Innovations

A Review of Road Connectivity in Ogbomoso North Local Government Area, Oyo State, Nigeria

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Abstract: *This study focuses on the review of the road network connectivity in Ogbomoso North Local Government Area (LGA) using graph theory principles. The topological structure of the road network is considered a pivotal factor influencing urban dynamics and emphasizing the importance of reviewing road network characteristics in urban transportation planning. The study divides the case study into ten (10) wards using advances in geographical information system (GIS) and employs the Network Analyst extension of ArcGIS to compute various connectivity indices, including cyclomatic number, alpha index, beta index, gamma index, network density, and completeness. The analysis reveals Osupa ward with the highest connectivity indices and congestion but the second-highest network density result, while Okelerin ward, with the highest network density, exhibits the lowest connectivity indices. Furthermore, road types are delineated, highlighting Ogbomoso-Ilorin as the only highway with secondary and primary designations, devoid of bridges. Additionally, a modest correlation is observed in the degree of nodes and edges across all connectivity indices. Osupa ward, with superior connectivity indices, exhibits the highest degree of nodes and edges. In contrast, Abogunde ward, with the lowest degree, still demonstrates slightly better connectivity indices than Okelerin ward, identified with the lowest connectivity indices. The completeness of road connectivity is inversely proportional to other connectivity indices, as demonstrated by Osupa ward's 0% completeness in contrast to Abogunde's 4%. In conclusion, these findings contribute valuable insights into varying degrees of connectivity, density, and road types, enhancing our understanding of road network dynamics.*

Keywords: *Road connectivity, GIS., Connectivity indices.*

I. Introduction:

The structure and design of road networks influence the overall usefulness and accessibility of an area as well as how goods and people move through it, both of which have a big impact on urban development.Roads are the spine of society and are vital to the development of the economy and social cohesion.In urban settings, especially in business hubs like marketplaces, easily accessible transportation choices are essential.However, unplanned urban growth typically leads to shoddy road infrastructure, which worsens traffic conditions and decreases overall road connection.Good roads and strong connections make planning regions more attractive, reduce travel expenses, and boost economic productivity.According to Akinola (2023), traffic congestion is caused by a combination of factors such as increased motorization and inadequate road networks, and it significantly affects both productivity and urban infrastructure.Multidimensional development indicators cannot work well without an improved road link.It expands employment opportunities and significantly improves access to needs including markets, medical care, and education (Munir et al., 2021).Greater accessibility promotes local economic growth and improves quality of life.However, inadequate connectivity impedes development by isolating regions and obstructing socioeconomic progress by limiting access to opportunities and vital resources.

The geography of Ogbomoso North is presently represented by its road connection, which has both major strengths and challenges.While several areas boast outstanding connectivity and accessibility, others suffer from subpar infrastructure, including low capacity and poor maintenance.Road irregularities hinder economic activity and reduce transit efficiency, causing issues for both businesses and residents.Certain locations particularly residential districts and significant commercial hubs need immediate attention due to traffic and inadequate infrastructure.These issues must be resolved in order to meet the increasing needs of urban growth.To facilitate smooth connections and meet the region's growing socioeconomic demands, the road network will need to be strategically enhanced and improved (Oluwaseyi, 2021).Ideally, Ogbomoso North's road system will connect all of the communities, facilitating smooth transportation and business transactions.However, the current infrastructure in some areas of study, which is characterized by inconsistent road conditions and poor infrastructural upkeep, hinders the region's socioeconomic development.These difficulties have a significant impact on day-to-day living, making it harder for residents to obtain essential services, limiting their access to economic opportunities, and generally lowering their standard of living.

II. Literature Review:

Roads are essential to the socioeconomic foundations of communities worldwide and serve as the backbone of connectivity.By linking producers with markets, they act as the backbone of the economy, fostering trade, industry, and wealth.These business channels facilitate the smooth exchange of goods and services, which fosters economic growth, increases market accessibility, and lowers transportation costs.In addition to facilitating commerce, highways also serve to link communities and give access to necessities like healthcare and education, strengthening the social fabric.They are vital to rural agriculture because they make it possible for products to be transported to markets, reduce spoilage, and improve farmers' quality of life.Robust road networks serve as the cornerstone of urban development, shaping city plans, managing traffic, and promoting cities' sustainable expansion. Road width, surface materials, drainage systems, and signage are all part of the design and engineering process, which guarantees longevity and security. Maintenance and upkeep, which is essential to extending the life of a road, includes routine resurfacing, repair, and inspection. Additional features, interchanges, bridges, and tunnels complete the network by promoting connectivity and allowing for smooth transitions. Tools for traffic management, road markings, speed limit signs, and traffic signals control the flow of traffic, guaranteeing efficiency and safety. Dependability of road infrastructure depends on these essential components.

II A. Road Connectivity in Urban Development:

One of the fundamental ideas of urban development is the concept of road linkage, which explains how linked road networks advance social growth.It is crucial to urban environments because it makes it easier for people, goods, and services to move freely, which promotes economic growth and shapes the urban fabric(Maity et al, 2021).Urban transportation planning concepts emphasize the basic theories and methods that guide the strategic planning and building of road networks.These rules are necessary to ensure accessibility, facilitate smooth mobility within cities, and coordinate the thoughtful placement of road infrastructure to meet the evolving needs of urban regions.(Ali et al, 2021).

II B. Traffic Flow Analysis:

Traffic flow analysis is the process of obtaining, examining, and assessing data regarding the movement of vehicles on roadways. Analysts can discover trends, understand the dynamics of congestion, and pinpoint areas that are prone to bottlenecks or inefficient traffic movement by using traffic flow patterns. This study makes use of a wide range of data sources, including traffic count, manual observations, and historical data. The core heart of the city (Oja-igbo, Patemata, Ojajagun among others) was where the sprawl started from to the peripherals.

III. Methodology:

The present Ogbomoso North Local Government Area with its Administrative Headquarters at Kinnira was carved out of the Old Ogbomoso Local Council on the 27th September, 1991, the Old Ogbomoso Local Council was however established on 1st of April, 1973. The Local Government being an urban area is strategically located and serves as link to Northern part Nigeria.

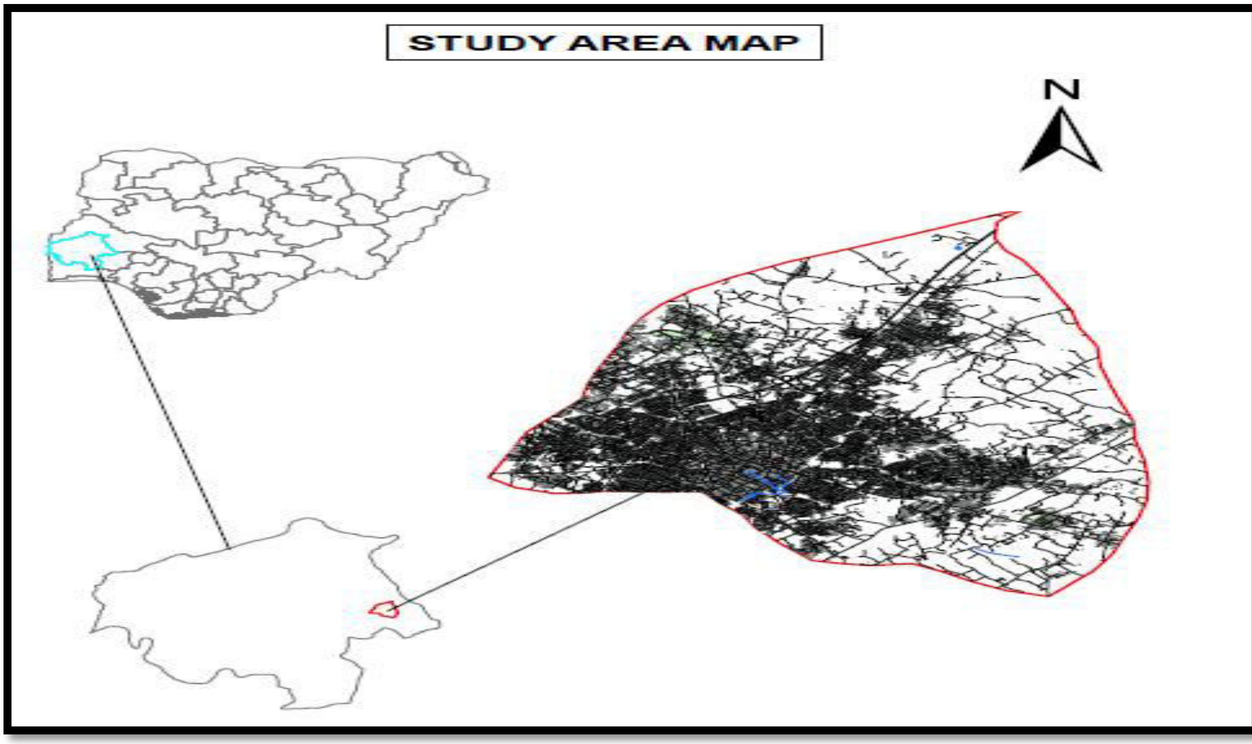

Fig 1.1: Map of Ogbomoso North Local Government Area

Source: Arc GIS Software

The population of the study comprises of all the roads connecting areas within Ogbomoso North LGA including, Abogunde, Alasa, Jagun, Aje-Ogunbado, Saja/Isale-Ora, Isale-Afon, Okelerin, Osupa, Aguodo-Masifa and Sabo/Tara are the ten (10) political wards in the study area. Various areas made up of each political ward such as Abogunde, Baaki, Ojude-Atunlakate, Ojude-Alagutan among others in Abogunde ward. Alasa ward comprises of Ita-alasa, Al-toeed, Omosin, Owode, Oke-owode, Ile-ewe, Ogbegun among others. Jagun ward comprises of Oja-jagun, Ojude-abosa, Laka, Atunlakate among others. Aje-ogunbado comprises of Ajee, Ogunbado, Okeagbede, Ojude-abese, Ojudeladanu among others.Isale-afon comprises of Isale-afon, Oja-igbo, Ode elenji, Ebu-akandie, Ode-olode among others. Saja/isaleafon comprises of Isaleora, Saja, Oloko, Ojude-aremo, Osaa-roo among others. Osupa ward comprises of Takie, Adiatu, City, Aje-ikose, Kinnira, NTA

area, Papa-alajiki, Randa, Blind centre, Ayedade, Papa ajiboye, Olomi among others. Masifa-Aguodo comprises of Masifa, Kuye, Aduhin, Gaa-masifa, Lautech, Stadium among others. Sabo/tara comprises of Taraa, Sekoni, Apake, Oja-tuntun, Sabo, Okeanu, Iwagba, Maryland among others. Oke-elerin ward comprises of Oke-elerin, Ojudeabegan, Ojudejagilegbo, GB-area, Ogede among others. The data analysis was conducted using the ArcGIS software, specifically employing the Network Analyst extension. The process involved importing and integrating the collected data into the ArcGIS environment, configuring network datasets, and executing analyses to generate the desired connectivity indices, the dataset of the case study road network was first digitized into wards and processed to eliminate all topological errors, which was then converted into a network dataset for use in Network Analyst toolbox. Network datasets were created from source features, including simple features (lines and points) and turns, to store the connectivity of the source features. Afterwards, the count of nodes and edges was obtained from the network dataset to compute the aforementioned connectivity indices. Finally, the model was created and further analyzed to check for correlations between the road connectivity indices. The following steps was done to actualize the whole analysis:
Step 1: Import the OSM data and use the DivGIS as the overlay.
Step 2: Data Processing:

- Clip the dataset to the study area boundary using the World Geodetic System (WGS) 84 Northern hemisphere Zone 32 Coordinate system.
- Analyse road's topology and check for errors.

Step 3: Comprehensive analysis of the following:

- the degree of Node to check the count of cluster areas and points
- the connectivity indices such as alpha index, beta index, Gamma index and network density
- Classify the data based on the types of road and congestions.

Step 4: Brief correlation analysis between all the connectivity indices to answer the research question using Excel Software.

IV. Results & Discussions:

The connectivity indices as well as the number of nodes and edges of each wards in Ogbomoso North was collected due to the analysis done in ArcGIS software as shown in Table 1.1 (a and b).

Table 1.1 (a): Nodes, Edges and Other Connectivity indices of each wards

S/N	Wards	Edges (e)	Node(v)	Alpha (α)	Beta(β)	Gamma (μ)	Cyclomatic Number (μ)	Completeness
1	Abogunde	53	36	0.238806	1.472222	0.519608	18	4%
2	Alasa	115	73	0.29078	1.575342	0.539906	43	2%
3	Jagun	85	61	0.196581	1.393443	0.480226	25	2%
4	Aje-Ogunbado	321	211	0.261391	1.521327	0.511962	111	1%
5	Saja/Isale-Ora	321	199	0.307888	1.613065	0.543147	123	1%
6	IsaleAfon	124	94	0.15847	1.319149	0.449275	31	1%
7	Okelerin	162	124	0.152263	1.306452	0.442623	39	1%
8	Osupa	3886	2372	0.319266	1.63828	0.546554	1515	0%
9	AguodoMasifa	1450	923	0.285714	1.570964	0.524792	528	0%
10	Sabo / Tara	2637	1671	0.289182	1.578097	0.526663	967	0%

Table 1.1 shows high value of the cyclomatic number which indicates a highly connected network($u = e-v+1$). Gamma index measures connectivity that considers the relationship between the number of observed links and the number of possible links. The value of gamma is between 0 and 1, where a value of 1 indicates a completely connected network and would be extremely unlikely in reality. Alpha measures graph connectivity. Beta index is used to assess the connectivity of city road networks. A higher index indicates better connectivity, whereas a lower index shows insufficient connectivity in some places.

Table 1.1 (b): Area, length and Network densities of each wards

S/N	Wards	Area	Length (km)	Network density
1	Abogunde	4562805	15	0.003287451
2	Alasa	9534098	32	0.003356374
3	Jagun	3282180	17	0.005179484
4	Aje-Ogunbado	4384369	47	0.010719901
5	Saja/Isale-Ora	12516917	63	0.005033188
6	IsaleAfon	1896583	18	0.009490753
7	Okelerin	1633804	25	0.015301713
8	Osupa	49885257	533	0.010684519
9	AguodoMasifa	49408611	433	0.008763655
10	Sabo / Tara	60345141	443	0.007341105

A brief statistical description of all the parameters used which is provided in Table 4.2 below. The following subsection explains each of the network parameters in details.

Table 1.1b shows sabo/tara to have the highest road area of 60345141m^2 and 443km length while osupa has 49885257m^2 and 533km length of roads. Aguodo/masifa ward has a total of 49408611m^2 area for road with 433km length. The smallest wards has 1633804m^2 (oke-elerin) with 25km length of road while Abogunde ward has the lowest road length of 15km.

Table 1.2: Descriptive statistics of connectivity indices

Network Parameters	Average	Standard Deviation	Max	Min
Alpha	0.250034	0.058018	0.319266	0.152263
Beta	1.498834	0.114653	1.63828	1.306452
Gamma	0.508476	0.036073	0.546554	0.442623
Cyclomatic Number (μ)	2.348951	0.472555	2.63828	0.973388
network density	0.007916	0.003628	0.015302	0.003287
Edges	915.4	1266.833	3886	53
Nodes	576.4	778.9008	2372	36

Alpha (α) Index

As shown in Figure 1.1, the alpha index whose value is between 0 and 1, indicates a more or less connected and efficient network. Figure 1.2, shows that Okelerin ward has the smallest alpha index while Osupa has a slightly better value, though the average value recorded was 0.25, which still depicts that Ogbomoso North roads are not well connected.

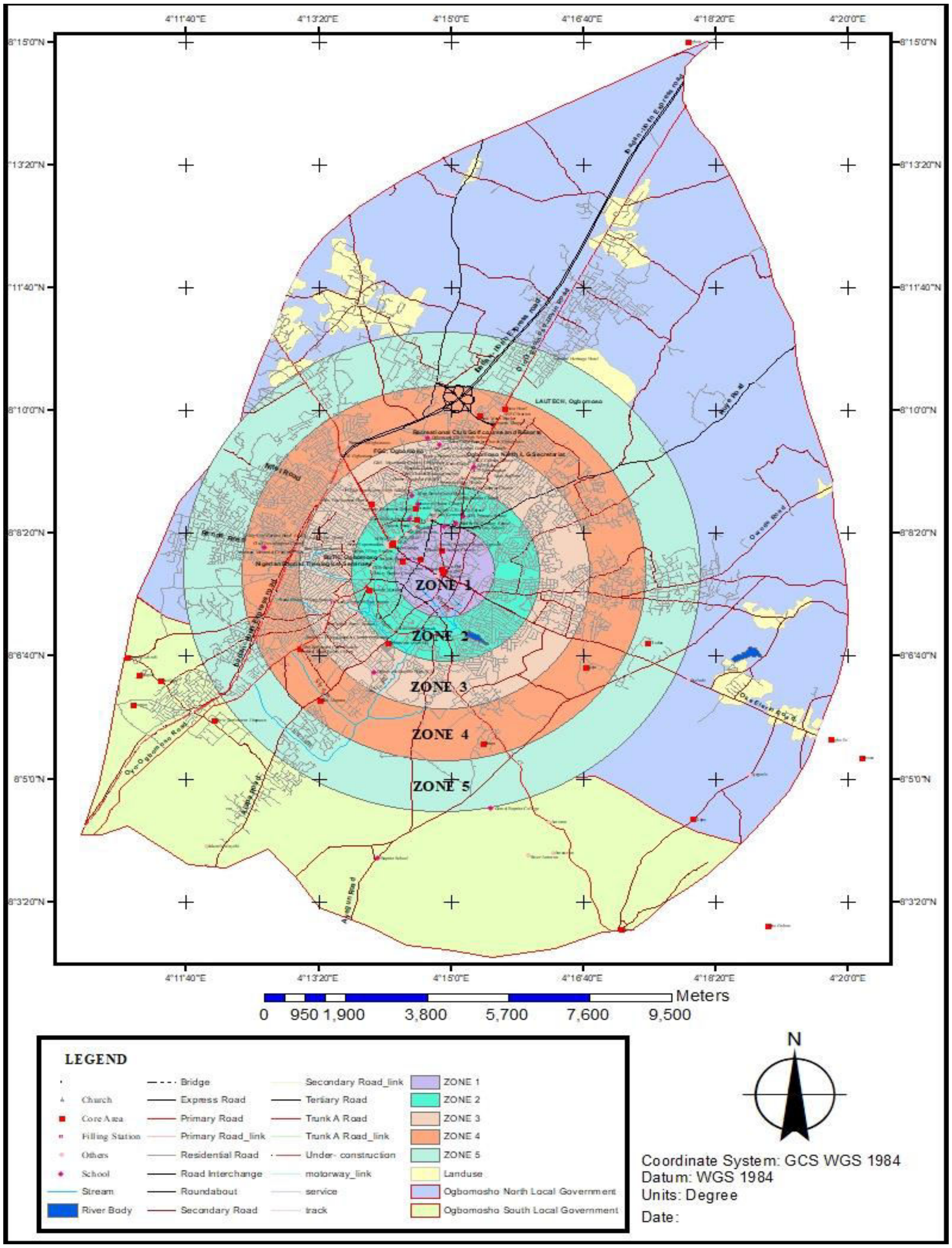

Fig 1.2: Ogbomoso North map
Source: author's field work, 2024.

Point of Congestion:

Congestion points are typically areas where the volume of vehicles exceeds the capacity of the road infrastructure, resulting in reduced traffic speed and potential disruptions, was done for elucidating Objective 4, as illustrated in Table 4.5. As shown in Figures 4.16 - 4.17, Osupa ward is identified as a high congestion point.

This observation is validated by the Alpha, Beta, and Gamma indices, all of which exhibited the highest values within this specific ward.

Table 1.3: Point of Congestion (PoC)

Wards	Number of PoC
Abogunde	0
Alasa	0
Jagun	0
Aje-Ogunbado	1
Saja/Isale-Ora	0
IsaleAfon	1
Okelerin	1
Osupa	14
AguodoMasifa	7
Sabo / Tara	9

V. Conclusion

This study evaluated the effectiveness of the road network in terms of connectivity and coverage, which in turn highlights its accessibility. The quantitative assessment of connectivity of road network provides a better understanding of the road structure and helps the transportation system to propose new routes to enhance accessibility and coverage. The road connectivity analysis of Ogbomoso North LGA conducted in ArcGIS software revealed some intricate patterns. Osupa ward despite having the highest connectivity indices and congestion, ranks second in network density, while Okelerin ward, with the highest density, exhibits the lowest connectivity indices. Notably, a modest correlation in node and edge degrees influences connectivity. Surprising results show Abogunde ward, with fewer nodes and edges, displaying slightly better connectivity than Okelerin. The inverse relationship between completeness and congestion is evident, with Osupa highly congested but 0% complete, and Abogunde less congested but 4% complete. The unique characteristics of Ogbomoso-Ikirun road further emphasize the complexity of the road network in the region.

Despite the significant breakthrough in this analysis, this study was hampered by a major drawbacks that can be improve upon by other researchers in this area, dataset, this study’s analysis only relied on satellite imagery data which cannot be accurate enough as it was limited to other data sources through a proper ground survey of the case study to confirm the validity of the data used.

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