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THE STRUCTURE OF INTRA-URBAN ROAD NETWORK DEVELOPMENT IN ILORIN, NIGERIA

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ABSTRACT

The paper describes the structure of road network development in Ilorin between 1963-1999. This was done by determining the network pattern of the city for the study period and identifying some socio-economic variables considered to be responsible for road network development to build models of network structure.

Data on road network pattern of the city were acquired through mapping from sequential aerial photographs and land use maps of Ilorin. Data on socio-economic variables considered to be responsible for road network development were collected from State Ministries, Parastatals, Local Government offices and National Population Commission.

Using graph theoretic concept measures of network development for the city were determined. Multiple Regression procedure was then used to develop models of the structure of road network development of the city.

The results showed that the identified socio-economic variables are important in the explanation of road network development in Ilorin.

Key words: Ilorin, Road network development, graph theory, Socio-economic variables, Road network structure.

INTRODUCTION

Road Network development connotes changes in the structure of transportation network over time. These changes are brought about as a result of the need for additional links in the network or the expansion of existing network systems. Such developments require capital investments by governments in order to satisfy the transportation needs of the society.

Various methods have been used to study the structure of transportation networks. These include the morphological approach (Appleton, 1967); the functional approach (Garrison and Marble 1965); and the topological approach (Kansky, 1963). However, the topological approach using graph theoretic concepts has been more widely used. Graph theory is a method of understanding, representing and manipulating spatial structure and in this respect it differed considerably from other thrusts in the quantitative revolution (Tinkler, 1979). According to Harvey (1969), graph theory is an important descriptive device in the analysis of the structure of systems.

One of the advantages of graph theory is its relative simplicity. Garrison (1960) recognized this relative simplicity of graph theory and its ability to look at the system as a whole or to look at individual parts of it in terms of the whole.

According to Tinkler (1979), a major attraction of graph theory is the radical simplification it is possible to achieve.

Graph theoretic methods have been widely used in transport geography at both regional and intra-urban levels. Garison (1960) used graph theory to model the accessibility and connectivity of regional highway networks in the United States. Burghat (1969) also applied graph theoretic concepts to analyse the development of road network of the Niagara Penisula, Ontario (see also Carter, 1969; Haggett and Chorley 1969).

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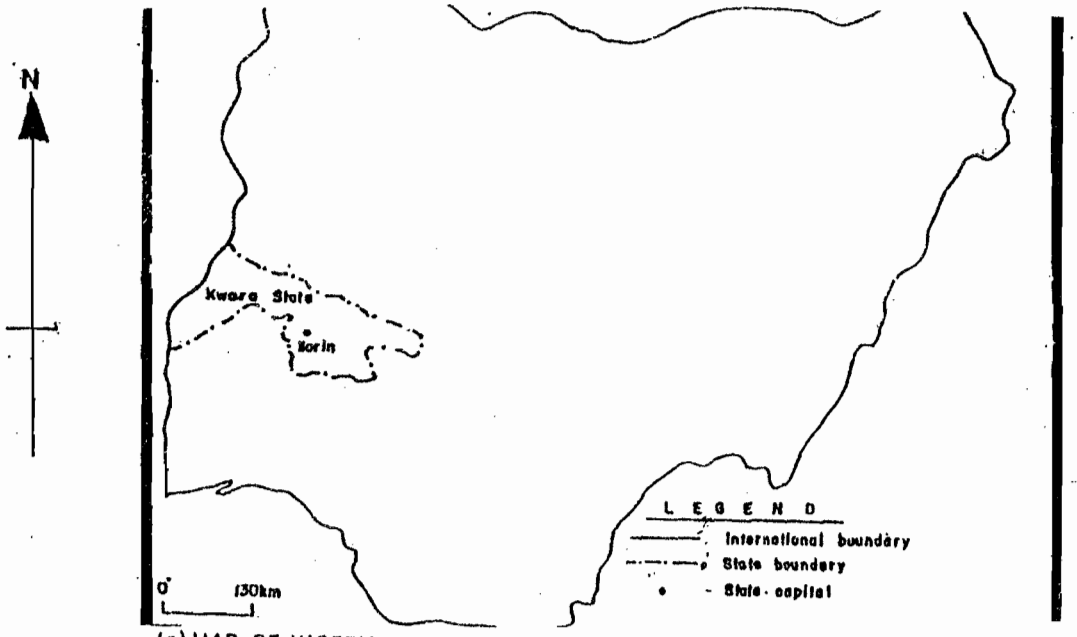
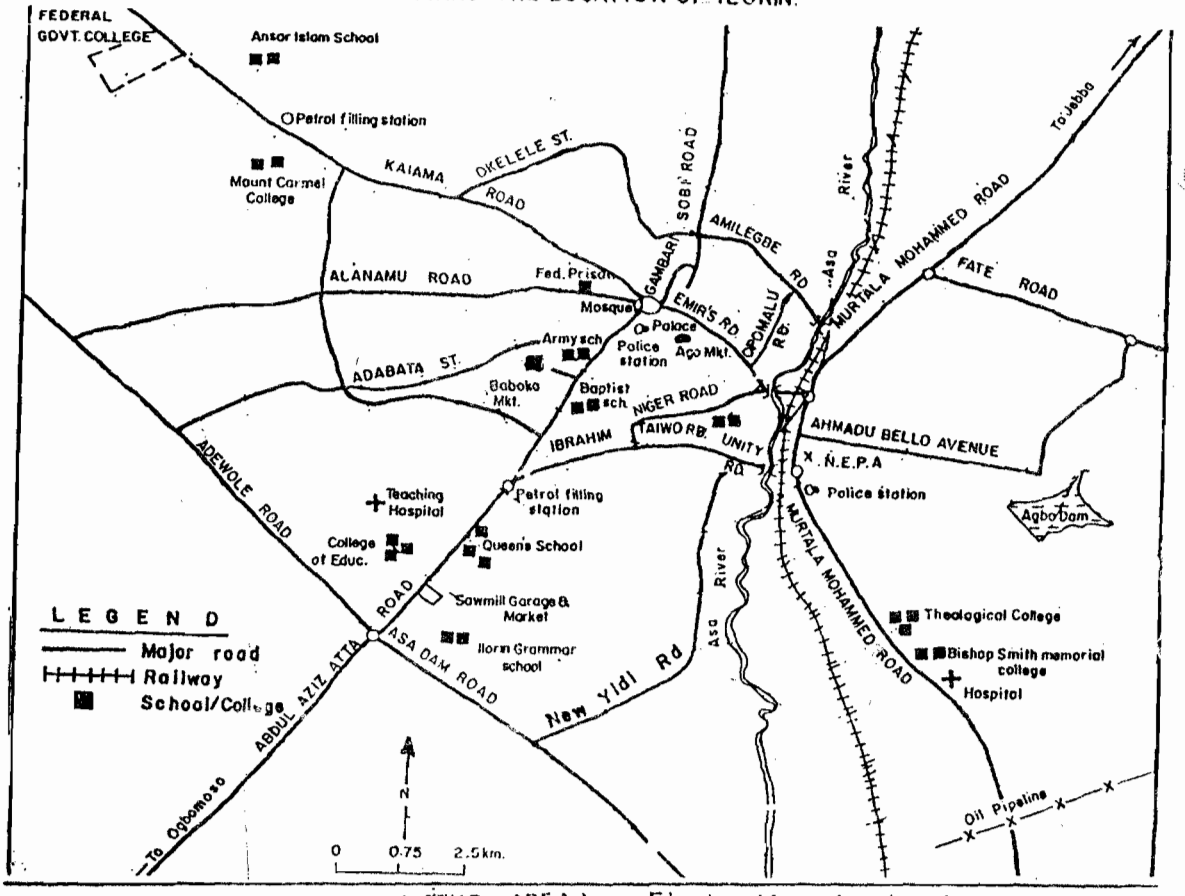


(a) MAP OF NIGERIA SHOWING THE LOCATION OF ILORIN.



(b) MAP OF ILORIN (THE STUDY AREA). Fig. 1. Map showing the study area.

On nodal analysis, Nystuen and Dacey (1961) determined functional connections between Central places in the state of Washington based upon communication flows in a network with the help of graph theoretic concept (see also Soja, 1968, Clayton, 1977; Cates 1978). Wood (1975) also used graph theoretical concepts to examine the functional structure and integration of rural markets in Kisii District, Kenya and found a highly connected nature of the marketer and trader network.

Kansky (1963) made simple structural analysis of regional networks using graph theory and found that a direct correlation exists between transport facilities and levels of economic development (see also Lowe and Moryadas, 1975; Tinkler, 1977a).

In an application of graph theory for assessing the effect on intra-urban accessibility of interstate highways in Columbus and Indianapolis, U.S.A; Muraco (1972) found the existence of spatial regularities in their pattern of accessibility. Also, Ogunsanya (1986) using graph theoretic approach in network flow estimation for Barnsley, U.K., concluded that graph theory would prove useful in network structure identification at the intra-urban level. These studies affirm the utility of graph theory in the analysis of transportation networks and its applicability at both regional and intra-urban levels. This study applies graph theory to Ilorin, a medium-sized city in a developing country, Nigeria. The objective is to show the applicability of this useful quantitative technique in transport geography in identifying the structure of intra-urban road network development in a developing environment.

STUDY AREA

The study area is Ilorin the Kwara State Capital. It is located on latitude 8^0 30' North and longitude 4^0 35' East. (fig.1). The creation of Kwara State in 1967 and the choice of Ilorin as the State capital has resulted in its rapid population increase and area expansion. Over the years, the city has grown from what can be described as a "foot-city" with residential houses located around the Emir's palace to an automobile city.

The development of intra-city roads to cope with the demand of the city when it became a state capital has affected the spatial expansion of the city. Thus developments have concentrated along the routes. The growth of the city has been in terms of physical expansion and growth of traffic The Western section of the city which is predominantly residential generates a lot of traffic daily which have to go through the three bridges linking the West and East. This creates a condition which makes traffic concentrate on and overstrech such routes as Emirs road, Taiwo and Unity roads and Michael Ibru road.

The location of markets and other centres of commercial activities in the city also act as traffic generation points and has significant effect on the city's traffic pattern. The distribution of various other land uses such as institutional, public and semi-public buildings, industrial and recreational all sum up to dictate the pattern of city traffic and route expansion. The study of road network development in Ilorin can serve as a guide for similar studies in other urban centres in developing countries.

TOPOLOGICAL ANALYSIS OF TRANSPORT NETWORKS

In graph theoretic applications of transport network, locations or points are interpreted as nodes or vertices while the routes are links or edges. In the regional scale application of graph-theoretic technique, settlements are taken as nodes and the routes as links in a network.

In the intra-urban application however, the nodes are considered as intersections or junctions and the roads as links in the network. This allows for the abstraction of an urban road network as a graph for the determination of its structural pattern.

In using the graph theory, various indices have been suggested (See Kansky, 1963). In this work however the indices used are:

a. Alpha index, defined as the ratio between the actual number of loops in a graph and the maximum possible number. The range

of the alpha index is from 0 to 1.0 indicating absolute non-connectivity to perfect connectivity.

b. Beta index, defined as the number of linkages per place or node and measures the linkage intensity. The range of the beta index is from 0.5 for minimally connected graph and 3.0 for maximally connected graph.

c. Gamma index, defined as the ratio between the number of edges in a network and the maximum possible number of edges in the graph. The limits of the gamma index are 0 and 1.0 indicating non-connectivity to maximal connectivity.

Although these simple indices have limitations, yet when used properly, they have a lot of usefulness (Monmonier, 1972; Royaltey et al 1975). The utility of the indices stems from their ability to provide a yardstick of comparability for transportation networks (Tinkler, 1979). Besides, the measures are useful in evaluating not only the accessibility of nodes but also the connectivity of networks (Lowe and Moryadas 1975). Also, such topological indices are very useful indicators of development in terms of economic achievement in general and technological achievement in particular (Leung, 1982).

However, the indices have limitations for sophisticated purposes. James et al (1970) found out that the indices do not discriminate adequately between networks of different sizes. Also, Lowe and Moryadas (1975) noted that not all the indices can be modified to accommodate physical or economic distance. But if one's interest is in studying the geographic or structural properties of a network, physical distance between vertices is not of much importance and therefore may be ignored.

DATA COLLECTION STRATEGY AND METHODOLOGY

The data required for this study are the road network pattern of the city for 1963, 1973, 1982, 1988, 1991, 1997, 1999, and the socio-economic variables considered to be responsible for network developments.

In the original works of Kansky (1963), a relationship was found to exist between the structure of transportation networks and the economic characteristics of an area. Indeed, areas with highly developed economies were expected to have well-developed networks while areas that were economically less developed exhibited simple transportation networks. Using this notion, a multiple regression equation can be formed using indices of network structure as dependent variables while the socio-economic factors served as independent variables. In this study, the socio-economic variables identified and used as independent variables are Population of the city; Land use, Commercial development, provision of amenities, land speculation and transportation. Our choice of these variables is strengthened by the assertion of White and Senior (1983) that the existence of economic activities will create a demand for transport. This is because locations of population and of commercial and industrial activities create a demand for transport to close the gap between them. As some of these variables cannot be measured directly, surrogate measures were used for them. The choice of a surrogate measure for any socio-economic variable depends on the problem of study. An important requirement of the variables however, is that they must be easily measurable and that they are projectable as aid to forecasting.

The first independent variable is the population of the city. Rapid population growth is a common phenomenon in urban centres of Nigeria. The effect of continuos urban population growth is that demand for transport services is very high (Ikya, 1993). Thus population growth has been chosen as a factor of transport development. As for measurement procedure, most population figures used for planning purposes rely on census information and their projections. The population census figures for Ilorin for 1963 and 1991 and their projections were used.

The second explanatory variable is transport demand. Transport demand is

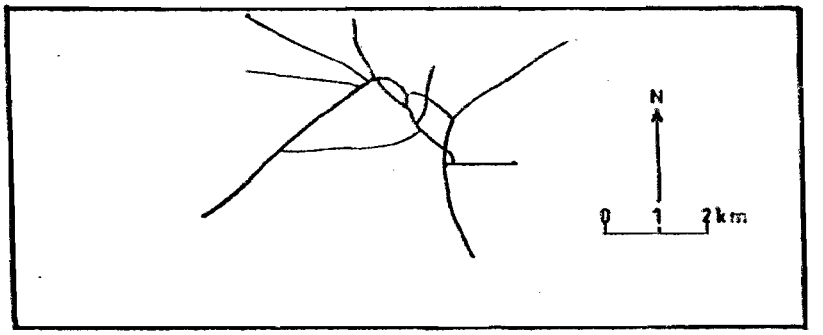


Fig.2 Road network pattern of Ilorin, 1963.

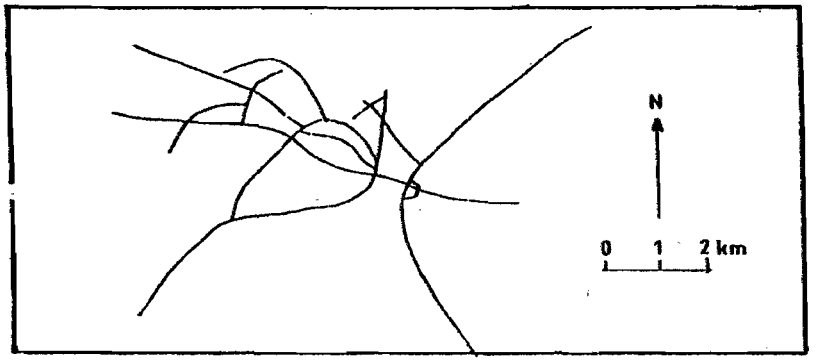


Fig 3 Road network pattern of Ilorin, 1973.

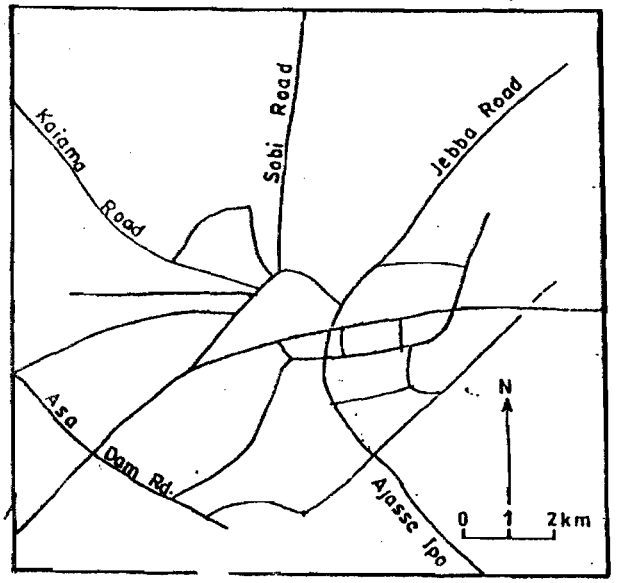


Fig.4 Road network pattern of Ilorin, 1982.

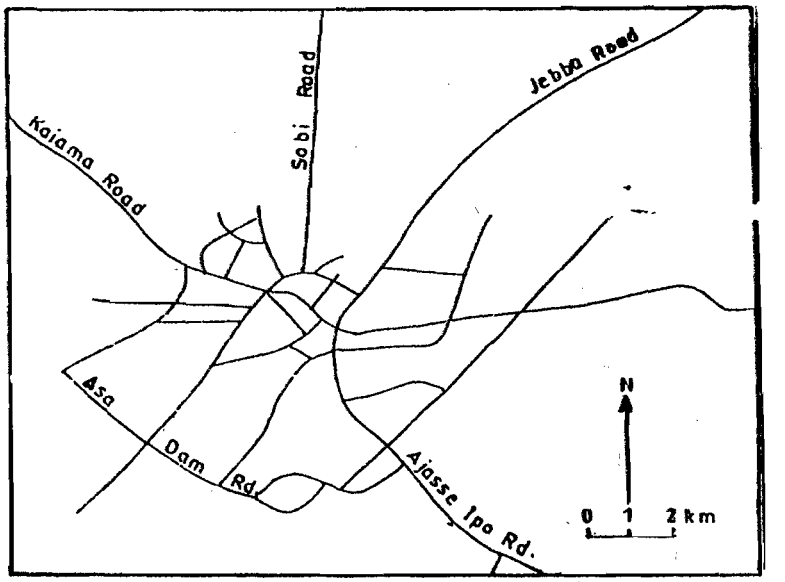


Fig. 5 Road network pattern of Ilorin, 1988.

considered a key factor in city development since transportation is a catalyst of urban development. As for measurement of transport demand Maunder (1982) had found out in a study of bus operations in Delhi, India that transport demand is a function of income level, car ownership and personal preferences (see also Abdullahi 1998). He thus, used per capita income as a surrogate for transport demand. In this study per capita income has also been used as a surrogate of transport demand.

The third variable is landuse. The intimate relationship between transportation and landuse is acknowledged by the fact that at the heart of every city's master plan is a long-run transportation network (Bland, 1992): As for measurement of landuse, Stakie (1967) found that a relationship exists between a landuse type and the number of people employed in his study of traffic generation in Medway towns in Great Britain. He therefore used employment size to measure landuse. Employment size has also been used here as surrogate for landuse.

The fourth explanatory variable is land speculation. This entails the with-holding of land for development in anticipation of future high land prices. This type of growth process permits a sprawl pattern usually found along transportation routes (Clark, 1965). As for measurement of land speculation, Clawson (1962) had suggested that when land comes within the zone of suburban influence for possible later development its prices and taxes often rise. A reasonable surrogate for land speculation is thus the changing cost of land. This study therefore used the average cost of land in Ilorin as surrogate for land speculation.

The fifth variable is commercial development. This is considered important because transport development promotes commercial activities. As for measurement of commercial development, Krakover (1982) in a study of spatial reorganization of growth in urban fields in Eastern United States had used the number of employees in retail activity as surrogate measure for commercial development. In this study data on employment in retail trade in Ilorin was also used as proxy for commercial development.

The sixth variable is provision of amenities in the city. The extension of social amenities to different parts of an urban area is facilitated through transport provision. Also urban dwellers seek housing environments which offer accessibility to urban facilities. As for measurement of social amenities, Berry (1961) used 43 indices for 95 countries in order to measure the degree of economic development of those countries. These include energy consumption, electricity consumption. per capita, exports per capita and similar indices Pred (1976) however suggested that composite as well as single-dimensional variables can also be used. This study uses primary school enrolment as surrogate measure for social amenities in the city. This is because in Nigeria primary education is free and universal while secondary and tertiary education are optional.

The data used were collected from various primary and secondary sources. Data on road network pattern for 1963, 1973 and 1982 were extracted from aerial photographs of Ilorin on scales 1:12,000, 1:10,000 and 1:6,000 respectively. The 1982 aerial photograph was updated through field survey conducted by the author in 1988 to obtain the network pattern for 1988 (See Aderamo, 1998). The network patterns for 1991, 1994, 1997 and 1999 were obtained from records of the Kwara State Ministry of Lands and Housing. Only the major roads were extracted for the study. (figs .2 - fig.9).

Data on population, were collected from National Population Commission; data on per capita income, total employment and manufacturing employment were collected from the State Ministry of Economic Development while data on schools enrolment were collected from the State's Schools Board and Ministry of Education. Data on cost of land were obtained from records of Ilorin West Local Government. These were used as input variables for the socio-economic indices of network development.

MODELLING INTRA-URBAN NETWORK DEVELOPMENT FOR ILORIN

The modeling of network development for Ilorin can be conceptualized to take the following general form:

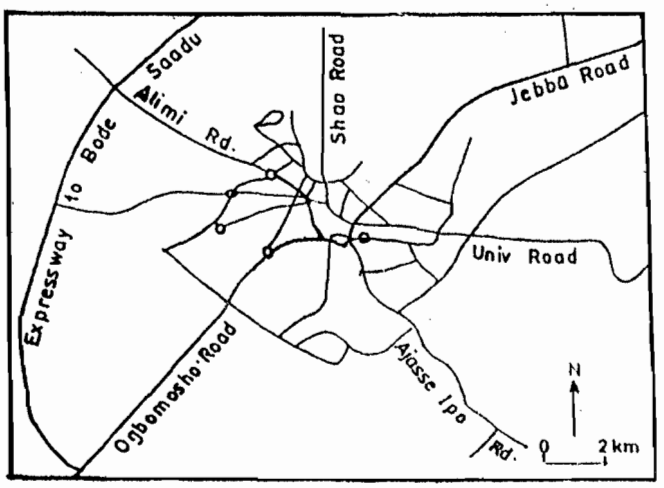


Fig. 6 Road network pattern of Ilorin, 1991.

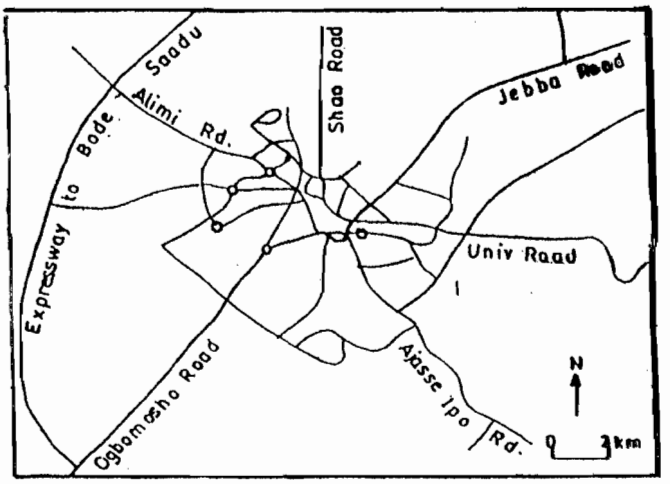


Fig. 7 Road network pattern of Ilorin, 1994.

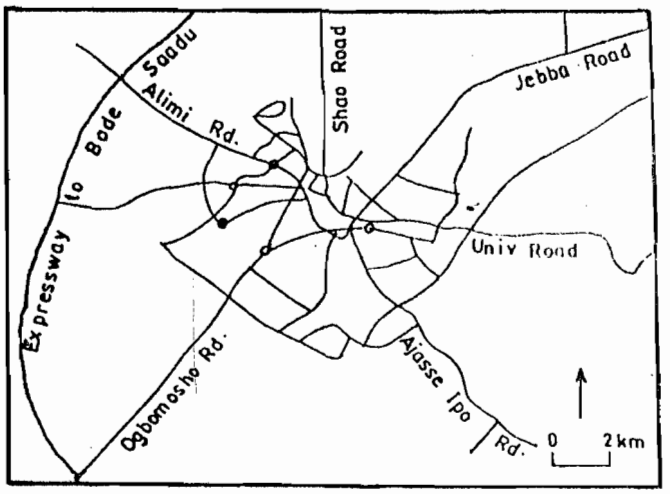


Fig 8 Road network pattern of Ilorin, 1997.

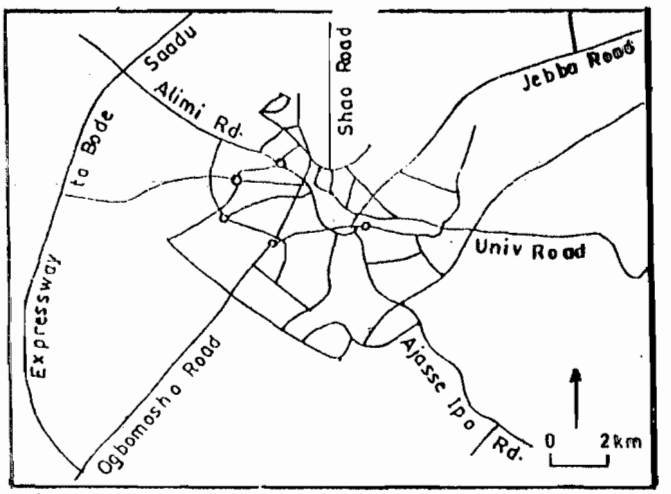


Fig. 9 Road network pattern of Ilorin, 1999.

$$Y=F(X_1,X_2,.....X_n) \quad .....(1)$$

Where Y= Measures of Network Structure and

$X_1,X_2,.....X_n$ are measures of socio-economic variables considered as factors of network development.

The model for our specific case is of the form

$$Y=F(X_1,X_2,X_3,X_4,X_5,X_6,) \quad ..... \quad (2)$$

Where Y= Measures of Network Structure (Alpha index; Beta index; Gamma Index).

X_1 is the Population of the city; X_2 is transportation demand; X_3 is land use control; X_4 is land Speculation; X_5 commercial development; X_6 social Amenities.

This can be made operational in the form

$$Y= a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+e.....(3)$$

RESULTS

Table 1.0 shows the topological measures of network structure for the city from 1963-1999

TABLE 1.0 TOPOLOGICAL MEASURES OF NETWORK STRUCTURE FOR ILORIN (1963-1999)

Indices	1963	1973	1982	1988	1991	1994	1997	1999
α	0.2381	0.3143	0.2824	0.2581	0.2323	0.2130	0.2056	0.2202
β	1.3077	1.5000	1.5111	1.4694	1.4231	1.3889	1.3750	1.4035
γ	0.5151	0.5556	0.5271	0.5106	0.4933	0.4808	0.4753	0.4848

Source: Authors Data Analysis 1999

TABLE 2.0 REGRESSION SUMMARY FOR 'ALPHA INDEX'

Dependent variable	Independent variables	Parameters estimates	Multiple R	R-Square
Alpha index	X_4	-0.004818	-0.6789	0.4609
	X_2	0.002178	-0.7099	0.5039
	X_1	-0.001442	-0.7105	0.5048
	X_5	0.016999	-0.7232	0.5229
	X_6	-0.003396	-0.7468	0.5577
	X_3	-0.003975	0.7485	0.5602

Where *a* is the intercept, b_1, b_2, b_3, b_4, b_5, b_6 are parameters determined by empirical evidence and *e* is the error term which explains the effects of the unspecified variables.

The structural indices of network and the socio-economic variables were used as dependent and independent variables for the period 1963-1999.

These were used as inputs into the regression models. Table 1.0 shows the structural indices of the city's network for the studied period, while figures 2.0 9.0 show the network patterns.

The topological measures of network structure for Ilorin show the progressive development of the city's network over the years. The pattern shows that the city's network experienced significant growth between 1963 and 1973. This can be attributed to the fact that within this period, Ilorin grew from being a Provincial headquarters to a State headquarters when special attention was paid to the construction of new roads and the improvement of existing ones.

Between 1973 and 1982, there was still some attention paid to the development of intra-urban road network but the stringent measures being adopted by government in respect of funds being allocated to all sectors of the economy affected road construction. The pattern of changes in the network between 1982 and 1988 is a clear indication of the general state of the country's economy. In subsequent years to date, various economic reforms introduced by successive governments in Nigeria significantly

affected all sectors of the country's economy including the transport sector (Taiwo, 1992). Although some links were added to the city's network between 1988 and 1999 the growth of the network had been at a very slow pace.

The initial rapid growth experienced by the city's network was also commensurate with the city's rapid expansion. As the city's expansion slowed down, there was also a decline in road construction.

The data on table 1.0 and on socio-economic variables were used as input for the multiple regression analysis using the SPSS (Statistical Package for the Social Sciences). The indices alpha (α) Beta (β), Gamma (γ) were used separately as dependent variables which resulted in obtaining three (3) multiple regression equations. Tables 2.0, 3.0 and 4.0 show the regression summaries for the 3 models.

Regression constant =0.639316; Coefficient of determination for all variables R^2 =0.9961. Adj - R^2 =0.9727. Regression equation is

$Y=0.639316-0.00442X_1+0.002178X_2-0.003975X_3 -0.004818X_4+0.01699X_5-0.003396X_6$

Table 2.0 shows that all the six independent variables have strong negative correlation coefficients with the dependent variable. The correlation coefficients range from -0.6789 for X_4 (Land speculation) to -0.7099 for X_2 (Transportation); - 0.7105 for X_1 (Population); - 0 7485 for X_3 (Land use). Thus there is very strong direct but negative relationship between alpha index which is an index of network development with all the six identified independent variables.

Further the combined variables explain 97.27% of the total variation in the dependent variable with all of them significant at 0.15 level of significance, and can be used with any degree of confidence in the explanation of the development of intra-urban network in Ilorin.

Regression constant =2.283763,. Coefficient of Determination for all variables R^2 = 0.9959. Adj - R^2 = 0.9714. Regression equation is:
$Y=2\ 283763-0.004017X_1+0.005793X_2 -0.009321X_3 - 0.009354X_4 + 0.043102X_5 -0.007493X_6$.

Tables 3.0 shows that many of the explanatory variables have weak relationships with the dependent variable. For instance, X_4 (Land peculation) has correlation coefficient of -0.3936 with the dependent variable. All the other explanatory variables have coefficient of correlations ranging from -0.1369 for X_2 (Transportation) to -0.1522 for X_6 (Social amenities); -0.1904 for X_1 (Population); -0.2291 for X_3 (Land use) and -0.2489 for X_5 (Commercial development). This implies that a weak relationship exists between the Beta index and the identified socio- economic variables.

TABLE 3.0 REGRESSION SUMMARY FOR 'BETA INDEX'

Dependent variable	Independent variables	Parameters estimates	Multiple R	R Square
Beta index	X_2	0.005793	-0.1369	0.01873
	X_6	-0.007493	-0.1522	0.0215
	X_1	-0.004017	-0.1904	0.0363
	X_3	-0.009321	-0.2291	0.0525
	X_5	0.043102	-0.2489	0.06195
	X_4	-0.009354	-03935	0.1548

TABLE 4.0 REGRESSION SUMMARY FOR 'GAMMA INDEX'

Dependent variable	Independent variables	Parameters estimates	Multiple R	R-Square
Alpha index	X_1	-0.028551	-0.3115	0.09704
	X_5	0.021783	-0.4410	0.19450
	X_1	-0.012114	-0.4577	0.20951
	X_2	0.027694	-0.4681	0.21914
	X_3	0.024792	-0.4793	0.22970
	X_6	-0.086427	-0.5636	0.31768

However the combined variables explain 97.14% of the total variation in the dependent variable. Thus the model can be used with reliable level of confidence in the explanation of the development of intra-urban network in Ilorin.

Regression constant =-2.131225; Adj -R^2 = 0.5551; Coefficient of Determination for all variables

R^2 = 0.9364. Regression equation is:

$Y=-2.1312250.012114X_1+0.027694X_2+0.024792X_3 - 0.02855X_4 +0.021783X_5 -0.086427X_6$.

Table 4.0 shows that only X_6 (Social amenities) has strong relationship with the dependent variable. The other five explanatory variables have weak relationship with the dependent variable.

The correlation coefficients are -05636 for X_6 (Social amenities). -0.4793 for X_3 (Land use); -0.4681 for X_2 (Transportation); -0.4577 for X_1 (Population).

Thus there is a weak relationship between the Gamma index and many of the identified independent variables.

Further the combined variables explain only 55.51% of the total variation in the dependent variable.

In all, the results of the analysis of the structure of intra-urban road network development in Ilorin show that all the independent variables are important in the explanation of Alpha index, Beta index, and Gamma index, which are all measures of road net work development.

The results also show that socio-economic variables contribute significantly to intra-urban network development in Ilorin. Consequently the level of economic development of the country can be said to reflect very strongly on the development of transportation networks.

CONCLUSION

This study has been used to show the contributions of various socio-economic variables to the development of intra-urban road network in Ilorin. The study has used the simplicity and reliability inherent in graph-theoretic concepts to identify the structure of network development in the city between 1963 and 1999.

The results of the study revealed that six socio-economic variables namely population, transportation, land use, land speculation, commercial development and social amenities can be used with varying degrees of contribution to explain the development of the city's road network. Specifically all the six independent variables contribute significantly to the explanation of the Alpha index. Similarly these six variables also contribute fairly to the explanation of the Beta index and Gamma index. Overall, the six independent variables can be used reliably to

explain the structure of intra-urban road network development in Ilorin.

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