Evaluation of Connectivity Algorithms in Road Network Analysis of Oriire Local Government Area of Oyo State, Nigeria

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ABSTRACT: *Rural road network has been considered as the combinations of several routes into a more or less integrated structure permitting movements between many nodes. The study evaluated road network level of seven (7) villages in Oriire LGA of Oyo State. Oriire LGA is one of the agricultural producing areas of Oyo State this is because the major occupation is agriculture. Geographical information system was used to capture the road network pattern of the study area. Connectivity indices such as alpha (α), beta (β), gamma (γ) and cyclomatic number (μ) were adopted to evaluate the level of connectivity. The result revealed that, (α = 0.87), (β = 1.87), (γ = 0.78) and (μ = 7) which are significant as 0.5, 0.1, 0.5 and 1-10 respectively. These values indicated that, the selected villages have nodal connectivity of at least three (3) and that, the connectivity level is at medium. The study concluded that, the study area is connected by roads however, the connectivity do not tend to the most important village (Tewure) the rural commercial center. It is therefore suggested that, Onigba with the highest nodal connectivity be made a mini-rural market.*

KEYWORDS: connectivity indices, network, rural roads

INTRODUCTION

The study of transportation networks has long been a nexus of scientific fields (Cesar & Igor, 2011). Historically, transportation networks have been examined from the perspective of graph theory, which is a field of mathematics that provides standards and measures for the topology of networks represented as sets of nodes (vertices) connected by hyperlinks (edges) (Adebayo, 2015). The ease with which activities at one location can be reached from another using a specific transport model is referred to as accessibility (Suxia and Xuan, 2003). Rural road networks are becoming an increasingly important level of research for determining how transportation patterns are distributed throughout geographical locations. Networks are commonly used to portray transportation architecture as analogies for its systems and flows. The term network refers to the architecture of pathways that exist within a system of nodes. A route is a single link between nodes that may be part of a larger network. It can apply to physical routes such as roads and railroads, as well as less tangible routes such as air and sea corridors (Abba & Bala, 2019). In other words, a network is defined as the interconnection or connections of a group of system components to form a whole that provides a geographic and well-defined pattern. A network can be either a static property at a specific point in time or dynamic phenomena that changes over time (Chapman, 2008). Nigeria's economic progress has paralleled the advancement of her transportation systems. This is especially true of the country's road transportation infrastructure, which is by far the most popular means of transportation. At least two-thirds of all commodity movements to and from seaports are now handled by road, and up to 90% of all other internal goods and person movements are now handled by road (Abass et al, 2018). A robust rural road network will increase the distribution of agricultural products and provide new prospects for agricultural trade (Cesar et al, 2011). The study therefore, selected seven (7) villages in Oriire LGA of Oyo State, Nigeria with a view of evaluating the level of road connectivity to the rural central place.

LITERATURE REVIEW

Transport network is done to evaluate a certain transportation network and determine unique elements through it. This assessment is accountable for the flow of cars in the developed environment, the network's engineering, and the available forms of transportation. The information acquired during the evaluation is utilized to make changes to the network in order to improve the overall transportation system. The examination of transportation networks must be conducted out by professionals who will consider a variety of factors such as people, freight, car kinds, and road connection, among others. The flow of vehicles through a transportation network is determined using Transport Network Analysis, which commonly employs mathematical graphic theory. It may mix many modes of transportation, for instance, walking and driving, to create multimodal journeys. Finding the most efficient trip route, creating travel directions, locating the nearest facility, and defining service regions based on travel time, are all problems that network analysis may help to solve. In the study of social networks, network analysis is frequently employed, but in the spatial analysis of cities, it has received little attention. While the study of spatial networks dates back to Euler's famous puzzle of Konigsberg's seven bridges in the 18th century, city designers and planners have had no free tools to calculate computation-intensive spatial accessibility measures on dense networks of city streets and buildings until recently. In geographic information science, network analysis is one of the most important and persistent research fields (GIS). This is followed by a succinct but thorough examination of GIS's existing capabilities for network analysis, as well as the resulting flaws in network GIS implementations.

Through expanded implementation of current network theory, development of existing theory and practice in the areas of network design and location, and interactions with a wide variety of other disciplines, set of challenges for network analysis in GIS is offered. The fact that, it represents a major map feature, the line feature is more essential on the maps. Many GIS software packages provide a Line Feature Generalization feature. This generalization involves geometric operations such as selection, merging, symbolization, and elimination, among others. However, there is no official definition of generalization. The Douglas-Peucker (DP) technique is used by the point removal tool in ArcGIS 9.3. This was the most widely used approach, and it was utilized in a variety of applications such as road, river, and coastal line generalization. The graph is composed of set V and set E, denoted as G = (V, E). Set V is a set of vertices of a graph, which are generally used to represent individuals in a real system, set E is a set of edges of a graph, which is a set of relations between vertices, most of which are used to represent the relationships or interactions among individuals in a real system. In G = (V, E), if any node for a, b 2 V, when (a, b) 2 E, (b, a) 2 E may not be true, then this graph is called a directed graph. In the directed graph, two related nodes are usually connected by the edges with an arrow; when (a, b) 2 V, (b, a) 2 E, it is called graph of an undirected graph. An undirected graph's edge has no direction, and an edge without an arrow represents the relationship between vertices.

In an undirected and unweighted graph, the shortest path is the one with the smallest total distance between the source and destination nodes among all feasible pathways, meanwhile in an undirected and weighted network, the shortest path is the one with the smallest sum of weights.This paper models and analyzes a road network using connectivity algorithms and the basic theory of simple networks, with edges occurring between two adjacent villages belonging to the same district as the node j next to each other or on the same line. The road network investigated in this study is a undirected graph that distinguish between uplink and downlink symmetric villages, and uplink and downlink symmetric villages are treated as one and the same.

The road network's adjacency matrix A (n * n) is used to express the connection relationship between these villages, where represents the number of villages in the network, aij = 1 indicates that villages I and j belong to the same villages route and are adjacent, and aij = 0 indicates that stations I and j are not adjacent or do not belong to the same line. Connectivity is a broad term that refers to social bonds formed via the use of mediated communication systems.

Connectedness has been discreetly naturalized as vital to a solidifying global imaginary since the emergence of the World Wide Web and the expansion of mobile communications. One facet of this is the potential of social media platforms to use particular architectural mechanisms. Many studies have been conducted in the field of transportation analysis, with the majority of them focusing on path analysis, such as determining the shortest way and the closest facility. There has also been some work done on the network's accessibility as well as its connectivity. There are many various types of methodologies, each with its own formula for different reasons, which approach should be chosen for network analysis is determined by the study objective. These approaches are used to compare two or more networks at the same time. Which network has the most accessibility and connectivity, for example. Grasp the urban structure necessitates not only a basic understanding of land use but also network connectivity, accessibility, density, and trends. The term connectedness in Transportation Network Analysis refers to a connection between nodes inside a specific network, and it is used to extract the structure of a transportation network. This extraction is far more beneficial for transportation network evaluation.

Connectivity Matrix First must reduce the transportation network to a matrix consisting of ones (1) and zeros (0). If two locations (vertices) are directly connected by a link (edge), code with a 1. If two locations (vertices) are not directly connected by a link (edge), code with a 0, Figure 1 Connectivity is based on topologic distance.

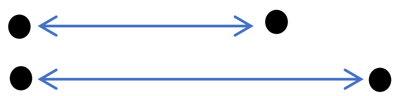


Figure 1: Both of these have a topological distance of 1.

For analyzing the effectiveness of a road network, indices are provided. These indices assist in measuring the level of road network connectivity, accessibility, and density in order to analyze the road network's efficiency. These indices aid in determining the level of road network connectivity, accessibility, and density. Index expresses the relationship between the number of nodes in a network and the number of linkages. Kansky (1963) developed a range of graph theoretical indexes for assessing the interconnectedness of various road networks. Kansky established three of the most widely used graph theoretical measurements of indices which are:

Alpha (α): This is closely related to the gamma index, but its ratio is based on the number of circuits in a network rather than the number of edges/arcs. It is one of the most useful, and perhaps the best measure of the connectivity of a network, especially a fairly complex network. This index expresses the ratio of the number of fundamental circuits to the maximum possible number of circuits, which may exist in the network. It is represented by the formula:

$$\alpha = \frac{\text{Actual circuits}}{\text{Maximum circuits}} = \frac{e - v \times 100}{2v - 5}$$

Beta index (β): This is calculated by dividing the total number of links by the total number of nodes for instance,

$$\beta = \frac{\text{Number of links}}{\text{Number of nodes}} \qquad \beta = \frac{L}{N}$$

Gamma (λ): This index describes in numerical terms, the connectivity of a network. It is the ratio of the number of arcs in a network to the maximum, which may exist between a specified number of vertices or to the maximum possible in that network. The maximum number of edges/arcs possible may be computed from the number of vertices or nodes in the system.

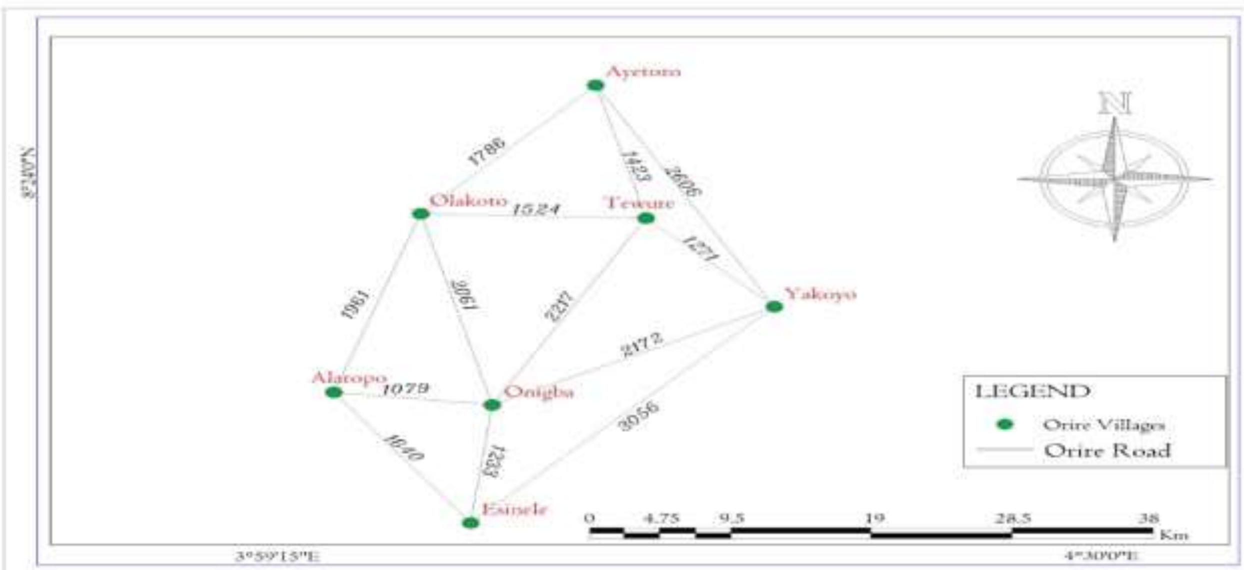
$$\lambda = \frac{\text{No. of arcs}}{3(\text{no. of nodes} - 2)}$$

METHODOLOGY

Oriire local government area (Oyo North) has it headquarter at Ikoyi-Ile. Oriire has an area of 215.4km^2 and a human population of 150,628, (NPC, 2006). Oriire LGA was created on 10th May, 1989 and it was carved out of the former Oyo LGA its land extends from Ipeba river along Oyo-Ogbomoso road to Dogo junction near Igbeti. It shares boundaries with Olorunsogo, Atiba, Ogo-oluwa, Ogbomoso South, Ogbomoso North, Surulere LGAs and Kwara State. The LGA has 10 political wards with principal ethnic groups being Ikoyis, Ogbomosos, Oyos and Ilorins with over

800 towns and villages. Farming is the basic occupation of the inhabitants. The mean height for Oriire L.G.A is 400m above sea level. Oyo North (Ogbomoso South, Ogbomoso North, Orire, Olorunsogo, Orelope, Atisbo,Saki-West, Saki East, Irepo, Iseyin, Itesiwaju, Iwajowa, Kajola). The study population consists of all members of All Farmers Association of Nigera (AFAN) in Oriire. Seven hundred and seventy-four (774) villages, (Adopted from the Map of Oyo State by Ministry of Physical Planning and Urban Development, 2020). Attribute Database Creation, the road attribute database was created from the acquired secondary data in GIS environment. The attributes of each road section or segment digitized was be populated in the database table.

RESULT AND DISCUSSIONS



GIS Map of the Seven Selected Villages in Orire LGA
Source: Author's Field Survey, (2021).

Alpha Index (α)

$$\alpha = \frac{e-v+1}{2v-5} = \frac{13-7+1}{2(7)-5} = \frac{7}{9} = 0.78$$

The alpha index (α = 0.78) showed that the selected villages in Oriire LGA are connected since the alpha value is greater than 0.5. This further explained that, the selected villages (Ayetoro, Olokoto, Tewure, Yakoyo, Alaropo, Onigba and Esinele) are moderately connected with the least direct modal connectivity at 3.

Beta Index (β)

$$\beta = \frac{e}{v} = \frac{13}{7} = 1.86$$

The beta index (β = 1.86) revealed that the selected villages in Oriire LGA are well connected because the beta value is greater than 1.0.

Gamma Index (γ)

$$\gamma = \frac{e}{3(v-2)} = \frac{13}{3(7-2)} \quad \frac{13}{15} = 0.87$$

The gamma index (γ = 0.87) showed that the selected villages in Oriire LGA have high connectivity since the gamma value is greater than 0.5.

Cyclomatic Number (μ)

$$\mu = e-v+1 = 13-7+1 = 7$$

A cyclomatic complexity below 4 is considered good; a cyclomatic complexity between 5 and 7 is considered medium complexity, between 8 and 10 is high complexity, and above 10 is extreme complexity. The cyclomatic value for the plannar network in the selected villages was therefore considered as medium complexity. These results corroborates with Cynthia et al (2020) that, alpha, beta, gamma indices with cyclomatic number are the fundamental of network evaluation and also intending with Lee & Chi (2021) that, a well developed transportation network has higher values on both alpha and gamma induces which correspond to higher level of connectivity and complexity.

Table 1: Summary of connectivity indices

Connectivity indices	Calculated value	Level of significance
Alpha (α)	0.78	0.5
Beta (β)	1.86	1.0
Gamma (γ)	0.87	0.5
Cyclomatic number (μ)	7	1-10

Table 1 summarizes the values of all the indices, (α), (β), (γ) and (μ) are all significant, which shows connectivity between the selected villages however, the village with the highest nodal connectivity (Onigba) was not considered a service or commercial centre.

CONCLUSION

Based on the findings of the study, it was concluded that rural road transport network in the seven selected villages in Oriire local government area are highly connected however, even though the roads in the villages are well connected, the roads are in bad conditions. There cannot therefore be any meaningful and consistent development unless rural transportation is recognized as an integral part of the national economic system. There is the need for more emphasis to be place on transport network needs as the vast majority of the country's population resides in the rural areas. Such emphasis requires a better balance in the sharing of responsibilities for financing rural transport development among- the three tiers of government i.e. the federal, state and local government. No doubt road constitutes an important backbone for fast access across the network. Rural roads are very important rural developmental elements.

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