Barriers and Limitations of Implementing Smart City Initiatives for Environmental Sustainability in Developing Countries: A Case Study of Nigeria

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Abstract

In recent years, the concept of smart cities has gained prominence around the world. Smart cities are urban areas that leverage technology and data to improve the quality of life for citizens, enhance efficiency, and promote sustainable development. Nigeria, as a rapidly urbanizing country, faces numerous environmental challenges, including air and water pollution, inadequate waste management, and deforestation. Environmental sustainability policies are of great significance in the context of smart cities. Nigeria has recognized the need to develop smart cities to address urbanization challenges and promote sustainable development. Smart city initiatives, such as renewable energy integration, smart grids and energy management systems, intelligent transportation systems, smart waste management and the rest, can drive economic growth, improve quality of life, and enhance resilience to climate change. While Nigerian cities are making efforts to address environmental sustainability using smart city policies and strategies, there are still several challenges in the implementation. Existing literature on smart cities and environmental sustainability in Nigeria primarily focuses on the potential of adopting smart technologies to enhance environmental conservation, resource management, and sustainable development. This study uses existing related literature and case studies to explore the barriers and limitations of implementing smart city initiatives for environmental sustainability in developing countries, specifically focusing on Nigeria. The study investigates the challenges faced in terms of technology infrastructure, policy frameworks, funding, and citizen participation. It also examines the potential strategies and solutions for overcoming these barriers and maximizing the benefits of smart city projects in achieving environmental sustainability in developing countries.

Keywords: *Smart city, Smart city initiatives, Environmental challenges, Environmental sustainability, Environmental sustainability policies.*

Introduction

As urbanization continues to accelerate, the concept of smart cities has emerged as a potential solution for addressing environmental challenges. Smart cities are characterized by the use of technology and data to improve infrastructure and services, leading to increased efficiency and sustainability (Caragliu, et al., 2011). Environmental sustainability is a key focus of smart cities, as they aim to reduce resource consumption, minimize pollution, and mitigate climate change impacts (Hollands, 2008). In developing countries such as Nigeria, rapid urbanization has led to significant environmental challenges, including air and water pollution, inadequate waste management, and deforestation (Umar, 2021). The current state of urbanization in Nigeria is characterized by increasing population growth and unplanned development, exacerbating these challenges (Jenkins, 2013). As a result, there is a pressing need to address these issues through sustainable urban development strategies. Environmental sustainability policies are of great significance in the context of smart cities in Nigeria. These policies can help mitigate environmental degradation and promote the efficient use of resources (Oyebode, 2018). By implementing smart city initiatives, such as renewable energy integration, intelligent transportation systems, and smart waste management, Nigeria can work towards achieving its environmental sustainability goals (Adelaja, 2020). Moreover, these policies can drive economic growth, improve quality of life, and enhance resilience to climate change (Hollands, 2008).

Smart City (Definition and Importance)

Smart cities are urban areas that leverage technology and data to enhance the quality of life, sustainability, and efficiency of their residents. They have the potential to address environmental challenges by integrating smart technologies and innovations to create more sustainable and resilient cities. According to Bibri and Krogstie (2017),

smart cities combine information and communication technologies (ICT) with urban infrastructure and services to promote sustainable development.

Smart city technologies and innovations can contribute to sustainability goals in various ways. Firstly, they can enhance energy efficiency. For example, smart grids and energy management systems enable better monitoring and control of energy consumption (Cominola, et al., 2015). Additionally, smart buildings equipped with sensors and automation technologies can optimize energy usage (Mariano-Hernández, et al., 2020).

Secondly, smart city technologies can improve waste management. Smart waste management systems utilize sensors and real-time data to optimize waste collection routes, resulting in reduced fuel consumption and decreased traffic congestion (Zhang, et al., 2019). The experiences and insights gained from successful smart city initiatives such as those in Singapore, Barcelona, London, San Francisco, and Oslo can serve as valuable guidance for other cities that are making significant long-term investments in smart cities and the advancement of waste management practices (Esmaeilian, et al., 2018). For instance, the city of Barcelona implemented a smart waste management system that reduced the number of waste collection trucks by a significant percentage and achieved savings in fuel and emissions. Their smart street lighting system can also serve as a relevant example, as it reduced energy consumption by 30% (Bibri & Krogstie, 2017) and (Mila, 2018).

Furthermore, smart city initiatives contribute to transportation optimization. Intelligent transportation systems and smart mobility solutions help reduce traffic congestion, promote public transportation, and encourage the use of electric vehicles (Hernández Gracia & Corichi García, 2018). Singapore's smart transportation initiatives, such as their Electronic Road Pricing system, have effectively managed traffic congestion and reduced carbon emissions (Haque, et al., 2013). Additionally, smart city technologies aid in resource conservation. For instance, water management systems that leverage sensors and data analytics can identify leaks, reduce water waste, and enable efficient water usage (Singh & Ahmed, 2021). The city of Melbourne in Australia implemented a smart water system that reduced water consumption by 25% (City of Malbourne, 2017).

Environmental Policies in Nigeria

In Nigeria, the basis of environmental policy is outlined in the 1999 Constitution. Section 20 of the Constitution grants the State the power to protect and improve the environment, safeguard water, air, land, forests, and wildlife. The Environmental Impact Assessment Act of 1992 also stipulates that projects or activities cannot be undertaken without considering their environmental impact (Oruonye & Ahmed, 2020). To enforce these policies, the Federal Government of Nigeria has established laws and regulations. The Federal Environmental Protection Agency Act of 1988, which has been replaced by the National Environmental Standards Regulation Agency (NESREA) Act of 2007, plays a crucial role. NESREA is responsible for protecting and developing the environment, conserving biodiversity, and promoting sustainable development. It coordinates with stakeholders both within and outside Nigeria to enforce environmental standards. Additionally, other regulatory agencies have issued guidelines to regulate specific industries' impact on the environment. For example, the Department of Petroleum Resources (DPR) has published the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) in 2002. The NESREA Act allows each State and Local Government to establish their own agencies for environmental protection and improvement. Each state can also create laws to protect the environment within its jurisdiction. At the state level, many states including Lagos, Akwa Ibom, and Abuja, have their own environmental agencies and laws. Abuja, the Federal Capital Territory, has specific regulations known as the Abuja Environmental Protection Board Regulations, which primarily govern solid waste control, environmental monitoring, planning, and pollution control. While Lagos has implemented the Lagos Development and Urban Renewal Policies, which focus on sustainable urban planning, waste management, and public transportation (John-Adegbesan, & Nwaorgu, 2021).

While Nigerian cities have made efforts in terms of policies to address environmental challenges, there are still several issues in their implementation. One of the strengths of these policies is the recognition of the importance of sustainable development and the integration of environmental considerations into urban planning. For example, the Lagos Development and Urban Renewal Policies promote sustainable urban development and consider environmental impacts in land use planning. However, weaknesses persist. One major challenge is the lack of enforcement of existing environmental regulations, which leads to non-compliance and inadequate environmental protection (Osuyi, 2012) and (Oladoji & Ogunmakinde, 2021). Additionally, inadequate funding and technical

capacity hinder the effective implementation of sustainability policies. These limitations can undermine the potential benefits of these policies and hinder progress towards environmental sustainability.

Existing Literature

Existing literature on smart cities and environmental sustainability in Nigeria primarily focuses on the potential of adopting smart technologies to enhance environmental conservation, resource management, and sustainable development. The historical and chronological evidence of smart city research in Nigeria is demonstrated by the launch of the Nigeria Smart City Initiative (NSCI) on 8th August 2017 in Abuja, Nigeria (Kabir, 2019 as cited in Nkwunonwo, et al., 2022). Some key studies in this area include that of Akujobi, et al. (2017) titled "Smart city in urban development", the author discusses the issue of urban decay in the context of increasing urban growth globally and the challenges it poses which include environmental and social risks specifically in developing countries. The study used the library research method and explores the potential role of smart city initiatives in achieving sustainable urban development in Nigeria. The author believes that guiding policymakers in integrating smart city initiatives into sustainable urban development policies in Nigeria will go a long way in solving the problems of urban decay. Table 1 below is a summary of the relevant literature that provided information and basis for discussion in the current research, the table is adopted and updated from Nkwunonwo, et al.

Table 1. Summary of the relevant literature that provided information and basis for discussion in the current trend of smart city research (adopted and updated from Nkwunonwo, et al., 2022).

S/No.	Author(s)	Study	Context
1.	Dada (2014)	Towards understanding the benefits and challenges of Smart/Micro-Grid for electricity supply system in Nigeria	Smart city for electricity supply system in Nigeria
2.	Jiriko, et al. (2015)	The evolution of Abuja as a 'Smart City's prognosis	Abuja and the context of a smart city
3.	Ajibade (2017)	Can a future city enhance urban resilience and sustainability? A political ecology analysis of Eko Atlantic City, Nigeria	Prospects of a smart city in Lagos, Nigeria
4.	Akujobi, et al. (2017)	Role of a smart city in sustainable urban development in Nigeria	Prospects of smart city for sustainable urban development in Nigeria
5.	Adamu, et al. (2017)	Smart cities: the foundation for future citizen service delivery in Nigeria	Smart city and citizen's welfare in Nigeria
6.	Adejuwon (2018)	Internet of Things and Smart City Development:	Nigeria's readiness for a smart city based on emerging technology
7.	Monyei, et al. (2018)	Nigeria's energy poverty: Insights and implications for smart policies and framework towards a smart Nigeria electricity network	Smart city and electricity in Nigeria
8.	Kabir (2019)	Nigeria smart city initiatives (NSCI): The geospatial perspectives	Smart city and geospatial tool
9.	Kadiri, et al. (2019)	Smart Cities Implementation: Challenges in Nigeria	Challenges of smart city development in Nigeria with focus on policy modification.
10.	Nwakanma, et al. (2019)	Model-Driven Decision Support System for Broadband Penetration in Nigeria: Smart City Challenge	IoT challenges to building a smart city in Nigeria
11.	Okehielem, et al. (2019)	Evolution of a Smart City from the Challenge of Flood Disaster: Case Study of New Owerri Capital City,	Pathway, and strategies of setting up a smart city in Owerri, Imo state

		Southeast of Nigeria	
12.	Olarinmoye, et al. (2020)	Microplastic Presence in Sediment and Water of a Lagoon Bordering the Urban Agglomeration of Lagos, Southwest Nigeria	Current urban agglomeration in Nigeria Lagos
13.	Aghimien, et al. (2020)	A fuzzy synthetic evaluation of the challenges of smart city development in developing Countries	Challenges of smart city development (not implementation) in developing countries
14.	Zubairu (2020)	Assessment of the implementation of the national urban policy, 2012 and formulation of sub-national urban policy and smart city strategy by Niger State government, Nigeria	Pathway, and strategies of setting up a smart city in Niger state Nigeria
15.	Dukiya (2020)	Climate change and smart city development: The challenge of non-implementation of Abuja, Nigeria light rail project	Climate change and smart city: pathway for Abuja
16.	Dano, et al. (2020)	Transformative urban governance: Confronting urbanisation challenges with geospatial technologies in Lagos, Nigeria	Urbanisation challenges and geospatial technology in Lagos, Nigeria
17.	Agboola, et al. (2022)	The Role of Smart Environment Initiatives on Environmental Degradation: Consolidating the Resilient Built Landscape	Resilience in Lagos State and other Nigeria's smart cities projects
18.	Nkwunonwo, et al., 2022)	A review of the pathways, opportunities, challenges and utility of geospatial infrastructure for smart city in Nigeria.	Urbanisation challenges, geospatial technology, and use of radical policies and more research to support smart city realization.
19.	Okafor, et al., (2022)	Environmental knowledge and policy sustainability: A study of pro environmental policy support among the southeast Nigerian rural communities.	Environmental knowledge and policy understanding among rural populations to achieve sustainability.
20.	Haladu, and Bin-Nashwan (2022)	The moderating effect of environmental agencies on firms' sustainability reporting in Nigeria.	Contribution of environmental agencies and cooperate attributes on sustainability.
21.	Akinwamide, et al. (2022)	Barriers to the Adoption of Smart Housing Concept in African Smart City Projects: Case of Akwa Millennium City.	Challenges of adopting Social Smart Housing in African Smart Cities (Akwa Millennium City)
22.	Onomhoale, & Elishama (2023)	Exploring the Sectoral Development and Sustainability Potentials of Renewable Energy Resources in Nigeria	Renewable energy resources and environmental sustainability.
23.	Anagah (2023)	Review of Green Technologies Use by Farmers: Implications for Environmental Sustainability in Nigeria	Green Technologies, Agriculture and environmental Sustainability

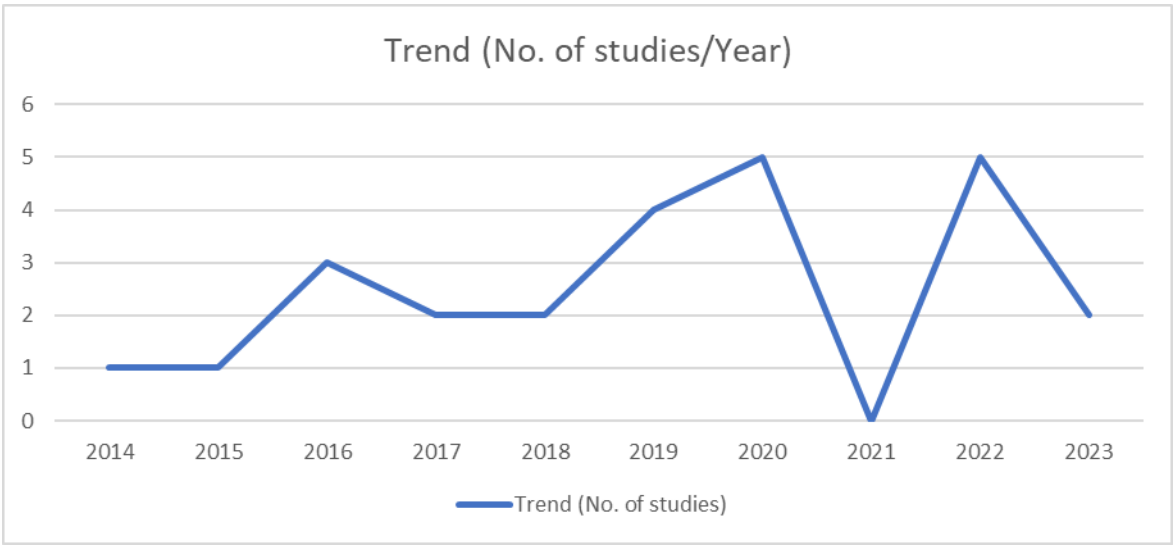

Fig. 1: Number of studies on smart city in Nigeria with time.

Considering the data above, it is still evident that there is very little research on smart cities in Nigeria, which indicate the poor level of knowledge of smart cities and their implementation in the country as declared by Nkwunonwo, et al. (2022).

This study uses library approach to explore the barriers and limitations of implementing smart city initiatives for environmental sustainability in developing countries, specifically focusing on Nigeria. Using case studies and related literature, the study investigates the challenges faced in terms of technology infrastructure, policy frameworks, funding, and citizen participation. It also examines the potential strategies and solutions for overcoming these barriers and maximizing the benefits of smart city projects in achieving environmental sustainability in developing countries.

Methodology

This study employed library and case study methods particularly to explore the barriers and limitations of implementing smart city initiatives for environmental sustainability in developing countries, specifically focusing on Nigeria. The study investigates the challenges faced in terms of technology infrastructure, policy frameworks, funding, and citizen participation. It also examines the potential strategies and solutions for overcoming these barriers and maximizing the benefits of smart city projects in achieving environmental sustainability in developing countries.

Library Method

This method of data collection involves gathering data from various sources such as books, academic journals, articles, and research papers available in libraries. This method is advantageous as it allows researchers to access a wide range of information compiled by experts in different fields. For example, a research study conducted by Nkwunonwo, et al. (2022) used the library method to collect data from various academic journals and books to review pathways, opportunities, challenges and utility of geospatial infrastructure for smart city in Nigeria. The library method offers a comprehensive and reliable approach to collecting data from credible sources in an efficient manner.

Barriers and limitations of Implementing Smart City Initiatives for Environmental Sustainability in Nigeria;

a) Technology Infrastructure

Technology infrastructural barriers and limitations of implementing smart city initiatives include Inadequate Telecommunications Infrastructure, Insufficient Power Supply, challenges regarding Data Management and Security, and limited Internet of Things (IoT) Infrastructure.

Inadequate Telecommunications Infrastructure:

Reliable connectivity is crucial for the successful implementation of smart cities. However, Nigeria faces significant challenges in this regard. Limited broadband access and network congestion hamper the real-time transmission of data between devices and systems. Nigeria's telecommunications infrastructure is still underdeveloped, with limited broadband coverage and unreliable network connectivity in many areas. According to the Nigerian Communications Commission (NCC), the country's broadband penetration rate stood at 44.5% as of February 2022, even though there is a hope of rising it to a target of 70% by 2025 (NCC, 2022). This can affect critical functions of smart cities, including traffic management, public safety, and energy management.

Insufficient Power Supply:

A major limitation to technology infrastructure in Nigeria is the unreliable power supply. Frequent power outages and inconsistent electricity access pose significant challenges to the deployment and functioning of smart city technologies, such as sensors, smart grids, and IoT devices, which rely on a stable power source.

Data Management and Security:

Smart cities generate vast amounts of data from various sources, including sensors, cameras, and citizens' devices. However, Nigeria faces challenges in terms of data management and security infrastructure. Inadequate data storage and management systems hinder efficient processing, analysis, and utilization of data for smart city applications. Additionally, concerns over data privacy and cybersecurity pose barriers to the adoption of smart city technologies.

Internet of Things (IoT) Infrastructure:

IoT devices form the backbone of smart city ecosystems, enabling the collection, transmission, and analysis of real-time data for informed decision-making. However, Nigeria's IoT infrastructure is limited, with a lack of widespread deployment and connectivity of IoT devices. The absence of a comprehensive IoT ecosystem impedes the seamless integration of various smart city components and services.

b) Policy Frameworks;

Current Policy Frameworks and Regulatory Environment in Nigeria Regarding Smart City Initiatives.

Nigeria has recognized the potential of smart city initiatives in enhancing urban development, improving quality of life, and promoting sustainable growth. While there is no specific national policy framework exclusively dedicated to smart cities, various policies and initiatives contribute to the development of smart cities in Nigeria. One key policy that supports smart city development is the National Broadband Plan (NBP) 2020-2025. The NBP aims to increase broadband penetration across the country, which is essential for the implementation of smart city technologies and services.

Additionally, the Nigerian Communications Commission (NCC), as the regulatory authority for the telecommunications sector, provides guidelines and regulations for the deployment of telecommunications infrastructure, which is a critical component of smart cities. Furthermore, the Federal Ministry of Communications and Digital Economy is actively involved in promoting digital transformation and has initiatives in place to support smart city development. For example, the ministry has established the Smart City Initiative (SCI) to encourage the adoption of smart technologies and solutions in Nigerian cities.

At the state level, some states in Nigeria have taken steps towards smart city development. For instance, Lagos State, the commercial hub of Nigeria, has launched the Lagos Smart City Initiative (LSCI) to transform Lagos into a smart city. The LSCI focuses on areas such as transportation, e-governance, and public safety.

According to the data, lack of a comprehensive national policy framework dedicated to smart cities is hindering the implementation of environmental sustainable goals. While there are various policies and initiatives in place, the absence of a specific framework limits coordination and integration of sustainable practices across different cities and states. This leads to inconsistencies and fragmentation in the implementation of environmental sustainable goals. Without clear policies and regulations, there is a lack of standardized practices and benchmarks for measuring and evaluating environmental performance in smart city initiatives. This hinders effective monitoring and tracking of progress towards sustainability targets.

To address this gap, Nigeria needs to develop a national policy framework that provides specific strategies, targets, and guidelines for integrating environmental sustainability into smart city initiatives. This framework should cover areas such as energy efficiency, renewable energy, waste management, green infrastructure, and sustainable transportation. However, developing a comprehensive policy framework for smart cities presents several challenges. Interdisciplinary collaboration among stakeholders from different sectors is necessary but difficult to achieve due to differences in priorities and decision-making processes.

Rapid technological advancements also pose a challenge; as smart city technologies are constantly evolving. Policymakers need to ensure that policies remain adaptable and flexible to accommodate emerging technologies and changing needs.

Data privacy and security is another major concern in smart city initiatives, as large amounts of data are collected and analyzed. Policymakers need to establish regulations and mechanisms to protect data privacy and ensure the secure handling of sensitive information.

Securing funding and resource allocation is also challenging, especially for developing countries with limited financial resources. Policymakers need to explore innovative financing mechanisms and public-private partnerships to support the implementation of smart city policies.

Legal and regulatory barriers need to be addressed to enable the adoption and implementation of smart city technologies and services. Policymakers should revise or create new laws and regulations to facilitate innovation and ensure compliance with ethical and legal standards.

Lastly, stakeholder engagement and public participation are important for inclusivity and effectiveness. Policymakers need to employ transparent and participatory approaches to gather input and build consensus among citizens, businesses, and community organizations.

c) Funding;

Financial Challenges and Limitations Faced in Funding Smart City Projects in Nigeria

Finding financial resources for smart city projects in Nigeria can be challenging due to several limitations. Some of the financial challenges faced include Limited Government Funding, Lack of private sector investment, Inadequate access to capital markets, Unclear revenue models and Dependency on external funding. According to the World Bank (2021), the Nigerian government face constraints in allocating sufficient funds to finance smart city projects. Budgetary limitations and competing priorities in sectors such as healthcare, education, and infrastructure development can restrict the amount of funding available for smart city initiatives. Attracting private sector investment for smart city projects can be challenging, especially in areas where the business case or return on investment is not immediately evident. The private sector is usually hesitant to invest in long-term projects with uncertain financial returns or in areas with inadequate infrastructure and regulatory frameworks (International Finance Corporation, 2020).

Furthermore, Nigeria's capital markets have limited capacity to provide long-term financing for large-scale smart city projects. Accessing capital markets for project financing can be challenging due to factors such as lack of financial instruments, inadequate credit ratings, and low investor confidence (African Development Bank, 2019).

Implementing smart city projects often requires sustainable revenue models to cover operational and maintenance costs. However, developing clear revenue models can be challenging, particularly in the early stages of smart city development. Identifying viable revenue streams and ensuring their sustainability can be complex, especially in contexts where there are disparities in income levels and affordability (United Nations Economic Commission for Africa, 2018).

Nigeria may rely on external sources of funding, such as development aid and international partnerships, to finance smart city projects. However, securing external funding can be competitive and uncertain, and it may come with specific conditions or limitations on project scope and implementation (Organisation for Economic Co-operation and Development, 2021).

Lack of Investment and Funding Options Specific to Environmental Sustainability Initiatives

The lack of investment and funding for environmental sustainability initiatives poses a significant challenge in achieving sustainable development goals, particularly in smart cities. Several factors contribute to this issue, including the prioritization of short-term financial gains, limited awareness and understanding, uncertain regulatory and policy frameworks, limited financial instruments and mechanisms, and the perception of high costs.

In many cases, investment decisions are driven by immediate financial returns rather than long-term sustainability. This can deter investors seeking quick profits from investing in environmental sustainability initiatives that require upfront investments with longer payback periods. The focus on short-term gains can overshadow the potential economic, social, and environmental benefits of sustainable projects.

The lack of awareness and understanding of the value and potential returns on investment in environmental sustainability initiatives can hinder financial support. Investors may not fully comprehend the long-term benefits, cost savings, and positive impacts associated with sustainable practices. Insufficient knowledge about green technologies, renewable energy, and resource-efficient solutions can result in a perception that these initiatives are high-risk or unfamiliar.

Inconsistent or inadequate regulatory and policy frameworks create uncertainty for investors, making it difficult to assess risks and returns. A lack of clear guidelines, targets, and incentives related to environmental sustainability can deter private investors who may be uncertain about future regulations and market conditions. Well-defined and stable policies that promote and incentivize sustainable practices can attract investment.

The availability of financial instruments tailored to environmental sustainability projects is often limited. Investors may struggle to find appropriate financing options that align with the unique characteristics of these initiatives. Financial institutions and markets need to develop specialized products, such as green bonds, impact investment funds, and venture capital specifically targeting environmental sustainability, to attract and mobilize funding.

Environmental sustainability initiatives are sometimes perceived as costly, particularly in developing countries where resources may be constrained. This perception can create barriers to investment, even though sustainable practices can lead to long-term cost savings, resource efficiency, and resilience. Raising awareness about the potential economic benefits and demonstrating successful case studies can help overcome the perception of high costs.

To address the lack of investment and funding, several actions can be taken. Governments need to establish clear and stable policies, regulations, and incentives that encourage investment in environmental sustainability. Financial incentives such as tax credits, subsidies, grants, and preferential loan rates can offset the risks and costs associated with sustainable projects. Collaboration between public and private sectors through public-private partnerships can unlock additional funding. Financial institutions should develop specialized financial instruments and mechanisms for environmental sustainability initiatives. Lastly, raising awareness and providing capacity building programs can address knowledge gaps and misconceptions about the financial viability of sustainable initiatives.

Case Studies of Successful funding models implemented in developing countries.

One example of a successful funding model for smart city initiatives implemented in a developing country is the "Kigali Innovation City" project in Rwanda. The project was developed as a public-private partnership and successfully attracted funding from various sources. The Kigali Innovation City project in Rwanda successfully utilized a variety of funding sources to support its smart city initiatives. The project involved a public-private partnership and received funding from the Rwandan government, foreign direct investment, public-private partnerships, development finance institutions, and grant funding and donor support (World Bank, 2019b). This funding model allowed for the development of infrastructure and support for innovation and entrepreneurship in sectors such as technology, biotechnology, and financial services. The success of the project can be attributed to the collaboration between the government and the private sector and the alignment with national development goals. This case study highlights the importance of leveraging diverse funding sources and establishing partnerships to finance smart city projects in developing countries.

Another example of a successful smart city project funding model in a developing country is the Tech City project in Lagos, Nigeria. The project was initiated by the state government in collaboration with private sector partners and international organizations. The funding for the Tech City project in Lagos was raised through a combination of public-private partnerships and foreign direct investment. The government provided land and infrastructure support while private sector entities and international organizations invested heavily in building the necessary technology

infrastructure and ecosystem. For instance, Andela, a global software development company, invested $100 million to build a tech campus in Lagos as part of the Tech City project. This investment created job opportunities for local developers and contributed to the growth of the technology sector in the city. Other sources of funding for the project included venture capital firms, angel investors, and development funds. These entities recognized the immense potential of the technology sector in Lagos and its ability to drive economic growth and innovation. Through a successful funding model, the Tech City project in Lagos transformed the city into a major tech hub, attracting both local and international technology companies. The project not only created employment opportunities but also fostered entrepreneurship and innovation, driving economic development in the region.

d) Citizen Participation;

Level of Citizen Participation and Engagement in Smart City Initiatives in Nigeria

There is currently a low level of citizen participation and engagement in smart city initiatives in Nigeria. This can be attributed to several factors, including limited awareness and understanding of smart city concepts among the general population, a lack of trust and confidence in government initiatives, and limited access to information and technology infrastructure.

A study by Ogunseye et al. (2022) conducted about Lagos State, Nigeria, found that only a small percentage of respondents were aware of the concept of a smart city, and even fewer were actively engaged in any smart city projects or initiatives. The study also noted that the lack of citizen involvement in smart city planning and decision-making processes can lead to a disconnect between government objectives and citizen needs. Furthermore, the research by Tadili & Fasly (2019) emphasizes the importance of citizen engagement in smart city initiatives, stating that it can enhance transparency, accountability, and ensure that projects are designed to meet the specific needs of the people. However, some studies highlights that current efforts in Nigeria are primarily driven by the government and private sector without significant input from citizens.

The barriers that hinder citizens' involvement and active participation.

These barriers can be categorized into social, economic, and infrastructural factors;

1. Lack of Awareness and Digital Divide: Many citizens in Nigeria, particularly those in rural areas, lack awareness about smart city initiatives and the benefits they can bring. Additionally, there is a significant digital divide in the country, with limited access to internet connectivity and technology devices, which hampers citizens' ability to actively participate (Moses et al., 2019).

2. Limited Digital Skills: A large portion of the Nigerian population lacks the necessary digital skills to effectively engage with smart city initiatives. This includes skills such as data literacy, digital literacy, and problem-solving skills, which are essential for citizens to actively participate and understand the functioning of smart city technologies (Moses et al., 2019).

3. Cost and Affordability: The affordability of smart city technologies and services is crucial for citizens' active participation. High costs associated with acquiring necessary devices and accessing the required infrastructure can be a significant barrier, particularly for low-income individuals (Gade & Aithal, 2022).

4. Limited Trust and Security Concerns: Citizens' lack of trust in the government and concerns about data privacy and security can hinder their willingness to actively participate in smart city initiatives. The fear of surveillance and potential misuse of personal data acts as a barrier to citizens' engagement (Ferdous & Abdullah, 2019) & (Abdulrahman et al., 2020).

5. Inadequate Infrastructure: Insufficient physical and digital infrastructure, including poor road networks, erratic power supply, and limited broadband connectivity, pose a significant barrier to citizens' involvement in smart city initiatives (Lagos State Government, 2022) & (Moses et al., 2019).

In an effort to answer a question using a survey administered in different cities of the world about the extent to which each of the above issues represent barriers for a community to implement or expand the citizen engagement in a smart city project, Tadili & Fasly (2019) reported around 70% of city experts said that the biggest obstacle to involving citizens in smart city projects is the lack of a long-term vision or plan. Over half of the experts (53%) agreed that not knowing enough about smart cities and having limited funds are stopping decision-makers from including citizens in

their projects. Additionally, 47% of the experts said that the challenges of starting off, getting community support, having helpful policies, and coordinating different departments are also major obstacles.

Potential strategies and solutions for enhancing citizen engagement and participation in achieving environmental sustainability goals

To enhance citizen engagement and participation in achieving environmental sustainability goals, several strategies and solutions can be implemented. Firstly, education and awareness are pivotal in motivating citizens. Public awareness campaigns, workshops, and educational programs can inform citizens about the importance of environmental sustainability. Secondly, incentives can encourage citizen involvement. Governments and organizations can offer rewards, recognition, and benefits for sustainable practices, such as tax incentives and subsidies for renewable energy solutions. Strengthening community participation is another crucial aspect. Engaging citizens in decision-making processes, like public consultations and participatory budgeting, empowers them to influence sustainable policies. Technology and innovation can also play a significant role in engaging citizens, utilizing mobile applications, websites, and social media platforms. Collaboration and partnerships are vital, establishing platforms for dialogue and knowledge exchange between government, organizations, businesses, and citizens. Ensuring accessibility and inclusivity is important, prioritizing the involvement of marginalized communities. Monitoring, evaluation, and transparency foster citizen trust and engagement by providing information on the impact of their actions and progress towards environmental goals. Lastly, capacity building through training programs enables citizens to become sustainability champions in their communities. By implementing these strategies collectively, societies can work towards a sustainable future through empowered citizens, collaboration, and effective communication.

Discussion

Potential Strategies for Overcoming Barriers

According to the findings, the main barriers for implementation of smart city initiatives include inadequate technology infrastructure, lack of dedicated policy frameworks, inappropriate funding mechanisms, and poor citizen participation. Addressing these challenges requires significant investment in improving telecommunications infrastructure, expanding broadband coverage, enhancing power supply reliability, developing robust data management systems, and fostering the deployment of IoT devices.

By establishing a comprehensive policy framework, Nigeria can provide a clear roadmap for smart city development that prioritizes environmental sustainability. It would also enable better coordination among different stakeholders, foster knowledge sharing, and facilitate the implementation of innovative solutions to address environmental challenges. Policymakers should also actively engage with stakeholders, leverage expertise from multiple domains, monitor technological advancements, and establish mechanisms for ongoing policy evaluation and adaptation. Collaboration, flexibility, and a long-term perspective are key to creating robust policy frameworks that align with smart city objectives and support sustainable urban development.

To address financial challenges, it is important to explore innovative financing mechanisms and partnerships such as Public-private partnerships (PPPs) that involve collaborating with the private sector to leverage their expertise, resources, and funding for smart city projects. This allows for efficient project management and distribution of financial risks and responsibilities. Secondly is Impact investment, where investors prioritize social and environmental benefits alongside financial returns, this can provide an alternative funding source for smart city projects. Thirdly, by engaging with national and international development finance institutions, this can grant access to specialized financing facilities and technical assistance. Fourthly, Crowdfunding and community participation can also be utilized to raise funds and increase public support for specific smart city projects. Lastly, Structured finance mechanisms, such as project bonds or green bonds, can attract institutional investors and capital markets, providing long-term funding options and mobilizing capital for infrastructure investments.

Recommendations;

1. Improvement of technology infrastructure, especially in rural and underserved urban areas. This can be accomplished through investing in infrastructure development to provide high-speed internet access to

everyone. Additionally, promoting the deployment of 5G networks and open standards will support faster speeds and seamless communication between different platforms and systems, enabling emerging technologies like IoT and AI.

2. Regarding policy frameworks, it is crucial to enhance cybersecurity standards and regulations to protect critical infrastructure, personal data, and digital systems. In order to foster innovation, flexible regulations should be put in place that balance consumer protection with entrepreneurship and competition. Moreover, robust data protection laws should be implemented to give citizens control over their personal data, ensuring transparency and accountability.
3. The third recommendation highlights the importance of funding mechanisms. Public-private partnerships should be established to leverage the expertise and resources of private sector entities in funding and implementing technology initiatives. Governments should allocate specific budgets for technology infrastructure development, research and development, and digital literacy training programs. In addition, creating tax incentives and investment promotion initiatives that attract venture capital can help fund technology startups and drive innovation.
4. For citizen participation, huge investment should be made in digital literacy programs to ensure that individuals of all ages have the necessary skills to effectively engage with digital technologies. Feedback mechanisms should be established to allow citizens to provide input on technology initiatives, and their views and concerns should be considered in policy decisions. Citizen involvement in technology decision-making can be promoted through public consultations, online platforms, and participatory workshops.
5. Implementing these recommendations is not a single sector task, rather requires collaboration between government, academia, private sector, and civil society. It is also essential to continuously evaluate the impact of these initiatives to ensure sustainable and inclusive technological development.

Effective collaboration and partnerships among government, private sector, academia, and civil society are crucial for achieving environmental sustainability in smart city initiatives. These collaborations enable the sharing of knowledge, research findings, and best practices. Academia contributes expertise in sustainable urban planning, renewable energy, and environmental management, while the private sector brings technical knowledge and resources for developing smart technologies. Government agencies provide regulatory frameworks and policy guidance, while civil society organizations engage communities and advocate for environmental concerns. Collaboration allows for a holistic approach to urban sustainable development, considering interconnected systems like transportation, energy, waste management, and water. It also facilitates resource mobilization and promotes accountability and transparency in monitoring environmental indicators. Lastly, collaboration ensures a people-centered approach by integrating social, economic, and equity dimensions into environmental sustainability efforts.

Conclusion

In developing countries such as Nigeria, rapid urbanization has led to significant environmental challenges, including air and water pollution, inadequate waste management, deforestation and etc. There is a pressing need to address these issues through sustainable urban development strategies known as smart city initiatives. There are several successful smart city initiatives from around the world that can serve as relevant examples for Nigeria as a developing country. Environmental sustainability policies are of great significance in the context of smart cities in Nigeria. These policies can help mitigate environmental degradation and promote the efficient use of resources. The study particularly explores the barriers and limitations of implementing smart city initiatives and policies for environmental sustainability in developing countries, specifically focusing on Nigeria. It investigates the challenges faced in terms of technology infrastructure, policy frameworks, funding, and citizen participation. It also examines the potential strategies and solutions for overcoming these barriers and maximizing the benefits of smart city projects in achieving environmental sustainability in developing countries. Some of these solutions include improving technology infrastructure, provision of dedicated policy frameworks, development of proper funding mechanisms, and improving citizen participation. This is crucial for driving innovation, enhancing access, and fostering digital inclusion. Another important approach is Interdisciplinary collaborations and partnerships between government, private sector, academia, and civil society which greatly enhance the likelihood of achieving environmental sustainability through smart city initiatives. Such collaborations allow for knowledge exchange, innovation, holistic

approaches, resource mobilization, accountability, and a people-centered focus, thereby fostering effective and inclusive sustainable development in urban areas both in Nigeria and other developing countries.

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