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SPATIAL TEMPORAL ANALYSIS OF ROAD NETWORK DENSITY IN ILE-IFE METROPOLIS, NIGERIA

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Abstract
The road network density of Ile- Ife is assessed using a Geographic Information System (GIS). Global Navigation Satellite System (GNSS) receiver was used to acquire primary data, secondary data used for this study include; Topographical maps covering the study area for 1968, Landsat 5 and 7 images of 1986, 2000 and 2007 respectively, satellite image (SPOT 5) and Google earth Image (SPOT 5) of 2014 and 2019 respectively. Information of the road was also gathered through proper interactions with dwellers who have stayed in the geographical area long enough. Road intersections, also known as nodes, were digitally represented as points, while roadways, also known as arcs, were represented as lines. The study employed a simple descriptive analysis to characterize the various road network types. The Alpha, Beta, and Gamma Indexes were used to assess the degree of connection within the road network. The road density was determined with respect to the road length per unit area. Result of the road connectivity revealed that street network analysis showed a complex network with beta values of 0.50 (1968), 0.54 (1986), 0.55 (2000), 0.55 (2007), 0.56 (2014) and 0.55 (2019) respectively. However, the alpha index showed that the street network in all the years considered for this research were not perfectly connected as a negative value of alpha index were obtained and these were -0.25 (1968), -0.23 (1986), -0.23 (2000), -0.22 (2007), -0.22 (2014) and -0.22 (2014) %. Gamma index of Ile-Ife metropolis for the five years were 0.17, 0.18, 0.18, 0.18, 0.19 and 0.18. This implied that as much as 83, 82, 82, 82, 81 and 82% gaps respectively were needed to have a complete link within the network. The results of road density for each year varied from 6km/^{2}km (1968), 11.97km/^{2}km (1986), 13.93km/^{2}km (2000), 11.9 km/^{2}km (2007), 12.05km/^{2}km (2014), 9.08km/^{2}km (2019). These studies provide crucial empirical backing for planners and policymakers to comprehend how road network density affects mobility performance and create urban road networks that are more efficient.

Keywords: Mobility, Road transport network, Development, Connectivity, Transport planning.

Introduction

Mobility assumes a crucial part in the advancement of municipal centre as it provide adequate level of accessibility for all residents and for all road users (Soczowka *et al*, 2020), influence progress and levels of financial achievement through land openness, Regardless of a country's economic capability, population, or level of technological advancement, mobility is a necessity. Strong economic and political linkages between regions within a state depend on the movement of people and products between them. Obafemi *et al.* (2011), identified poor construction, inadequate drainage, very thin coatings that were easily washed away, and overuse of the road network considering the undeveloped state of railroads and rivers, to contribute to Nigeria's roads' continued poor condition. To guarantee sustainable advancement in municipal areas, a proficient transport network is fundamental for the operational performance of municipal road networks which is highly dependent on the network structure that consequently shapes the traffic flows on a network (Wang *et al.*, 2019).

The network topology that determines how traffic flows across a network has a significant impact on the operational performance of municipal road networks (Wang *et al.,* 2019). So, when the road network becomes more accurate, finding the optimal location could be difficult. In other words, the denser a network is, the more information is represented by edges and nodes and the higher the accuracy achieved. The old planning approach gives priority to motor vehicle travel, resulting in an abundance of local government (Trunk C) roads, few state government (Trunk B?) highways, and wide and sparse federal government (Trunk A) roads. According to Wang et al. (2020), a federal road's severe traffic congestion and uneven traffic flow distribution are caused by state and local government roads' incapacity to meet the rapidly rising demand for traffic.

Above all, many activities engaged by man in one way make or break cities. So, road mobility has been considered to be highly important as it determines the distribution, growth and accessibility to different locations.

Many studies have been conducted in relation to road network density but only few tend to analyse road network density in cities. For example, studies carried out by Zhao *et al.,* (2015) considered the influential factors to find the optimal location, Wang et al., (2020) studies the impact of road network density on motor vehicle travel through traffic flow, Mokhirev & Medvedev, (2020) assess the density of forest roads, Bennett, (2017) studies the effects of road density and pattern on the conservation of species and biodiversity.

Numerous writers have examined how daily living has been impacted by the density of motor mobility. For example, by resolving the particular situation of the p-median location problem, Zhao et al. (2015) examined how the density level of the road network influences finding optimal position. The road network and population geocoding of Dalarna, Sweden, were digitised for the project. According to the study, a denser network does not necessarily contain the ideal solutions as the density level increases.

In studying the traffic flow and network analysis of Chinese cities, Wang et al.'s (2020) study investigates the effects of road network density on motor vehicle travel. Three viewpoints were used in this study which are the multi-city comparisons with traffic flow data, and multi-city and multi-period comparisons with structural features. According to the comparative analysis results of three modern cities (Xiamen, Washington, D.C., and San Jose), as road network density rises, the average travel distance in various cities with comparable geographical areas won't increase noticeably. Findings from an analysis of Changchun, China's road network evolution reveal that as road network density increases, average road segment length and overall trip distance decrease.

Zhao and Lu, (2011) observe the influence of municipal expansion pattern on motorized travel using Beijing, China as a case study. Quantitative analyses were used on three indicators; density, diversified landscape and transport ease of access. The study reveals that a low distance between housing and work place will lead to a low spatial disparity consequently leading to increase in the need for motorized travel. They therefore recommended the need for new transport policies to change course of transport.

Abbas and Hashidu (2019) evaluate the growth of the road transport network in northeastern Nigeria from 1961 to 2011. Maps of the investigated years were analysed using topological abstractions, which actually represent a series of vertices (nodes) and set of edges (links), in order to assess the changes in connectedness and accessibility via road network over time. Road accessibility and connection in northeastern Nigeria have significantly increased between 1961 and 2011, according to the findings of the connectivity index, which includes the gamma, beta, and alpha indices. The beta index showed that, from 1.13 in 1961 to 1.46 in 2011, there is an increase in the number of roads that lead to each node. Alpha increased from 3.7% in 1961 to 23.4% in 2011. The gamma index also showed that during the last five decades, road connectivity has increased. The results showed that the region's transport network is advanced in large part by government investment.

Mokhirev and Medvedev (2020) use contemporary geographic information systems (GIS) to evaluate the density of forest roads and examine their evolution. Roads on the territory of the researched areas have been digitised and classified into three categories: logging roads, branch roads, and year-round highways. The outcome shows The results show that the analysed regions' mobility network and logging are primarily developing in a northeastern direction. The reason for this was the region's natural and climatic characteristics, coupled with a limited capacity for the advancement of alternate paths.

Weighted road density, a marker for traffic-related air pollution, and the spatial distribution of walkability within neighbourhoods of Sydney, Australia's are described by Cowie et al. (2016). The study utilised weighted road density and walkability to identify neighbourhoods that exhibit high walkability and low weighted road density, as well as low walkability and high weighted road density, referred to as "sweet-spots." These neighbourhoods were then compared in terms of walkability, weighted road density, and socio-economic status (SES). Findings showed that while a considerably greater percentage of Sydney neighbourhoods have health-limiting characteristics like high TRAP exposures or poor walkability, very few neighbourhoods have both health-promoting characteristics like high walkability and low Traffic Related Air Pollution (TRAP).

Bennett (2017) examined 215 research studies that looked at the effects of roads and road networks on a variety of species between 2011 and 2015 in order to study the effects of road density and pattern on biodiversity and species conservation. The research categorised those studies into four key areas: survey design and mitigation, which includes both innovations and assessments, the effects of road networks on wildlife populations, the direct effects of roads on wildlife, and the indirect effects of roads on wildlife. The analysis found that just 10% of the studies examined the consequences of road networks on wildlife, whereas 38% of the studies examined the indirect effects of roads on wildlife. Predictive models are becoming more and more popular as a tool for analysing the effects on road networks, determining landscape connectedness, and creating mitigation strategies. The ecological effects of roads and planned road development are typically covered in the study.

According to Vinod et al.'s 2003 study, the Kasaragod Taluk Road network has poor connectivity when analysed using the beta index. Dead ends were created by the streams that led the roadways to flow into the drainage. The road network of the studied region is in good shape, and there is still a high degree of connection, according to a 2011 study by Obafemi et al. that evaluated the road network system of the Trans-Amadi industrial layout using Geographic Information System (GIS). Olawole (2013) found that the Alpha values are abnormal and indicate the inadequate road connectivity while researching the geospatial analysis of rural road transport and socioeconomic development in Osun State, Nigeria.

Sreelekha et al. (2016) examined the relationship between the spatial pattern and road network connection in Calicut, India, in order to clarify how network connectivity explains the spatial pattern of the network structure. The outcome shows that there is a clear relationship between the fractality of the transport network and the coverage and connectivity of the research area. He highlights the important connection between the spatial arrangement of the network within the research area and the degree of road network development.

Since Obafemi Awolowo University (OAU) moved to Ile-Ife from Ibadan in 1967, the region has experienced rapid spatial expansion and infrastructure development related to mobility. This has led to multiple increases in municipal growth and the road transport network. Consequently, it is vital to comprehend the spatiotemporal analysis of the nation's road network density. This study evaluated the spatial-temporal analysis of the road network density in Ile Ife, Nigeria, using remote sensing (RS) and geographic information system (GIS) approaches.

The Study Area

The research area, Ile-Ife, is situated at the intersection of the routes leading from Ilesa and Ibadan, 64 km to the southwest of Nigeria. Ile-Ife is situated 200 kilometres from Lagos State and 56 kilometres from Osogbo, the capital of the State of Osun (Figure 1). The settlement is located between latitudes 7028'N and 7046'N and longitudes 4036'E and 4056'E on the Greenwich Meridian (Oloukoi, Oyinloye, and Yadjemi, 2014). There were 644,373 people living in the study area in 2006, which covered portions of Ife Central, Ife East, and Ife East area office, Modakeke, covering an area of 373.50 km^2 (NPC, 2009).

Over the years, the study area grew in area extent to annexed settlements that are once in the frontiers of the city. Some of the settlements include: Opa, Ile-fifun, Oranife, Idita, Ajebamidele, Kosere, Falolu, Kanmi, Irewunmi, Oke-Ogbo, Oniyarin, Apata, Sasa, Owoeye, Ita Osa, Modomo, Esuyare, Olorunsogo, Olojede, and Aserifa.

Road mobility is the main mode of transport in the city. Roads network in Ile- Ife are categorized into three namely: primary roads (Federal roads). secondary (State roads) and the tertiary (community / LGA roads), There are more secondary road and tertiary road than the federal roads. In all there are 111.48kms of federal roads (O.A.U community inclusive), 36.42km of secondary roads and 796.62km of tertiary roads in the city (Olapoju, 2016).

In Ile-Ife, the minority of people ride bicycles, while the majority of people commute by foot, in private vehicles, commercial buses, minibuses, and commercial motorcycles. Under the Road Transport Employees Association of Nigeria (RTEAN) or the National Union of Road Transport Workers (NURTW), the commercial buses are registered. The commercial bus travels on the main route, known as Ede Road, which connects Obafemi Awolowo University to Opa via Sabo and the Obafemi Awolowo University Teaching Hospital Complex. It also travels on the Ibadan Ondo Road, which circles around Modakeke's Municipal Day Secondary School before ending at the Ibadan-Ilesa-Akure bypass. Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) road, Lagere, Sabo, and other main roads in Ile-Ife are particularly congested due to frequent traffic (Olapoju, 2016).

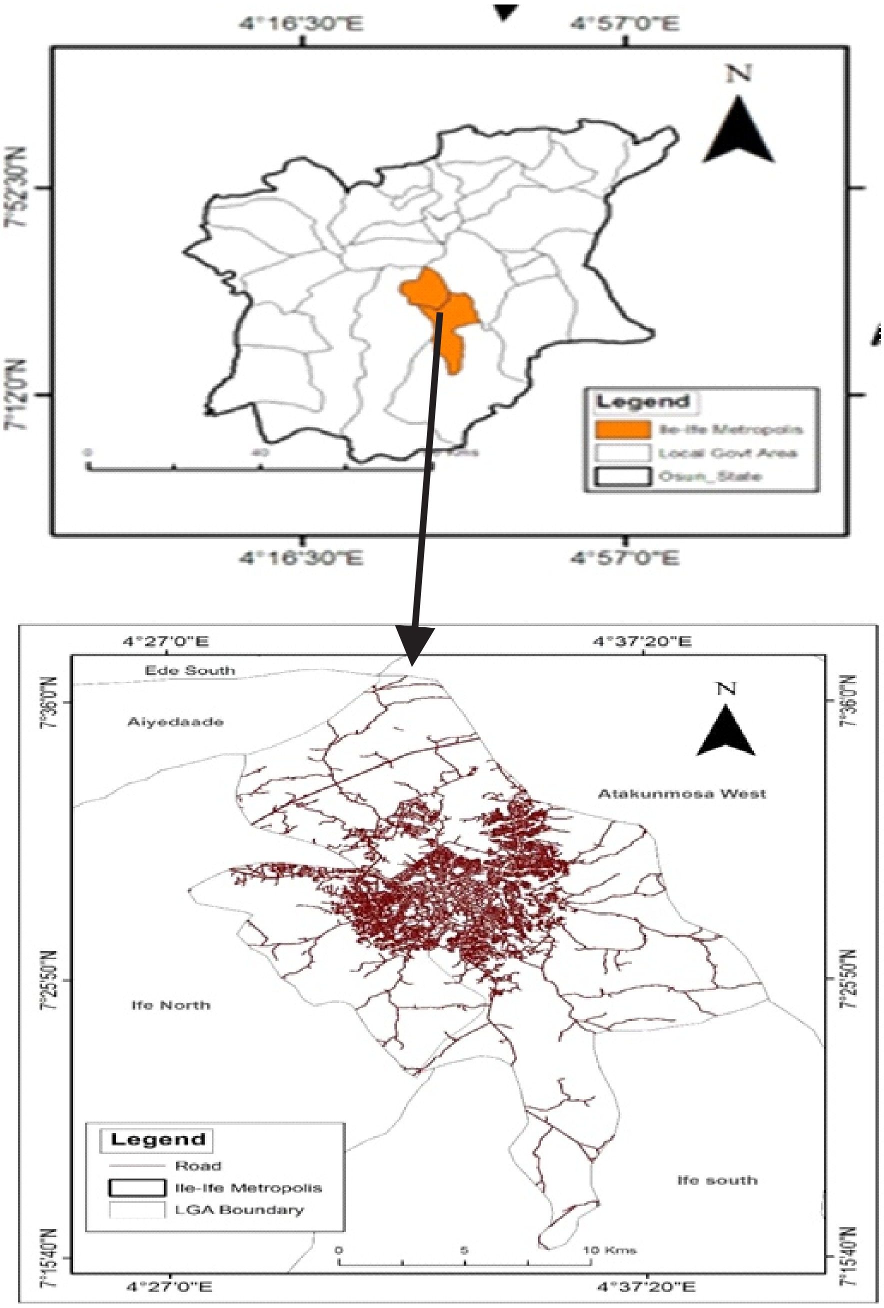

Figure 1: Location of the study Area- Ile- Ife, Osun State, Nigeria
Source: Adapted and modified from administrative map of Osun state.

Methodology

Data Collection Procedure

In analyzing the road network density in Ile Ife both primary and secondary data were collected. Data on Ground Control Point such as schools, road intersections, etc… were collected using Global Positioning System (GPS) for the purpose of ground-truthing and geo-referencing. The secondary data used in this study include topographical maps of Ilesha SW (Sheet 243 SW) and Ondo NW (Sheet 263NW) on a scale of 1:50,000; Landsat 5& 6 ETM+ (path 190, row 55) images for 1986, 2000 and 2007; and Spot 5 panchromatic Satellite image at a resolution of 5 meters for 2014 and 2019, census data for 1963, 1991 and 2006 sourced from National Population Commission were used to project the population figures of the years under consideration. The administrative map of Ife metropolitan area was also acquired from the two Local Government Areas (LGAs).

After scanning, the topographic maps were imported into the ArcGIS software environment. Following georeferencing and resampling of the maps, the research area's submap was retrieved, digitalized, and added to the database (Oloukoi et al., 2014). Every one of these maps was presented on the UTM projection system. The Landsat TM and ETM+ orthorectified satellite pictures (from source) were also imported in a similar manner into the ArcGIS software environment. To evaluate the coverage, an extract of the area's sub-scene was placed over the respective images. Using the same software, bands 4, 3, and 2 were combined to create red, green, and blue (RGB) bands, and the contrast was then improved. This enables the digitization of the study region's municipal area and road network as well as improved visualization of the relevant features.

Road Density Index

The research area's dense road network can be explained by its road density. Comparing the road density result to the standard result of Odaga and Heneveld (1995), it can be observed that the road density is low when it is less than 30 m per square km, medium when it is between 30 and 120 m, and high when it is greater than 120 m. From metres (m) to kilometres (km), the entire length of the roadways was converted. A road's length divided by its population and the study area can be used to illustrate changes in road density. The road density index (RDI) is considered to trace the change of road mobility network over time at Ile-Ife using the formulae.

$$RDI\_A_t = \frac{RL_t}{UA_t} \quad \text{….. Equation (1)}$$

$$RDI\_CAP_t = \frac{RL_t}{UP_t} \quad \text{….. Equation (2)}$$

Where:

RDI_AT = The road density index per area in km/km^2

RDI_CAP_t = The road density index per capita in km/person

RL_t = The total road length in km at time t

Ua_t = The total municipal area in km^2 at time t

Up_t = The total municipal population in the study area at time t.

Road Area Density Index

The purpose of the road area density index is to investigate the spatio-temporal relationships between the road transport network and municipal expansion. In relation to the entire metropolitan area and the municipal population, this determines the exact territory dedicated to the road transport network. The outcome is consistent with the extents of the overall municipal road transport network and the total road space per person over time. The ratio of the entire road area to the entire municipal population as well as the extent of the road transport network to the entire municipal region is known as the Road Area Density Index, or RADI.

Index, or RADI.

$$RDI\_A_t = \frac{RL_t}{UA_t} \times 100 \quad \text{….. Equation (3)}$$

$$RDI\_CAP_t = \frac{RA_t}{UP_t} \quad \text{….. Equation (4)}$$

Where:

RDI_{At} [%] = The road area density index in municipal area

RDI_CAP_t = The road area density index per municipal area in km/person

RA_t = The total road transport network area in km at time t

UA_t = The total municipal area in km at time t;

UP_t = The total municipal population in the study area at time t;

Connectivity Analysis

A transmission network's degree of connectedness, which can be determined by counting the number of connected components or by the degree of connections in a certain area, is one of its most crucial features (Mahdi et al., 2023). People's ability to relocate swiftly and affordably depends on the network's connectivity. Moreover, high connectivity is necessary for a place to thrive. A variety of graph theory-based metrics, including the aggregate transport score (ATS), cyclomatic number, alpha, beta, gamma, and eta, were devised by Kansky in 1963 and can be used to assess the degree of connectivity in transport networks. To examine the temporal changes in the level of road connectivity and the nature of the road network in the study area, three connectivity indices (Alpha index (α), Beta (β) index and Gamma index (γ) were used.

Alfa index (α)

It is an important metric for network connections. The range of values for the alpha indicator is 0 for the least connectivity and 1 for the highest connectivity.

$$\alpha = \frac{e-v+p}{2v-5} \qquad \text{….. Equation (5)}$$

Where
e is the amount of edges or links
v is the amount of Vertices or nodes
p is the amount of sub graphs of the link

Beta index (β)

It describes the relationship between a specific number of edges and vertices in a graph and is one of the most basic metrics used to evaluate the connectivity of mobility networks. In networks with strong connections, the beta index has larger values. Using the following formula:

$$\beta = \frac{e}{v} \qquad \text{….. Equation (6)}$$

Where
e is the amount of edges,
v is the amount of vertices

Gamma index (γ)

Kansky's third graph scale expresses the link between a network's maximum number of edges and the actual number of edges. As can be seen from the equation below, it has a range from zero to one, where one indicates a completely linked network and zero a low degree of connection.

$$\gamma = \frac{e}{3(v-2)} \qquad \text{….. Equation (7)}$$

Where e is the amount of edges
v is the amount of vertices.

Results and Discussion

Road network expansion between 1968 and 2019

Road network constitutes an important element in municipal development as roads provide accessibility to the different land uses in an municipal area (Rui & Othengrafen, 2023).

Road networks are crucial to municipal growth as it gives access to the many land uses in an municipal region, (Rui & Othengrafen, 2023). Road transport is the dominant mode in the study are, hence road network expansion aligned with the trend in municipal expansion between 1968 and 2019 in the study area. Table 1 shows the trend of road network expansion in Ile-Ife. In 1968, the length of road in the city was 34.26 km, the length of road network increased from 34.26km in 1968 to 379.44km in 1986. The length increased by 1007.53% within 18 years from 1968 to 1986 (Table 1). The total road network increased to 560.22km in the next 14 years (1986 to 2000) amounting to 47.83% increase in road length, by 2019 the total length of roads in Ile-Ife was 944.52km. Figures 1 to 4.2 present the spatial expansion of road network in the study area. Figure (2a- 2f) also shows that the number of road segments also increase as the network expansion, it increased from 39 segments in 1968 to 4,165 segments in 2019.

The development of the three categories of roads, primary (Federal roads), secondary (State roads) and tertiary (LGAs roads), in the study area is as shown in Table 2. Tertiary roads increased from 18.8km in 1968 to 796.62 km 2019. Secondary roads expanded in length from 11.52km in 1968 to 36.42km in 2019. The third category of road (Primary roads) increased in length from 3.92km in 1968 to 111km in 2019 (Table 2)

Road Density Index

The study area's road transport network development and municipal growth were examined in relation to each other in a spatiotemporal manner using the index. The results demonstrate how the road density changed over time, from 6 km/km2 in 1968 to 9.08 km/km2 in 2019. The road density increased from 6 km/km2 in 1968 to 11.97 km/km2 in 1986, marking the largest significant variations between 1968 and 1986 (Table 3 & Figure 3). As a result, this era saw a higher degree of openness to various land uses.

In addition, the research area's road density increased from 0.00023 km/p in 1968 to 0.0010 km/p in 2019, in contrast to the population density. Between 1968 and 1986, there were the biggest changes in road density per person, improving from 0.00023 km/p in 1968 to 0.0015 km/p in 1986 (Table 3 & Figure 3). The road network in the research area demonstrates that the road density was low when compared to the standard, as noted by Odaga and Heneveld (2009).

As compared to the extent of the road transport network, the different changes show how quickly the population is growing in the study area. This pointer could be used to observe that the establishment of the road network has not increasing as the same pace with population growth.

Road Area Density Index (RADI)

To explain the connection between metropolitan growth and mobility, road area density index equation was calculated. Also, the widths of the roads were measured. The total area dedicated to road mobility network enlarged from 4.03% in 1968 to 11.50% in 2000. The greatest increase was recorded in 2000 when the total area dedicated to road mobility network enlarged to 11.50% from 7.98% in 1970. This percentage further decreased to 7.94%, 7.89% and 5,85% in 2007, 2014 and 2019

Table 1: Road network expansion characteristics

Characteristics	**Years**					
	1968	1986	2000	2007	2014	2019
Number of road segments	39	1784	2357	3303	4090	4165
Total Length (km)	34.26	379.44	560.92	697.52	892.27	944.52
% change	_	1007.53	47.83	19.58	27.91	5.85
% annual rate of change	_	55.97	3.42	2.8	3.99	1.17

Table 2: Road expansion characteristics by road types: 1968 to 2019

Road Type	Characteristics	1968	1986	2000	2007	2014	2019
Primary	Segment of Road	2	300	302	352	412	416
	Length (km)	3.9	73.54	84.87	88.44	108.60	111.48
	Percentage	11.38	19.38	15.13	12.68	12.17	11.80
Secondary	Segment of Road	8	30	31	32	35	38
	Length (km)	11.52	21.84	26.16	26.80	31.30	36.42
	Percentage	33.63	5.76	4.66	3.84	3.51	3.86
Tertiary	Segment of Road	29	1454	2024	2919	3643	3711
	Length (km)	18.84	284.06	449.89	582.28	752.37	796.62
	Percentage	54.99	74.86	80.21	83.48	84.32	84.34

Table 3: Road density of Ile-Ife between 1968 to 2019

Year	Road Transport Network Length (km)	Municipal area (^{2}km)	Population Projected	Road Density Index (km/^{2}km)	Road Density Index (km/p)
1968	34.26	5.71	149,323	6	0.00023
1986	379.44	31.70	245,534	11.97	0.0015
2000	560.92	40.27	361,490	13.93	0.0016
2007	697.53	58.47	662,415	11.93	0.0012
2014	892.27	74.06	803,791	12.05	0.0011
2019	944.51	103.99	922,871	9.08	0.0010

Source: Author's Fieldwork

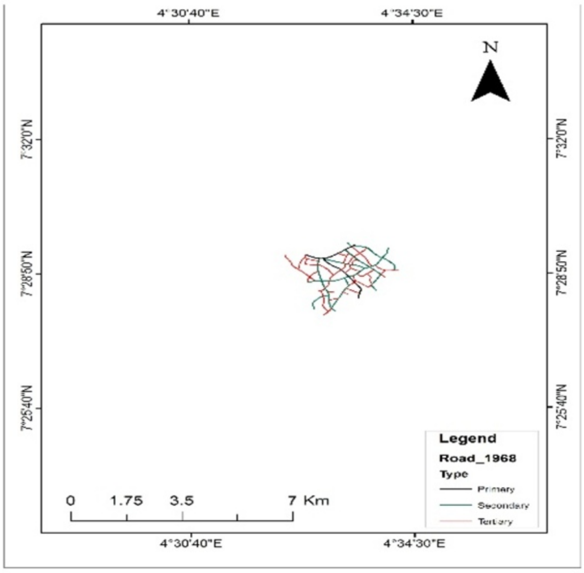

Figure 2a: Road Network 1968

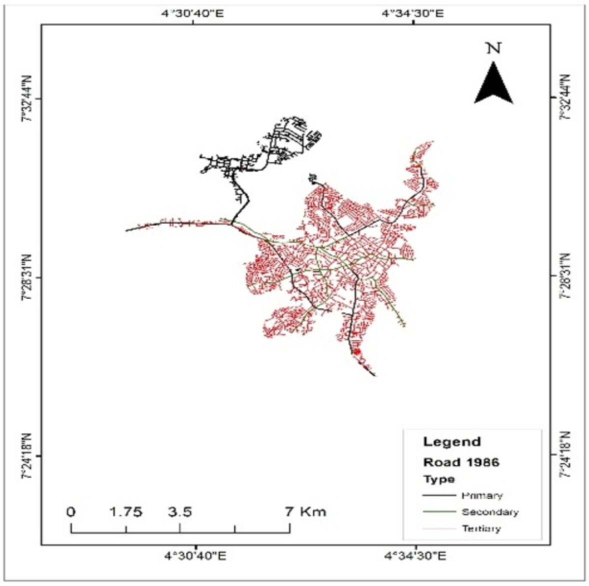

Figure 2b: Road Network 1986

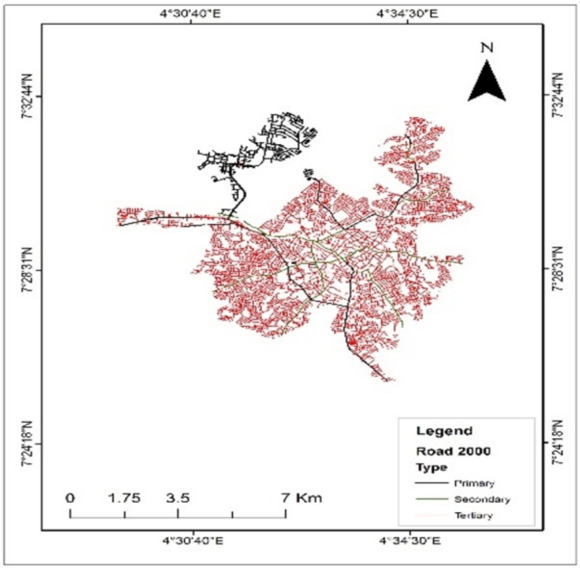

Figure 2c: Road Network 2000

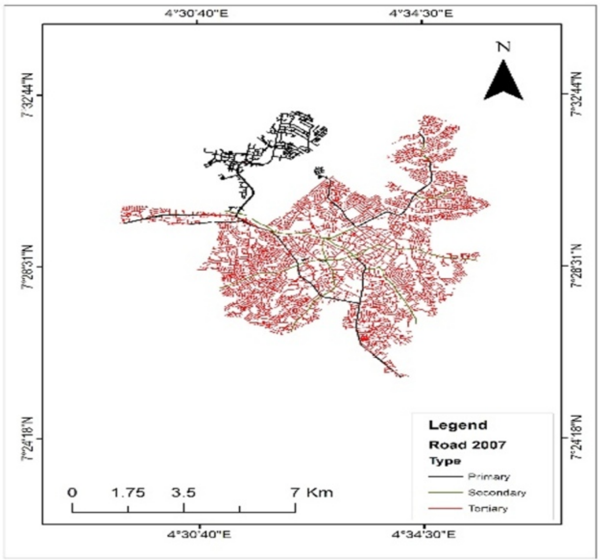

Figure 2d: Road Network 2007

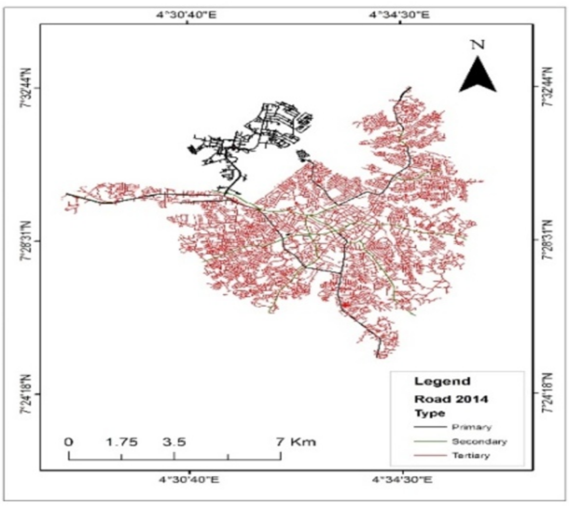

Figure 2e: Road Network 2014

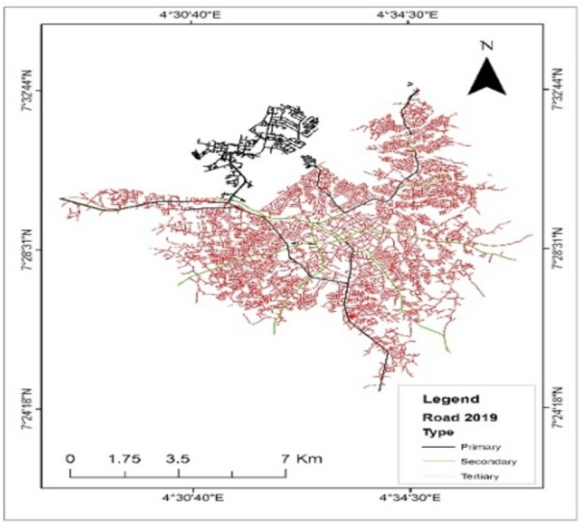

Figure 2f: Road Network 2019

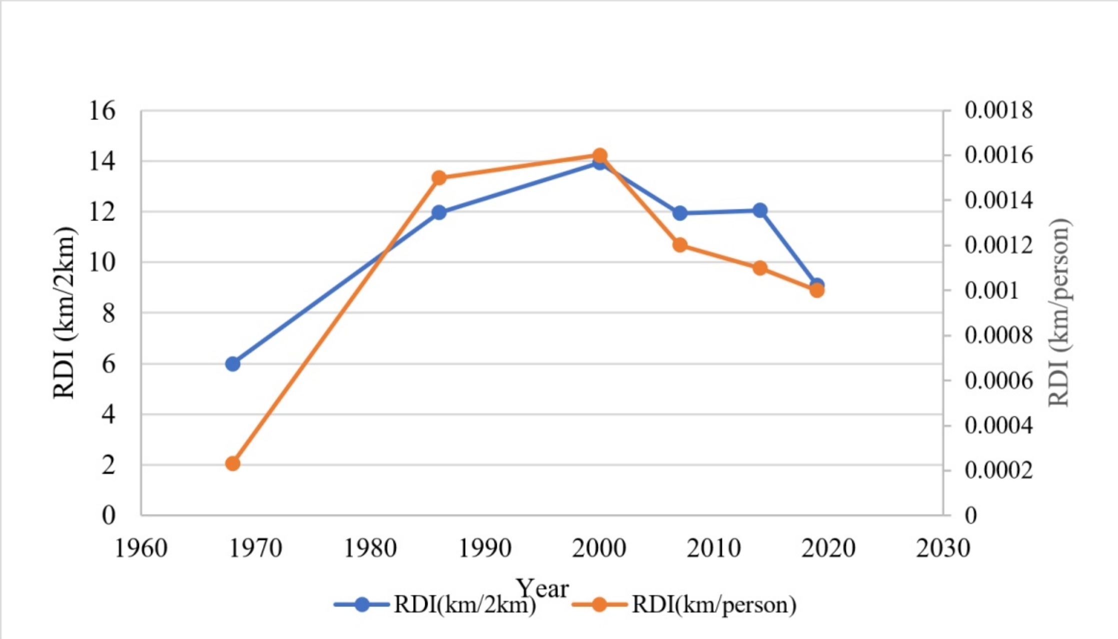

Figure 3: Road Density (RDI) of the study year

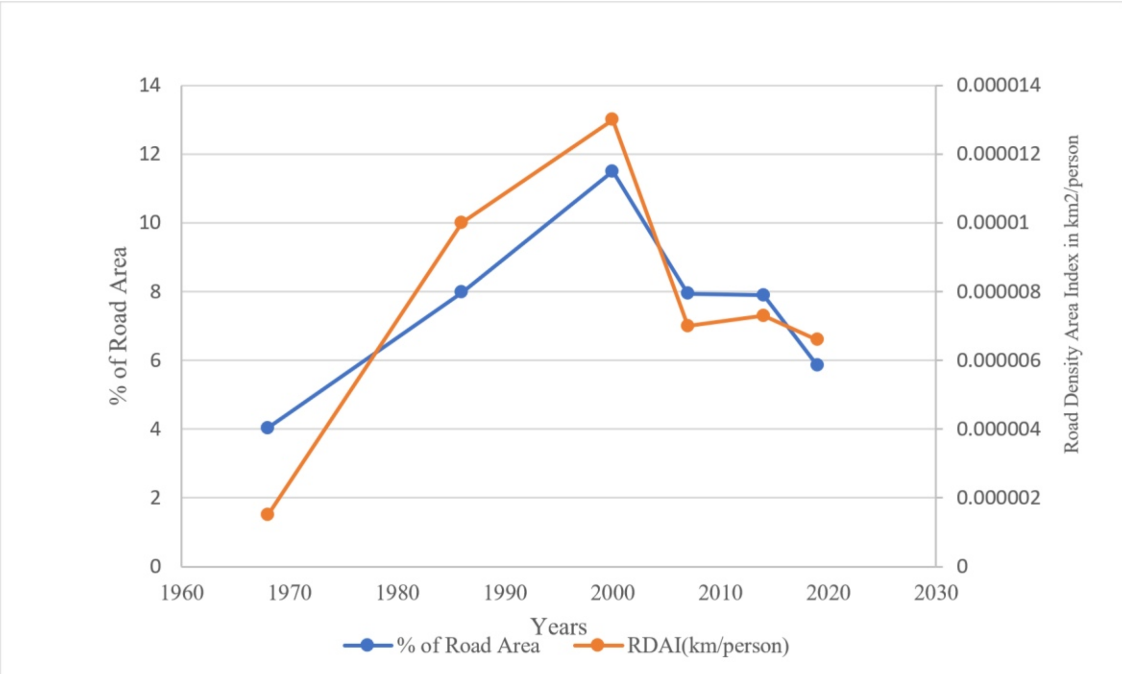

Figure 4: Road Density Area of the Study Period

respectively. Although, more roads were added over the years which should account for more length, these roads added have a low width thereby accounting for the low area of road length, which indicates that the variation in the total region dedicated to road mobility network doesn't coincide with the variation in the total metropolitan area of the study area (Table 4 & Figure 4).

The road area density in contrast to the people improved from 0.0000015 p/km^2 in 1968 to 0.000013 p/km^2 in 2000, this reveals a decreasing demand in the road mobility network. These values then decreased from 0.000013 p/km^2 in 2000 to 0.0000066 p/km^2 in 2019 (Table 4 & Figure 4). These statistics reveal the gap between the speedy increase of population and the road mobility network extension, which discloses the rise in the demand for road mobility network.

Table 4: Road Area Density of Ile-Ife between 1968 to 2019

Year	Road Transport Network area in (km^2)	Municipal area	% of road area	Road Area Density Index (p/ km^2)
1968	0.23	5.71	4.03	0.0000015
1986	2.53	31.70	7.98	0.000010
2000	4.63	40.27	11.50	0.000013
2007	4.64	58.47	7.94	0.0000070
2014	5.84	74.06	7.89	0.0000073
2019	6.08	103.99	5.85	0.0000066

Source: Author's Fieldwork

Table 5: Ile-Ife Road Network Connectivity Analysis

Variable	Years					
	1968	1986	2000	2007	2014	2019
Total Length	34.26	379.44	560.92	697.44	892.27	944.51
Coverage Area	5.71	31.7	40.27	58.47	74.06	103.99
Dead-end Node	22	1020	1253	1656	1927	1973
Real Node	56	2244	3055	4303	5351	5413
Total Node (v)	78	3264	4308	5959	7278	7386
Edges (e)	39	1784	2357	3303	4090	4165
Cyclometric value	39	1480	1951	2656	3188	3221
Beta Index	0.5	0.54	0.55	0.55	0.56	0.55
Alpha Index	-0.25	-0.23	-0.23	-0.22	-0.22	-0.22
Gamma Index	0.17	0.18	0.18	0.18	0.19	0.18

Source: Computed from Digitized Road Network

Road network connectivity in Ile-Ife: 1968 - 2019

Table 5, shows the connectivity analysis of roads in Ile-Ife metropolis in 1968, 1986, 2000, 2007, 2014 and 2019 using different indices. Most of the early roads of 1968 were untarred but, as more roads segments were constructed over time, the number of tarred roads increased. Table 4.6 displays the total length of the road within the study area in 1968, 1986, 2000, 2007, 2014 and 2019 respectively to be 34.26km, 379.44km, 560.92km, 697.44km, 892.27km and 944.51km. It is obvious that the metropolis witnesses a continuous increase in the road network development over the years. This can be attributed to the continuous increase in expansion of the city over the years.

In road connectivity analysis, the important variables or elements are node and edges. The elements are used in determining the connectivity level of the road networks. The study area has a total of 39, 1784, 2357, 3303, 4090 and 4165 edges in 1968, 1986, 2007, 2014 and 2019 respectively. The number of nodes in the study area are 78, 3264, 4308, 5959, 7278 and 7386 in 1968, 1986, 2000, 2007, 2014 and 2019 respectively. Table 4.6 shows that year 2019 has the highest number of nodes (7386) and the highest number of edges (4165).

The streets networks in the study area in the varying years are not complicated. This assertion is reached as a result of low beta index of street derived for the five years; 0.50, 0.54, 0.55, 0.55, 0.56 and 0.55 respectively. Furthermore, in 1968, street network has 39 actual circuit within the network, in 1986, street network has an actual circuit of 1480, year 2000 has 1951 actual circuit, in 2007, the total actual number of circuit is 2656, year 2014 has a total of 3188 actual number of circuit while 2019 has 3221 as its actual circuit. The implication of this is that the greater the amount of circuit, the greater the option of alternative routes available to road users. This further implies that there is higher level of spatial interaction in year 2019 while 1968 recorded the less level of spatial interaction.

Exploring further the connectivity level of the street network in the varying years, with 2019 considered having the highest number of actual circuit, yet network is not completely connected. The alpha index which measures if the actual circuit is a perfectly complete circuit, shows that the road network in the study region are poorly connected as the value for each varying years tends towards negative; -0.25, -0.23, -0.23, -0.22, -0.22 and -0.22 for 1968, 1986, 2000, 2007, 2014 and 2019 respectively.

This negativity value can however be attributed to the number of dead-end vertices in the municipal center.

Furthermore, the gamma index analysis that examines the amount of detected number of edges in relation to the maximum amount of edges within the network shows that 2014 with 0.19 value is more connected than the other three previous years and 2019. The computed gamma index are 0.17, 0.18, 0.18, 0.18, 0.19 and 0.18 for 1968, 1986, 2000, 2007, 2014 and 2019 respectively. The implication of this is that 1968, 1986, 2000, 2007, 2014 and 2019 has about 83%, 82%, 82%, 82%, 81%, 82% gap respectively to have a complete edge within the network.

According to reports, the transport network is a major dependency for many development initiatives. Mobility has been identified by Vinod et al. (2003) as a factor that influences a place's rate of development and expansion. Results by Vinod et al. (2003), supported by Olawole (2013), showed a poor level of road network connection, which was attributed to the hindrance created by the streams, which forced the roads to run parallel to the drainage system.The alpha, beta, and gamma values throughout this study were negative, indicating a low connectivity of road network in the area. The result of low degree of connectivity obtained means a low mobility of goods and services in the study area and suggested delay in the movement of goods and services from one place to another.

The study by Obafemi et al., (2011) on the other hand concluded that road network of the study area is in good condition with a high degree of connectivity. A positive result also buttressed by Sreelekha et al, (2016) are of the opinion that a spatial pattern of road network can be impacted by connectivity and development indices. Abbas and Hashidu (2019) when computing gamma, beta, and alpha indices result of North Eastern Nigeria, indicated that there is a significant increase in road connectivity and accessibility in the region from 1961 to 2011. Positive result of the connectivity indices was associated to the political processes and government investment in road mobility which brought about improvement in both accessibility and connectivity.

Discussion

The outcomes show that road density in relative to the metropolitan area different from 6 km/km2 in 1968 to 9.08 km/km2 in 2019. The greatest substantial variations happened between 1968 and 1986, when the road density enlarged from 6 km/km2 in 1968 to 11.97 km/km2 in 1986 (Table 4, Figure 4). Thus, in this epoch, greater level of openness to diverse land uses was delivered. Furthermore, road density in contrast to the population density of the study area increased from 0.00023 km/p in 1968 to 0.0010 km/p in 2019. The greatest substantial variations happened between 1968 and 1986, when the road density per people improved from 0.00023 km/p in 1968 to 0.0015 km/p in 1986 (Table 4, Figure 4). This result showed that the road density was low comparing it with the standard as highlighted by Odaga and Heneveld (2009), this can be seen in the road network of the study area.

The study area's road density determines how dense the road network is. The study area's road network connectivity was tested using the beta index, and the results indicate that the road network's connectivity is low. This finding may be related to the fact that the study area's road density was low for the various years. The low connectivity can be attributed to the numerous dead ends in the study area that resulted from the area's low levels of industrial development and low levels of local and societal effort directed towards the connections of various dead ends to which the area has been subjected over time.

According to Vinod et al. (2003), the road network in Kasaragod Taluk exhibits low connectivity when analysed using the beta index. This was explained by the fact that the streams created a barrier, forcing the roads to travel parallel to the drainage. This was against the findings of Obafemi et al. (2011), who demonstrated that the Trans-Amadi Industrial Layout's Road Network was a well-organized system that was dispersed uniformly throughout the region. They found that the majority of the roads were in good condition, which is directly related to the type of pavement, with over 90% of the entire length of the roads being paved, allowing for high traffic volume for both products and services.

Since road transit links points of origin to destinations, it boosts the local economy. According to the study by Amiegbebor (2007), Ife metropolis has had little progress in terms of its road network, and the study area's research has shown that the Port Harcourt Metropolis as a whole is disorganised and poorly connected. As compared to the extent of the road transport network, the different variations show how quickly the population is growing in the studied area. This pointer could be used to observe that the creation of the road network has not kept pace with population expansion.

Conclusion

When it comes to a nation's economic expanding, road networks are critical. By evaluating the road network's density, which emphasizes accessibility and connectivity, this study seeks to determine how effective the system is. In addition to helping municipal planners suggest new routes to improve accessibility and coverage, the quantitative assessment of the road network's connectedness and density of roads helps to clarify the structure of the network.

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