Pharmacies	Other Healthcare Facilities	Total
Onitsha North	30	8	3	41
Onitsha South	15	1	4	20
Total	45	9	7	61

Table 1. Inventory of mapped health facilities by type and Local Government Area, Onitsha

Visually, the distribution is strongly non-random. Facility density is highest in a contiguous band running through central Onitsha South — encompassing the Ochanja Market axis and the neighbourhoods immediately south and east of it — where individual 500 m buffers overlap extensively, in places three- and four-deep, producing a near-continuous zone of coverage redundancy. A secondary, smaller cluster is evident in the northern part of Onitsha North, again aligned with major road frontage rather than with any single residential nucleus. Between and beyond these two clusters, particularly toward the north-eastern edge of Onitsha North and the south-eastern boundary abutting the Onitsha–Owerri Road toward Ogidi, facility density falls sharply, and several buffer circles stand in isolation with wide unbuffered gaps between them.

5.2 Buffer Coverage and Accessibility Gaps

Dissolving the individual 500 m buffers into a single coverage layer and intersecting it with the LGA boundaries shows that the two clustered zones described above account for a disproportionate share of total buffered land area relative to their geographic footprint, while substantial contiguous portions of the eastern and north-eastern study area — including land flanking the Onitsha–Owerri Road corridor toward Ogidi and the northern extremity of Onitsha North — fall outside any 500 m Euclidean proximity buffer.

Metric	Onitsha North (km ²)	Onitsha South (km ²)	Total (km ²)
Study-area extent	37.5	9.9	47.4
Area within 500 m buffer	14.01	5.24	19.25
Area outside 500 m buffer (gap)	28.15	4.66	23.01
Percentage of LGA land area covered (%)	37.4%	52.9%	40.6%

Table 2. Summary of 500 m buffer land-area coverage by Local Government Area

5.3 Facility Type Composition

Hospitals constitute the largest single category of mapped points, distributed relatively broadly across both LGAs, while pharmacies show the tightest correlation with major road frontage, consistent with their dependence on passing commercial footfall. The ‘other healthcare’ category (clinics, maternity homes, and primary health centres, marked by the triangle symbol) is the smallest and most spatially restricted, appearing almost exclusively within or adjacent to the dense Onitsha North cluster — the category most directly associated with primary/preventive care is therefore also the least evenly distributed across the study area.

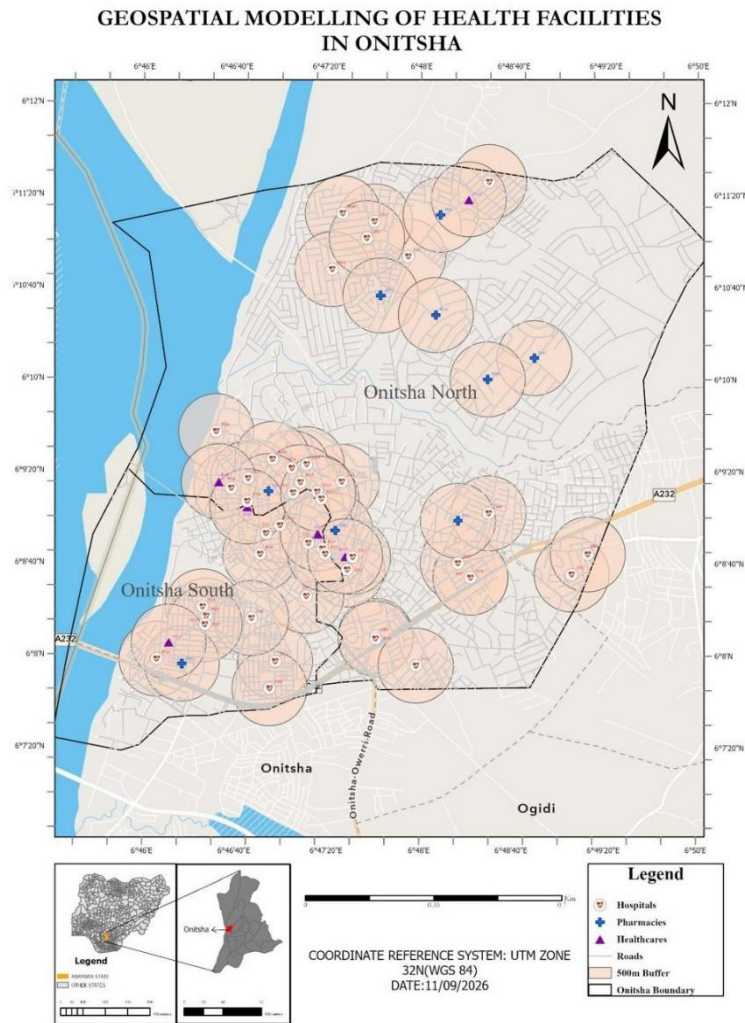


Figure 1. Geospatial modelling of health facilities and 500 m Euclidean buffer coverage, Onitsha North and Onitsha South LGAs, Anambra State, Nigeria.

6. Discussion

The results confirm, for Onitsha, a spatial pattern repeatedly documented elsewhere in Nigeria: health-facility siting tracks commercial and road-network advantage more closely than it tracks even geometric coverage of the administrative area (Abdurrahman & Nurünnisa, 2013; Ejiagha et al., 2012; Ogunmola et al., 2020; Danlami et al., 2023). The pronounced clustering around the Ochanja Market axis in Onitsha South is readily explained by the same commercial logic that has historically shaped the city's market geography: private hospitals and, especially, pharmacies benefit from locating where trading footfall is highest. The consequence, visible directly in the buffer map (Figure 1), is a coverage surplus — multiple overlapping 500 m Euclidean proximity buffers — in the commercial core, alongside a coverage deficit toward the urban fringe.

This has two related planning implications, stated carefully within the area-based scope of this study. First, from a coverage-equity standpoint, new public investment in primary healthcare centres should be directed toward the identified gap zones in north-eastern Onitsha North and the Onitsha–Owerri Road corridor toward Ogidi, rather than toward the already over-provisioned commercial core, echoing the siting recommendations made for Igabi LGA and Plateau State (Ogunmola et al., 2020; Danlami et al., 2023). Second, the fact that the ‘other healthcare’ category — the facility type most associated with primary and preventive services rather than acute or specialist hospital care — is also the most spatially restricted category suggests that Onitsha's apparent facility abundance is skewed toward curative, commercially viable service types. Compared with the WHO's broader standard for rural/peri-urban access benchmark, the 500 m threshold applied here is intentionally conservative and appropriate to Onitsha's pedestrian-dense, congested urban fabric, where a five-kilometre buffer would encompass nearly the entire study area and would obscure the fine-grained pattern the map reveals. This choice aligns methodologically with urban pedestrian-catchment conventions rather than the rural WHO standard, and is consistent with the one-kilometre threshold adopted in the comparable Yola study (Abdurrahman & Nurünnisa, 2013), scaled down further to reflect Onitsha's even higher density.

7. Conclusion and Recommendations

This study applied a GIS-based 500 m Euclidean buffer approach in ArcGIS, using the UTM Zone 32N (WGS 84) projection, to model the spatial distribution and area-based physical accessibility of hospitals, pharmacies, and other healthcare facilities across Onitsha North and Onitsha South LGAs. The analysis confirms a strongly clustered facility distribution aligned with Onitsha's commercial geography, producing redundant buffer coverage in the Ochanja Market core and material area-based accessibility gaps toward the northern and eastern margins of the study area, particularly along the Onitsha–Owerri Road corridor. These findings are consistent with, and extend to a previously unstudied city, a pattern of commercially rather than equitably driven health-facility siting documented across several other Nigerian urban and state-level studies.

On this basis, the study recommends that:

1. The Anambra State Ministry of Health and the two LGA planning authorities treat the identified gap zones as priority screening areas for new primary healthcare centre siting, pending confirmation against population and built-up-area data (recommendation ii, below).
2. Subsequent accessibility assessments in Onitsha adopt network-based service-area analysis to account for the River Niger, rail line, and road-congestion barriers to actual pedestrian movement.
3. The facility geodatabase underlying this study be maintained as a living dataset, updated periodically to reflect new facility openings and closures.
4. Future research — identified as the most immediate and highest-value next step — extend the present geometric-accessibility model with gridded population data and a built-up/land-use area layer, together with facility-level capacity, staffing, and service-quality data, to build a fuller, multidimensional, population-weighted picture of healthcare access in the city, in direct support of Universal Health Coverage and SDG 3 targets.

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