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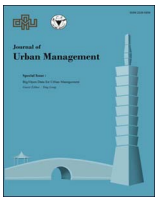

Research Article

Assessing smart infrastructure for sustainable urban development in the Lagos metropolis☆

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ABSTRACT

The challenges of sustainable urban development increases daily and the usual planning approaches to ameliorate these challenges are ineffective. This study assesses the applicability of 'smart infrastructure' to achieve sustainable urban development in Lagos metropolis. The study theoretical framework is based on 'smart' principles. The study adopts a mixed method of data collection and analysis with multi-stage sampling techniques of 460 households in six communities of Eti-Osa and Ikeja local government areas of Lagos metropolis. The objectives of the study were to examine the socioeconomic characteristics of the residents and assess the infrastructure, the building uses and the environmental conditions of the study areas in relation to smart principles and smart infrastructure application in the study areas. The data were analyzed using inferential statistics and the findings reflect that the building use is sprawl development in nature with the informal settlement and infrastructure inadequacy as the major challenges. Smart infrastructure approaches are identified as applicable for achieving sustainable development in the study areas with smart interventions in socioeconomic status of the residents, the environment, the building uses and the basic facilities and services in the study areas.

1. Introduction

Sustainable urban development is associated with various challenges, among which infrastructure and urban sprawl developments are significant challenges globally (Soyinka, 2014). Infrastructure challenges are global and it was identified as one of the major determinants or measures of adequate and good urban settlement (Aigbokan, 1999; Otegbulu, 2011; UN-Habitat, 2015a, 2015b). Urban sprawl challenge is the horizontal growth of a city's physical structures with associated growth patterns that present major urban challenges in both developed and developing countries (Adetokunbo & Emeka, 2015).

Wackernagel, Monfreda, Erb, Haberl, and Schulz (2004), states that human deplete their natural resources, biophysical and human potentials more than required and this create environmental degradation. (Zhang, Wu, Skitmore, & Jiang, 2015) also, notes that national development wealth and human resources are depleted, sustainable environment are destroyed daily and the people's standards of living are falling by the day globally, with a diverse threat to life. The global challenges of infrastructures are inadequate and over-utilization of basic facilities and services, abuse and miss-management of infrastructure facilities, and majorly the challenges of urbanization and urban sprawl which creates environmental chaos (Abiodun, 1997; Aigbokan, 1999; FAMILONI,

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2006; Gandy, 2006; Timmermans & Beroggi, 2000).

Adeyeye (2010) also states that the current metropolitan growth in Nigeria is characterized by urban sprawl and informal settlement that encourages haphazard population growth and the available competence is inadequate to ameliorate these challenges. Illegal structures, slum development, and informal settlements are the typical features of the Lagos metropolis and other developing countries. By 2010, it was obvious that the local councils in Lagos metropolis could no longer cope with refuse collection and disposal strategy, flood management, traffic congestion and other environmental responsibilities that arise from urban sprawl and informal settlement in the city. Loss of life and property, urban insecurity, informal settlement and slum developments are the physical features of Lagos metropolis and other kinds of these settlements globally (ARUP, 2014; Solis, 2012).

Considering the severity of these challenges globally and the study area, there is a need for development approaches such as smart concepts, virtual city development, and other intervention mechanisms that can ameliorate the challenges of urban settlement and achieve sustainable development. The quest to provide solutions to this spatial development challenges and achieve sustainable urban development in developed and developing countries has created innovative 'smart development' thinking across the globe. Smart development is described as the physical development philosophy and planning activities that create efficient land use development, infrastructure adequacy and sustainable environment that are technologically driven (Howard, 2002).

Thus this study assesses the application of smart infrastructure concept for sustainable urban development in the Lagos metropolis so as to identify a way forward for Nigerian cities and other developing countries that are burdened with the challenges of infrastructure and sprawl development, with the view to identify actions that will ameliorate this challenges and promote integrated sustainable infrastructure development.

2. Literature review

'Infrastructure' is a network of interrelated basic facilities and services that provides an adequate environment for human living. A city infrastructure is a system of connected utilities, basic facilities, and services of that city, from the smallest units of the community (houses) to the significant city structures and buildings that render services such as electricity, sewage and sewerage and water supply. Infrastructures can be physical, social and economic (O'Grady and O'Hare, 2012). Smart infrastructure is an interconnected network of basic facilities and services with efficient land use pattern, transportation network with coordinated information technology devices (Litman, 2003). The smart concept is an urban design principle and practices that promote efficient integrated basic facilities and services with real-time information communication technology (ICT) so as to achieve sustainable development. The concept of smart infrastructure is derived from the concept of smart city and smart city is described by several literature as a comprehensive system with different elements such as the people, governance, environment, economy, mobility and the living conditions of a given geographical space with efficient ICT that promote smart sustainable environment (Anthony, 2001; Belanche, Casaló, & Orús, 2016; Danielsen, Lang, & Fulton, 1999; Edwards & Haines, 2007; Isa, Dodo, Ojobo, & Alkali, 2016; Miller, 2016; O'Grady & O'Hare, 2012).

The concept of smart infrastructure is an approach that is contemporary in urban planning and design for sustainable infrastructure development because of its integrated ICT approach adopted for sustainable development (Meijer & Bolívar, 2016; O'Grady & O'Hare, 2012; Vanolo, 2013). According to (Miller, 2016), applying the smart concept in smart infrastructure 'include the use of real-time information and the integrated evolution of urban form, multi-modal transport networks that are cost-effective, efficient, adequate and equitable for movement of the people, goods, and services in a more social, environmental, and physically sustainable area over a long period of time'. It also includes the integration of all real-time information and activities with a viable effective technology to promote sustainable living. The universal perspective of smart infrastructure concept in any settlement or urban development is described according to Figs. 1 and 2 below to include six basic elements such as; governance, people, environment, economy, mobility and the living condition of the people, which are inclusive in its definition and is described as a system. Figs. 1 and 2 illustrate the concepts of smart city and smart infrastructure as applied in this study and which is described as a system of several elements that are integrated with effective functioning technology (ICT).

Smart cities are described by different authors in different ways, but most definitions include six basic elements which are similar in most literature and are identified in Figs. 1 and 2 above (Meijer & Bolívar, 2016; Vanolo, 2013). The Figs. 1 and 2 above describe smart infrastructure as the integration of different element in a settlement with the aid of technology (Caragliu, Del Bo, & Nijkamp, 2011; Miller, 2016). This study adopts the smart infrastructure concept as described above as the research framework of this study and its application is discussed in section 2.2 aspect of this study below for the assessment of smart infrastructure for the sustainable urban development of Lagos metropolis.

Infrastructure in Lagos metropolis is a significant challenge that poses a social, economic and physical threat to sustainable living (Oduwaye, 2009). The situation of smart infrastructure in Lagos metropolis according to (Fadare & Oduwaye, 2009) and other literature shows that smart infrastructure in Lagos metropolis is a mirage and the condition of infrastructures such as road, drainage, electricity and other infrastructure is described as appalling with ugly environmental sights, slum areas, poor electricity, poor sanitation, inadequate and inappropriate use of open spaces, informal settlement, unorganized commercial areas and disjointed transportation system. The study of (Fadare & Oduwaye, 2009) advocate rebranding the Lagos metropolis through regeneration of the city with heavy investment in modern infrastructural facilities, especially electricity supply, roads, bus rapid transit (BRT) and railway system based on the evidence of severe infrastructure challenge in the metropolis. The study concludes that the "Lagos metropolis infrastructure is classified as very low in terms of her economic infrastructure, social infrastructure, physical infrastructure and other global quality indicators for sustainable development" (Fadare & Oduwaye 2009. pg. 797).

The study of (Bansal, Shrivastava, & Singh; Belanche, Casaló, & Orús,2016) identified several urbanization challenges and

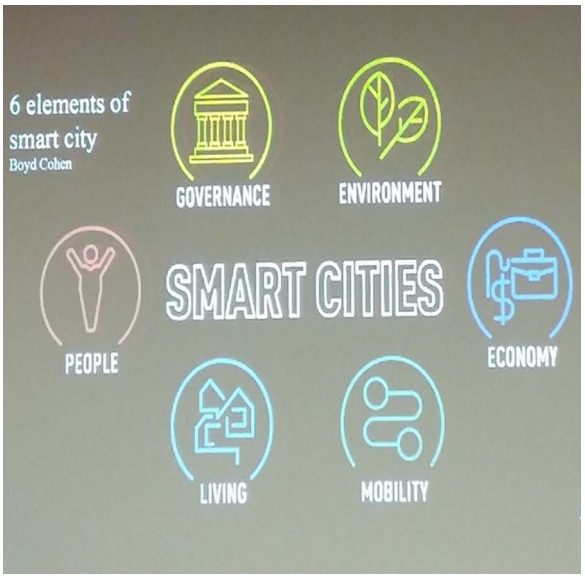

Fig. 1. Elements of a smart city.
Source: (Xing, 2016)

describes the approach adopted to ameliorate these challenges as smart urbanization strategies with basic standards of smart infrastructure concept. The study identifies poverty and deteriorated the quality of life, environmental pollution and degraded ecosystem, the housing crisis, infrastructure and urban services challenges among several other challenges as the critical anti-smart infrastructure development. (Bansal, Shrivastava, & Singh) identifies six basic elements of smart infrastructure as the standard criteria for smart infrastructure classifications and the strategies for assessing smart infrastructure for achieving sustainable smart infrastructure in any settlement to include; 1, the sources of renewable energy like wind energy, thermal power energy, solar energy etc., 2, smart grid for smarter city, 3, smart physical planning/land use morphology, such as compact city with mix land uses, diverse transportation choices, 4, smart eco-friendly environment, 5, intelligent cities, smart transportation, and 6, ICT as the major factors (Aigbokan, 1999; Bansal, Shrivastava, & Singh; Belanche, Casaló, & Orús,2016; Edwards & Haines, 2007; Isa, Dodo, Ojobo, & Alkali, 2016; Litman, 2003; Meijer & Bolívar, 2016; Newman, 1992; Timmermans & Beroggi, 2000).

Despite the positive literature evidence of smart city and smart infrastructure towards achieving sustainable developments, there exist arguments against the application of smart infrastructures globally. (Litman, 2003) describes the view of smart growth critics in his study by comparing it with the sprawl development challenges. The study states that few critics identify the concept as harmful and that families prefer large space homes in automobile dependent than smart policies. The comparison of smart concept with sprawl development concept approaches according to (Litman 2003) is discussed in Table 1 below as follows:

The summary of critics according to (Dowling, 2000; Litman, 2003) and other literature review identifies the basis of smart growth critic as baseless without facts. They described the perspectives of critics with the following major concerns and highlights of

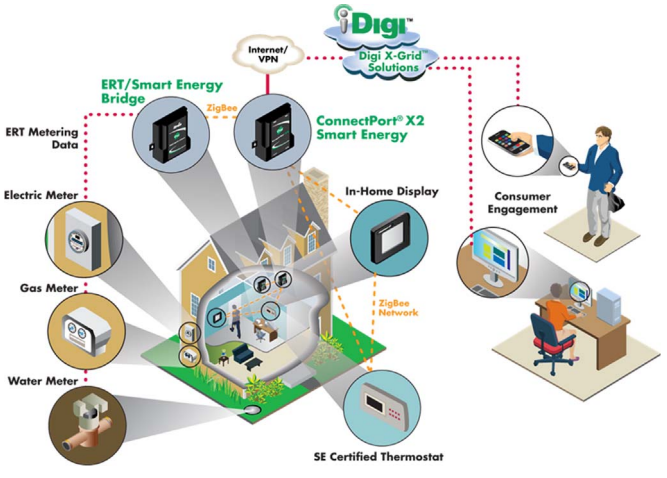

Fig. 2. Elements of smart infrastructure in a smart city.
Source: https://www.google.com.hk/search?q=smart+infrastructure&client=firefox

Table 1
Smart concept critics.
Source: Adapted from (Litman, 2003).

S/N	Factors for critic	Critics	Benefits ignored by critics
1.	Policies	1. Urban growth boundaries 2. Restrictions on urban driving	1. Allow smaller higher densities and more mixed development 2. Allow more compact affordable housing types (townhouses, multi-family, accessory units, lofts, etc) 3. Reduced and more flexible minimum parking requirements 4. Lower impact and utility fees for compact, infill development 5. More integrated and multimodal transport planning 6. More efficient traffic and parking management
2.	Impacts	1. Increased density, reduced per-capita land consumption	1. More infill, less urban expansion 2. More mixed development 3. More affordable housing types, such as townhouses and apartments with reduced parking supply 4. More connected roads and paths 5. Reduced parking supply, more sharing of parking facilities 6. Improved walking, cycling, public transit and car sharing 7. Reduced vehicle ownership and use 8. More walking, cycling and public transit
3.	Outcomes	1. Farmland preservation destroyed 2. More efficient public services reduced 3. Higher single –family housing prices 4. More intense traffic and parking congestion 5. Energy conservation and emission reduction.	1. Habitat preservation 2. Reduced public infrastructure and services costs 3. Reduced impervious surface and stormwater management 4. More urban green space 5. More affordable housing options 6. Household transportation cost savings 7. Reduced traffic casualty rates (deaths per capital) 8. Improved mobility for non-drivers, reduced chauffeuring burdens 9. Reduced time spent driving and less per capital congestion delay 10. Improved public fitness and health.

critics as follows:

1. It harms resident and the habitat.
2. Infringes on freedom.
3. Increases traffic congestion
4. Increase air pollution
5. Reduces housing affordability
6. Causes social problems
7. Increase public service costs
8. Requires wasteful transit subsidies and is unjustified (Dowling, 2000; Litman, 2003).

The review of literature in this study, and the analysis of (Caragliu, Del Bo, & Nijkamp, 2011; Danielsen, Lang, & Fulton, 1999; Dowling, 2000; Litman, 2003) among several other significant research that emphasizes the important of smart concepts, shows that it's evident that smart growth is a positive developmental principles and planning strategies that promote efficient land use and transportation patterns with the aid of technology for sustainable development. The application of smart infrastructure, smart growth for smart cities according to this literature review also identifies the integration of several basic facilities and services with the aid of ICT so as to achieve sustainable smart settlement (Dowling, 2000; Meijer & Bolívar, 2016). The study of (Meijer & Bolívar, 2016) also applied the smart concept to city governance for sustainable development, stating that 'comprehensive perspective of the city governance is about crafting new forms of human collaboration through the uses of ICTs to obtain better outcomes and open governance processes in a city'.

Thus the application of 'smart' concepts in the Lagos metropolis considering the infrastructure challenges should include the smart city elements and its approach for smart infrastructure, and smart data management to ameliorate urban challenges. Considering this perspective, this study research framework as discussed in section 2.2 below is based on this premises with the view to solving the challenges of infrastructure development in the study areas.

2.1. Research framework

Smart infrastructure is a structure of basic facilities and services that are interconnected and driven by technologies. Smart infrastructure is regarded as a recent global approach for achieving sustainable urban development over time, and it includes basic facilities and services such as; solar energy generating systems, big data sources, light rail and geospatial transport monitoring technologies just to mention few (Anthony, 2001; Liu, Siu, Gong, Gao, & Lu, 2016; Meijer & Bolívar, 2016; Miller, 2016; Vanolo, 2013; Xing, 2016; Zhang, Wu, Skitmore, & Jiang, 2015).

Fig. 3. The 'smart' concepts considered in this study.

Considering, the challenges of infrastructure in Lagos metropolis, the literature perspective of smart infrastructure and the potential of smart infrastructure towards achieving sustainable development, Fig. 3 illustrates the elements of smart city and smart infrastructures as a catalyst for sustainable development as adopted in this study. The figure describes the smart concept as the theoretical framework for the assessment of smart infrastructure in Lagos metropolis. Each element namely; the human capital, social capital, economic capital, physical capital and the environmental capital are the different types of infrastructure or elements that must be integrated and aided with technology capital to achieve smart infrastructure for sustainable development. This research framework describes achieving sustainable development through 'smart' concept as the combination of all these elements with efficient smart technology so as to achieve sustainable development. These elements as described in Fig. 3 below also serves as the criteria for assessing the infrastructure (assessing the availability and the smartness of infrastructure in Lagos metropolis and this is adopted for making adequate recommendations for sustainable development in the study area.

The research framework for this study in relation to Fig. 3 above seeks to bridge the gap in knowledge of sustainable infrastructure in Lagos metropolis by assessing the application of smart infrastructure strategies for sustainable urban development in Lagos metropolis. The research question of this study tends to answer includes; 1, what is the potential of smart infrastructure in Lagos metropolis to achieve sustainable urban development? 2, how can smart infrastructure concept be applied to achieve sustainable development? To answer this research questions and bridge the gap in knowledge through the use of this research framework as described in Fig. 3 above, the following hypothesis was tested as follows:

Ho: There is no significant relationship between physical environment and infrastructural development towards achieving sustainable development.
H_1: There is a significant relationship between the physical environment and infrastructural development towards achieving sustainable development.

This study, therefore, adopts a case study methodology and mixed method data collection to achieve the aim of this research and the techniques adopted is discussed in Section 3 research methods as follows.

3. Research methods

3.1. Context of the research: lagos metropolis

This study adopts two case study areas namely: Ikeja LGA and Eti-Osa LGA in Lagos metropolis to assess the applicability of smart infrastructure for sustainable development. The focus of the research assessed the spatial development pattern of the Lagos metropolis such as the building type, the building uses infrastructure, environmental condition and applied smart infrastructure concept based on this study theoretical framework so as to develop strategies for sustainable infrastructure development in the study areas.

Lagos metropolis grew from predominantly farming and fishing villages to an urbanized commercial hub of Nigeria. Lagos is a

Table 2
Sample Frame, Sample Size and Number of Questionnaires Returned.
Source: Field survey/ Lagos state social security exercise and population data (2010)

Research area	Male	Female	No. of wards	Selected wards population and number of questionnaires analyzed			
				Selected wards	Population size	Number of households	No. of questionnaires analyzed
Ikeja LGA	328,778	319,942	10	A2- Ojodu/Agidingbi/ Omole	30,160	5026	102
				A3-Alausa/Oregun/ Olusosun	25,268	4211	86
				B2-Ipodo/SerikiAro/ Wemabod Estate	25,476	4246	86
Eti-Osa LGA	460,124	523,391	10	Victoria Island I	25,207	4201	85
				Ilado/Eti-Osa and Environs	18,639	3106	62
				Ado/Langbasa/Badore	11,688	1948	39
Total					**136,438**	**22,738**	**460**

megacity with over 17 million population (Lawanson, 2007) and t has a population of 20,000 in every square meter and an annual population increase of 275,000 persons. The metropolis is regarded as the destination of people moving from the Nigerian hinterlands and nearby African cities (Lawanson & Fadare, 2015).

Lagos metropolis, in particular, the Ikeja and Eti-Osa LGAs, is the commercial, industrial and administrative hub of Lagos State, which has contributed to the high rate of migration into the city. For this study, questionnaires were administered in three major wards of Ikeja and Eti-Osa L.G.A respectively: Ojodu/Agidingbi/Omole, Alausa/Oregun/Olusosun and Ipodo/Seriki Aro/Wemabod Estate, and Victoria Island, Ilado/Eti-Osa and environs, and Ado/Langbasa/Badore. The environmental characteristics, socio-economic characteristics and infrastructural development data collected in these areas were analyzed and assessed within the context of smart concepts for sustainable development.

3.2. Methods

To obtain meaningful and useful information, mixed method data collection and analysis with multi-stage sampling techniques were used. Questionnaires were distributed strategically within Ikeja and Eti-Osa L.G.A of Lagos metropolis. Multi-stage sampling techniques used includes the stratification of the local government areas of the Lagos metropolis into two major study areas (Island and Mainland), followed by the systematic selection of Ikeja and Eti-Osa within the stratified LGAs and simple random sampling selection to determine the samples. Cochran's sample size determination for continuous data, categorical data and discrete data at 10% sample size was used to determine the sample size. Four hundred and sixty questionnaires were administered and returned for analysis, 274 from Ikeja and 186 questionnaires from Eti-Osa. The details of the sampled areas, the sample size and the wards sampled are given in Table 2 below. The distribution of the questionnaires as shown in Table 2 below also emphasizes the strategies adopted for the research methods, the analysis of the study and consequently the decision for the recommendations make in the study.

Considering the target population, the nature of the research and the research focus, the survey question includes the different types of questions which are five point Likert scale and several other numeric scale questions with questions from four sections namely; socioeconomic questions, land uses and environmental questions, infrastructures and smart growth indicators questions respectively. The study adopts inferential statistical techniques and the techniques include the parametric data analyzed through the use of figures, tables and chi-square results generated from SPSS. The spatial description of the study area graphically is presented in Fig. 4 below within the context of the Lagos metropolis.

4. Discussion

This section of the research discussion discussed the data collection results in relation to the assessment criteria and the study area. The most significant variables relevant to the element of assessing smart infrastructure for sustainable urban development such as environmental conditions, building use and infrastructure are discussed as follows:

4.1. Environmental conditions

The environmental conditions of the study areas is a sprawl development with associated growth challenges, transport challenges, informal settlement, inadequate infrastructure, dispersed and uncoordinated infrastructure. Assessing the environmental condition of the study areas (Ikeja and Eti-Osa LGA) with the research framework criteria, the data collected (Table 3 and its discussion below) and the literature review, the study areas reflect a critically challenged sprawl settlement. The environmental conditions of the study area is a sprawl development with several environmental challenges such as bad drainage with flooded areas,

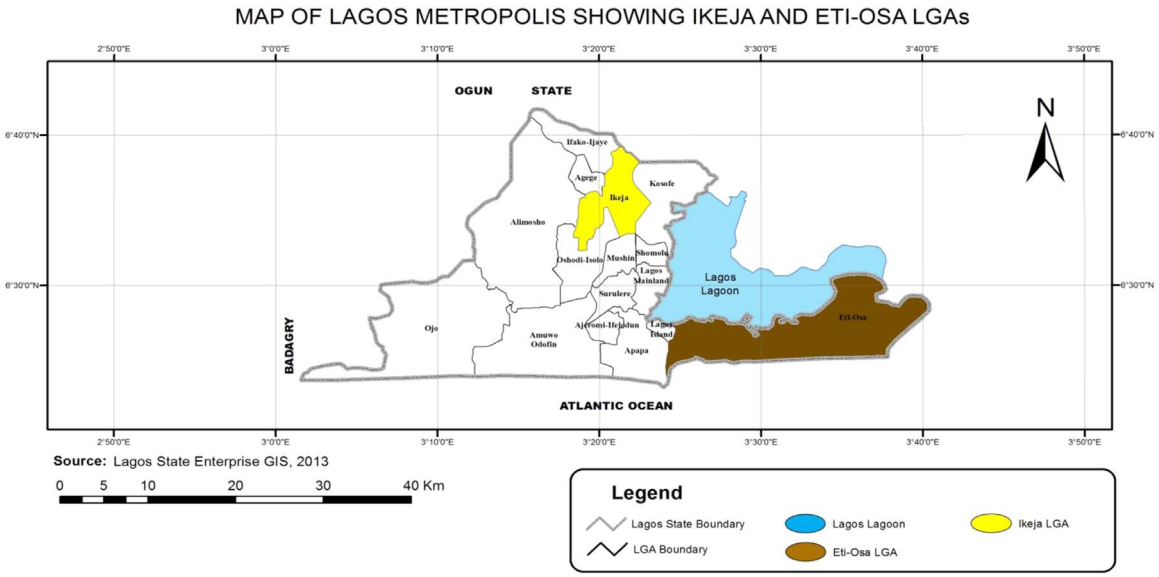

Fig. 4. Map of the Lagos metropolis showing the study areas.

bad roads with several potholes and traffic challenges, littered dirt, haphazard building arrangement, and inadequate environmental conditions. Fig. 5 below further present the challenging situation of environmental conditions in some parts of the study areas. Considering the environmental challenges of the study areas and smart infrastructure as the developmental strategies and planning principles that promote efficient land use, the study area is identified ideal for application of smart infrastructure so as to achieve sustainable urban development. The hypothesis tested for this assertion states that:

Ho: There is no significant relationship between building use and environmental condition (neighborhood sanitation).
H_1: There is a significant relationship between building use and environmental condition (neighborhood sanitation).

Table 3 above shows that the Chi-square test is significant at the 0.00 level, which is below the 0.05 significance level; we thus accept H_1: there is a significant relationship between building use and the environmental sanitation. That is, the types of building use or activities in a building induce environmental pollution and this also corroborates the study of (Adeyeye, 2010) which also describe the environmental challenges of Lagos metropolis as overwhelming. Thus the concept of smart infrastructure in environmental sustainability is applicable to promote sustainable environmental development in the study areas and reduce sprawl developments that are identified as inducers of environmental deterioration. This analysis suggests that the study area urgently requires integrated and coordinated building infrastructure that can be effectively monitored through technology to promote sustainable environmental development.

4.2. Building and infrastructure development

The finding of the study areas in terms of building and infrastructure development such as the residential building conditions, infrastructure such as the road infrastructures, modes of transport, electricity, recreation space, car parks and refuse management reflects that the building and the infrastructural conditions of the areas are inadequate. The assessment of building use and infrastructure development condition of the study areas in relation to standard measurements such as United Nations (UN), Millennium Development Goals (MDGs), European Union Economic Intelligent Units (EU, EIU) Report 2014 and smart growth principle indicators in this study, the study areas reflects inadequate building and infrastructure conditions with critical challenges. Infrastructure in the study areas is greatly challenged with supply and management of infrastructural facilities at the detriment of industry and business activity development in the area. This also consequently affects the environmental and building development

Table 3
Chi-Square test of building use and neighbourhood sanitation.
Source: Authors' field analysis (2014)

	Building Use	Neighbourhood Sanitation
Chi-Square	461.965[a]	395.496[a]
df	3	3
Asymp. Sig.	.000	.000

[a] 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 115.0.

Fig. 5. Infrastructure and building conditions at Ikeja and Eti-Osa.
Source: Authors' field work, 2015

of the area. Also, the findings of this study on income in relation to UN definition of poverty (person living below one dollar per day) describe the study area infrastructure as been affected by poverty. The Millennium Development Goals 2020, Agenda 7 and Target 8 on infrastructure and building conditions are far from being realized in the study areas and the urban development is not in any way sustainable. The hypothesis tested in the study areas to validate this assertion states that:

Ho: There is no significant relationship between monthly income and infrastructure
Ho: There is a significant relationship between monthly income and infrastructure

The study analysis according to Table 4 above on average income of the residence shows that the Chi-square test is significant at 0.00 level which is below the 0.05 significance level, thus we accept H_1: there is a significant relationship between monthly income and the infrastructure and this creates avenue for integration of smart infrastructure in the study area. The assessment of these study areas in relation to infrastructure in the study areas is not different from the findings of (Dekolo & Oduwaye, 2011; Fadare & Oduwaye, 2009; Oduwaye, 2009, 2013) on the challenges of infrastructures. However, this study assesses the infrastructure in relation to income and the application of smart infrastructure concept in the study area. The condition of building and infrastructure development in the study areas is further described in Fig. 5 below as follows.

The summary of environmental conditions, building and infrastructure development assessment in the study area in relation to smart infrastructure concept and this study research framework so as to achieve sustainable development, describes the study area in relation to the figures in Table 5. The building condition of the study areas are predominantly bungalows with more than half of the residential buildings in the study areas as buildings between 1–2 floors and the building use are majorly residential with three-quarter of the buildings used for residential, and the buildings with residential and commercial are almost half of the building use in the study area. The use of the recreation, waste generation system, traffic congestion, car park and other infrastructures in the study areas are inadequate. The open space is described by more than half of the respondent as not available, waste regeneration systems are largely not available, traffic congestion is high, the car park is basically not available and infrastructure is generally regarded as not available and not effective when available.

The assessment the study area according to the analysis of this research, the facts and figures presented in Table 5 above, the study area is critically challenged and the application of smart infrastructure for sustainable development is applicable as a potential strategy for ameliorating these challenges. Thus the recommendations for the application of smart infrastructure concept to achieve sustainable development are discussed in Section 5 below.

Table 4
Chi-Square test of income and infrastructure.
Source: Authors' field analysis (2014).

	Monthly income	Closer infrastructure
Chi-square	71.991[a]	307.843[b]
df	5	3
Asymp. Sig.	.000	.000

[a] 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 76.7.
[b] 0 cells (0%) have expected frequencies less than 5. The minimum expected cell frequency is 115.0.

Table 5
Building, infrastructure, and environmental conditions.
Source: Author's Fieldwork

Variables		Frequency		Total Feq. & Percentage	
		Ikeja	Eti-Osa	Frequency	Percentage %
Types of building	Bungalow	93	77	170	36.9%
	Compound house	41	32	73	15.9%
	Duplex	34	27	61	13.3%
	Flats/Semi-detached	106	50	156	33.9%
	Total	**274**	**186**	**460**	**100**
Building floors	1–2	196	104	300	65.2%
	3–5	78	80	158	34.3%
	5–7	0	2	2	0.5%
	Above 7	0	0	0	0
	Total	**274**	**186**	**460**	**100**
Building use	Residential	109	143	252	54.7%
	Commercial	16	18	34	7.3%
	Commercial & Institution	15	5	20	4.5%
	Residential & commercial	134	20	154	33.5%
	Total	**274**	**186**	**460**	**100**
Public/Private recreation	Available	109	105	214	46.5%
	Not available	165	81	246	53.5%
	Total	**274**	**186**	**460**	**100**
Waste regeneration system	Available	80	62	142	30.9%
	Not available	194	124	318	69.1%
	Total	**274**	**186**	**460**	**100**
	Effective	30	24	54	11.7%
	Satisfactory	78	34	112	24.3%
	Not effective	31	54	85	18.5%
	Not available	135	74	209	45.5%
	Total	**274**	**186**	**460**	**100**
Traffic congestion	Very high	42	36	78	16.9%
	High	108	86	194	42.4%
	Undecided	24	11	35	7.6%
	Very low	43	19	62	13.4%
	Low	57	34	91	19.7%
	Total	**274**	**186**	**460**	**100**
Car park	Available	96	47	143	31.1%
	Not available	130	66	196	42.6%
	Not efficient	48	73	121	26.3%
	Total	**274**	**186**	**460**	**100**
Infrastructure	Available	73	80	153	33.3%
	Not available	201	106	307	66.7%
	Total	**274**	**186**	**460**	**100**
	Effective	15	20	35	7.6%
	Satisfactory	45	25	70	15.2%
	Not effective	94	67	161	35.0%
	Not available	120	74	194	42.2%
	Total	**274**	**186**	**460**	**100**

5. Recommendations

The assessment of environmental conditions, buildings and infrastructural development in the study areas revealed that smart infrastructures are applicable as strategies for sustainable development in the study areas as follows:

1. The smart infrastructure in the study area can be applied by developing blueprints that identify spot clearance areas for the redevelopment and integration of smart infrastructure concepts. The areas involved should be cordon and connectivity through technology mapping and linkages for adequate functionality should also be developed.

a. The blueprints must be designed to identify harmonious land uses within the same vicinity and develop the synergy with the public facilities such as schools, grocery stores and recreational facilities within these areas to promote sustainable residential areas.

2. The land use development that accommodates smart infrastructures and community amenities and its integration within the existing built-up areas of Lagos metropolis should be encouraged.

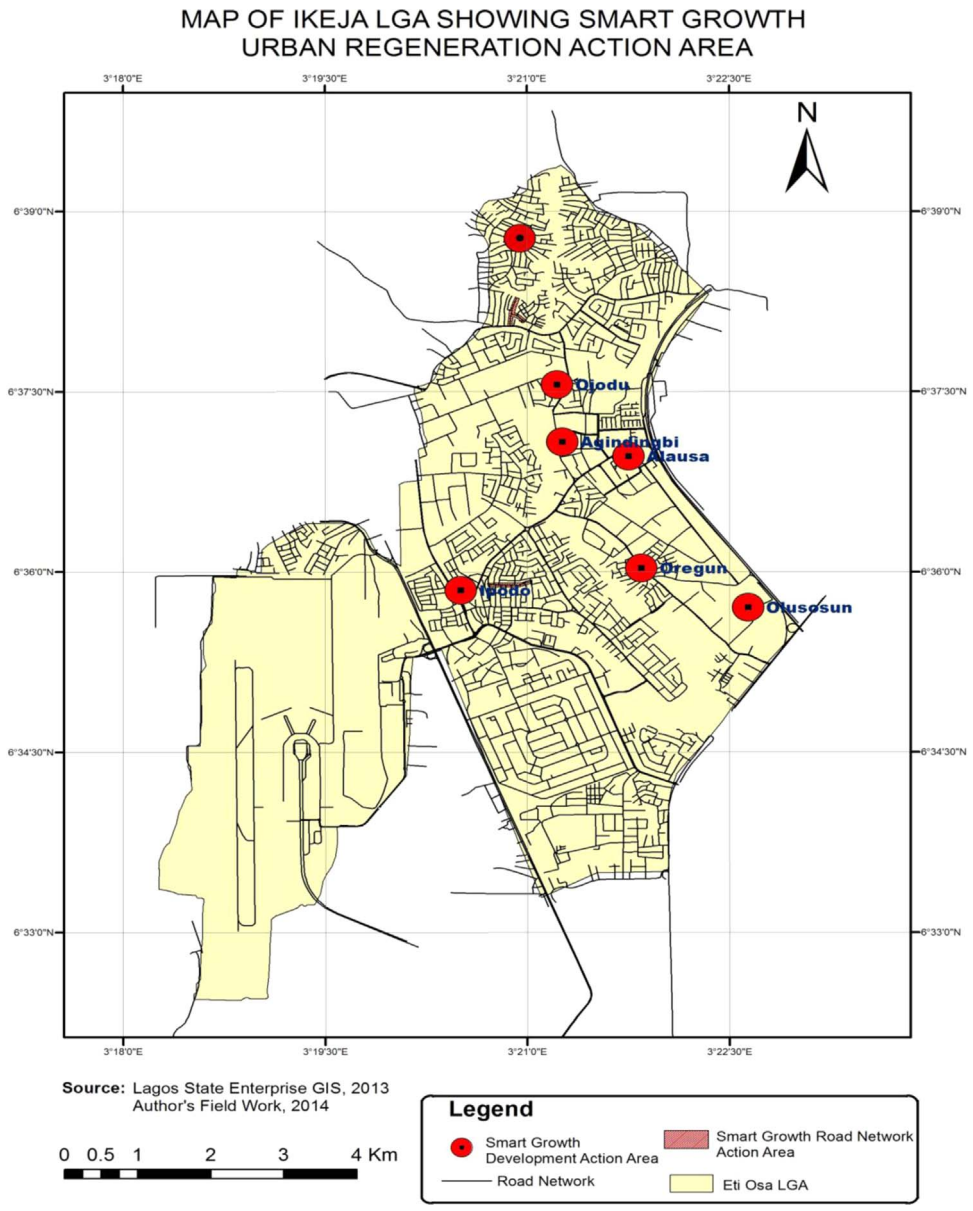

Fig. 6. Action areas for the application of a smart infrastructure strategy in Ikeja LGA.

a. The infrastructures, public services, and building infrastructures should be integrated within existing vacant areas of the study areas through spot clearances. A practical example of such integrations with smart infrastructure concepts that should be encouraged includes the Shoprite at Ikeja and the jetty transport in Badore area of Eti-Osa LGA, but this integration should be with adequate technology and smart infrastructure concept. The Figs. 6 and 7 below describes the identified areas of such applications in the study areas, see Figs. 6 and 7 below for details.

a. The application of smart infrastructure in the study areas through spot clearance of obsolete structures and maintenance of others with smart infrastructure concept by both the government and the citizens to allow adequate smart infrastructure and public utilities at an effective allocation should be encouraged.

3. Smart infrastructure in the study area can be achieved through the creation of coordinated, functional socio-economic transport system that accommodates the mobility, safety, comfort and convenience of all inhabitants, including the dependent and the disabled citizens. An example of such infrastructures that can be developed to smart infrastructure transport is the Badagry-Lasu Lagos Metro line connecting nodal areas of Lagos metropolis and the proposed Badagry–Lasu express road.

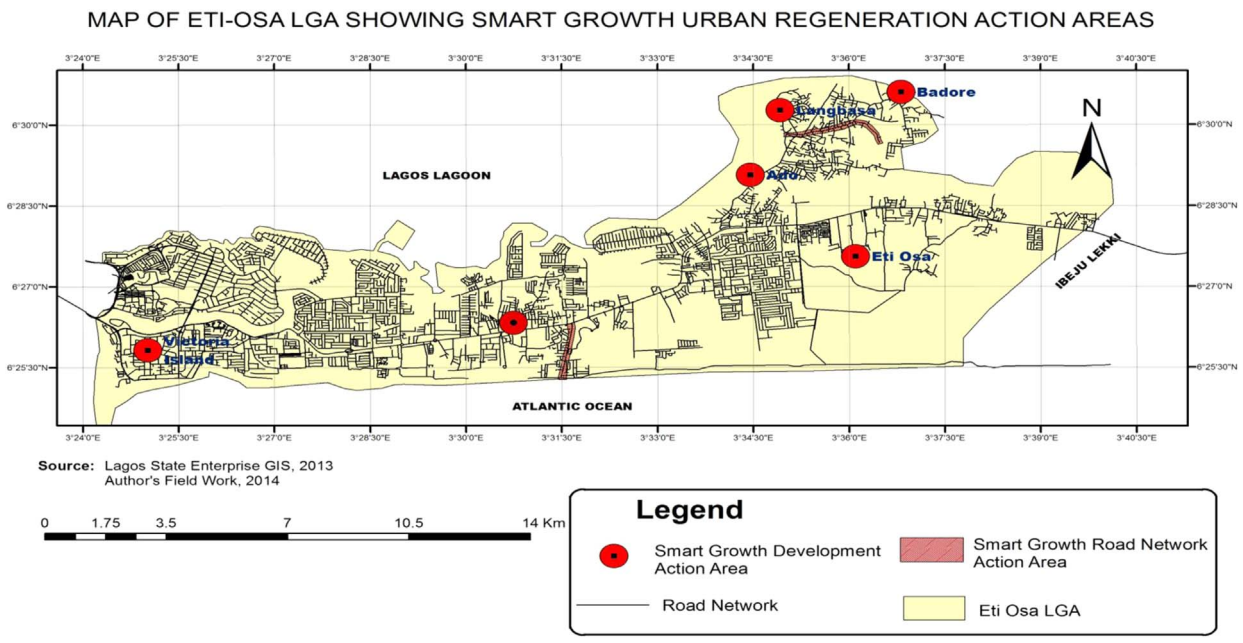

Fig. 7. Action areas for the application of a smart infrastructure strategy in Eti-Osa LGA.

a. These infrastructures and similar once should be designed, provided and integrated into built up areas of the Lagos metropolis with smart infrastructure concepts such as technology, real-time information devices in a more efficient and fewer energy consumptions among others.

a. The development of big data, consumer engagement devices, certified thermostat, efficient energy grid and geographical real time information devices should be developed with this infrastructure to enable its smart infrastructure standard.

4. The smart infrastructure in the study areas can be achieved through the development of an improve non-motorised transport facilities, promote pedestrian and bicycling facilities by improving sidewalks, footpaths and creating sidewalk bike sheds. These improvements could include but are not limited to, facilities such as trees, sunshades, benches and pedestrian-oriented lighting.

a. These facilities and these non-motorised facilities should be designed, developed and integrated appropriately in the study areas with smart concepts and coordinated technology with pathfinder/tracker device such as street and path identified by Google map and others.

a. The networks of interconnected street paths should be design and constructed to encourage the use of light capacity interconnected narrow roads as much as practicable. This is more important within the housing and business activity areas of Lagos metropolis with pedestrian and bicycle tracks.

5. Encourage neighborhood and city designs that support a range of transportation choices, infrastructure developments and adequate housing conditions with the technological database. A practical example of such designs that should be encouraged more in Lagos metropolis is the proposed Eko Atlantic City Development and such development should be effectively implemented with smart infrastructure concept.

a. This kind of development can be integrated into built up areas with spot clearance strategy or can be developed in identified developing areas.

a. The mixed housing types with adequate infrastructural facilities that include affordable housing for employees with commercial and transport centers in a more vertical development should be introduced and encouraged.

6. The development of smart power supply options is essential for the application of smart infrastructure in Lagos metropolis and should be encouraged. The focus should not only be on hydropower electricity alone but rather other options like fossil fuels, nuclear energy and renewable energy such as biomass, geothermal, solar energy and wind energy should be considered and adopted with smart concepts in Lagos metropolis.

These recommendations are smart if they are connected in the study areas with smart technology and smart human capacity to

adequately implement and operate sustainable infrastructure in the study areas. The identified areas applicable based on the study and recommendation above is described graphically in Figs. 6 and 7 below.

6. Conclusions

The assessment of infrastructure, building use and spatial pattern of buildings, and environmental development of Ikeja and Eti-Osa LGA of Lagos metropolis reflect the area as an urban sprawl development with rapid urbanization challenges. Smart concept (especially smart infrastructure) is identified applicable for sustainable urban development in the study area through transport integration, environmental and building use integration with basic facilities and services that are coordinated by smart technology.

The test of hypothesis in the study areas also reflects that the application of smart concepts is capable of uniting formerly disparate constituencies, regenerate degraded environments, infuse and maximize the effective use of infrastructure through smart infrastructure concept. The application of the smart concept in the study areas encourage effective high-density land use, community development and build a strong, self-supported force for change that is smart technology based.

The study concludes that smart growth concept is a design philosophy that is suitable for sustainable development and enhances interconnected infrastructural and residential development of the Lagos metropolis with the help of adequate technology assistance. The integration of rapid population growth, the social reshaping of the city, the environment and the market economy with smart technology can also create sustainable development in the study areas. The study also concludes that there are a basic element that must be available and integrated into the reshaping and the application of the smart concept in the two LGA (Ikeja, Mainland region, and Eti-Osa Island region) within the Lagos metropolis to achieve sustainable development in the state, the nation, and the surrounding nations.

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