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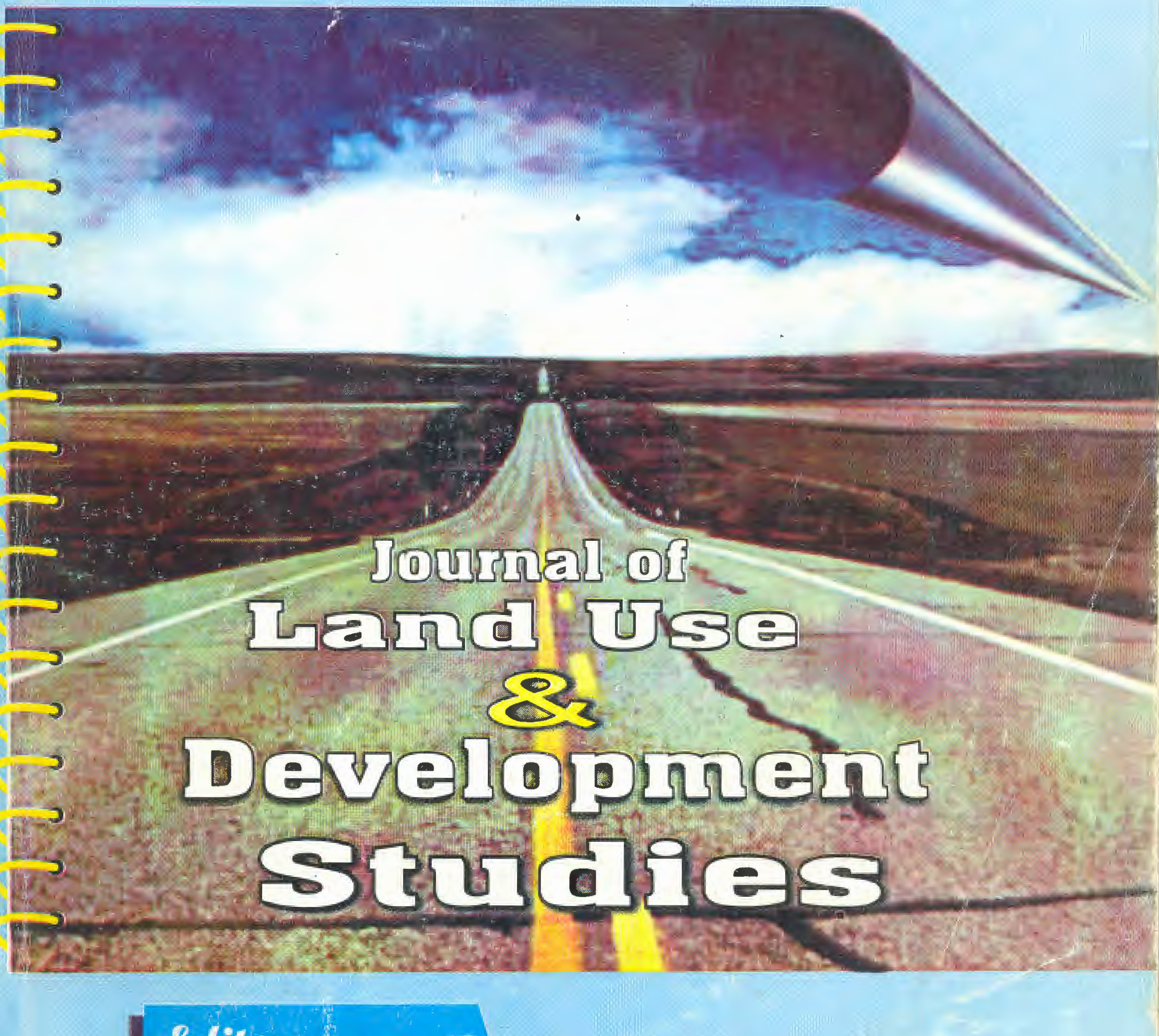

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A STUDY OF THE ACCESSIBILITY AND CONNECTIVITY OF IKEJA ARTERIAL ROADS

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Abstract
The estate surveyors and valuers strongly believe that accessibility has strong effects on property values but without justifiable empirical technique to prove their assertion. The paper examined the network of roads in Ikeja with the aim to empirically determine its accessibility and connectivity. The graph of the road network of the study area was derived from its street map and a graph theoretic qualitative technique adopted to determine the levels of accessibility and connectivity, while correlation and analysis of variance techniques were used to prove the relationship between the variables. The research finds empirical way of determining accessibility, and recommends the application of the finding to estate valuers in proving accessibility which they hitherto decide intuitively in relation to property values.

Introduction

The configuration of the routes network and the impedance for traversal along the routes are two influences that affect accessibility, and route network coupled with increased investment in roads results in changed levels of accessibility. This also is equally reflected in the cost benefit analysis, savings in travel time with other benefits noticeable in increased catchments areas for services and facilities like shops, schools, offices, banks, and leisure activities (Wyatt, 1999). Two influences in particular were found to affect the accessibility and locational value using the network model, these are – the configuration of the route network and impedance for traversal along the routes with implications for transport planning and its consequent effect on property values (Wyatt, 1999).

Road network constitutes an important element in urban development with roads providing accessibility to different land uses in the urban areas and proper functioning of human settlement depends on an efficient transportation network, to the extent that human settlements and urban developments generally are incapable of existence except when adequate transport facilities, like roads and road networks, exist (Aderamo, 2003). The urban road transportation system is one of the important factors that are responsible for shaping the urban centers (Dickey, 1975); not only that the transportation system acts as a basic component of urban areas' social, economic and physical structure, it plays essential role in the determination of the scale, nature and form of urban areas (Balchin, et al, 1991).

The relationship between accessibility, property values and land use patterns has been the pre-occupation of earliest theorists with indication that travel costs were traded off against rents and population densities from the Central Business District (CBD) to suburbs of a mono-centric city. Accessibility has become more complicated requiring more sophisticated treatment; thus, the importance of studying accessibility in order to understand the locational advantages of individual properties rather than rely on traditional bid-rent theory that places the peak rent contour in the CBD (Henneberry, 1998); and transportation networks have major impact on land use and land values with increasing accessibility leading to higher land use and property values in U.K. as remarked by Royal Institute of Chartered Surveyors (RICS, 1998) in response to a Transport White Paper.

In determining the degree of accessibility, a number of approaches have been adopted, one of which is the graph theoretic technique. The theory has been used extensively on regional and local levels with implications for estate surveying, physical development and planning in the study of the growth pattern of a community and can be extended to wider and more complex study on the correlation of road network and value of properties. The graph theoretic approach is applicable to this study as it assists in the analysis of the road network pattern of the study area giving clearer picture of the various inter-nodal points for each of the routes within the study area, which otherwise cannot be achieved through a quantitative approach. It also enables a clear comparison to be made between the nodes, and confirmed the ability of the theory to make objective comparison of different networks therefore fitting into scientific research, involving the identification of changes that could have taken place in the spatial pattern of a network.

The Lagos metropolitan area spreads over much of Lagos State, which itself covers an area of approximately 3,345 square kilometers located on four principal islands and adjacent parts of the Nigerian mainland with the islands connected to each other and to the mainland by bridges and landfills. Major sections of the metropolis include the old city, which now serves as the commercial district, on western Lagos Island; Ikoyi Island (situated just east of Lagos Island and joined to it by a landfill); Apapa, the chief port district, located on the mainland; residential Victoria Island; and industrialized Iddo Island with important mainland suburbs, incorporated as part of the city in 1967, consists of Ebute-Metta, Yaba, Surulere, Ajegunle, Shomolu, Agege, Mushin, and Ikeja. (Microsoft Encarta, 2006).

Ikeja is the capital city of Lagos State, with commercial properties and employment opportunities aggregating close to the seat of governance in the state. The choice of the study area was based on many factors. First, Lagos is a socially heterogeneous city with a variety of road type, and the property market in the study area is well developed, and so it is possible to identify and analyse variations. Second, comprehensive data is available on the network of roads in the Lagos metropolis; third, judging from what is applicable in Nigeria, the Lagos road network is probably the most complex in terms of linkages and human activities with availability of computerized and up-to-date data on the network of roads.

Apart from these reasons, Ikeja has been selected due to the fact that it is the economic, social, commercial, industrial and political nerve-center of Nigeria, and by implication the nerve-centre of the West African sub-region. The metropolitan Lagos itself represents the melting pot of various races, and of economic activities with high net-worth manufacturing, commercial entities, high grade residential precincts, highly productive industrial concerns that have congregated to take advantage of the nearness to sea and international air ports, and rail systems which originate and terminate at the city to and from other parts of the country; all served with networks of trunk roads.

The estate surveyor and valuer believe that accessibility has great impact on property values and often conclude that properties located at the point where two or more roads meet would command greater value than those located off the nodal points (Omoogun, 2006). However, this assertion lacks empiricism, and this research therefore becomes relevant to show the qualitative technique useful in analysing both inter- and intra- communities road networks. The research will also serve as a means to arouse the interests of professional and academic estate surveyors and valuers in this respect, particularly, with regards to proving the effects of accessibility and transport infrastructures on property values.

A number of factors impact positively and negatively on values of commercial properties, one of which is accessibility the subject matter of which earlier researchers have laid sound foundation but many of such earlier studies have ignored the connection between road network and values of commercial properties. In respect thereof; this research will adopt a two-pronged approach to examining accessibility in terms of road network pattern and determine its relationship with the values of commercial properties in the Lagos metropolis adopting the graph theoretic qualitative technique, and the regression parametric technique to attain the stated aim of the research.

This paper examines the road network pattern of Ikeja, Nigeria, to determine the most accessible and best connected points. In doing this, the road network pattern of the study area will be examined, while the degree of accessibility and connectivity of the various nodal points along the arterial routes in the study area will be determined, in addition to an analysis of the accessibility and connectivity of the nodal points.

Related Studies

A lot of earlier works on transportation, road network and accessibility have been carried out on regional level but studies of Ikeja intra-urban network using the graph-theoretic concept are non-existent. For instance, Garrison and Marble (1960) applied graph-theoretic technique to measure regional highway network in the United States of America; Nystuen and Dicey (1961) adopted the technique to analyze functional connection between central places in the state of Washington based upon communication flows in a network. Similarly, Muraco (1972) applied the graph-theoretic technique in his study of intra-urban accessibility of inter-state highways in Indianapolis and Columbus in the United States of America; while Ogunsanya (1986) applied the technique in the estimation of traffic flow in Barnsley, United Kingdom.

In Nigeria, Aderamo (2003) studied the growth of intra-urban network in Ilorin using the graph theoretic analysis and found various indices of network developments for the periods 1963, 1973, 1982 and 1988 thereby making it possible to trace the growth of the intra-urban network of the study area between 1963 and 1988. The study found a relationship between road development, expansion of the city, and significant effect on transportation planning with conclusion that road network is a significant factor in growth and development of a city and community. Also, Oduwaye (2004), in a study of land value determinants in medium density residential neighbourhoods of metropolitan Lagos tested the hypothesis that there is no significant relationship between accessibility and land values using the Spearman's correlation analysis to determine the relationship between the variables with further test using Chi-square to check its validity, with the conclusion that accessibility is a major determinant of residential values in the study area while improvement in transportation facilities, especially roads, brings about improved accessibility. The technique was also applied by Oni (2007) to analyze the intra-community road network of Covenant University, Ota, Nigeria. He found that there was strong relationship between accessibility and connectivity, with the correlation coefficient (r) being –0.74, while the coefficient of determination was 0.545, with the conclusion that only about 55% of the variation in accessibility was explained by the connectivity of the study area, and found empirical way of determining accessibility and connectivity.

The graph theory is relevant to studies on accessibility and connectivity of two or more locations. In graph theory, line patterns occur which is referred to as network defined as a set of geographical locations interconnected in a system by a number of routes thereby making the use of quantitative approach in giving accurate description in transport and land use planning very difficult, and it is equally difficult to determine accessibility and connectivity of two points to all other points in quantitative terms. Also, the quantitative description is also unsuitable for comparing the characteristics of one network with another, while it is also not useful in the evaluation of the present and future trends of elements in the road networks. Based on these shortcomings, amongst others, the graph qualitative approach emerged as alternative to the quantitative approach in capturing adequately all aspects of networks.

The graph theory was first proposed by Garrison and Marble (1960) and further developed by Kansky (1963). It is described as a branch of combinational topology, a powerful and versatile language which allows one to disentangle the basic structure of transportation networks (Lowe and Moryada, 1975); while it is also described as a directed, weighted graph or network in relation to transport typically as networks of roads, streets, pipes, aqueducts, power lines, or any structure that permit either vehicular movement or flow of some commodity (Wikipedia online, 2007c).

Transport networks are spatial structures designed to channel flows from the points of demand to points of supply to link the points together in a transportation system, useful for transport network analysis in determining the flow of people, goods, services and vehicles. Similarly, spatial networks are networks of spatial elements derived from maps of open space within the urban context or building, a form of negative image of the standard map, with the open space cut out of the background buildings or walls. The resulting space map is broken into units of road segments, called the nodes of the graph, and linked into a network through their intersections, called the edges of a graph; and by divorcing the function of transport network from their inert spatial form, some useful descriptive indices are derived, while it is possible to evaluate alternative structures by reducing the complex transportation network to its fundamental elements of nodes and links, such evaluation is carried out using elementary mathematics from the graph theory (Wikipedia online, 2007a).

Also, transport network can be considered as a topologic graph with three parameters from which quantitative measurements may be computed as a basis for the objective description, comparison and evaluation of networks. The parameters are the number of separate non-connecting sub-graphs in the network represented by G, the number of links (or edges) in the network (E) and the number of nodes (or vertices) in the network (V) (Hodder and Lee, 1982). The description of a network varies between whether the network occurred on a plain, referred to as the planner graph or if non-planner graph. In planner graphs, all the nodes and links occur on a surface whereas in non-planner graph there are infinite numbers of links that are developed; and in graph theory links are referred to as lines, edges or arcs while the points are called nodes, vertices, junctions, intersections or terminals. The graph theory therefore serves the means by which the theory, nature, form, and characters of the network can be described, analyzed, with temporal changes of the elements observed within a particular geographical space and between one node of the network or another.

The spatial pattern of a network can be carried out in three ways: connectivity index analysis, accessibility index analysis, and measure of compactness. These indices are concerned with network and such analysis can yield valuable measures of the accessibility, connectivity, and compactness of individual nodes. The connectivity of a network refers to the completeness of the lines or links between the nodes or vertices, and can be measured using four indices, namely, beta index (β), chromatic number (CN), alpha index (α), and gamma index (γ) (Cole and King, 1968; Hay, 1973; Hodder and Lee, 1982; Rallis, 1988). The Beta Index is a measure of connectivity in terms of the average number of links per node within the network and indicates the relationship between the number of edges (E) and the vertices (V) defined as:

$$\text{Beta Index } (\beta) = \frac{E}{V} \qquad \text{...Eqn. 1}$$

The Gamma Index (γ) measures the ratio of the observed number of links and the maximum number of links in any network, given by the formula:

$$\text{Gamma Index } (\gamma) = \frac{E}{3(V - 2G)} \times 100 \qquad \text{...Eqn. 2}$$

Similarly, The Chromatic Number (CN) indicates the number of circuits within a network. Where there is no complete loop, CN will be equal to zero and where the result is one it indicates one loop, up to any number that thus corresponds to the number of loops using the formula:

Chromatic Number (CN) = E – V + G; while the alpha index is obtained by dividing the chromatic number with double the number of vertices less five multiples of the sub-graphs.

$$\text{Alpha Index } \alpha = \frac{(E - V + G)}{(2V - 5G)} \times 100 \qquad \text{...Eqn. 3}$$

These indices are concerned with network and such analysis can yield valuable measures of the accessibility of individual nodes, derived from the connectivity matrix, which represents the links between the nodes of a network in a matrix form.

A figure of one in the matrix indicates that there is one inter-nodal link while zero indicates that there is no link. The distance between pairs of nodes is expressed as the number of intervening links along the shortest path that connects them. The total of the figures in the row for each node is a measure of its accessibility in terms of the measure of the total size of the network and total number of links. This measure is known as the dispersion value of the graph, and the average length of path in the network is obtained by dividing the row sum by the total number of positive values in the row (Hay, 1973).

Road networks consist of a large amount of roads which interlink each other, and many patterns exist in road networks these are star-like, grid-like and irregular patterns. Star-like patterns display a radial structure where many roads converge at a point, or a set of dense points. Grid-like patterns consist of two groups of roughly perpendicular roads, corresponding to Manhattan-style street networks. As for irregular patterns, no regular shape and structure can be discerned as the networks consist of a large amount of roads that interwoven each other (Zhang, and L.U., 2004). Patterns in this respect are defined as characteristics and properties which are found in repeated and regular manner within one object, or between a number of objects with such repetition in the form of shape, density, distribution, linkages, connection or orientation occurring among the same kind of objects or different kinds of objects (Mackaness and Edwards, 2002).

Other studies, namely Mackaness and Beard (1993); Mackaness (1995); Thomson and Richardson (1995); Jiang and Claramunt (2004); and, Jiang and Harrie (2004), however used the concepts and parameters of connectivity, shortest path spanning tree, and minimum cost spanning tree, to analyse road network; while Thomson and Richard (1999) used perceptual grouping to analyse road network and group road segments according to continuation principle by ordering and selecting strokes into which the roads are segmented; yet another approach is the simulation of the amount of road use and selection of roads that have high level of usage through agent-based simulation consisting of algorithm base for road generalization and creating a version of network of roads that exhibits certain properties of good connectivity, length of the roads, degree of continuation, and degree and frequency of usage. However, as good and exploratory as the agent-based simulation approach is, it does not guarantee that some important properties of road network are not distorted, as some of the approaches ignore the analysis of the road network pattern thereby losing the patterns (Morisset and Ruas, 1997).

Similarly, spatial networks are networks of spatial elements, derived from maps of open space within the urban context or building, and space map could be likened to the negative image of the standard map, with the open space cut out of the background buildings or walls with the resulting space map broken into units of road segments, called nodes of the graph linked together into a network through their intersections called the edges of a graph (Wikipedia, 2007c); and in transportation network analysis, a common instance reverses this and treats the road segments as edges and the street intersections as nodes in the graph and by divorcing the function of transport network from their inert spatial form, it is possible to derive some useful descriptive indices through the reduction of the complex transportation network to its fundamental elements of nodes and links thereby making it possible to evaluate alternative structures; with such evaluation carried out using elementary mathematics from graph theory (Hodder and Lee, 1982).

In modelling network pattern, a parameter-based descriptive method may be used, with every kind of pattern having a set of properties that can be described as shape, orientation, connectedness, density and distribution in terms of which certain properties are identified, and evaluated in map generalization, with the possibility of using parameters that indicate the main properties of the patterns; while in computing density of the road networks, the networks are partitioned into different parts in order to extract the roads inside each part and calculate the density of each part by density indicator, and number of connections thus recording the number of roads that connect to the road (Zhang and L.U., 2004).

Accessibility is a general term used to describe the degree to which a system is usable by as many people as possible and it is the degree of ease with which it is possible to reach a certain location from other locations, and can also be viewed as the ability to access the functionality, and possible benefit; while in transportation, accessibility refers to the ease of reaching destinations with people in places reaching many other activities or destinations quickly, while people in inaccessible places can reach many fewer places in the same amount of time (Wikipedia, 2007b).

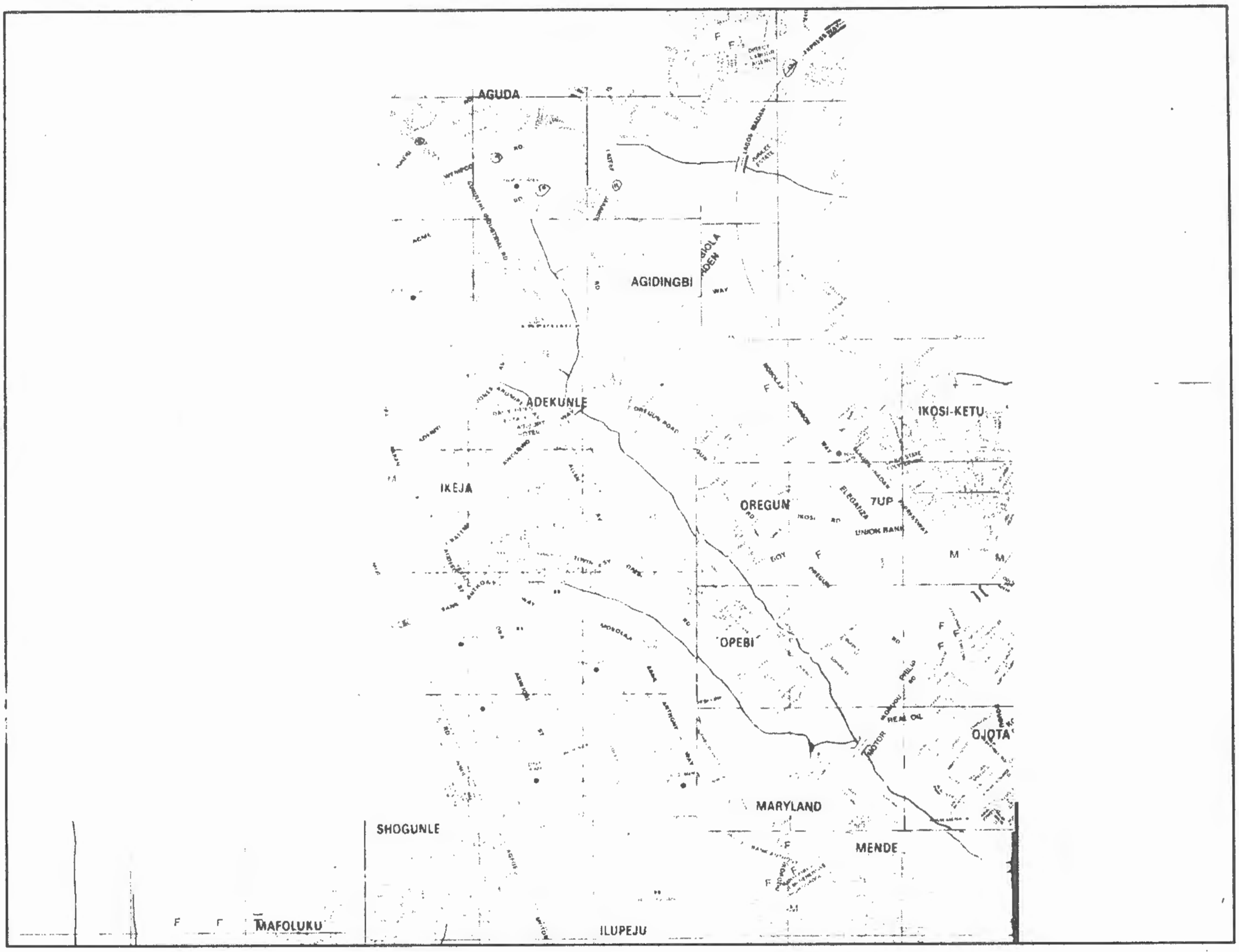
Considering property value in relation to transportation and accessibility, the Washington, D.C.'s Metro rail for example encouraged more downtown development than would otherwise have occurred, with Metro rail converging downtown from all directions thus concluding that the market for office and other space within a business center is to build more off-road transit facilities to serve it (Downs, 1992); while contemporary land market theory established that differential firm's access to business activity clusters eliciting significant effects on commercial land market as exemplified in firms valuing main and secondary centers accessibility in the urban areas (Sivitanidou, 1996).

Urban road transportation system is one of the important factors responsible for shaping urban centres, and the system does not act as basic component of urban areas' social, economic and physical structure, playing essential role in the determination of the scale, nature, and form of urban areas (Balchin, et al, 1991); and the relationship between accessibility, property values and land use patterns that was the pre-occupation of the earliest theorists indicate that travel costs were traded off against the rents nd population densities from the Central Business District (CBD) to suburbs of a mono-centric city with accessibility becoming a more complicated phenomenon that requires more sophisticated treatment thereby making the study accessibility more rigorous in order to understand the location advantages of individual properties rather than rely on traditional bid-rent theory that places the peak rent contour in the CBD (Henneberry, 1998).

In explaining the effects of accessibility on property values, modern techniques have equally been introduced. These techniques range from geographically weighted regression technique, multinomial logit models, to geo-spatial analysis using the Geographical Information Systems (GIS). For instance, Desyllas (1998) used regression model was used in a study on office rents in Berlin, Germany between 1991 and 1997, in which he derived a residual figure for the amount of rent not explained by non-location factors suggesting that in order to find an independent variable it is appropriate to model the street system as a network and calculate accessibility values based on the relationship between individual streets and configuration of the system as a whole.

Data Collection and Methodology

Data required for this study were generated mainly from the secondary source, with the Street Map of Ikeja used to analyze the network of roads in the community. The street map of the study area is shown in Fig. 1



Source: Curled from Lagos Street Map (West Africa Book Publishers Limited, 2002)

Furthermore, the arterial routes in the street map of Ikeja were traced out using transparent paper to obtain the graph of the road network, and the resulting graph thereafter analyzed to determine the levels of connectivity and accessibility of each node within the network using the Graph Theoretic Analytical technique. In using the graph theoretic qualitative technique, the road network as indicated in the road map was converted into linear graph, with each route represented by single line regardless of the width, quality, shape, and standard of the roads but taking the shortest route possible, the connectivity and accessibility matrices were consequently derived, and the nodes within the graph numbered serially as shown in Fig. 2.

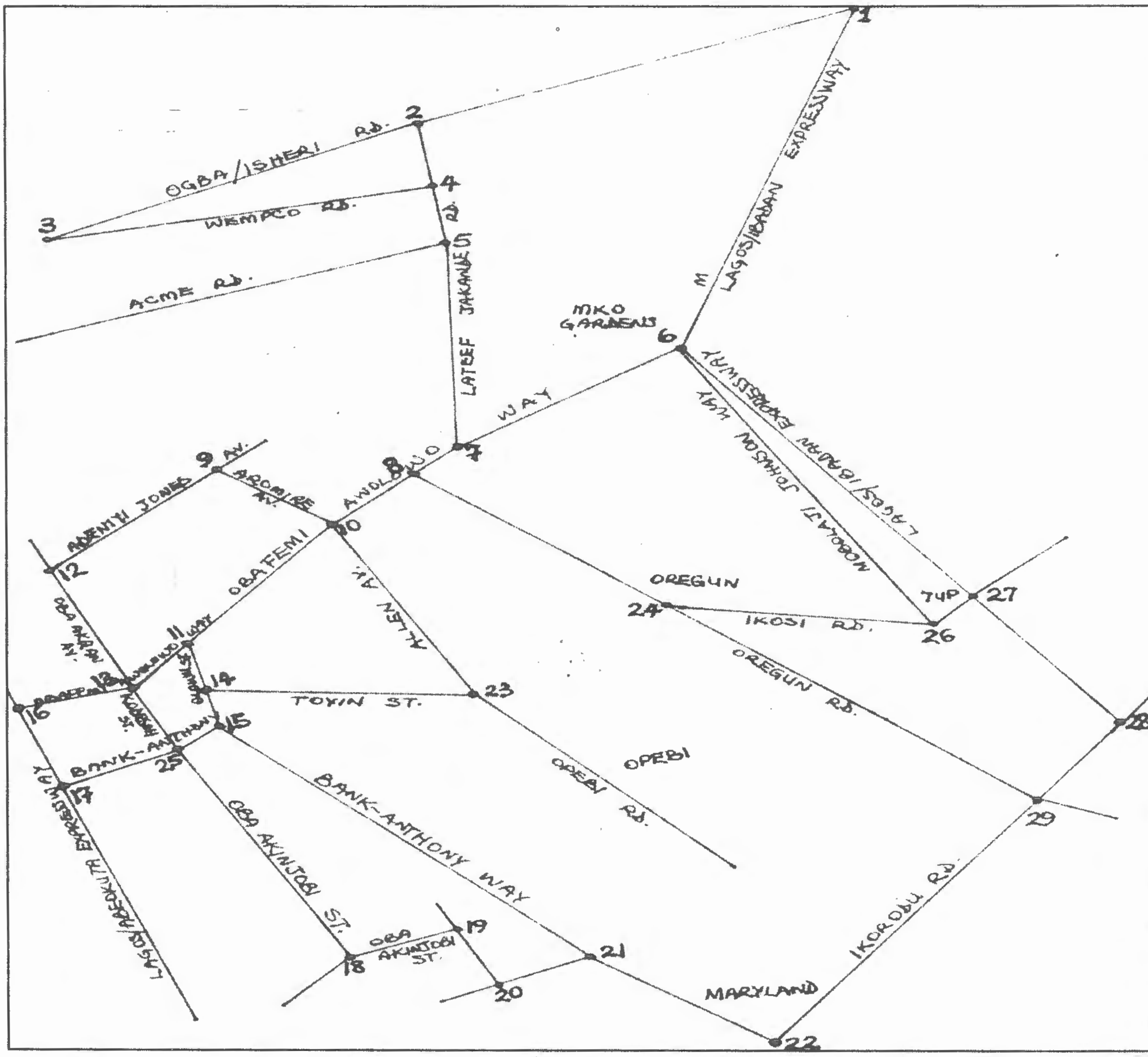


Fig. 2: Graph of Arterial Routes in Ikeja.

From Fig. 2, the levels of accessibility and connectivity using the Shimbel Index and Connectivity Matrix (Tables 1 and 2) were determined. In this regard, the Shimbel Index indicating the accessibility indices summarizes the number of edges required to connect each node or vertex with other nodes in the network through the shortest path as shown in Table 1, and in the Connectivity Matrix, a score of 0 or 1 was given to each node, that is where two nodes are directly linked, a value of 1 point was given and where they are not directly linked, a score of 0 point was given. The Connectivity Matrix therefore indicates the number of other nodes that a particular node is directly linked with and the node with the highest number of points is therefore considered as the most connected while the node or vertex with the least Shimbel Index is regarded as the most accessible as detailed in Tables 1 and 2

Table 1: Analysis of Accessibility of the Arterial Routes in Ikeja

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Accessibility Index
1	*	1	2	2	3	1	2	3	2	4	5	6	6	6	7	7	8	9	8	7	6	5	5	3	7	2	2	3	4	**126**
2	1	*	1	1	2	2	3	4	6	5	6	7	7	7	8	8	9	9	9	10	7	6	6	4	8	3	3	4	5	**151**
3	2	1	*	1	2	4	3	4	6	5	6	7	7	7	8	8	9	9	11	10	9	8	6	5	8	4	4	5	6	**165**
4	2	1	1	*	1	3	2	3	5	4	5	6	6	6	7	7	8	9	10	9	8	7	5	4	7	5	4	5	5	**145**
5	3	2	2	1	*	2	1	2	4	3	4	5	5	5	6	6	7	7	9	8	6	5	4	3	6	3	3	4	4	**120**
6	1	2	3	3	2	*	1	2	4	3	4	5	5	5	6	6	7	7	7	6	5	4	4	2	6	1	1	2	3	**107**
7	2	3	3	2	1	1	*	1	3	2	3	4	4	4	5	5	6	6	7	[illegible]	6	7	3	2	5	2	2	3	3	**103**
8	3	4	4	3	2	2	1	*	2	1	2	3	3	3	4	4	5	7	6	[illegible]	4	3	2	1	4	2	3	3	2	**88**
9	5	6	6	5	4	4	3	2	*	1	2	1	2	3	4	3	4	4	5	6	5	6	2	3	3	4	5	5	4	**107**
10	4	5	5	4	3	3	2	1	1	*	1	2	2	2	3	3	4	4	5	5	4	5	1	2	3	4	4	5	3	**90**
11	5	6	6	5	4	4	3	2	2	1	*	2	1	1	2	2	3	3	5	5	3	4	2	3	2	4	5	5	4	**94**
12	6	7	7	6	5	5	4	3	1	2	2	*	1	3	3	2	3	3	4	5	5	7	3	4	2	5	6	6	5	**115**
13	6	7	7	6	5	5	4	3	2	2	1	1	*	2	2	1	2	2	3	4	3	4	3	4	1	5	6	6	5	**102**
14	6	7	7	6	5	5	4	3	3	3	1	3	2	*	1	3	3	3	4	5	2	3	1	4	2	5	6	6	5	**108**
15	7	8	8	7	6	6	5	4	4	3	2	4	3	1	*	3	2	2	3	4	1	2	2	5	1	6	7	7	6	**119**
16	7	8	8	7	6	6	5	4	3	3	2	2	1	3	3	*	1	3	4	5	6	7	4	5	2	6	7	7	6	**131**
17	8	9	9	8	7	7	6	5	4	4	3	3	2	3	2	1	*	2	3	4	3	4	4	6	1	7	8	8	7	**138**
18	8	9	4	8	7	7	6	5	5	4	3	3	2	3	2	3	2	*	1	2	3	4	4	6	1	7	8	8	7	**132**
19	8	9	10	9	8	8	7	6	5	5	4	4	3	4	3	4	3	1	*	1	2	3	5	5	2	6	6	5	4	**140**
20	7	8	9	9	9	6	7	7	6	7	5	5	4	5	4	5	4	2	1	*	1	2	4	4	3	5	5	4	3	**141**
21	6	7	8	7	7	6	5	4	5	4	3	5	4	2	1	4	3	3	2	1	*	1	3	3	4	4	4	3	1	**110**
22	5	6	7	6	5	4	4	3	6	4	4	6	6	3	2	5	4	4	3	2	1	*	4	2	3	3	3	2	1	**108**
23	5	6	6	5	4	4	3	2	2	1	2	3	3	1	2	4	4	4	5	4	3	4	*	3	3	4	5	5	4	**101**
24	3	4	5	4	3	3	2	1	3	2	3	4	4	4	5	5	6	6	5	4	3	2	3	*	5	1	2	2	1	**95**
25	7	8	8	7	6	6	5	4	3	3	2	2	1	2	1	2	1	1	2	3	2	3	3	5	*	6	6	5	4	**108**
26	2	3	4	4	3	1	2	2	4	3	4	5	5	5	6	6	7	7	7	6	5	4	4	1	6	*	1	2	2	**111**
27	2	3	4	4	3	1	2	3	5	4	5	6	6	6	7	6	8	7	6	5	4	3	5	2	8	1	*	1	2	**119**
28	3	4	5	5	4	2	3	3	5	4	5	6	6	5	4	8	6	6	5	4	3	2	5	2	5	2	1	*	1	**114**
29	4	5	6	5	4	4	3	2	4	3	4	5	5	4	3	6	5	5	4	3	2	1	4	1	4	2	2	1	*	**101**

Table 2: Analysis of Connectivity Index of Arterial Routes in Ikeja

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Connectivity Index
1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
4	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
5	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
6	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	4
7	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
8	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
9	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
10	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
11	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
12	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	4
14	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	3
16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	2
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20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	3
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
23	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	3
25	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	4
26	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	3
27	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	3

Test of the Hypothesis

The hypothesis tested is: there is no correlation between accessibility and connectivity of the various nodes within the Ikeja road network. In doing so, the Pearson's Product Moment Correlation Coefficient Technique (PPMCC) was adopted using the formula:

$$r = \frac{n\sum XY) - (\sum X)(\sum Y)}{\sqrt{\left[n(\sum X^2) - (\sum X)^2\right][n\Sigma Y^2 - (\Sigma Y)^2]}} \quad \text{...Eqn. 5}$$

where, r : co-efficient of correlation;

Y: accessibility index for each node;

X: connectivity index for each node;

n : number of nodal points

Furthermore, in using the technique to determine the relationship between accessibility (dependent variable) and connectivity (independent variable), details of the indices for the variables extracted from Tables 1 and 2 are used for the analysis as shown in Table 3.

Table 3: Indices for Accessibility and Connectivity of Arterial Roads in Ikeja

Nodal Point	Accessibility Index (Y)	Connectivity Index (X)
1	126	2
2	151	3
3	165	2
4	145	3
5	120	2
6	107	4
7	103	3
8	88	3
9	107	2
10	90	4
11	94	3
12	115	2
13	102	4
14	108	3
15	119	3
16	131	2
17	138	2
18	132	2
19	140	2
20	141	2
21	110	3
22	108	2
23	101	3
24	95	3
25	108	4
26	111	3
27	119	3
28	114	2
29	101	3

Source: Extracts from Tables 1 and 2

Analysis and Discussion

The graph of arterial road network of Ikeja consists of 29 vertices and 43 edges as shown in Fig. 2; while Table 2 shows the connectivity indices of the study area ranging from 2 to 4 and accessibility indices range from 88 to 165. The nodal point 8 indicates the least index of 88 followed by node 10 (Index of 90), and node 11 (Index of 94).

The analysis shows that the connectivity indices range from 2 to 4, with each of the nodal points 6, 7, 10, 13, and 25 having the highest index of 4. This implies that the nodal points are the most connected affording the highest number of linkages thus aiding easy movements. These locations are found along Awolowo Way, except point 25 which is at Bank-Anthony/Kodesho junction. The locations along Awolowo Way that have good connectivity are Mobolaji Johnson Road/Awolowo Way/Lagos-Ibadan Expressway by Abiola Gardens, Aromire Avenue/Awolowo Way/Allen Avenue, and Oba Akran Avenue/Kodesoh Street/Awolowo Way.

The percentages of connectivity of locations with regard to number of links with others within Ikeja are detailed in Table 4.

Table 4: Percentages of Connectivity of Locations along the Arterial Roads of Ikeja

S/No	Locations	Nodal Points	No. of links	Percentage of total No. of
1.	Lagos-Ibadan Expressway/Isheri Rd., Ogba-Isheri Rd./WEMPCO Rd., ACME Rd./Lateef Jakande Rd., Aromire Ave./Adeniyi Jones Ave., Adeniyi Jones Ave./Oba Akran Ave., Awolowo Way/Lagos-Abeokuta Expressway, Bank-Anthony Rd./Ikorodu	1, 3, 5, 9, 12, 16, 17, 18, 19, 20, 22, and 28 **(12 nodal points)**	2	41.38
2.	Isheri Rd/Lateef Jakande Rd., WEMPCO Rd/Lateef Jakande Rd, Oregun Rd/Awolowo Way, Awolowo Way/Olowu Junction, Olowu Str./Toyin Str., Bank-Anthony Way/Oba Akinjobi Str. (Opp. EKO Hospital), Oregun Rd./Ikosi Rd., Ikosi Rd./Mobolaji Johnson Way (7-up Junction), 7-Up Junction/Lagos-	2, 4, 7, 8, 11, 14, 15, 21, 23, 24, 26, 27 and 29 **(13 nodal points)**	3	44.83
3.	Awolowo way/Mobolaji Johnson Way, Mobolaji Johnson Way/MKO Gardens/Lagos-Ibadan Expressway, Awolowo Way/Aromire Ave./Allen Ave., Awolowo Way/Kodesoh/Oba Akran Ave., Oba	6, 10, 13, and 25 **(4 nodal points)**	4	13.79
TOTAL		**29**		**100.00**

As shown in Table 4, out of total of 29 nodal points in the network of arterial routes in Ikeja, only four nodal points (representing about 14%) have direct links with four other nodes; thirteen nodal points (about 45%) have links with three other points; and twelve nodal points (about 41%) have direct links with two other points. It can therefore be deduced that Awolowo Way is the best of the arterial routes in Ikeja urban centre with many of its nodal points having the highest number of four links to other nodal points, and implying that a commercial user desiring high degree of connectivity will thrive best along Awolowo Way.

Similarly, the accessibility index in Table 1 shows that nodal point 8 is the most accessible; this is the point where Oregun Road and Awolowo Way meet followed by nodal point 10 (Aromire Avenue/Allen Avenue/Awolowo Way junction), and nodal point 11 (Olowu Street/Awolowo Way). Nodal point 3 with index of 165 is the least accessible, lying at remote location within the study area; this is the point where Ogba/Isheri Road and WEMPCO Road meet. This therefore confirms that Awolowo Way is equally the most accessible arterial route in Ikeja.

Statistically, the results of fitting a linear model to describe the relationship between accessibility and connectivity indicates that Accessibility = 155.395 - 14.145Connectivity derived from Table 5

Table 5: Coefficients of Connectivity and Accessibility Indices of Ikeja Road Network

Parameter	Least Squares Estimate	Standard Error	T Statistic	P-Value
Intercept	155.395	12.69920	12.23660	0.0000
Slope	-14.145	4.51915	-3.13001	0.0042

The linear model shows that as the connectivity indices of the study area increase the accessibility indices decreases.

In addition, the Analysis of Variance (ANOVA) was used to further analyze the data at alpha level of 0.05; the resulting figures are shown in Table 6.

Table 6: Analysis of Variance of Connectivity and Accessibility in Ikeja Road Network

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	2,759.74	1	2, 759.740	9.80	0.0042
Residual	7, 605.71	27	281.693		
Total (Corr.)	10, 365.40	28			

Table 6 shows the result of the analysis of variance set at alpha level of 0.05; P-value is 0.0042 and F-Ratio at 9.80. Since the resulting P-value of 0.0042 is less than 0.05 this indicates that there is statistically significant relationship between accessibility and connectivity at 95.0% confidence level. The analysis further indicates that the correlation coefficient (r) is -0.52, thus the R-squared statistic indicates that the model as fitted explains 27.04% of the variability in accessibility. This means that there is a moderately strong relationship between the variables. It also indicates that a linear relationship between connectivity and accessibility is capable of explaining up to 27% variability in the parameters at 95% confidence level.

Recommendations and Conclusion

This work has demonstrated that graph theoretic technique is useful in analyzing accessibility and connectivity of routes within an urban community. It is evident that Awolowo Way is the major, most accessible and most connected of the arterial routes in Ikeja; and there is strong relationship between connectivity and accessibility of the various nodal points in the network of Ikeja, while it was indicated that apart from connectivity other factors could be used to explain changes in accessibility of a point within a community.

The estate surveyors and valuers hitherto strongly believe that accessibility has great effects on property values but without empirical means to prove it, the paper has therefore shown that accessibility and connectivity of a location can be proved empirically. However, further research will be required to determine the correlation between the findings and values of properties along the network of arterial routes.

Some questions may follow from this study and open the vista for further research. Now that this study has proved that accessibility and connectivity in a community can be determined empirically, are property values within a community related to the level of accessibility and connectivity within the network of roads? What are the property values along the various roads in the network within a community? Are locations that are less accessible and less connected commanding higher property values than those that are more accessible and more connected? If this is so, what factors are responsible? Further research will be carried out to answer these questions and assist estate valuers in giving unbiased and scientifically-tested property values in relation to accessibility and connectivity which they consider as major determinants of property values and so prevent valuers from relying on intuition in doing so.

References

Aderamo, A. J. (2003). A Graph Theoretic Analysis of Intra-Urban Road Network in Ilorin, Nigeria. ***Research for Development – The Journal of the Nigerian Institute of Social and Economic Research.*** 17 (1 & 2), 18 (1 & 2), 221 - 240

Balchin and P.N., Kieve, J.L., and Bull, G.H. (1991). *Urban Land Economics and Public Policy (Fourth Ed.)* Hampshire: Macmillan Educational Limited

Cole, J.P. and King, C.A.M. (1968). *Quantitative Geography Techniques and Theories in Geography*. London: John Wiley & Sons.

Desyllas, J. (1998). *When Downtown Moves: Isolating, Representing and Modelling The Location Variable in Office Rents*. Cutting Edge, RICS, Leicester

Dickey, J. W. (1975). *Metropolitan Transportation Planning*. Washington, D.C: Scripta Books.

Downs, A. (1992). *Stuck in Traffic: Coping with Peak-Hour Traffic Congestion*. Brookings Institution/Lincoln Institute of Land Policy

Garrison, W.L. and Marble, D.F. (1960). Connectivity of the Inter-State Highway System. *Papers of the Regional Science Association*, 6:121-137

Hay, A. (1973). *Transport for the Space Economy. A Geographical Study*. London: The Macmillan Press Limited

Henneberry, J. (1998). Transport Investment and House Prices. ***Journal of Property Valuation and Investment.*** 16(2), 144 -158

Hodder B. W. and Lee, R. (1982). *Economic Geography*. London: Methuen & Co. Limited

Jiang, B. and Claramunt C. (2004). A Structural Approach to the Model Generalisation of an Urban Street Network. ***GeoInformatic*** 8(2): 157-171

Jiang, B. and Harrie L. (2004). "Selection of Streets from a Network Using Self-Organizing Maps".***Transactions in GIS*** 8(3): 335-350

Kausky, K.J. (1963). The Structure of Transportation Networks. *Chicago Department of Geography Research Paper* No 84

Lowe, J.C and Moryada, S. (1975). *The Geography of Movement*. Buston: Houghton Mifflin Co.

Mackaness W. A. and Beard M. K., (1993). "Use of Graph Theory to Support Map Generalisation".***Cartography and Geographic Information Systems,*** 20, 210 – 221.

Mackaness W. A., (1995). "Analysis of Urban Road Networks to Support Cartographic Generalization". ***Cartography and Geographic Information Systems***, 22, 306 – 316.

Mackaness, W. and Edwards, E., (2002). "The Importance of Modelling Pattern and Structure in Automated Map Generalisation", Joint ISPRS/ICA workshop "Multi-Scale Representations of Spatial Data", Ottawa, Canada, 7-8 July 2002

Morisset, B. and Ruas, A. (1997). "Simulation and Agent Modelling for Road Selection in Generalisation". In *Proceedings of the ICA 18th International Cartographic Conference* (Stockholm, 23-27 June 1997), pp.1376-1380

Muraco, W.A. (1972). "Intra-Urban Accessibility: A Quantitative Analysis Use of Graph Theoretic Method". ***Economic Geography*** 48:388-405

Nystuen, J. D. and Dicey, M.F. (1961). "A Graph Theory Interpretation of Modal Regions". *Papers and Proceedings Regional Science* 7: 29-42

Oduwaye, L. (2004). "*Land Value Determinants in Medium Density Residential Neighbourhoods of Metropolitan Lagos*". ***Journal of the Nigerian Institute of Town Planners,*** XVII (1) October, 2004; 97 – 111

Ogunsanya, A. A. (1986). "Graph Theory in Intra-urban Traffic Flow Estimation". ***Geo-Journal,*** 12. 334 – 336

Omoogun, C. B. (2006). "The Centripetal Effects of Location on Rental Values of Residential Property in Metropolitan Lagos". Conference Proceedings on the Built Environment: Innovation

Policy and Sustainable Development. Department of Architecture, Covenant University, Ota, Nigeria. 328 – 334

Oni, A. O. (2007). "Graph-Theoretic Analysis of Intra-Community Road Network Pattern – Case Study of Covenant University, Ota, Nigeria" Paper delivered at the Departmental Seminar organized by the Department of Estate Management, Covenant University, Ota on 1st August 2007

Rallis, T. (1988). *City Transport in Developed and Developing Countries*. London: The Macmillan Press Limited.

Sivitanidou, R. (1996). "Do Office-Commercial Firms Value Access to Service Employment Centres? A Hedonic Value Analysis within Polycentric Los Angeles". ***Journal of Urban Economics*** *40:2, 125 – 149*

Thomson R. C. and Richardson D. E. (1995). "A Graph Theory Approach to Road Network Generalisation". In *Proceeding of the 17th International Cartographic Conference*, 1871–1880.

Thomson, R. C., and Richardson, D. E., (1999). "The 'Good Continuation' Principle of Perceptual Organization Applied to the Generalization of Road Networks". *Proceedings of the ICA 19th International Cartographic Conference* (Ottawa, 14-21 August 1999), 1215–1223.

Wyatt, P. (1999). "Geographical Analysis in Property Valuation". *Research Report, Royal Institution of Chartered Surveyors*, London.

Wikipedia, online, (2007a). http://en.wikipedia.org/wiki/Graph_theory;[Accessed June 10, 2007]

Wikipedia, online, (2007b). http://en.wikipedia.org/wiki/Road_network;[Accessed June 10, 2007]

Wikipedia, online, (2007c). http://en.wikipedia.org/wiki/Transport_network; [Accessed May 14, 2007]

Zhang, Q. and Lund University GIS Centre (2004). *Modelling Structre and Patterns in Road Network Generalization.* ICA Workshop on Generalisation and Multiple Representation, 20-21 August 2004 - Leicester in http://ica.ign.fr/Leicester/paper/Zhang-v2-ICA Workshop.pdf

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