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Spatio-Temporal Growth of Benin City, Nigeria, and Its Implications for Access to Infrastructure

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Abstract

The study looks at population growth, spatial expansion and its implications on access to public infrastructure in Benin City. Remote Sensing and GPS were used to generate data for the study. Image processing was carried out with ENVI to assess the spatio-temporal growth of Benin City while ArcGIS was used for neighbourhood analysis of residents' access to public facilities. The study reveals that there is a strong positive relationship between population and built-up area with correlation coefficient of 0.794 at p=0.05level. It further reveals that both the population and spatial growth of Benin City are faster than the pace of infrastructure provision and that the lag between the growth of Benin City and infrastructure provision is impacting negatively on the quality of lives of the residents and threatens the sustainability of urban environment. To bridge the infrastructure gap the study suggests that alternative sources of fund other than federal allocation be sought for, as the capacity of the urban government to finance infrastructure within the current available revenue is limited.

Keywords: infrastructure, proximity, response time, sustainability, threshold population

1. Introduction

About 54 percent of the world's population lives in urban areas, a proportion that is expected to increase to 66 per cent by 2050 (UN, 2014). According to a United Nations report, projections show that urbanization, combined with the overall growth of the world's population, could add another 2.5 billion people to the urban population by 2050, with close to 90 percent of the increase concentrated in Asia and Africa (UN, 2014). In 2014, The *World Urbanization Prospects* by UN predicted that the largest urban growth will take place in India, China and Nigeria. Nigeria, the most populous country in Africa has a population of 140 million in 2006 of which 60 percent live in rural areas and 40 live in the urban areas. Projection shows that the urban proportion will rise to 46 percent in 2020 (NpopC, 2006). The result of this rapid growth of cities is that many urban inhabitants will lack access to public facilities such as adequate housing, health services, potable water, good roads, and electricity if the provision of these social facilities is not commensurate with population growth. The economic vitality of our cities is shaped by the quality and availability of key infrastructure services (Onokerhoraye, 1984; Allen consulting group, 2003). Urban infrastructure constitutes the support system and carrier of various economic and social activities in a modern city. It sets the basic conditions and safeguards for the improvement of urban environmental quality and ecological balance (Pangestu, 1997). Urban area cannot function properly without urban infrastructure, which provides crucial facilities and services. If appropriate infrastructure is not provided in a timely manner, it can seriously constrain development. Thus, urban infrastructure is the key to development and proves essential to making our cities healthier and more equitable. The rapid economic growth of urban regions has increased the demand for basic infrastructure. Currently many studies have confirmed a gap exists between the demand for basic urban infrastructure and the existing financial ability to provide it (Boakye, 2013; Bird and Slack, 2013; McCluskey and Trinh, 2013; United Nations, 2013; Ingram, Liu and Brandt, 2013; Pearson, 2013; Phatak, 2013; UN-Habitat, 2013; UN Habitat, 2015; DfID, 2015).

Benin City provides a case study that can provide needed data for sustainable policy. This study examines the spatio-temporal growth of the Benin City vis- a-vis its implications for public access to basic facilities and

infrastructure. This information becomes necessary to achieve urban sustainability particularly when a city experiences a shift in growth from vertical (densification) to an outward horizontal mode of lower density sprawl.

The growth of Benin City in the post-colonial era was linked with the creation of the Mid-West Region (later Bendel State) out of the former Western Region in 1963. In 1991 Bendel State was split into two states: Edo State and Delta State. Benin City became the State Capital of Edo State. With Benin City serving as the State capital and the opening of Benin-Ore-Ijebu Ode-Shagamu road, consequent growth occurred in its commercial, cultural, industrial administrative and service sectors (Sada, 1975, Onokerhoraye, 1977, Omuta, 1984). Rapid growth and development continues until today. For example, the population rose from 53,753 as in 1952-1953 census to 100,694 in 1963, thus giving an inter-censal annual growth rate of 5.5% (Sada, 1984). In 1972 Doxiadis (1973) estimated its population had nearly doubled at 201,000. A 1976 estimate by Sada (1976) yielded 314,219 total population. Of this figure, the in-migration component represented an influx of 15,000 persons per annum between 1963 and 1976. According to Ozo (1982) the growth rate of Benin was 5.5 percent for 1952 to 1963 about 8.6 percent for 1963 to 1976, while the national growth rate (that is rate of natural increase) was 2.5 - 3.0 percent Benin's rapid population growth stemmed largely due to in-migration as a result of great disparity between the city and the rural environs in the distribution of social, educational and infrastructural facilities as well as economic opportunities. Using the 1985 total housing stock of 26,485 and the 1972 housing unit occupancy factor of 20, the population was estimated at 429,698, thus suggesting an annual growth rate of 8.8% (Muoghalu, 1987). In the 1991 census, Benin had a population of 780,976 while in 2006 it rose to 1,147,188 (NPopC, 2006).

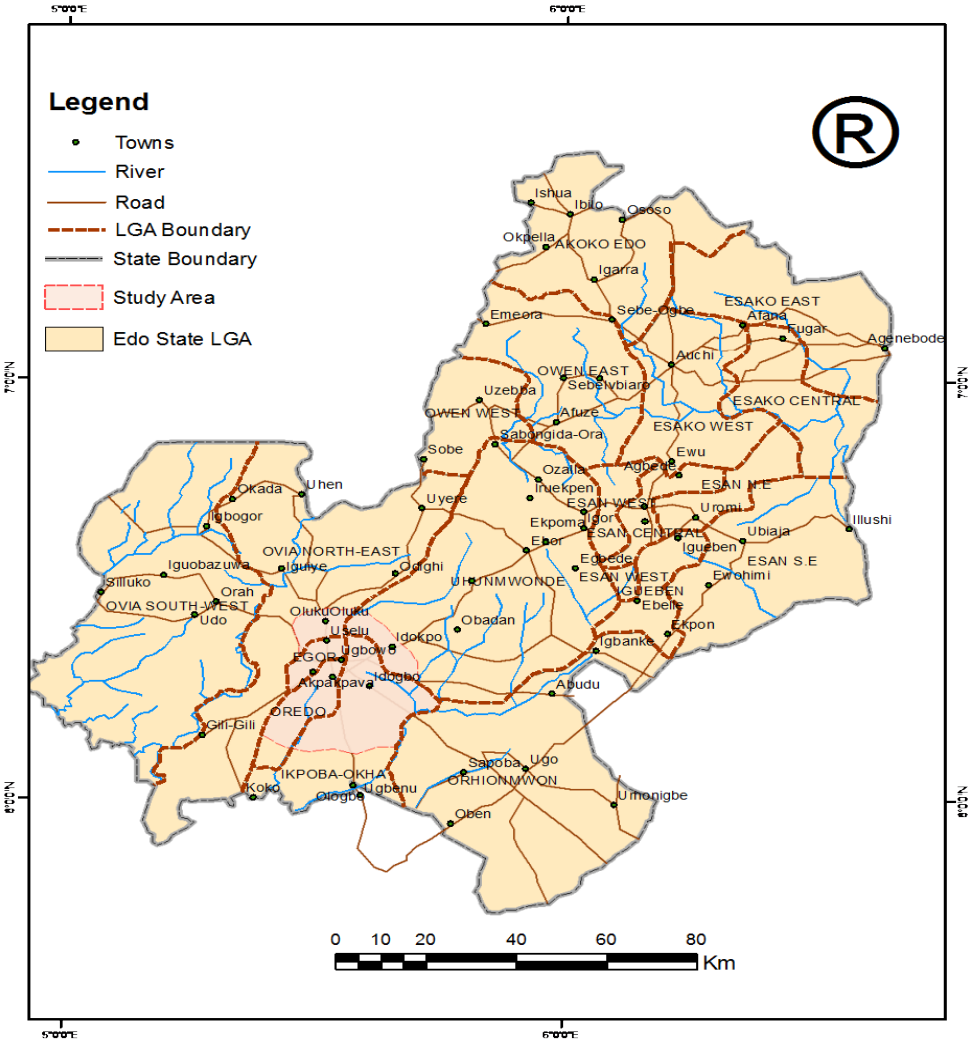

Figure 1. Edo State showing Benin City

The implication of this growth in population is an increase in demand for land in and around Benin City for a variety of uses, including residential, recreational, industrial, cultural, and other purposes. The provision of these land uses causes a corresponding increase in sheer physical size of the city. For example, from accounts of the size of pre-colonial Benin given by Hodgkin (1975) and available from aerial photographs and map, Benin enclosed within the first city moat an area of 384.2 hectares (Ikhuoria, 1984). From 384.2 hectares of build-up area in 1800 it increased to 486.0 hectares in 1938 (Ikhuoria, 1984) and by 1979 it has jumped to a record high of 7413.7 hectares (Ikhuoria, 1984) representing a 10.3% annual increase in land consumption as against 8% annual population growth rate.

2. Method

The geographical co-ordinates of Benin City lie within the Latitudes 6°10′ and 6°30′ N and Longitude 5°30'and 5°45′ E (Figures 1). Spatio-temporal growth of Benin City was quantified using multi-temporal spatial data set based on three sets of satellite images taken in 1987, 2002 and 2013 and downloaded from *glovis.usgs.gov*. The three sets of satellite images and the scanned road map of Benin City were geo-referenced to the earth coordinates using the Universal Traverse Mercator (UTM) with reference to WGS 1984, zone 32N. The downloaded satellite images covered an area larger than the area of interest, thus requiring the extraction of the region of interest from the image scene. The subsets of the three satellite images were classified with ENVI 4.7 software using supervised classification method. The supervised classification was combined with Maximum Likelihood Algorithm that assumes each class in each band can be described by a normal distribution. The classification scheme used consisted of only three classes: (1) built-up area, (2) vegetation, and (3) water bodies for 1987 and 2002 images. Cloud cover was added as the fourth class for 2013 image. However, the area covered by clouds was less than 10% the image.

On-screen digitizing of the scanned road map was carried out in ArcGIS 10.2 for the purpose of spatial analysis. To assess the implications of urban sprawl on residents with respect to urban infrastructure provision, distance measurement and geographic locations of some key infrastructure were taken with a handheld Geographical Positioning System (GPS) at selected urban limit along the eight arterial roads that radiate from the city centre. The selected infrastructure included markets, police stations, public secondary schools, fire service stations, and recreational centres. Based on recommended travel distance by Council for Scientific and Industrial Research (CSIR) (2012) buffer operation was created around each of the infrastructure to assess urban residents' proximity to the nearest infrastructure. This was used to determine the distances residents at the city limit travel to access each of the facility. The analysis was also used to determine the implications of the urban sprawl on the government.

3. Results

The limit of urban area of Benin City was extracted from landsat images. The analysis of the satellite images of 1987, 2002, and 2013 show outward expansion from the core of Benin City towards the fringe. Each image indicates an outward shift in the urban limit from the previous position. Figures 2 an overlay of the three interpreted images show the urban limit of Benin City at year 1987, 2002 and 2013Table 1 shows the relationship between population growth and urban expansion of Benin City. It is observed that in 1987 when the population of Benin City was 524,000 the area extent of Benin City was 300.8km^2. When the population of Benin City grew to 1,164,673 in the year 2002, the area extent also increased to 311 km^2. This amounted to 3.92 percent increase. By the year 2013, the population rose to 1,419,087 and the area extent increased to 607.5 km^2. As shown in 2013 satellite image of Benin metropolis, development has extended beyond Oluku junction to Ekiadolor junction along Benin - Lagos road axis. In the south, development has also reached Presco Company along Benin - Warri road. While the growth rate of urban area in Nigeria is put at 3.2 and that of population is 5.4 (both natural growth and migration) (NpopC 2006), the built-up area of Benin City grew at the rate of 11.8 percent annually between 1987 and 2013. This implies that the rate of growth of Benin City is more than triple that of Nigeria's average urban growth.

Table 2. Population density of Benin City

YEAR	POPULATION	AREA (Km)	DENSITY (per sq km)
1987	524,000	300.8	1742
2002	1,164,673	311	3744
2013	1,419,087	607.5	2335

In Table 2 population density per sq km was 1742 in 1987, in 2002 it rose to 3744 per sq km and in 2013 it came down to 2335 sq km. The developing areas at the urban periphery show a great disparity from the core area of Benin City. While compact and high density development was observed within the core area of Benin City (especially 1987-2002), leap-frog development and large area of low-density development became a common phenomenon in the developing area of urban fringe after 2002. At the urban fringe, a discontinuous pattern of urbanization with patches of developed lands that are widely separated from each other with bushes is observed. As shown in Figure 2 urban limit in 2013 shifted outward from where it was in 2002. Probable reason for this was the improvements in communication and transportation. This was the period when Global System for Mobile Phone was introduced in Nigeria. Physical distance was no longer a barrier for interaction. One could live far from his love ones and interact through phone. Previously this was difficult hence people live close to their love ones. It was also at this period that workers salary in Nigeria was increased. This led to increase in the number of car owners and property development. Mobility made commuting easier as it became possible for people to build and live far from their places of work. This accounted for the leap-frog development and low population density observed in the urban fringe in 2013.

Table1. Population and Spatial Growth of Benin City from 1800 to 2013

Year	Population	Built up Area in hectares	Absolute growth	% Change	% rate of growth
1800	15,000	384.2	-	-	-
1938	-	480.0	95.8	24.9	0.9
1952 / 53	53,753	949.5	469.5	97.8	6.5
1963	100,694	2217.6	1268.1	133.6	13.4
1972	201,000	3000.0	782.4	35.3	3.9
1979	371432	7413.7	4413.7	147.1	21.0
1987	524,106	30,080.3	22,666.7	305.7	38.2
2002	1,164.673	31,101.4	6,101.4	24.4	2.21
2013	1479,400	60,748.3	29,646.9	95.3	8.66

Source: *Ikhuoria, 1984; Ogu, 1996* *Fieldwork, 2014*

Population and built-up area in Table 2 were subjected to regression analysis. The result shows a strong positive relationship between population and built-up area with correlation coefficient of 0.794 at p=0.05 level. Similarly, population has a strong positive impact on built-up area given the coefficient of determination (r^2) of 0.63 and adjusted r^2 of 0.577 which is significant at 5% level. Hence variation in population of Benin City is able to account for about 58% of the systematic variations in built-up area of Benin City. The built-up area model, which is a function of the population of Benin City is well specified given the F-Statistic of 11.92, which is significant at p = 0.05 level. Given the unstandardized beta coefficient 0.036 of population, it shows that a unit of increase in population of Benin City will lead to an increase in built-up area of about 0.036 hectare (i.e. if the population of Benin City increases by 1000, then the built-up area will increase by 36 hectares of land.

$BA = 2554.591 + 0.036*POP$ (3.453)

$r = 0.794$; $r^2 = 0.630$; adj. $R^2 = 0.577$; $F0.05 = 11.920$; * significant at 5% level (where figure in bracket is the t – value).

As the population of Benin City is increasing, pressure is exerted on the lands and this invariably leads to frequent shifts in the urban limit. As the population is increasing, the urban spatial area is also increasing. This has implication on Land Consumption Rate (LCR) and urban residents. The LCR was calculated and found to have progressively increased from 1.2 in 1986 to 2.7 in 2002 and to 4.1 in 2013 (Table 3).

Table 3. Land Consumption Rate (LCR), Land Absorption Coefficient (LAC)

Year	Area (Km^2)	Population	LCR (%)
1987	300.8km^2 (30,080.38ha)	240,820	1.2
2002	311.0 km^2 (31,101.38ha)	1,164,673	2.7
2013	607.5 km^2 (60,748.3ha)	1,479,400	4.1

Figure 2. Land use/cover change 1987 – 2013

4. Discussion

4.1 The Implications of the Urban Sprawl On Residential Access to Public Facilities

As Benin City is expanding, the surrounding villages are engulfed. The impacts of this expansion on these surrounding villages include the loss of identity of the villages, which now exist in name only as neighborhoods within Benin City. They have changed from rural life and rural economy to urban life and urban economy. It also implies greater demand for infrastructure since the change-over from rural to urban land use is sudden. The 21st century implications of the urban sprawl on residents in terms of distance covered in order to access infrastructure were examined. Proximity to a fire station ensures a faster response time and in turn, reduces fire related losses. In the same vein, police station locations can determine their response time to crimes or health emergencies. The accessibility of such public goods provides a function of the distance required to respond to emergency situations. Thus, CSIR (2012) suggests 8km as the acceptable travel distance for police station in urban area. Figure 3 shows the result of an 8 Km buffer relative to the assessment of access to police station. All the eight arterial routes are adequately covered by police stations.

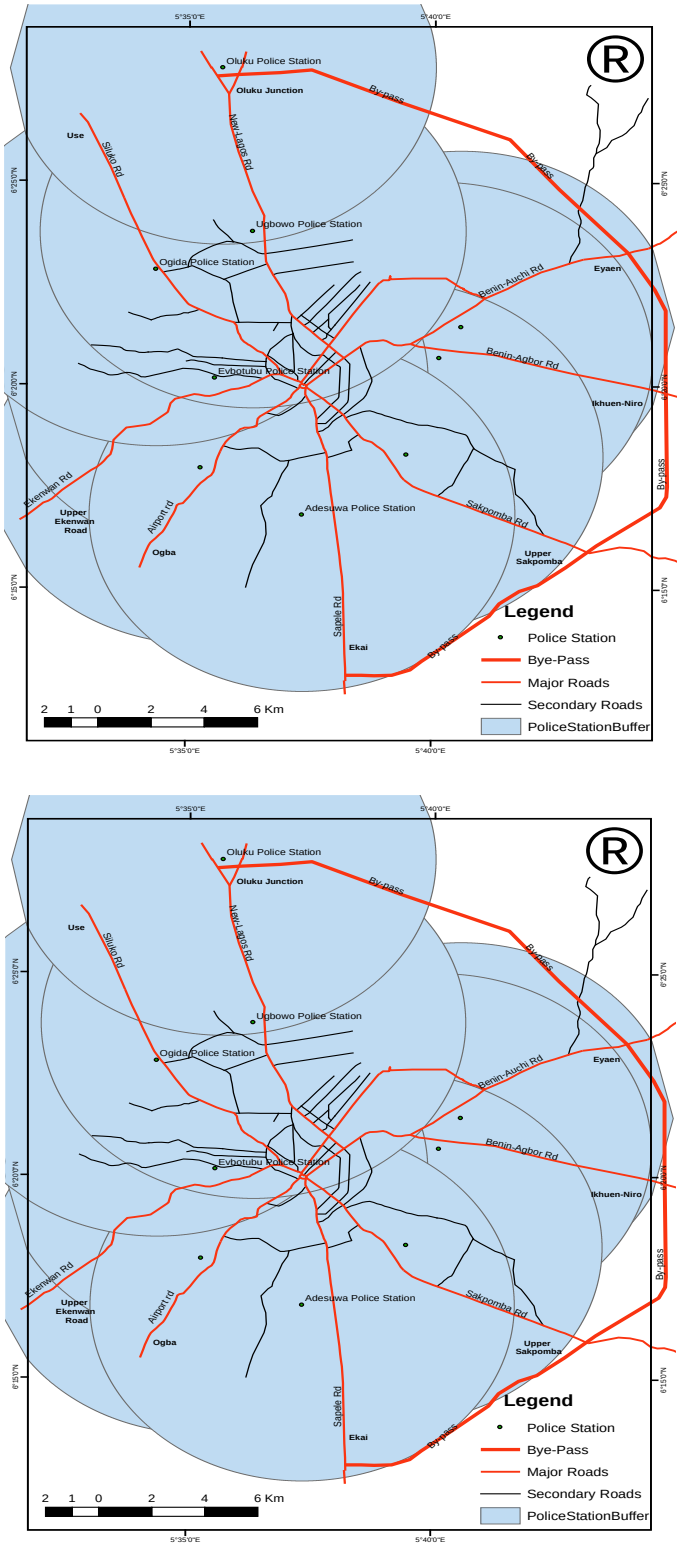

Figure 3. Buffer of 8km around the nearest police station to the urban limit

Daily commodity markets along the eight arterial roads were given a buffer of 5km as suggested by CSIR as the acceptable travel distance to the market in an urban area. Figure 4 shows that none of the neighborhoods under consideration falls within the 5km buffer of the nearest markets. Resident in Eyaen for example will travel a distance of 8km to access Oregbeni market. Proximity to an urban market according to Ajani and Igbokwe,

(2015) promotes economic activities in both farm and non-farm enterprises.

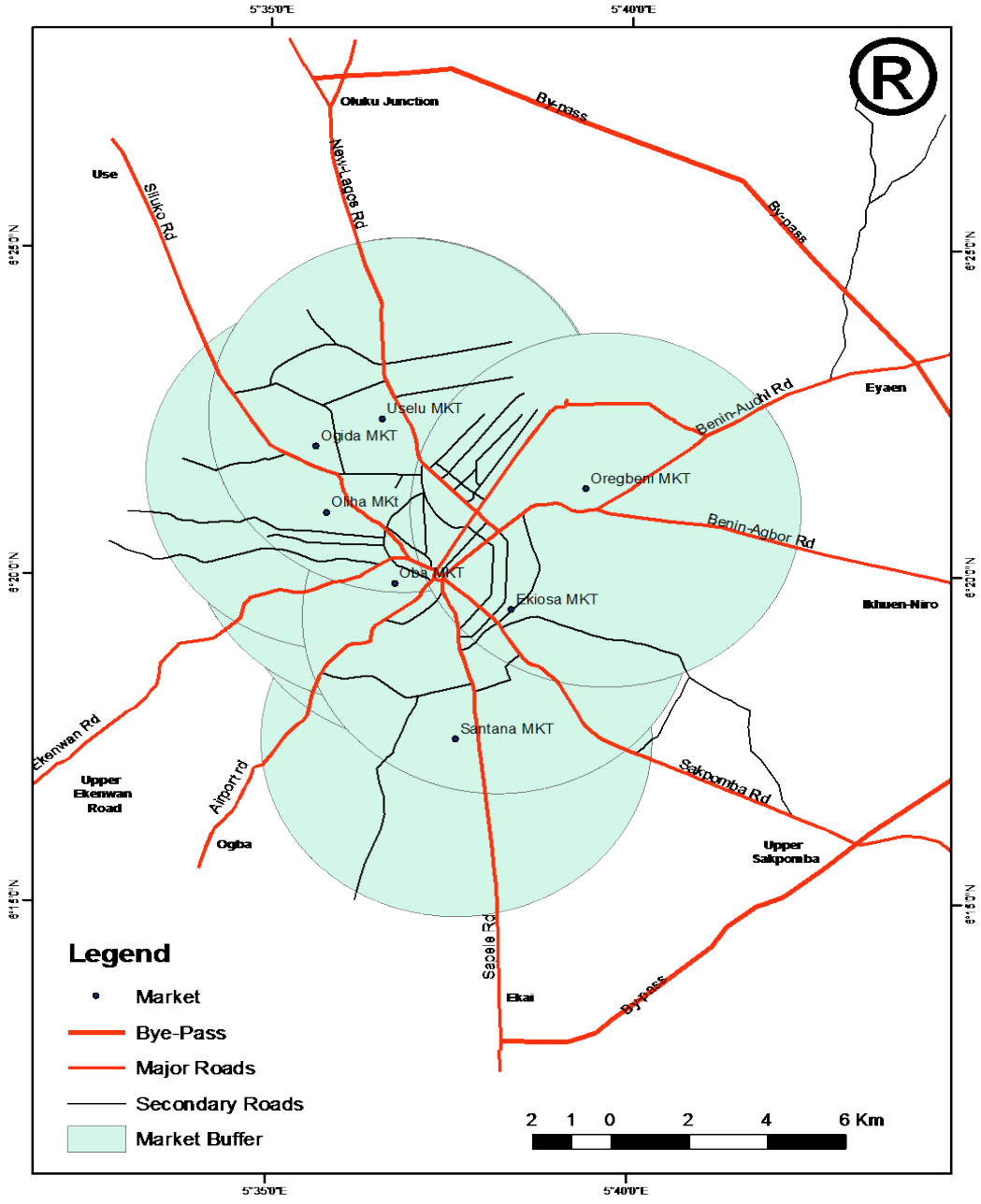

Figure 4. Buffer of 5 km around the nearest market to the urban limit

In the case of recreational facility, the distance of the eight neighborhoods to the six major facilities: (1) Kada plaza in Sapele road, (2) Museum at Kings' Square, (3) Stadium off Ekenwan Road, (4) Ramat park at Ikpoba hill, (5) Ogba zoo along airport road, and (6) Oba Akenzua cultural centre close to Ring Road were considered. A 10-kilometer acceptable travel distance suggested by CSIR (2012) was used as the basis of assessment. Figure 5 shows that all the eight neighborhoods, except Use and Oluku, fell within the 10 kilometer buffer relative to recreational facilities. Residents of these two neighbourhoods must travel thirteen or more kilometers to access the nearest recreational facility.

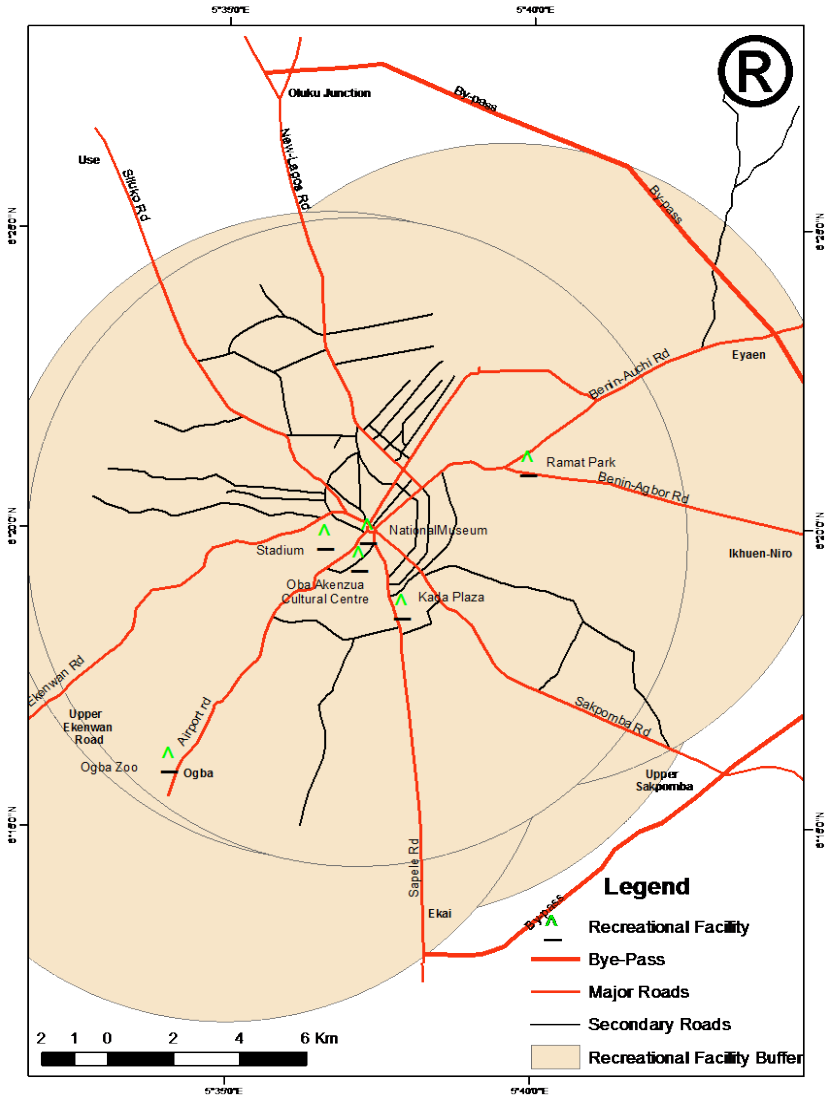

Figure 5. Buffer of 10 km around recreational facilities

Another very important facility in an urban area is the fire service. There are six unevenly distributed fire service stations in Benin City. The State Fire Service at Akpakpava Road at the city centre and University of Benin Fire Service at Ugbowo, University of Benin Teaching Hospital Fire Service at Ugbowo, Fire Service at the Benin Airport, Guinness Brewery Fire Service and the Fire Service at the Nigeria National Petroleum Company (NNPC). The fire service stations in Benin metropolis were given 3.8 kilometer buffer, based on a 13-minute response time as recommended by CSIR (2012). This response time includes the provision of 3 minutes for the capturing of the call and mobilizing the requisite resources to deal with the reported emergency. If a 50-kilometer per hour speed is permitted within Benin City, then 50 kilometers divided by 13 results in a distance of 3.8 kilometers. Figure 6 reveals that many of the neighborhoods are not within the 3.8 km buffer. The suggested threshold population per one fire station is 100,000 (CSIR, 2012). Considering the population of Benin City as of 2006 was 1,147,188 there should be at least 11 fire stations evenly distributed within Benin City. The current six fire stations are grossly inadequate. Out of the six fire service stations only one belong to the State Government others belong to private or public organization whose area of operation and mandate are limited to their organization. If there is no concrete arrangement between the State Government and these five organizations it is unlikely that they will respond if there is any emergency in the city. The urgency with which this service is required in the event of fire disaster demands that this facility should be within the reach of every neighborhood.

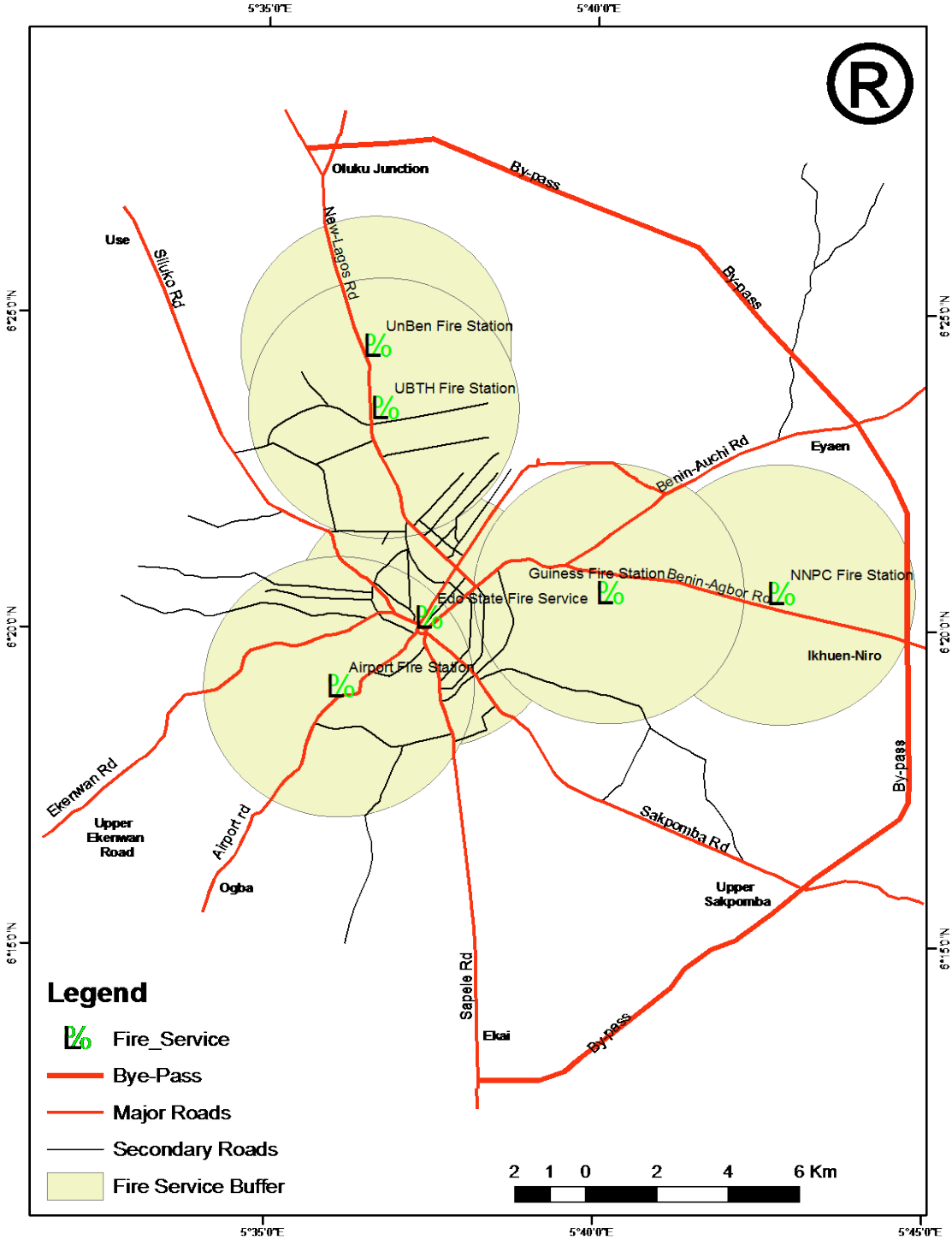

Figure 6. Buffer of 3.8km around fire service stations in Benin metropolis

In Figure 7, public secondary schools appeared to be concentrating in the city core while the periphery is inadequately covered. Only the residents at the city limit in Eyaen and Ogba are within 5 kilometer radius of CSIR recommended acceptable travel distance for public secondary schools. Others residents at the city limit will have to travel at least between 6 to 9 kilometers to get to the nearest public secondary schools. This is one of the reasons why private schools are thriving in Benin City. All the public schools were established prior to the year 2000. This signifies that there has been non-planning and provision of public school for more than two decades in Benin City in spite of the fact that population and students distance to school are increasing.

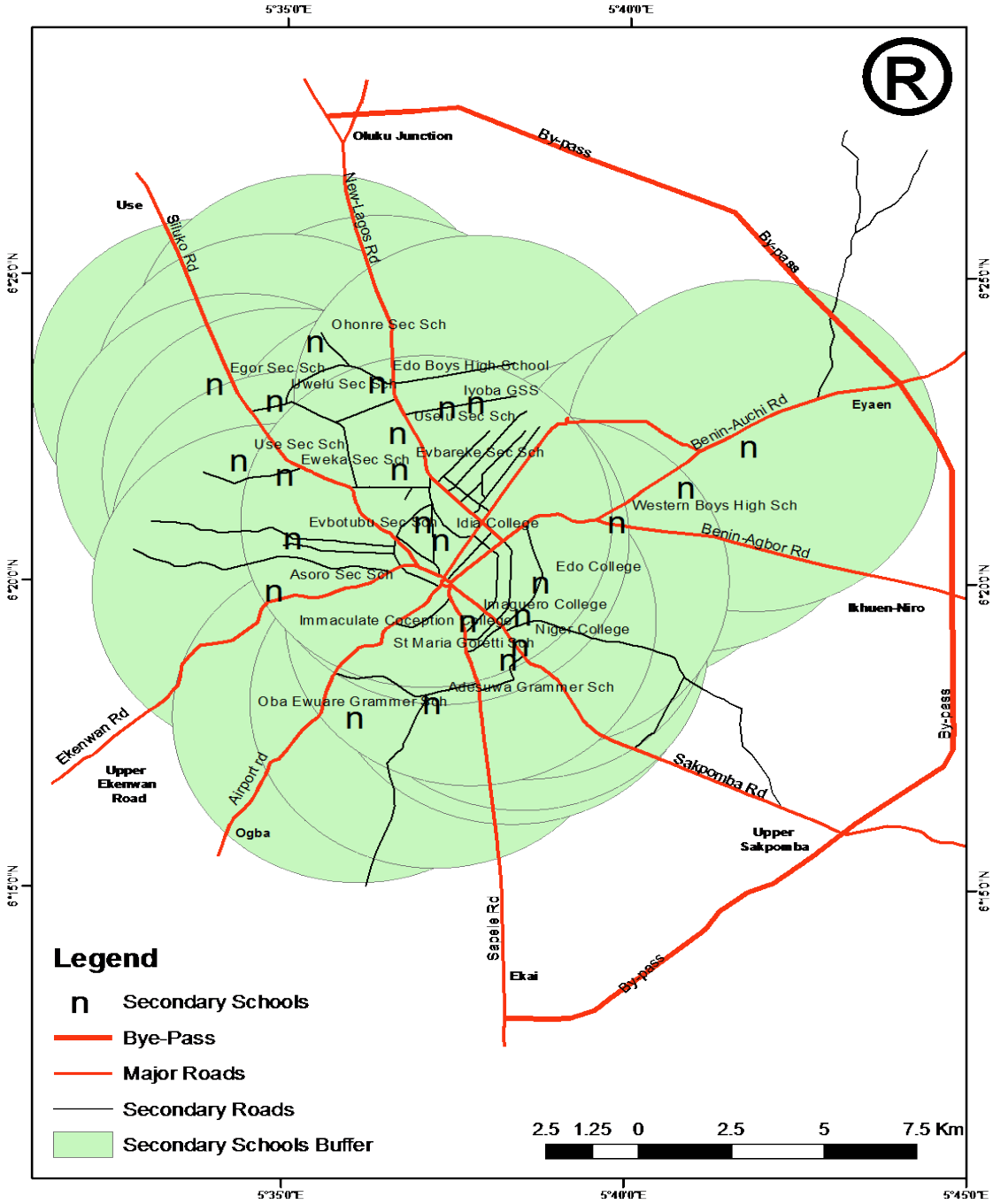

Figure 7. Buffer of 5km around public secondary schools in Benin metropolis

Available facilities in the suburbs were established to cater for the surrounding villages before the city expanded and engulf the villages. These facilities are grossly inadequate to serve the expanding population. Hence residents at the urban limit are compelled to commute to city centre to access these facilities. Commuting increases traffic congestion on the collector roads which already are in bad conditions and commuting infringes on the residents' meager incomes.

4.2 The Implications of the Urban Sprawl on Government

Urban expansion has varied implications on the government. Major among these is the need to meet the expanding demand for urban infrastructure. It could be observed in this study that the rapidity of urban expansion creates infrastructure deficit as the urban managers could not match the dynamism of growth with infrastructural provision. If the gap between urban expansion and infrastructure provision is not addressed, it will

continue to impair growth, and the aspirations of sustainable urban development will not be achieved.

Leapfrog and horizontal development rather than compact and vertical growth has financial implications on infrastructure provision in Benin City. One of the spatial factors that influence the cost of municipal services is the density of the development and its location especially relative to linearly related facilities like roads, water pipeline, sewer, drainage etc. Given the fact that the cost of services increases directly with distance and inversely with the density of development (Speir and Stephenson, 2002; Siedentop and Fina, 2008), the highest cost area to service will be the low-density development at or near the urban fringe. This implies that cost of financing infrastructure will be less expensive in a compact contiguous development in the core than in leapfrog development observed in the urban fringe. The observed leapfrog development in the fringe of Benin City has the tendency to increase pressure on land, costly and expensive for infrastructure provision. The challenge however is that compact and vertical growth requires regular power supply to operate the lift and cooling system and this is lacking in Nigeria.

Another implication on the government is that as the urban area is increasing the impervious surface area is also increasing. Imperviousness reduces infiltration rate. The resultant effect of this is increase in flood generation. This partly explains why many areas that previously did not experience flooding presently suffer from flooding problems in Benin City (Odemerho, 1988). Three decades after, the situation has not abated but getting worst. This implies the government will need to fund more drainage facilities. Considering the magnitude of the outward expansion from the core of Benin City to the periphery, if alternative sources of fund other than federal allocation are not secured, the costs of urban infrastructure may become greater than the capacity of the urban government to handle using current available revenue. This suggests the reason why major part of the city especially the suburbs lack necessary infrastructure which results in traffic congestion, flooding, erosion, poor waste management, inadequate schools, markets, health care facilities, and fire service.

This study revealed that both the population and spatial growth of Benin City are faster than the pace of infrastructural provision. It further revealed that Benin expansion has varied implications on the urban residents and government. Among these is the infrastructure deficit that manifests itself as poor roads, inadequate drainage and the inability to easily access such basic urban services as police, fire and health care. It was observed that the rapidity of urban expansion in a low density horizontal trajectory rather than in a more compact, denser and vertical direction makes urban management more difficult because urban managers cannot match the dynamism of urban growth with infrastructural provision. The lag between the growth and infrastructural provision in the Benin City negatively impacts the quality of lives of the residents and threatens the sustainability of urban environment. This demands urgent attention. However, with present revenue it may be difficult for the Benin government to bridge the gap between urban growth and infrastructure provision. Though Nigeria is rich in oil, fluctuation in oil price coupled with high population size of the country, the Federal Allocation from oil revenue is inadequate to meet developmental projects. Hence, the need for urban government to secure an alternative mean of internally generated revenue.

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