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An Analysis of the Growth of Road Connectivity in Kaduna State

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Abstract
Network is the interconnectivity, or linkage of a set of components of a system into a complete whole to produce a spatial and structured pattern. A network may be either a static feature at a point in time or a dynamic phenomenon, it grows with time or as such, it is subjected to change through time. In the course of making the nodes and linkages easily identifiable, a network is transformed into a topological graph. This is a representation of the geometry of a network showing the relationship between nodes and linkages without considering the scale of the map and morphology of the actual route. The nodes refer to the settlements while the edge refers to the roads. This study attempts to determine the degree of road network connectivity over three time periods and how such growth has led to an improvement in the economy of the people of Kaduna State. To determine the degree of road network connectivity in the study area, the road network structures were converted into topological graphs. From the graphs, the following three graphic theoretic indices (alpha, beta and gamma) were measured. Twenty-five (25) main settlements in Kaduna State were used as nodes on the topological map. The indices of the three periods were then pooled together to show the trend in the growth in road connectivity in the state. The study revealed that the calculated values of alpha increased from 17.8% to 51% , beta from 1.36 to 1.96 and gamma from 49% to 71% between 1957 and 2009. While the number of nodes on the road network in the state remains constant at 25, the number of roads, increased from 34 in 1957 – 1989 period, to 49 in the 1999 - 2009 period. The study has been able to determine that road connectivity indices increased over the three time periods. This is an indication that there has been an increase in road network from one period to another, and that the economic activities of the people of Kaduna State has improved thereby.
Keywords: Network, Growth, Interconnectivity, Topological Graph, Nodes, Economy

BACKGROUND TO RESEARCH PROBLEM

Road network is defined as the interconnectivity, or linkage of a set of components of a system into a complete whole to produce a spatial and structured pattern. The elements that make up a road network are called by various names. These are nodes, vertices or points, the edge, linkage or route and the sub-graph in unconnected path. The nodes, vertices or points refer to the settlements while the edge; linkage or the route refers to the roads. Chapman (1979) observed that a road network may be either a static feature at a point in time or a dynamic phenomenon, which is subjected to change through time. This means that a road network can grow with time.

The domineering factor of road transport over other transport systems in most countries is more and more appearing. It has improved the mobility and accessibility of the majority of the world's population. Hilling in Hoyle and Knowles (2001). In Nigeria, the road is the only mode of transport by which all the states in the Federation are linked. Road transport has become the most ubiquitous mode of transport, and is available to, and made use of by, the greatest proportion of the populace and covers the largest part of Nigeria's land area. Bolade in Abiodun (1985). The vast majority of Nigerian national transport movements are performed by the road transport sub-ector, with railway and inland waterways playing important supporting secondary roles. The Federal Government of Nigeria considers road as the key to realizing the nation's economic potentials (Guardian February 13 2007.p-26). More recently, road networks have been expanded as national leaders have attempted to link up previously isolated areas. The aim of this study is to determine the level of road network connectivity over three time periods and how such growth has led to an improvement in the economy of the people of Kaduna State, Nigeria.

METHODOLOGY

In the course of making the nodes and linkages easily identifiable, a network is transformed into a topological graph, without considering the scale of the map and morphology of the actual route. This is called a representation of the geometry of a road network showing the relationship between nodes and linkages

To the road network structures were converted into topological graphs, to permit application connectivity indices (alpha, beta and gamma) to determine the level of road connectivity over three time period in the study area. Twenty - five main settlements in Kaduna State were used as nodes and road linking as route on the topological map. These settlements are shown in Table 1

METHOD OF DATA ANALYSIS

Map analysis was done on road network using topological abstractions that represent series of vertices (representing nodes on the network) and set of edges (representing network linkages). Then structure of the road network in the study area was compared over three periods (1957-1989, 1993-1995, and 1996-2005), which helped to determine the degree of network connectivity. The three graphic theoretic measures used in analyzing the network connectivity are alpha, beta and gamma indices. The road network in Kaduna state during each period were converted into a topological graphs. The graphs were then analysed to determine the alpha, beta and gamma indices. These indices help to determine the connectivity level. These indices are all based upon the relationship between the number of edges and vertices in a network.

$$(\quad \alpha)= \frac{e-v+1}{2v-5} \times \frac{100}{1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1) \qquad ,$$

The Alpha index is closely related to the gamma index, but is a ratio based on the number of circuits in a network rather than the number of edges. When comparing periods, the higher the ratio of one the greater the number of additional or alternative path in that network. Thus when a traveler is faced with a network with =0 it means he can only proceed along a single path whereas several options exist in the case of a network with =1. This therefore means that the period with the highest connectivity is the one with the highest ratio.

$$(\beta) = \frac{e}{v} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

Beta expresses the number of edges present in relation to the number of vertices to be connected and therefore may be regarded as indicating the average number of links leading into or out of each node. When the average of each is considered the period with the highest value indicates the one with maximum connectivity while the one with the least indicates least connected.

$$(\gamma)= \frac{e}{3(v-2)} \times \frac{100}{1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Gamma index is the ratio of the number of edges in a network to the maximum which may exist between specific numbers of vertices. The denominator in the expression reflects the fact that the addition of a single vertex necessarily increases the number of possible edges by 3. When comparing the various periods the network with the highest percentage indicates the period with the highest connectivity while the one with the least percentage is least connected. Chapman (1979)

RESULTS AND DISCUSSION

The alpha, beta and gamma indices were calculated from the map. The indices of the three periods were then pooled together to show the trend in the growth in road connectivity in the state. Table 1, shows the selected settlements used for the research.

Table 1: Towns as nodes on the topological map

Settlements	Settlements
Birnin Gwari	Hunkuyi
Kujama	Makarfi
Giwa	Kaduna
Turukun	Gwantu
Ikara	Zaria
Kwoi	Maigana
Kafanchan	Zonkwa
Kachia	Soba
Kubachai (Kagarko)	Pambegua
Kasuwa Maigani (Kajur)	Saminika
Kagoro (Kaura)	Jere
Kauru	Gidan waya
Anchau	

The following figures are maps showing road network and topological graphs.

The calculations for Connectivity

THE BETA INDEX (β) 1957 - 1989

Beta index $(\beta) = \frac{e}{v}$

Links (e) =34 and nodes (v) =25

$$= \frac{34}{25}$$

=1.36

The above calculation shows that there is approximately 1.36 roads leading to each node.

THE GAMMA INDEX (γ) 1957-1989

Gamma index (γ) $= \frac{e}{3(v-2)} \times \frac{100}{1}$

$= \frac{34}{3(25-2)} \times 100$

$= \frac{34}{69} \times 100$

=49.3%

The connectivity ratio for this period has a percentage of 49.3

THE ALPHA INDEX (α) 1957-1989

Alpha index (α) $= \frac{e-v+1}{2v-5} \times \frac{100}{1}$

$= \frac{34-25+1}{2\times25-5} \times \frac{100}{1}$

$= \frac{34-26}{50-5} \times \frac{100}{1}$

$= \frac{8}{45} \times \frac{100}{1}$

=17.8%

This index shows a percentage of 17.8 for the first period

THE BETA INDEX (β) 1993-1995

Beta index (β) $= \frac{e}{v}$

Links (e) =44 and nodes (v) =25

$= \frac{44}{25}$

=1.76

The beta index for the second period shows that there are approximately 1.76 nodes leading to each node in the study area

THE GAMMA INDEX (γ) 1993-1995

Gamma index (γ) $= \frac{e}{3(v-2)} \times \frac{100}{1}$

$= \frac{44}{3(25-2)} \times 100$

$= \frac{44}{69} \times 100$

=63.8%

The gamma index for this period shows a percentage of 63.8.

THE ALPHA INDEX (α) 1993-1996

Alpha index (α) $= \frac{e-v+1}{2v-5} \times \frac{100}{1}$

$= \frac{44-25+1}{2\times25-5} \times \frac{100}{1}$

$= \frac{44-26}{50-5} \times \frac{100}{1}$

$= \frac{18}{45} \times \frac{100}{1}$

= 40%

For this period, the alpha index shows the connectivity ratio of 40%

THE BETA INDEX (β) 1996 – 2005

Beta index (β) $= \frac{e}{v}$

Links (e) = 49 and nodes (v) =25

$= \frac{49}{25}$

=1.96

The above value of beta shows that there are approximately 1.96 nodes leading to each of the selected towns at this period.

THE GAMMA INDEX (γ) 1996-2005

Gamma index (γ) $= \frac{e}{3(v-2)} \times \frac{100}{1}$

$= \frac{49}{3(25-2)} \times 100$

$= \frac{49}{69} \times 100$

=71%

The gamma index for this period shows 71 percent.

THE ALPHA INDEX (α) 1996-2005

$$\text{Alpha index } (\alpha) = \frac{e-v+1}{2v-5} \times \frac{100}{1}$$
$$= \frac{49-25+1}{2\times25-5} \times \frac{100}{1}$$
$$= \frac{49-26}{50-5} \times \frac{100}{1}$$
$$= \frac{23}{45} \times \frac{100}{1}$$
$$= \mathbf{51\%}$$

The study revealed that the calculated values of alpha increased from 17.8% to 51% , beta from 1.36 to 1.96 and gamma from 49% to 71% between 1957 and 2009. While the number of nodes on the road network in the state remains constant at 25, the number of roads, increased from 34 in 1957 – 1989 period, to 49 in the 1995 2009 period.

The calculated value of alpha for this period indicates that connectivity index is 51 percent.

It can be seen from the topological graphs (Fig 1a ,1b ,2a, 2b ,3a, 3b) that while the number of nodes on the road network in the state remains constant at 25, the number of links i.e. road stretches increased from 34 in 1957-1989 period to 49 in the 1995-2009 period, see Table 2.

Table 2: Number of road links and nodes in Kaduna State (1957 - 2009)

Periods	No. of links	No. of nodes
1957 to 1989	34	25
1993 to 1995	44	25
1995 to 2009	49	25

Source: Author's computation 2010.

Table 3 shows that the three measures of connectivity increased over the three time periods under investigation. This is an indication that there has been increase in road development from one period to another. Table 3 shows that connectivity indices respectively increased from one period to another. Gamma (γ) was 49.3% in the first period, 63.8% in the second and 71% in the third period. Alpha ( ) index was 17.8%, 40% and 51% in the first, second and third period respectively. Each of these indices shows a general increase from one period to another.

Table 3 : Road Connectivity Indices of Kaduna State over Three – Time Periods

Period	Beta (β)	Gamma (γ)	Alpha ( )
1957-1989	1.36	49.3%	17.8%
1993-1995	1.76	63.8%	40%
1996-2005	1.96	71%	51%

Source: Author's computation 2010.

CONCLUSION

The study has been able to determine road connectivity indices increased over the three time periods. Transport improvement has effects on development. Areas that have good network of roads will increase in productivity, standard of living and improve its social economic development. This is an indication that there has been an increase in road network from one period to another, and that the economic activities of the people of Kaduna State has improved.

RECOMMENDATIONS

1. The Ministry of works and others and similar outfits should be introduced and intensified to help in further road development. The ministry should also identify where there are no roads, where resurfacing and realignment of road network will facilitate connection between settlements, population and location of basic facilities.
2. There is the need for more links to be added to the existing ones this will create room for increase of road network in the state. The new roads will connect existing road network to facilitate linkages .Which will improve the level of the process of national integration. Also the populated discrete isolated settlements will become accessible from the core.
3. Latest technical and technological innovations should be used in rehabilitating roads to provide efficient and profitable services

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