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RESEARCH ARTICLE

Smart Cities and Environmental Sustainability: Evaluating the Nexus in South-West Nigeria

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Abstract. Smart cities leverage advanced technologies like Internet of Things (IoT) devices, Artificial Intelligence (AI), and large-scale data analytics for gathering and interpreting data for informed decision-making and improved service delivery. This study focuses on the nexus between smart city development initiatives and environmental sustainability geared towards enhancing a better human settlement in the South-west region, of Nigeria. One of the objectives is to identify and evaluate the factors contributing to the development of smart city initiatives and to evaluate their contributions towards environmental sustainability. An empirical Quantitative approach method comprising Questionnaires was used. A total of three hundred (300) sample Questionnaires were administered and two hundred and eighty-six (286) questionnaires were retrieved and used for analysis. The distribution of Questionnaires cut across professional experts within the built environment and relevant stakeholders. Analysis was done, using the regression technique of the Statistical Package for the Social Sciences (SPSS) software, Version 22. Some of the results included the following: smart economic factors such as Entrepreneurship and Innovation (B = 0.899, sig. = 0.001) Productivity, (B = 0.794, sig. = 0.001) Local and global interconnectivity (B = 0.713, sig. = 0.001). Similarly, the smart mobility factors, have mixed and modal access (B = 0.632, sig. = 0.001); Prioritized clean and non-motorized options (B = 0.604, sig. = 0.001); Integrated ICT (B = 0.656, sig. = 0.001). Generally, the study revealed that smart economy, smart mobility, and smart environment have the most influence on the achievement of environmental sustainability in South-west, Nigeria.

1. Introduction

Smart cities aim to create a more livable, sustainable, and inclusive urban environment that meets the needs of residents and addresses urban challenges. These challenges include urbanization, inadequate physical infrastructures, and vulnerability to disasters and climate change (Ahad et al. 2020; Vainio and Sankala 2022). To address the various cities' problems calls for the adoption of the idea behind "smart cities," which leverage ICTs (information and communication technologies) to promote sustainable development (Ismagilova et al. 2019; Kaluarachchi 2021). Accordingly, the city's technology and amenities have impacted both the city's physical features and its inhabitants in a variety of ways, following the local features acquainted with its cultural, social, environmental, and economic circumstances. Smart cities, according to the United Nations, are "smart innovations for the sustainable development of communities to accomplish all 17 Sustainable Development Goals and the 2030 Agenda, which aims to uphold the principle of ensuring that nobody is being overlooked" (Kumar and Isha 2019). Smart cities leverage advanced technologies like Internet of Things (IoT) devices, Artificial Intelligence (AI), and large-scale data analytics for gathering and interpreting data for informed decision-making and improved service delivery (Ahad et al. 2020; Kaluarachchi 2022). Conversely, environmental sustainability can be defined as a condition of safety, flexibility, and interconnectedness that enables the social structure to achieve its goals (Agboola et al.,2015; Njar & Enagu 2019). The major focus of sustainable development is geared towards integrating environmental management towards efficient economic development across all sectors. Therefore, countries around the world have created a variety of smart cities to fulfill the Sustainable Development Goals (SDGs) by leveraging cutting-edge technologies and urban design ideas. This is with a view of creating healthy, livable, and prosperous human environments with reduced impact on the environment (Hollands 2020; Agboola et al. 2022). As a result, it is possible to adopt a city-development plan encompassing the design, development, execution, assessment, and enhancement of urban systems that support urban sustainable development.

Shortage of housing due to the recent increase in urban population demands for 'Smart Buildings', that incorporate advanced technologies and connectivity to enhance energy efficiency, and comfort, and reduce environmental impact (Alberti 2016; Ahad et al. 2020). A smart building has an integrated building management system that connects and controls all of the building's systems, including Heating, Ventilation, Air conditioning (HVAC) lighting, and security. The effort in integrating appropriate technology in buildings increases the optimization of energy usage and reduces the carbon footprint. Smart buildings planning regulation and smart cities are critical for urban disaster-resilience (Rachmawati *et al.,*2023) The interactions between Smart Cities, Resilience, and Sustainable Growth of the Built Environment are vital for solving the problem posed by rapid urbanization and climate change, therefore ensuring a better future for urban communities (Rezvani, et al., 2017; Cugurullo 2018; Hollands 2020; Agboola et al., 2023). Rapid Urban growth amid improper planning, lack of infrastructural development or poor policies implementation is a major threat to sustainability(Ogochukwu *et al.,*2022) The rapid urbanization, increased urban population, and expansion of Nigerian cities such as Lagos, Ibadan, and Akure all located in South-West Nigeria have greatly impacted negatively on several environmentally sustainable indicators and increased the Climate change vulnerability in cities across the Nigeria South-West, region (Agbola, Zakka and Olatunji, 2024). One of the smart City initiatives in South-West Nigeria can be traced to the self-service smart city agenda in Lagos was championed by the urban residents with little support and input from the city Management (Gandy, 2006). The initiative was focused on entrepreneurial networks in the provision of City basic amenities and technology hubs.

Considering the challenges faced by Cities in South-West Nigeria as mentioned above, the need for smart city initiatives remains very imperative. The integration of smart cities' principles into the built environment fosters sustainable urban planning, and eco-friendly infrastructure development (Rezvani, et al., 2017; Cugurullo 2018; Hollands 2020; Agboola et al., 2022). This alignment between smart cities and environmentally sustainable growth creates a virtuous cycle, where smart technologies enhance resilience, which, in turn, supports the continued growth of sustainable urban areas. In this regard, recent research has looked at how to include sustainability in smart city initiatives to promote sustainable city paradigms. This research aims to establish the nexus between smart city development initiatives and environmental sustainability geared towards enhancing a better human settlement in the South-west region, of Nigeria. This one aim will be achieved through the underlying objectives of this research: (i) to identify and evaluate the factors contributing to the development of smart city initiatives and their contribution towards environmental sustainability in South West region, Nigeria; (ii) to establish the contribution of the smart city buildings towards enhancing the environmental sustainability in the region (iii) to established the influence of smart city initiatives and environmental sustainability towards the development of resilience in the region.

A Review of Smart City Growth and Environmental sustainability

The comfortability index that is necessary for smart city initiatives to make living in them desirable is present (Grossi & Pianezzi 2017; Homepage Smart City 2019). With the aid of numerous variables, ICTs are now extensively utilized in city administration and management as resources and instruments to improve livability, attain environmental sustainability, and create creative urban environments (Anthopoulos and Tougountzoglou 2014;Smeets-Kristkova et al., 2019). Smart cities are distinct and defined according to their performance (Backhouse 2015). Some of the three major areas of performance exhibited by smart cities as pointed out by Hollands (2020) include the following: Harnessing infrastructure-based services using the knowledge of Information and Communication Technologies (ICT) as critical components of a Smart city function. The second aspect is concerned with business-led urban development; the focus is on creating a favourable condition for infrastructure development and skilled manpower that will drive a vibrant economy through business. Smart cities should be able to assume a projected economic growth that will uphold the tenant of investment and developed skills manpower growth (Caragliu et al.,2011). The third area of performance for smart cities is in the area of social inclusion, learning, and development to satisfy the community's needs. It is expected that smart communities seen as the product of smart cities should connect businesses, government, and residents using new technology to enhance and transform urban life and work (Komninos 2016) The general emphasis is geared towards enhancing the quality of life in the urban environment and how the urban dwellers will take advantage of benefits derives from smart living (Odendaal 2003; Caragliu, et al.,2011). Smart city growth embraces the green growth concept approach (Freire 2013) and the compact growth concept based on design objectives. The major attributes of green growth are rooted in the drive towards green economy investment as an impetus for economic growth and the well-being of the citizens (World Bank, 2012) The compact city growth is seen as a component of smart cities approach presented by (Pemer 2001)revealed a departure from the old approach of land use by zoning for the city of Stockholm Sweden towards a concept of compact growth that integrate the residential areas with job-matching program especially in the field of Information Technology (IT) and Communication industry. Based on the general review by (Hamamurad, et al., (2022) a smart city conceptual frame was developed on a structure that comprises the brain ware, hardware, software, and social ware. Secondly, we have the smart city Domains which comprise city resources and services. Lastly, the framework is built on improving the following variables: Quality of life, local economy, climatic conditions, traffic management, and engagement with the government.

A state of safety, ability to adapt, and connectedness that enables the societal structure to achieve its goals is known as environmental sustainability (Agboola et al.,2015; Njar & Enagu 2019). The major focus of sustainable development is to integrate environmental management towards efficient economic development across all sectors. The environmental component of sustainable development is very paramount in the development of nations towards economic growth and development (Zakka 2018). The environmental component of sustainable development was branded to stand as a concept of environmental sustainability. The Statistical Commission and Economic Commission for Europe (EUROSTAT, 2001) were able to outline some variables as indicators to measure the overall performance of settlements. Some of the indicators were: air and environmental quality, energy consumption, urban growth transportation, and land use (UN, 2007). These

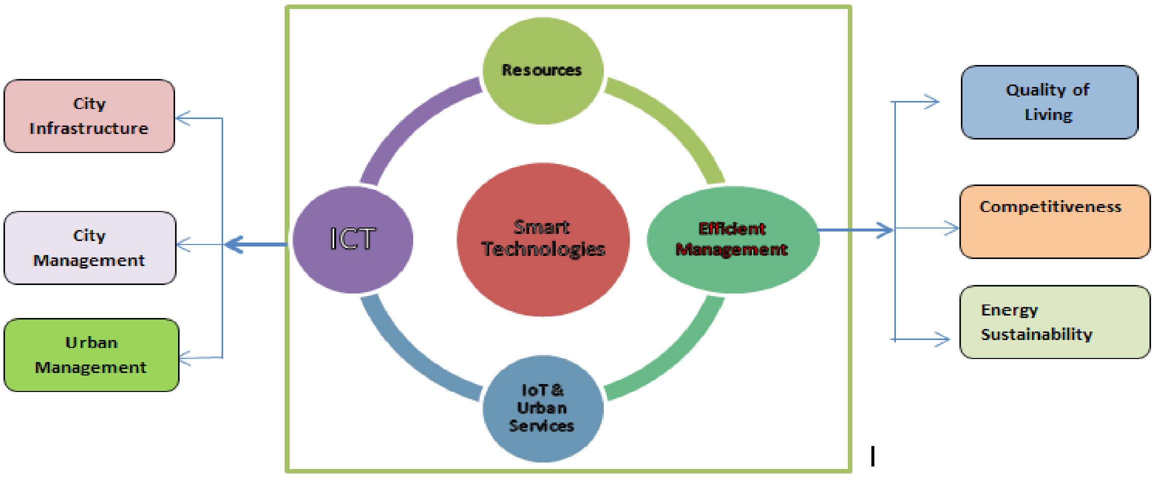

Figure 1. ICT inclusion in urban management for smart cities within the context of urban decarbonization. Adapted: (Homepage Smart City 2019) and (Smeets-Kristkova et al., 2019).

indicators are very important if relevant stakeholders are to be held accountable for the transitional changes that may be detrimental to the Built Built Environment (Moldan et al., 2012) and sustainability. Smart city initiatives play a vital role in enhancing environmental sustainability, by leveraging technology to optimize urban services and infrastructure, improve resource management, and reduce environmental impact. For example, smart energy management systems can optimize energy use in buildings and public spaces, reducing energy consumption and associated greenhouse gas emissions. By promoting the use of electric automobiles, public transit, and active forms of transportation like walking and cycling, innovative transportation systems can support environmentally friendly mobility (Offiong et al.,2014; Kaluarachchi 2021). Across the globe, traditional towns are evolving into smart cities through the utilization of the Internet of Things. As Figure 1 illustrates graphically, this validated the smart city indicators and the use of information and communication technology (ICTs) in urban administration, both of which are critical to achieving the sustainability of the environment.

A perspective of the Smart Cities initiative in South-West Nigeria as pointed out by Gandy (2006) was the case of the city of Lagos. The Lagos smart city agenda as highlighted by Gandy (2006) was a self-service initiative. The residents-driven agenda was focused on entrepreneurial networks in the provision of city basic amenities and technology hubs. Similarly, Okewale & Atobatele (2022) mentioned Lagos and Ibadan in South-West, Nigeria as cities that adopted the smart city arrangement to conduct socio-economic activities, but are limited due to lack of infrastructure and unstable policies of the various state governments. These reasons have made it very difficult for cities in southwest, Nigeria to key into the smart city arrangement properly.

2. Methods

Data Collection, Distribution, and Analysis

An empirical Quantitative approach method comprising Questionnaires surveys was used in evaluating the nexus between smart Cities and environmental sustainability in the study. A total number of two hundred and eighty-six (286) responded out of the 300 samples used. The response rate amounted to 95.33 percent, which was a justifiable percentage, and good for the analysis (Moser and Kalton, 1917). The testing of the data set's normality was a critical step in the variable screening. Normalcy tests are used to assess the distribution of data to confirm the normalcy of the data gathered (Hair et. al., 2017). The standard errors, kurtosis, and skewness are used to calculate it. Kurtosis is a property of both positive (high-peaked) and negative (flat-peaked) distributions. Positive skewness (on the left with the data scattered) and negative skewness (on the right with the data spread) are other definitions of skewness. The recognized range of kurtosis and skewness is +2 to -2 (Kline, 2015); and this was achieved in this study's data analytical testing. In this study, respondents' opinions were gathered using a closed-ended survey that addressed the established goals of this research investigation. Based on the variables that were found in the examined literature, the questionnaires were divided into three sections. The first section covered the backgrounds of those who participated, as stated by Kaluarachchi (2021); section two explored the various aspects influencing smart cities, such as the smart economy, people, mobility, governance, environment, and living. The third section focused on smart buildings as iterated by Hou et al. (2016); all used a 5-point Likert scale for agreement; ranging from "Strong agreement" of "5"; 'Agree' of '4'; 'Neutral' of '3' to "Strongly disagree" of "1."; Disagree of '2'. Smart variables were measured based on the Smart City and Sustainability Model (SCS Model) as previously tested by the studies of Bamwesigye and Hlavackova, (2019) and Voordijk and Dorrestijn (2021). These include (i) smart mobility; (ii) smart technology; (iii) smart people; (iv) smart governance; (v) smart economy; (vi) smart environment (such as waste management, public spaces, and greenery spaces/parks); and (vii) smart living.

The questionnaires were delivered online to a main network of experts working on smart city initiatives (smart transportation, smart security, and smart living) to implement the snowball sampling technique. Convenience sampling procedures were used in the survey distributions, which took place in the study areas between April and August of 2023 (Akinola et al. 2020). A total number of n=300 survey questionnaires were distributed to the experts in the targeted states of Ekiti (50 numbers), Lagos (50 numbers), Ogun (50 numbers), Ondo (50 numbers), and Osun (50 numbers), and Oyo (50 numbers) respectively. The survey questionnaires captured both demographic and socio-economic variables such as age, education, and gender among others. The distribution of Questionnaires covers respondents within the majority age bracket of 31-50 years. The distribution of Questionnaires cut across professional experts within the built environment and relevant stakeholders in the area of Smart Building in the South West of Nigeria. These include consultants, site supervisors, city planners, cost engineers, structural engineers, designers, computer specialists, and software engineers are all examples of professionals who work in the construction industry. The background data received from the respondents demonstrate that they have the necessary professional credentials, real-world experience, and expertise to provide an expert opinion regarding the study's goal. They already know what resilient city construction and smart city development are.

The questionnaire data were analyzed using the regression technique of the Statistical Package for the Social Sciences (SPSS) software package, precisely Version 22. The use of SPSS aided in the statistical analysis of the acquired data, allowing for a thorough investigation of the research variables and the generation of important conclusions for the study.

Cronbach's alpha (α) results were used to evaluate the survey's internal consistency. Furthermore, composite reliability (cr) was employed to estimate the instrument's internal consistency dependability. For all variables, the data reliability measure exceeded Cronbach's Alpha coefficient (α) of 0.6, indicating a reliable value. Cronbach and Shavelson (2004), agreed that scores more than 0.6 are acceptable. The examination aided in the clarity and degree of the questionnaire instrument's use. Meanwhile, the results of reliability and validity tested using Cronbach's alpha on the data were shown for the following variables as follows: Smart People(Speo) =0.94, Smart Mobility(Smob)=0.87, Smart Living (Sliv)=0.93, Smart Government(Sgvt)=0.88, Smart Environment(Senv)=0.95, Smart Economy(Secon)=0.98, Smart Buildings=0.91 and Urban Resilience=0.89 The statistical technique is trustworthy when Cronbach's alpha values range from 0.75 and 0.90, with values close to 0.90 indicating a high degree of dependency across the numerous ideas examined or studied mostly in research (Tavakol & Dennick 2011)

As depicted in Figure 2, the states of Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo comprise the southwest area of Nigeria. The study region's population census count was projected to be 27,581,992 in the Nigerian government gazette of 2006, with a gender distribution of 51% male and 49% female. With an average density of 481 persons per square kilometres and an annual growth rate of 2.6%, Adelowokan et al. (2019) estimated that by 2018, the population would have reached 37,531,330, or 20% of Nigeria's total population. Some of the major urban Centre's in the region include Lagos, Ibadan, Abeokuta, Akure, Oshogbo, and Ado-Ekiti.

3. Results and Discussion

The regression study of predictors that influence smart city initiatives on the environmental sustainability of the built environments is shown in Table 1. It is shown that all the predictor variables of the smart cities are significant with p values ≤ 0.005. These include all the variables of smart people, smart mobility, smart living, smart government, smart environment, and economy. The findings of this study show that smart economy and smart mobility have a greater influence on achieving the sustainability of the environment. These included the smart economic factors such as Entrepreneurship and Innovation (B = 0.899, sig. = 0.001) Productivity, (B = 0.794, sig. = 0.001) Local and global interconnectivity (B = 0.713, sig. = 0.001). For smart mobility factors, which have mixed and modal access (B = 0.632, sig. = 0.001); Prioritized clean and non-motorized options (B = 0.604, sig. = 0.001); Integrated ICT (B = 0.656, sig. =

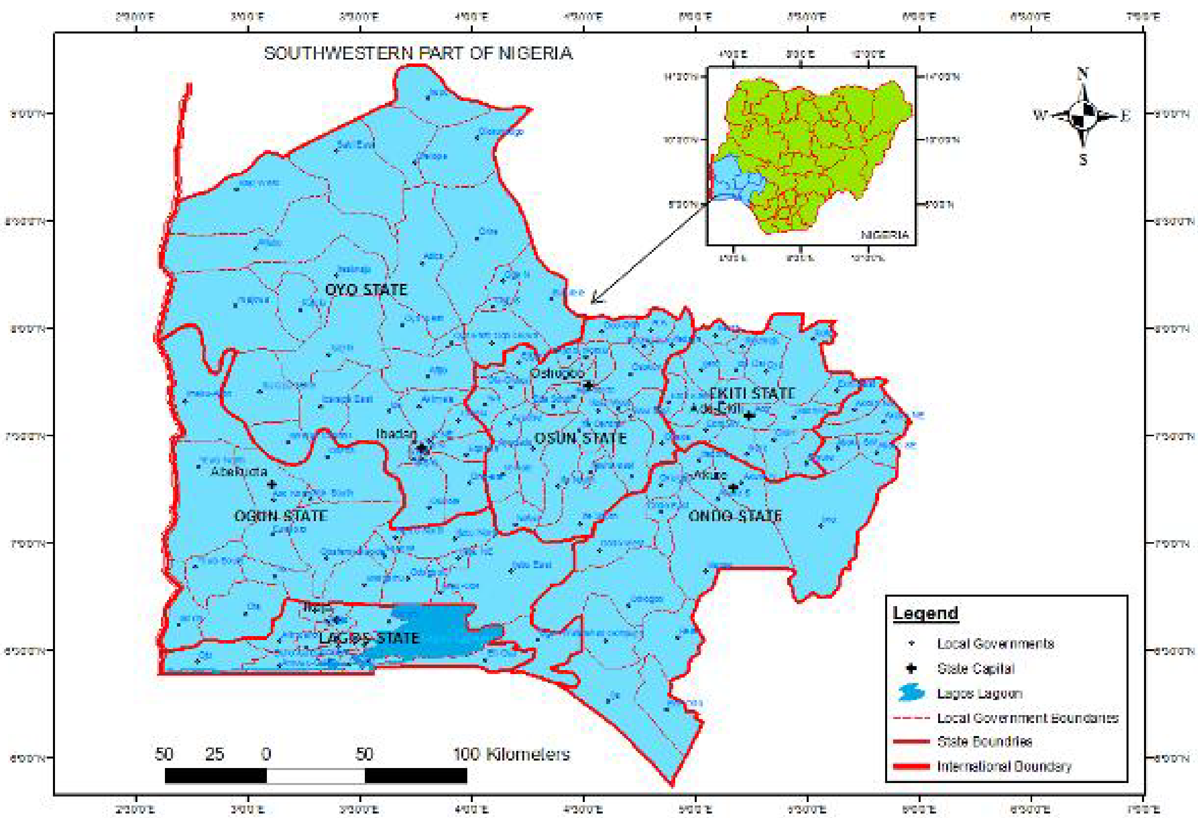

Figure 2. Geographic location of the study area (South West States, Nigeria)
Adapted from (Olumuyiwa and Saheed 2014)

0.001). This has shown that the smartness of the economy has the potential to increase environmental sustainability and resilience drives. This is in line with the previous study by Vesco (2015) in which it asserted that sustainable, socially inclusive, and smart cities may contribute to the balanced, equitable growth of the economy. This supports the growth of the economy and encourages entrepreneurship in both the formal and non-formal businesses of the environment. Smart mobility is equally ranked next. This is supported by the study of Porru et al., (2020) which stated that; to satisfy the requirements of future travelers and move the changes forward in a sustainable manner, it is up to all levels of decision-making to consider all the difficulties resulting from anticipated trends and to fully utilize the future opportunities of IoT technology in the smart cities. Following smart mobility is smart living. According to Porru et al., (2020) to enable residents to carry out their daily tasks, enhance the quality of their lives, and partake in entertainment and leisure activities, it is necessary to first comprehend the services that residents of smart living environments require before developing key technologies to meet those needs. To make sure that the interests of the people are effectively protected, it is essential to involve the people in government decision-making. When it involves smart people, the populace has to be prepared to engage in tasks that help in improving the city. Smart citizens, according to Giffinger *et al.,* (2007), should engage in civic activities, pursue higher education and creative expression, and be adaptable to everyday tasks. According to Giffinger *et al.,* (2007) achieving a smart environment requires paying careful attention to waste disposal and management, and sustainable energy use. It also involves the provision of social amenities that can meet the needs of the city. However, to preserve the natural environment, strategies, and policies must be put into place that are geared toward reducing carbon emissions from metropolitan areas.

Similarly, Table 2, indicates the model of the influencing factors of smart city initiatives in achieving environmental sustainability of the built environment; with $F(5, 286) = 368.570$, $p < 0.000$, and R2 value (0.648). The results of the analysis also indicate that about 73.5 % of the variance in smart city initiatives is explained by the regression model. Given these findings, the integration of smart technologies and practices into urban environments enables more efficient resource utilization, reduced emissions, enhanced environmental protection, and improved overall sustainability. Through these measures, smart cities and buildings play a crucial role in contributing to environmental sustainability and creating a healthier and more resilient future for urban communities as supported by Caragliu *et al.,* (2011); Neirotti et al., (2014) and Marsal-Llacuna et al., (2015).

The implementation of smart city initiatives facilitates the optimization of various urban systems, including transportation, energy, waste management, and water resources. Through the use of real-time data and IoT devices, smart cities can monitor and manage these systems more efficiently, resulting in reduced resource consumption and lower greenhouse gas emissions (Caragliu et al.,2011). One of the key areas where smart city programs contribute to environmental sustainability is transportation. By promoting the use of electric vehicles, implementing intelligent traffic management systems, and offering innovative mobility solutions, smart cities aim to reduce air pollution and traffic congestion (Bibri, 2018). These initiatives will not only assist residents in the South West region live better overall, but they will also lessen the negative effects of transportation on the environment. Energy efficiency is another vital aspect of smart city programs. By deploying smart grids, intelligent building systems, and energy management technologies, smart cities can optimize energy consumption and foster the integration of renewable energy sources (Albino et al., 2015). This results in lower energy consumption decreased reliance on fossil fuels, and a transition towards a more sustainable energy future. Furthermore, smart city programs promote waste management strategies that prioritize recycling, waste reduction, and smart waste collection systems (Albino et al., 2015). The integration of smart transportation, energy, waste management, and water systems enhance resource efficiency, reduces environmental impact, and fosters a more sustainable urban environment. As cities continue to grow and face increasing environmental challenges, embracing smart city programs becomes imperative for creating livable, resilient, and environmentally conscious urban spaces. Considering the synergy between the smart city variables and the conceptual framework for environmental sustainability, this study is in line with the assertion of Bibri et. al., (2023) that highlighted the potential of smart cities in promoting environmental sustainability.

While taking into cognizance the influence of smart buildings on the attainment of environmental sustainability (Table 3); the findings of this study revealed that optimizing the Heating, Ventilation, and Air Conditioning (HVAC) system as well as maximized Building and Environmental Security (BES); are the most influential factors with the values of ($B = 0.635$, sig. = 0.012) and ($B = 0.544$, sig. = 0.003) respectively. This result is corroborated by the study of Calautit and Chaudhry (2022). The findings from the study by Calautit and Chaudhry (2022) underscore the substantial contribution of smart buildings to environmental sustainability. As pointed out by Freire (2013) in Africa, buildings consume more than 50% of the energy supply, making it the leading consumer of energy compared to other sectors. By optimizing HVAC systems, maximizing building and environmental security, employing smart sensors for lighting, and enabling remote appliance control, smart buildings can significantly reduce energy consumption and environmental impact. These features, combined with the integration of autonomous control and surveillance systems, as suggested by Mahvi et al., (2012), empower smart buildings to maintain a cozy, efficient, and eco-friendly indoor environment. One of the most influential factors identified in the study is the optimization of the Heating, Ventilation, and Air Conditioning (HVAC) system. HVAC systems are known to be major contributors to a building's energy consumption, and optimizing them can lead to substantial energy savings. This, in turn, reduces the building's carbon footprint and helps promote environmental sustainability (Calautit and Chaudhry, 2022). By controlling the temperature, humidity, and air quality, smart HVAC systems efficiently manage energy use while ensuring the comfort and safety of occupants. HVAC controls the temperature, humidity, and quality of the air in a structure. Similarly, in support of the influencing factors of maximized Building and Environmental Security (BES); Mahvi et al., (2012) concurred that creating highly reliable structures with significant capacity for autonomous control and surveillance to optimize ambient smart settings could act as a strategy to balance the morality, well-being, and quality of life which is a vital goal for the twenty-first century. Maximizing Building and Environmental Security (BES) is another critical

Table 1. Regression of respondents' rating of the influence of smart cities' initiatives on achieving environmental sustainability of the Built Environment

Independent Variables /Predictor for Smart Cities	Standardized Coefficients		Degree of freedom *(df)*	Frequencies *(f)*	Sig. value *(p)*
	Beta coefficients	Estimate of Standard error			
1.0 Smart people (Speo)					
21st-century education	0.236	0.019	3	5.040	0.007*
Inclusive society	0.230	0.015	2	4.533	0.005*
Embrace creativity	0.247	0.019	2	4.437	0.002*
2.0 Smart mobility (Smob)					
Mixed–modal access	0.632	0.023	2	5.001	0.002*
Prioritized clean and non-motorized options	0.604	0.009	1	3.230	0.001*
Integrated ICT	0.656	0.016	1	5.207	0.001*
3.0 Smart living (Sliv)					
Safe	0.567	0.403	4	5.492	0.000*
Culturally vibrant and happy	0.514	0.060	3	6.954	0.001*
Healthy	0.598	0.411	3	4.254	0.001*
4.0 Smart Government (Sgvt)					
ICT & e-Government	0.320	0.025	3	3.743	0.002*
Transparency and open data	0.336	0.019	3	5.040	0.001*
Enabling Supply and demand policy	0.327	0.015	2	3.177	0.002*
5.0 Smart environment (Senv)					
Green building	0.103	0.016	2	4.039	0.001*
Green energy	0.128	0.015	2	3.279	0.004*
Green urban planning	0.120	0.025	3	3.743	0.002*
6.0 Smart economy (Secon)					
Entrepreneurship and Innovation	0.899	0.025	5	5.869	0.001*
Productivity	0.794	0.015	1	6.743	0.001*
Local and global interconnectivity	0.713	0.019	2	1.899	0.001*

*Significant predictors ($p \leq 0.05$)

Table 2. Model Summary b Model for the respondents' rating of the influence of smart cities' initiatives on achieving Environmental sustainability of the Built Environment

Model	R.	R. Square	Adjusted R. Square	Std. error in the Estimates	Change Statistics				
					R. Square Change	F Change	df1	df2	Sig. F Change
1	.853	.648	.735	.45233	.761	368.570	5	286	.000

[a]Predictors: (constant); Smart people (Speo); Smart Mobility (Smob); Smart living (Sliv); Smart Government (Sgvt); Smart environment (Senv); Smart economy (Secon); [b]Dependent Variable: Environmental Sustainability of the Built Environment

factor highlighted in the study. Smart buildings equipped with advanced security measures not only protect occupants and assets but also contribute to overall sustainability. Enhanced security measures help prevent incidents that may result in wastage of resources or environmental damage, making smart buildings more efficient and resilient in the face of potential threats Calautit and Chaudhry (2022).

Ranked next are smart sensors for lighting (B = 0.367, sig. = 0.001). The importance of this factor is supported by Jeyasheeli et al., (2017). It was stated in the study that IOT in green buildings is crucial, and that energy efficiency in green buildings is viable for ensuring the sustainability of our planet. It was proposed that using LEDs to control environmental parameters like sunlight and temperature will adjust the power supply policy and boost energy efficiency. The factor-controlled appliances from remote locations (B = 0.314, sig.= 0.001) ranked next. In this vein; (Santo et al., 2015) supported the assertion that a smart home may handle some grid equipment and have remote control over its household appliances. This lessens the negative effects of strong environmental stimuli.

A look at Table 4, indicates the model of the influencing factors of smart building on achieving environmental sustainability of the built environment; with $F(5, 286) = 252.570$, $p< 0.000$, and R2 value (0.582). The results of the analysis also indicate that about 56.1% of the variance in smart city initiatives is explained by the regression model. The integration of smart sensors for lighting has proven to be instrumental in achieving energy efficiency and environmental sustainability. According to Jeyasheeli et al., (2017), smart sensors in green buildings enable precise control of lighting systems, optimizing energy consumption by adjusting parameters like sunlight and temperature. This not only reduces energy waste but also supports the sustainable use of resources, making smart buildings a significant contribution to environmental preservation. Another factor that plays a vital role in the quest for environmental sustainability is the ability to control appliances from remote locations within smart homes. As suggested by Santo et al., (2015), remote control over household appliances allows for better energy management and reduces the negative impact of environmental stimuli. By empowering occupants to remotely control their appliances and devices, smart buildings enable responsible energy usage and contribute to a more sustainable environment.

Lastly, in Table 5, the model of the influence of resilience on achieving Environmental sustainability of the Built Environment is presented; with F (5, 286) = 367.650, p< 0.000, and R2 value (0.688). The results of the analysis also indicate that about 75.5 % of the variance in resilience is explained by the regression model. This result implies that resilience involves considering a broad range of factors that can impact a city's ability to respond to challenges. These include green infrastructure, adoption of sustainable building practices, renewable energy adoption, climate adaptation strategies, eco-friendly mobility, and community engagement and participation. This requires incorporating multiple perspectives and engaging a diverse range of stakeholders in smart city development. By considering the needs and priorities of different communities and groups, smart cities can build a more inclusive and resilient urban environment supported by studies by Pickett et al., (2014) and Berkes & Ross, (2013).

Based on the result from the regression study of predictors that influence smart city initiatives on the environmental sustainability of the built environment in Tables 1 and 2 it revealed a strong affinity between all the variables components of a smart city and it derives towards a better city performance and environmental sustainability. The variables of a smart city embrace the tenant of city resilience as demonstrated in the reviewed literature. Urban resilient is defined as the capacity to withstand and overcome the consequences of any threat or hazard through a strong natural or Manmade mechanism of resistance or adaptation during stress and gradual recovery back to its original condition (Twigg, 2007) The mechanism of resilient for cities may be in the form of it natural components as defined in its greenery. Furthermore, resilient urban planning can contribute to the preservation of natural ecosystems and biodiversity. By considering the natural landscape and ecological processes in city planning, resilient cities can protect green spaces, wetlands, and natural habitats. This not only supports biodiversity, but also provides essential ecosystem services, such as flood mitigation, air purification, and temperature regulation (Reckien et al., 2018). Preserving natural areas within urban environments enhances environmental sustainability and improves the overall quality of life for residents. Manmade effort is defined in human technology considered to be the second aspect of the resilient mechanism. Human technology is revealed by the ability to adopt resilient design principles in smart cities

Table 3. Regression of respondents' rating of the influence of smart buildings on achieving environmental sustainability

Independent Variables /Predictor	**Standardized Coefficients**		**Degree of freedom (*df*)**	**Frequencies (*f*)**	**Sig. value (*p*)**
	Beta coefficients	Estimate of Standard error			
Smart Building					
Optimized heating, ventilation, and air conditioning (HVAC) Systems	0.635	0.018	2	2.230	0.012*
Maximized Building and Environmental Security (BES)	0.599	0.025	5	1.899	0.001*
Smart Sensors For Lighting (SSL)	0.367	0.203	6	2.492	0.001*
Controlled Appliances From Remote Locations (CARL)	0.314	0.030	4	2.954	0.001*
Communication via voice, video, and data (CVVD)	0.303	0.005	3	2.039	0.002*
Security and access for doors, windows (S & A)	0.128	0.005	3	2.279	0.006*
Fire (detectors services, routine checks, etc.	0.022	0.066	3	1.899	0.009*

*Significant predictors ($p \leq 0.05$)

Table 4. Model Summary[b] Model for the respondents' rating of the influence of smart building on achieving environmental sustainability of the Built Environment

Model	**R.**	**R. Square**	**Adjusted R. Square**	**Std. Error of the Estimates**	**Change Statistics**				
					R. Square Change	F Change	df1	df2	Sig.F Change
2	.623	.582	.561	.37162	.581	252.570	5	286	.000

[a]Predictors: (constant); Optimized heating, ventilation, and air conditioning (HVAC); Maximized Building and Environmental Security (BES); Smart Sensors For Lighting (SSL); Controlled Appliances From Remote Locations (CARL); Communication via voice, video, and data (CVVD); Security and access for doors, windows (S&A); [b.]Dependent Variable: Environmental sustainability of the Built Environment

Table 5. Model Summary[b] Model for the respondents' rating of the influence of resilience on achieving Environmental sustainability of the Built Environment

Model	R.	R. Square	Adjusted R. Square	Std. error in the Estimates	Change Statistics				
					R. Square Change	F Change	df1	df2	Sig. F Change
1	.768	.688	.755	.46173	.752	367.650	5	286	.000

[a]Predictors: (constant); Green Infrastructure; Adoption of Sustainable Building Practices; Renewable Energy Adoption; Climate Adaptation Strategies; Eco-friendly Mobility; Community Engagement and Participation; [b]Dependent Variable: Environmental Sustainability of the Built Environment

that can mitigate risks using built infrastructure that is more resistant to shock and stresses (Pickett et al., 2014). The smart city initiatives rely on advanced technology and accessible data to improve efficiency, sustainability, and city resilience.

According to Mboup & Oyelaran-Oyeyinka (2019), African cities are commonly vulnerable to disasters. Therefore, it is imperative that the resilience of all countries to disaster be translated into tangible actions at all levels. The geographical location of major cities in the southwest, Nigeria like Lagos, Ibadan, Abeokuta, Akure, Oshogbo, and Ado-Ekiti falls along the low-lying coastal areas prone to excessive flooding. This single reason and others largely affirmed the threat and need to embrace the initiative of smart cities as a major drive to environmental sustainability and resilience for the region. Resilience has emerged as a critical concept in the context of achieving environmental sustainability in the built environment.

4. Conclusion

This study adds to the body of knowledge on the dynamic relationship between smart cities and environmental sustainability in the context of urbanization in South-West, Nigeria. Leveraging information and communication technology, smart cities are an emerging urban paradigm that seeks to foster sustainable growth by efficient resource management while enhancing livability and functionality. In this quantitative research, we examine the key factors that contribute to the development of smart environments and their impacts on achieving environmental sustainability. The research identifies crucial factors that significantly influence the attainment of environmental sustainability in both smart cities and smart buildings. Among the factors, the study highlights the pivotal roles played by the smart economy, smart mobility, and smart environment in driving environmental sustainability within smart cities. Additionally, the optimized Heating, Ventilation, and Air Conditioning (HVAC) systems and maximized Building Energy Systems (BES) emerge as influential factors in facilitating sustainable practices within smart buildings. The novelty of the study encompasses the following:

- ✓ Exploring Dynamic Relationship: The study focuses on investigating the dynamic relationship between two significant concepts: smart cities and environmental sustainability. While both concepts have been studied individually, this study, delve into their interplay and how they impact each other within the specific context of South-West, Nigeria.
- ✓ The study's novelty lies in its contextual specificity. The study focused on the south west region, Nigeria and is distinct. It can present unique challenges and opportunities for implementing smart city initiatives across other regions in Nigeria. By focusing on this region, the study acknowledges the importance of tailoring smart city strategies to the local context, which can differ from global trends.
- ✓ Emerging Urban Paradigm: The study positions, smart cities as an emerging urban paradigm. This suggests that while the concept of smart cities is gaining traction globally, its implications and implementations are still evolving. The study's focus on this emerging paradigm adds novelty by contributing to discussions on the evolving nature of urban development strategies. The study stems from its contextual specificity of urbanization in South-West, Nigeria, its exploration of the dynamic relationship between smart cities and environmental sustainability, its integration of information and communication technology, its consideration of smart cities as an emerging paradigm, and its emphasis on dual objectives of sustainable growth and improved livability.
- ✓ Dual Goals: Sustainable Growth and Livability: The novelty also arises from the dual goals attributed to smart cities-efficient resource management for sustainable growth and enhancing livability and functionality. By emphasizing these two interconnected objectives, the study brings attention to the multifaceted nature of smart city initiatives, which go beyond just environmental concerns. This study establishes strong connections between smarter cities, smart buildings, and Environmental Sustainability. Additionally, smart city innovation strategies offer solutions to pressing environmental challenges in developing nations and contribute significantly to meeting the UN Sustainable Development Goals. The United Nations created an updated set of goals in the pursuit of global sustainable development in the 2030 Agenda. Among these instances, SDG #11 aims to make cities inclusive, safe, resilient, and sustainable environments in which individuals may live properly, generating prosperity and social well-being while minimizing environmental impact. However, fully embracing the advantages of smart city innovation strategies in South West region, Nigeria and other developing nations requires addressing challenges related to infrastructure, funding, and human capacity.

Recognizing the significance of these findings, we believe our research can serve as a guiding framework for policymakers and planners striving to implement sustainable practices within the urban landscape of Nigeria. Furthermore, the implications of this study extend beyond Nigeria, making it relevant on a global scale. As smart cities continue to emerge worldwide, the comparative analyses of factors contributing to environmental sustainability in multiple regions or countries can offer a broader understanding of this growing field. By shedding light on the connection between smart cities and environmental sustainability, our research sets the stage for future studies that can explore and adapt these principles across different socio-cultural contexts, ultimately contributing to a more comprehensive understanding of smart urbanization practices.

Several possible avenues for further investigation have been identified in light of the study's findings. Firstly, we recommend that future research explore comparative analyses across multiple regions or countries, which would provide a more comprehensive understanding of the factors influencing environmental sustainability in smart cities globally. This would extend the impact of the study and help inform the development of sustainable urban environments on a broader scale. Secondly, further investigation is needed to explore the potential for smart buildings to contribute to environmental sustainability beyond the optimization of HVAC systems and building security. For example, future studies could investigate the role of smart lighting systems, renewable energy technologies, and advanced waste management systems in reducing the environmental impact of buildings. Lastly, it might be beneficial to investigate the possible trade-offs and unforeseen effects of construction growth and smart cities. For instance, rapid implementation of automation and new technology may result in loss of employment and other economic issues. It will be essential to comprehend these trade-offs and how they affect various stakeholders if the smart city and construction development is to be inclusive and sustainable.

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