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Research Article

Road Transport Development and Urban Growth in Gombe Metropolis, Gombe State, Nigeria

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Abstract Road transport improvement and urban growth, particularly in developing countries of the world continue to draw attention as they happen to be amongst the crucial issues of global change in the 21st century affecting the physical dimension of cities. The study examines the impact of road transport development on urban growth in Gombe City, Nigeria. To achieve the objectives of this research, road maps of Gombe Metropolis of 1996, 2005 and 2014 were analysed to determine the changes in road network development using alpha, beta and gamma indices. Geographic Information System (GIS) and Remote Sensing (RS) techniques was also adopted to determine the pattern of urban growth. The results of the computation of gamma: 56.9%, 57.9% and 60.0%, beta: 1.61, 1.70 and 1.80 and alpha 31.3%, 35.3% and 38.9% indices indicated that there is a significant increase in the level of road network connectivity in Gombe Metropolis from 1996 through the 2005 to 2014. Results obtained from the analysis of urban growth pattern showed that the total built up area has grown from 809.28 hectare (8.29km^2) in 1996 to 1,655.05 hectares (16.55km^2) in 2005 and to 3,689.01 hectares (36.89km^2) in 2014. The study successfully captured the changing pattern of urban growth in the area during the period under study. The results of the urban growth pattern analysis reveal that Gombe is witnessing a fragmented urban growth process, especially at the fringe areas with considerable increase in built-up area, while the city centre underwent relatively compact growth by infilling open spaces and edge expansion over the period of time. Comparison of the changes in urban area and the 3 road network connectivity indices suggest an improvement in network connectivity with increasing urban expansion. It is concluded that road transport development is contributing to urban growth in the study area and therefore, recommends further expansion of existing road network and the introduction of light rail system in order to improve and diversify the commercial nature of Gombe Metropolis by ensuring free flow of people and goods.
Keywords *Road transport development; Remote sensing; Transport connectivity and remote sensing; Urban growth*

1. Introduction

Transportation plays a vital role in shaping the economy of any nation (or region) because modern industries and commercial activities rely on proper, well developed and efficient transport systems (Anyanwu et al., 1997). Wane (2001), pointed out that transportation is a crucial vector for urban insertion since it gives access to economic activity; facilitate family life, and helps in spinning social networks. Those cities with transport modes in an integrated system are more likely to evolve and

prosper as centers for trade, commerce, industry, education, tourism and services (Buis, 2009). Therefore, efficient transport system are required to sustain the high rate of growth of urban centers (Button, 1991).

Different conventional transportation modes exist: roads, rail, air, water and pipelines. These modes of transport are all important in one way or the other. Roads transport however, serves other modes of transport as it provides door-to-door services. Schneider (1994) described roads as an integrated system that is made up of nodes and routes. The nodes are towns which associated themselves to the roads, while the routes are the different types of roads. Road transport is the mst common and complex network covering a wide range of highly flexible and more accessible means of moving goods and services (Ajiboye and Afolayan, 2009). Thus, road networks are observed in terms of its components of accessibility, connectivity, traffic density, level of service, compactness and density of particular roads (Onakomaiya, 2012).

Filani (2003), noted that the vast majority of transportation in Nigeria is by road. Today, road transport accounts for more than 90% of the country's goods and passengers movements. Gombe is a typical example of the rapid growth and development of cities in Nigeria. The city became capital of Gombe State in 1996.

Urban growth patterns are indications of spatial changes that occur in metropolitan areas of the world (Aguilera et al., 2011). Wilson et al. (2003) recognized the following three main types of urban growth: infill, expansion, and outlying. Infill growth is a new development within the few remaining open spaces in already existing built up areas while expansion or sometimes reffered urban extension or edge expansion is a non-infill growth extending the urban foot print in an outward direction and sometimes called urban fringe development. Outlying or leap frog development is a change from non-developed to developed land cover happening beyond existing urbanized areas. Leap frog development is also referred as urban sprawl. It is the type of expansion of urban area in a way that required the extension of public facilities.

Historically, visual interpretations of high resolution aerial photographs were used to obtain comprehensive information for mapping of metropolitan urban areas. Although, this procedure is time consuming and often expensive. Recently, there are several RS satellite systems such as Land Sat (TM and ETM+), ASTER,IKONOS, Geo Eye, Quick bird and Rapid Eye that provides medium to high and very high resolution imagery that are less expensive and easier to analyse and map (Huang et al., 2007). Remote Sensing always provide fundamental observations of urban growth and environmental conditions in developing nations that are not available from other sources. (Miller and Small, 2003).

For this reason this paper integrates the study of road network connectivity analysis and urban growth pattern using GIS and RS techniques in order to understand the relationship between transport networks and urban growth. The study intends to achieve the following objectives:

Objectives

1. Determine the changes in road network connectivity over three periods (1996, 2005 and 2014).
2. Examine the pattern of urban growth between 1996 and 2014 in the study area.
3. Analyze the effects of road network development on urban growth over the period of time under study.

2. Materials and Methods

The study area

Study area is located between latitude 10° 15′ 02” – 10°20′00” North of the Equator and between longitude 11°05′00” – 11°15′05” East of the Greenwich Meridian line. It shares a common boundary with Akko Local Government Area in the south and west, Yamaltu-Deba L.G.A. to the east and Kwami L.G.A. to the north (Figure 1). It also occupies a total land area of 52Km^2. It is the capital of Gombe State with a population of 266,844 in 2006 (NPC, 2006) and a projected population of 399,531 based on 3.2% growth rate (NPC, 2009). Gombe is well linked to other regional centres by trunk “A” roads. A single gauge railway line on the Bauchi – Maiduguri route also links the town, in addition to an international airport.

The climate around Gombe Metropolis is the same with most part of Sudan Savanna. It enjoys a subtropical climate. It also has two distinctive seasons which are wet and dry seasons. As in other parts of the Nigerian Savanna precipitation is mainly triggered by a seasonal shift of the Inter -Tropical Convergence Zone (ITCZ). The average annual rainfall is concentrated between May and October with a single maximum in August. Much of the rainfall especially in July and August is associated with storms of high intensity. The mean maximum monthly temperature is 34°C occurring in (March – May), the mean minimum monthly temperature is 18°C occurring in December – February (Udo, 1970).

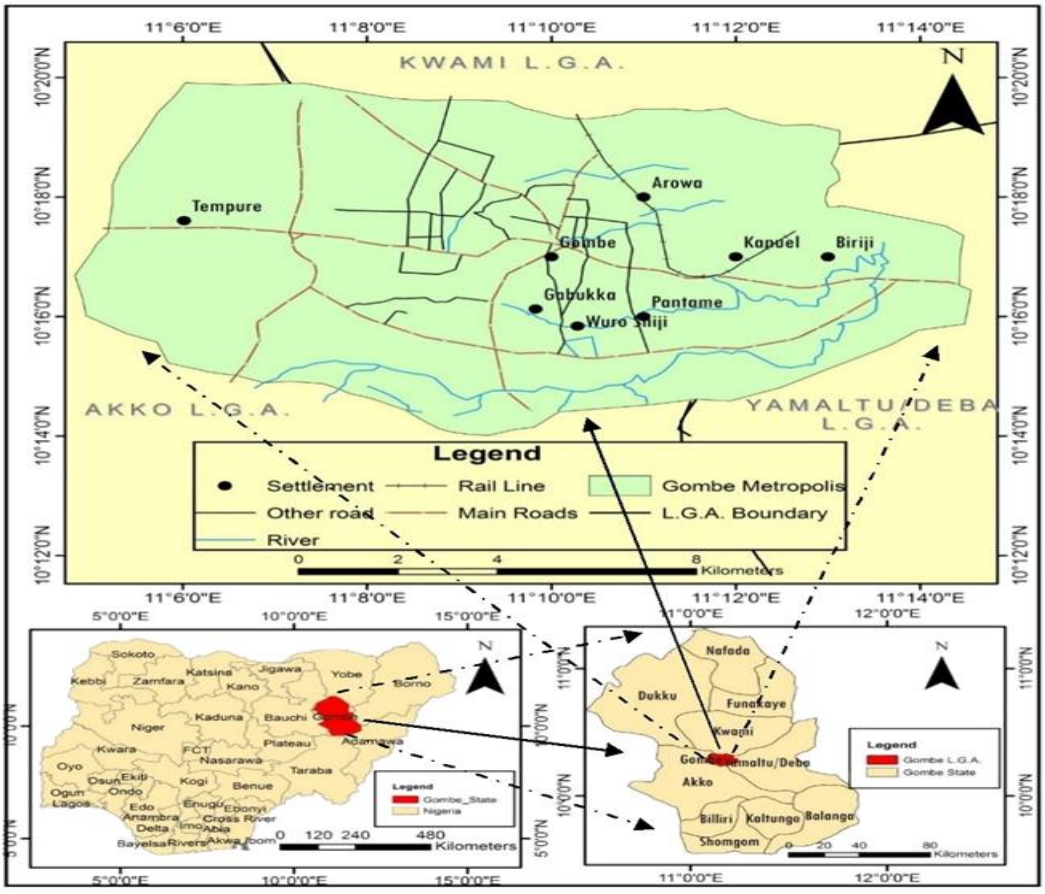

Figure 1: *Map of Gombe Metropolis*

Balzerek, 2003 stated that the relief of Gombe urban area developed on complex geologic crystalline bedrock. Furthermore, subsequent dissection and stream incision in the metropolital area have carved a landscape comprising of a relatively flat topped to conical hills, granitic residuals and pediment landscape. The Kerri- Kerri formation forming a plateau extends into Gombe town marking its northern boundary. The southern edge is marked by a breached and discontinuous escarpment rising in some places to form sandstone ridge over 150m above the surrounding plain. The area is generally surrounded by hilly terrain with steep side on the lower part of an east-facing (2°-3°), gently undulating slopes. As for the drainage, there are stream flows west to east such as the River Magariya and Kware. These waterways gradually transformed into gullies partly due to rapid demographic pressure on land (Pentagon Design Consultant, 2003). The entire land is drained by the head waters of the river Dadin kowa which is a tributary of the Gongola River (Balzerek, 2003). The natural vegetation of the study area is guinea savannah woodland. This can be observed at the boundaries and outskirts of the town. But as a result of rapid population pressure on the land such as urban expansion, cultivation, livestock grazing etc., the natural vegetation has disappeared resulting in exposure of land to gully erosion phenomenon (Balzerek, 2003).

Road Network Connectivity Analysis

Three graphic theoretic measures were used in analysing the road network connectivity: Alpha, Beta and Gamma indices. The road networks in Gombe Metropolis during each period were converted into topological graphs. These graphs were then analysed to determine the alpha, beta and gamma indices. These indices help to determine the connectivity level. A beta index greater than 1 indicates the complexity of a given network. Alpha and Gamma indices are measured 0 – 1 or as presented in this paper 0 – 100% where an index closer to 100% indicates higher connectivity.

Analysis of Urban Growth Pattern

GIS and RS techniques were used to determine the pattern of urban growth in the study area. In this respect, satellite imageries were sourced and analysed to reveal the pattern of urban growth and also to determine whether urban growth has linkage to road transport development. Three medium resolutions Landsat 5 TM, Landsat 7 ETM+ images of 1996, 2005 and Landsat-8 of 2014 (Table 1) were used to detect urban land cover change patterns of the study area. The images used were sourced from United States Geological Survey (USGS) website as standard products, i.e. geometrically and radio-metrically modified to suit the purpose of the research. In order to avoid the influence of seasonality on the resolution, all images were obtained from the same season so that the cloud cover will not exceed 10%. The images are also of the same quality and level of spatial resolution of 30m which makes it easier for detecting changes and patterns of urban growth that occurred in the time under consideration.

Supervised Classification technique using the maximum likelihood algorithm was adopted using Erdas Imagine and ArcGIS software. In the process of classification 3 land cover types were adopted; built up area, non – built up and rock outcrop. Simple descriptive statistical techniques such as percentages were used to describe changes in urban growth rate overtime.

Table 1: *Characteristics of satellite images used in the study*

S/No.	Satellite platform	Sensor type	Imagery date	Image resolution	Source
1	Landsat 5	TM	December, 1996	30 Meters	USGS
2	Landsat 7	ETM+	December, 2005	30 Meters	USGS
3	Landsat 8	TIRS	January, 2014	30 Meters	USGS

TM: Thematic Mapper (and Multi Spectral Scanner); ETM: Enhanced Thematic Mapper; TIRS: Thermal InfraRed Sensor (and operational land imager); USGS: United State Geological Survey

3. Results and Discussion

Changes in Road Network Development in Gombe City

In order to determine the changes in connectivity over time in Gombe Metropolis, three graphic theoretic measures were used in analyzing the network connectivity, which are all based upon the relationship between the number of edges and vertices in a network. They include: Beta, Gamma and Alpha indexes. From Table 2 below, it is clear that the number of both edges and vertices continue to increase from 1996 through the 2005 to 2014. The alpha, beta and gamma indices were calculated from the topological maps to show the degree of connectivity in Gombe.

Table 2: *Numbers of road edges and vertices in Gombe Metropolis (96, 05 & 2014)*

Periods	No. of Nodes (vertices)	No. of Links (Edges)
1996	36	58
2005	86	146
2014	122	216

The results of the measure of connectivity on Table 3 portrays the degree of changes in connectivity of road network in Gombe Metropolis. The results of the computation of gamma, beta, and alpha indices indicated that there is a significant increase in road network connectivity in Gombe Metropolis from 1996 through the 2005 to 2014. The beta index revealed that there is increase in connectivity in the area from 1.61 in 1996 to 1.70 in 2005 and 1.80 in 2014. In the case of alpha index, connectivity was 31.3% in 1996 but increased to 35.3% in 2005 and 38.9% in 2014. While, the gamma index further revealed an increase in road connectivity over the last two decades. The result shows that road connectivity witnessed an increase from 56.9% in 1996 to 57.9% and 60.0% in 2005 and 2014 respectively.

All the three indices calculated have indicated improvement in connectivity in Gombe Metropolis. Without doubt therefore, it can be concluded that a lot has been done in the area in terms of road construction for the period under study.

Table 3: *Road connectivity indices of gombe metropolis over three time period*

S/N	Year	Beta	Gamma	Alpha
1	1996	1.61	56.9%	31.3%
2	2005	1.70	57.9%	35.3%
3	2014	1.80	60.0%	38.9%

Pattern of Urban Growth in Gombe Metropolis (96-2014)

Results of Image Classifications

The classifications of multi-temporal satellite images in to built-up and non-built up areas for the three different time periods of 1996, 2005 and 2014 has resulted in a highly simplified and abstracted representation of the study area (Figure 2a, b and c). The images below show a clear pattern of increased urban expansion prolonging both from urban centre to adjacent non-built up areas along main transportation corridors. This is at the same time showing the urban growth pattern in the study area.

Furthermore, post classification analysis of the classified images revealed the growth pattern of the city in different directions, the infilling of the open spaces in the heart of the urban centre between the existing built up areas and the changes of urban expansion in the study area. Conversely, it is indispensable to support the findings with statistical evidences in order to describe the spatial extent and the different patterns of urban growth that have been taking place in the in the study area. This will help understand how the city is changing over time and to also compare the various growth patterns taking place in different periods.

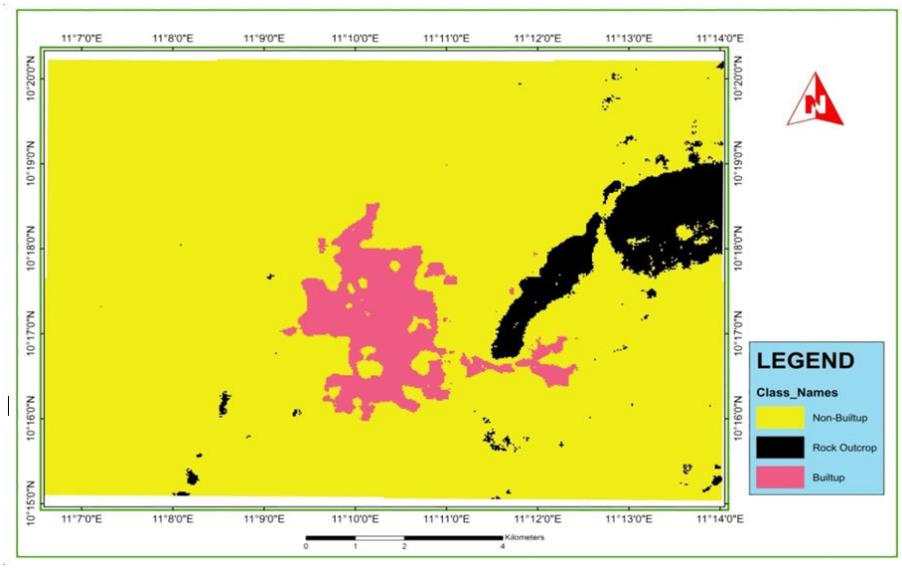

Figure 2a: *Classified Image of Gombe Metropolis (1996)*

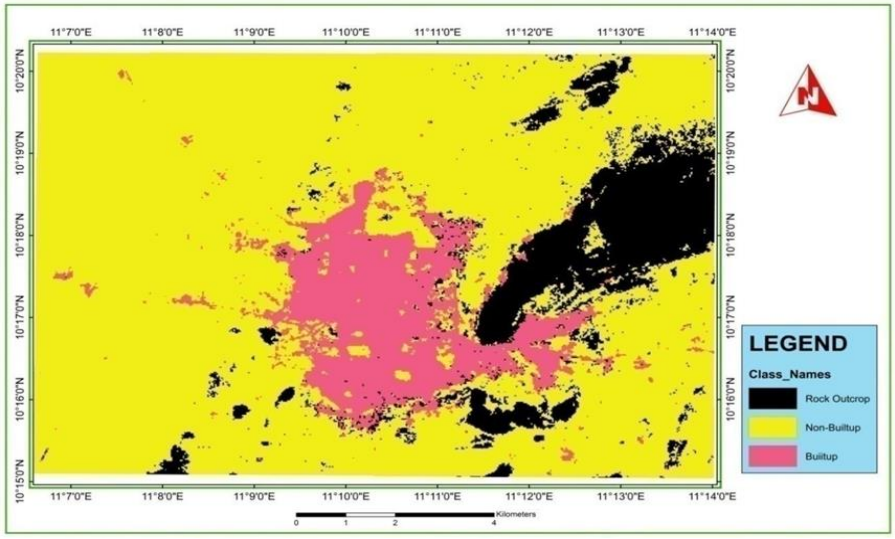

Figure 2b: *Classified Image of Gombe Metropolis (2005)*

Analysis of the Pattern of Urban Growth

The results presented in Table 4 show that the total built up area (TBA) has grown from 809.28 hectares (8.10 km^2) in 1996 to 1,655.05 hectares (16.55km^2) in 2005 and to 3,689.01 hectares (36.89km^2) in 2014. Urban area doubled twice from 13.15% of the area in 1996 to 26.90% in 2005 and 59.95% in 2014. However, the highest rate of urban growth is observed during the third period of urbanization (2014) in which the built up area increased more than twice (59.95%) within 9 years interval. This is followed by 13.2% and 26.9% during the first (1996) and the second (2005) periods of urbanization respectively. This indicates a more rapid urbanization taking place in the study area during the period of 2005 - 2014 compared to the two other periods 1996 - 2005.

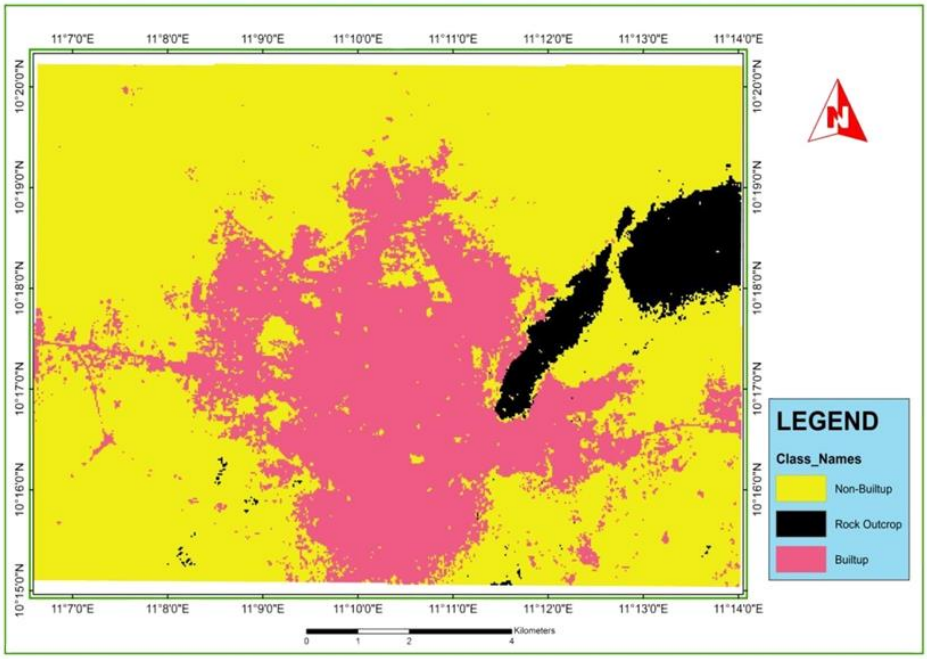

Figure 2c: *Classified Image of Gombe Metropolis (2014)*

Table 4: *Road connectivity indices of gombe metropolis over three time period*

Study Period	Area Hectare/Km^2		Area (%)
1996	809.28 /	8.10	13.15
2005	1,655.05/	16.55	26.90
2014	3,689.01 / 36.89		59.95
	6153.34/61.53		100.00

Generally, the analysis of urban growth in Gombe Metropolis over time as described above shows that urbanization process has greatly changed the land cover through substantial land conversion. The built up area has been undergoing fragmented development process in all periods under study, with a significant rise in built up area especially in the second and the third periods (2005 and 2014). In addition, the analysis also revealed that the city is experiencing infill and edge expansion around the urban core, mainly during the second period (2005). It equally, revealed the increasing patch shape complexity of the study area which could be as a result of infill development or as a results of the merger of new patches with the existing patches of settlement.

Relationship between Road Transport Development and Urban Growth

A comparison is made between urban growth and the three road connectivity indexes. This is achieved by plotting the urban area during the consecutive periods understudy with corresponding apha, beta and gamma indexes. This is shown in Figure 3(a) and (b) suggesting incre4ase in urban area with corresponding increase in road connectivity indexes. This suggest a relationship between road transport development and urban growth in the study area. Though, road network development has relationship with urban growth in Gombe, it may not be the sole determinant because other factors like: migration, personal increase in income, the desire to own personal home and loan scheme from banks are also contributors.

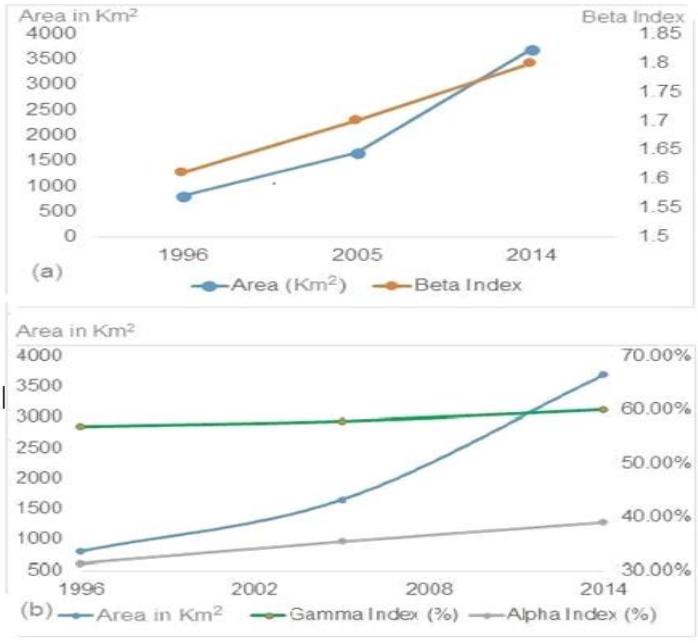

Figure 3: *Relationship between urban growth and road network connectivity indices*

4. Conclusion

The study allows the following conclusions to be drawn: The results of the computation of gamma, beta, and alpha indices indicated that there is an increase in road connectivity in Gombe Metropolis from 1996 through 2005 to 2014. In this study, it has been possible to successfully capture the changing pattern of urban growth. The study revealed that Gombe Metropolis has been experiencing fragmented urban growth process, particularly at the fringe areas with substantial increase in built-up area, while the city centre underwent relatively compact growth by infilling open spaces and edge expansion over time. In other word, the spatial-temporal analysis of the urban growth revealed that Gombe Metropolis is experiencing infill and edge expansion around the urban core mainly during the second period (1996 to 2005) and continue to the third period (2005 to 2014).

Recommendations

The study identified the similarities between urban growth and expanding of road networks in the study area. It is therefore, recommended that more roads should be constructed, renovated and expanded into dual carriage ways in order to improve the efficiency of the network with the overall goal of diversifying the commercial base of the study area ensuring free flow of people and goods.

Finally, due to the spatial extent of the metropolitan area particularly in the study area, it is important to look at driving forces of urban growth at disaggregate spatial scale such as: socio-economic and demographic variables. This will go along way in revealing detail causal factors of urban growth at local level.

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