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Impact of Smart City Initiatives on Environmental Sustainability: A Case Study of Banana Island, Lagos, Nigeria

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ABSTRACT

Using a quantitative cross-sectional survey design, this study investigated the impact of smart city initiatives on environmental sustainability in Banana Island, Lagos. The research employed stratified random sampling with 375 respondents (a 97% response rate). Data was collected using a structured questionnaire measuring smart city implementation, environmental sustainability, and implementation effectiveness. Results revealed a significant dichotomy between smart city technology adoption and environmental outcomes. While smart infrastructure implementation (86.2% positive response) and technology adoption (83.4%) showed high success rates, environmental sustainability metrics demonstrated negative trends. Energy efficiency (71.2%), waste management (78.1%), and environmental quality (73.9%) all indicated poor performance. Implementation effectiveness metrics further highlighted systemic challenges, with policy compliance (71.2%), stakeholder engagement (72.8%), and technical efficiency (70.9%) showing substantial deficiencies. The study concluded that there is a disparity between the implementation of smart city technology and the environmental sustainability of Banana Island, Lagos. Despite robust infrastructure and high adoption rates, the environmental effect shows that sustainability targets have not been met. The difference is apparent in energy efficiency, waste management, and resource conservation. The implementation-outcome disparity is seen in the subpar performance of key environmental quality indices. The governance-sustainability gap is seen in low policy compliance and little stakeholder involvement. Based on the findings of the study, the study recommends that The Lagos State Environmental Protection Agency and Banana Island Property Owners and Residents Association should collaborate to create an Integrated Environmental Technology Framework, a Smart City Environmental Management Office, and a Smart City Sustainability Governance Board to address the technological-environmental gap.

Keywords: Smart City, Environmental Sustainability, Urban Development, Technology Implementation, Stakeholder Engagement, Environmental Management

1.0 Introduction

The rapid urbanization of cities around the world has raised a rethink of conventional approaches to designing and managing cities, hence giving rise to initiatives for smart cities. These apply advanced technologies with data analytics to improve urban living, service delivery, and environmental sustainability. The challenges of this nature have given birth to the initiation of smart city projects that use ICTs to enhance urban services in an environmentally sustainable manner. According to Khansari et al. (2013), a new paradigm shift in urban development has taken place because of the integration of technological innovation with sustainable practices for the better living of its citizens and making urban space environmentally responsible. However, these projects have often presented daunting challenges to their implementation, especially within countries of the developing world, most of which are characterized by infrastructural deficits and striking socio-economic disparities (Khansari et al., 2013). Key issues such as resource allocation, citizen engagement, and integrating sustainable practices into urban development feature crucially within the global discourse on smart cities. In the background of rapidly growing global challenges regarding climate change, resource depletion, and environmental degradation, the search for sustainable strategies for urban development is gaining momentum (Lima et al., 2024).

Among these, smart city initiatives through smart grids, intelligent transportation systems, and automated waste management solutions have indeed shown prospects for such city dwellers concerning all the highlighted challenges. Successful implementation of smart city technologies can reduce urban energy consumption by 20-30% and largely decrease carbon emissions. However, the effectiveness of such initiatives is seriously fragmented across different urban settings and in developing countries, particularly the pace is slow. In developing countries, there are separate sets of challenges for the imposition of smart city initiatives to enhance environmental sustainability (Darma, 2023). Typically, fast-paced urbanization, infrastructure gaps, and lower technological abilities are the vital challenges delivered to the development of smart cities. Places like Banana Island in Lagos are very special exceptions, where modern infrastructure and high-income populations open up possibilities for smart city initiatives. Special areas also present challenges in embedding the technological solution with the already existing urban system and fair distribution of their benefits to the larger urban landscape. Perhaps in the case of Banana Island in Lagos, where there is an area of affluence but simultaneously with quite a few environmental challenges, understanding what impact a smart city initiative would have on sustainability is particularly fitting (Ringenson & Höjer, 2016).

Literature reviews have identified the shortage of empirical studies relating to localized contexts within developing nations. According to Ramli et al. (2024) and Lima et al. (2024), there is a lack of literature concerning localized smart city initiatives within developing nations. Therefore, this research explores the ways through which the smart city initiatives on Banana Island can contribute towards environmental sustainability on the island, given the exclusivity of its socio-economic dynamics. The synthesis of insights from global literature and their contextualization in the local framework of Lagos will provide an astute understanding of how technology and sustainability in urban settings relate. A few recent empirical studies have underlined strong awareness of significant gaps in our understanding of how smart city initiatives improve environmental sustainability in premium residential areas of developing nations (Aik Wirsbinna & Grega, 2021).

While studies have shown that smart city technologies could go a long way in advancing the living standards of residents within developed contexts, little or no empirical evidence has been ascertained in an area like Banana Island, Lagos. In particular, there is a shortage of comprehensive studies of the quantitative environmental impacts of smart city initiatives in areas of high-value residential development in developing nations, the role of public-private partnerships in implementation, and the long-term sustainability of interventions. This is a serious knowledge gap: there is a deficit of rigorous empirical studies investigating the impact of smart city initiatives on environmental sustainability in premium residential areas of developing countries.

This represents a significant knowledge gap, considering the role that cities such as Banana Island may play in providing examples for sustainable urban development in Nigeria and, by extension, other developing countries. The relationship that exists between smart city initiatives and environmental sustainability will be important to understand at this place to inform policy decisions that could extend the effectiveness of urban development strategies in a similar global context.

A major debate focuses on the use of intelligent technologies to promote sustainability. For example, Ramli, Azizi, and Thurairajah (2024) argue that although smart technologies can improve energy consumption, their progress depends on the input and behavior of the user. This is in line with Min Ma (2024), who discusses how urban metrics can improve service delivery and sustainability but emphasizes the need for regional planning to address the city's unique challenges. In addition, Lima, Edelenbos, and Gianoli (2024) show the dual nature of urban development in South Korea, showing both advantages and disadvantages, such as increased inequality.

2.0 Materials and methods

2.1 Research design

This is a quantitative cross-sectional survey investigation into the impact of smart city initiatives on environmental sustainability in Banana Island, Lagos. The general design normally deals with the collection and analysis of numerical data to test hypotheses and establish relationships between variables through statistical analysis.

2.2 Population, sample size, and sampling techniques

Following Ma's (2024), the Stratified sampling technique is therefore adopted for this study, where the sampling population is chosen by stratified random sampling so that representative participation takes place from all different kinds of stakeholder groups. For calculating sample size, the applied formula was:

$$n = \frac{N}{(1+N(e)^2)}$$

Where:

n = Sample size

N = Population size

e = Margin of error (5%)

Sample Size Banana Island: Estimated relevant stakeholder population, 12,000

Using a single population proportion formula gives a sample size of 387 respondents with a confidence level of 95% and a margin of error of 5%.

2.3 Data collection

The data collection in the research is done through the use of a structured questionnaire. The questionnaire is divided into four parts, designed to effectively capture information from the respondents regarding the impact that smart city initiatives have on environmental sustainability in Banana Island.

The demography of the respondents, in terms of age, gender, level of education, and technology adoption, is mapped using the surveying instrument. Infrastructure implementation, technology adoption, service integration, and innovation diffusion are measured through a 5-point Likert scale. Environmental sustainability is also assessed on a 5-point scale adapted from Darma (2023), relating to energy efficiency, waste management, environmental quality, and resource conservation. This survey measures the effectiveness of implementation on a 5-point scale, adapted from Chatfield and Reddick, 2015, regarding policy compliance, stakeholder engagement, technical efficiency, and performance outcomes. This survey is structured in a way that can give an overall view of the techno-environmental perspective of Smart City Initiatives in Banana Island.

2.4 Data analysis

Descriptive statistical analysis with SPSS version 20 was employed to analyze the influence of smart city initiatives on environmental sustainability at Banana Island, Lagos. The selection of descriptive statistics is informed by the studies conducted within the similar contexts-influenced scope of the research work and provides results in a form that is clear and interpretable for stakeholders.

3.0 Result and Discussion

The discussion of smart city initiatives as well as their impacts on environmental sustainability cannot be impactful without the establishment of a vivid understanding of the key components of such initiatives, especially as they affect the people and the government which bears the responsibility of establishing and enforcing such initiatives to benefit the people as well as the environment.

This section highlights the obtainable and applicable options and principles of smart city initiatives and discusses their globally recognized uses. Furthermore, the findings of this research work are discussed in detail in this section.

Out of the targeted 387 respondents for the study, only 375 respondents were able to respond to the question with a response rate of 97% approximately. The analyses are presented below.

Table 1 Demographic analysis of the respondents

Demographics	Frequency	Percentages
Age		
18-29 years	99	26.4
30-39 years	114	30.4
40-49 years	108	28.8
50 years and above	54	14.4
Total	375	100.0
Gender		
Male	245	65.3
Female	130	34.7
Total	375	100.0
highest level of education		
Secondary school	3	.8
Diploma	161	42.9
Bachelor’s degree	139	37.1
Master’s degree	41	10.9
PhD	31	8.3
Total	375	100.0

What function do you serve on Banana Island?		
Resident (Property Owner)	33	8.8
Tenant	254	67.7
Property Developer/Manager	31	8.3
Environmental Officer	31	8.3
Smart City Technology Implementer	26	6.9
Total	375	100.0
How long have you been staying in Banana Island		
Less than 1 year	134	35.7
1-5 years	158	42.1
6-10 years	78	20.8
Over 10 years	5	1.3
Total	375	100.0
How would you rate your adoption of smart technologies (e.g., smart meters, security systems, etc.)?		
Not adopted	21	5.6
Low adoption	157	41.9
Moderate adoption	166	44.3
High adoption	31	8.3
Total	375	100.0

The age distribution for the respondents shows a working-age population; most of them fall in the range between 30-39 years at 30.4% and 40-49 years at 28.8%. Such a middle-aged population is all the more important, especially for smart city initiatives, since such a population normally constitutes professionals who would be technologically savvy and conscious about environmental concerns. Another significant share of younger adults was 26.4% for 18-29 years, showing a population that is likely to adapt easily to smart technology adoption. The remaining 14.4% were 50 years and over, this expresses that most of the community is still quite young; thus, the implementation of smart city technologies and environmental sustainability practices may be easier to implement at a faster pace.

The male population is highly dominant at 65.3%, while the female population constitutes 34.7%. This may further cause an imbalance in gender representation and, subsequently, the perception of smart city initiatives and environmental sustainability, as many studies have pointed out that men and women differ in priorities and methods concerning environmental issues. Such dominance of males in response might indicate a need for elaboration of more inclusive strategies to ensure that the needs and concerns of all the city residents are duly considered by the proposed smart city initiatives.

The educational profile of the respondents is high, going by the fact that 98.4% have post-secondary education. These are dominated by diploma holders, totaling 42.9%, followed by bachelor's degree holders at 37.1%. Advanced degree holders, including master's and PhD, are at 10.9% and 8.3%, respectively, which is an indication that this could be a highly educated community that should understand and deploy complex smart city technologies. However, this educational distribution is beneficial in the case of environmental sustainability concerns because the higher the educational attainment, the more environmentally conscious people are and the more open they would be to adopting sustainable measures.

The functional distribution indicates that 67.7% of the respondents are renters, which is an important factor in promoting the implementation of smart cities. Relatively, a small percentage of the owners-8.8%-and developers/managers-8.3% indicate that most initiatives would need to consider the tenant-landlord dynamic in implementation strategies. The presence of dedicated environmental officers at 8.3% and smart city technology implementers at 6.9% points to existing infrastructures for sustainability initiatives, though their numbers are relatively small and perhaps may limit speed in implementation.

There is a trend in residency duration, with the majority relatively new to Banana Island: 77.8% having stayed for five years or less, 35.7% having stayed less than a year, and 42.1% between 1-5 years. This is either a positive or negative factor toward the implementation of a smart city initiative, as on one hand, relatively new residents may not be as resistant to adopting new technologies, but the high ratio could make long-term sustainability projects and community engagement quite complex.

The adoption of smart technology represented a perfect bell curve distribution, where moderate adoption was leading the race with 44.3%, seconded by low adopters at 41.9%. Low-adopters, with a small 8.3% and non-adopters at 5.6% hinted at the fact that though the implementation of smart technology is on its way, there remains considerable scope for increasing it. The distribution shown here would, therefore, suggest that at present, although the foundation for smart city initiatives is laid, further effort might be required to push more from the low/moderate level of adaption to higher levels of use of smart technologies for environmental sustainability.

Table 2 Smart City Initiatives

s/n	Statements	Responses	Frequency	Percentages
1	Implementation of Smart City Infrastructure Analysis	Strongly Disagree	28	7.5
		Disagree	24	6.4
		Agree	151	40.3
		Strongly Agree	172	45.9
		Total	375	100.0
2	Smart Technology Adoption Rate Analysis	Very Low	37	9.9
		Low	25	6.7
		Moderate	137	36.5
		High	176	46.9
		Total	375	100.0
3	Integration of Smart City Services Analysis	Very Ineffective	31	8.3
		Ineffective	32	8.5
		Effective	159	42.4
		Very Effective	153	40.8
		Total	375	100.0
4	Innovation Diffusion Analysis	Strongly Disagree	29	7.7
		Disagree	35	9.3
		Agree	156	41.6
		Strongly Agree	155	41.3
		Total	375	100.0

The results show that smart city infrastructure implementation in Banana Island is very well received; a combined total of 86.2% of the respondents agreed, while 40.3% agreed and 45.9% strongly agreed. Such a positive response points to the fact that smart city infrastructural development has found acceptance as part of the urban fabric on the island. The minor perceptible percentage of disagreement, 7.5% strongly disagree and 6.4% disagree, may reveal isolated areas or an aspect of the infrastructure that would need attention. This strong positive perception about infrastructure implementation is essential for environmental sustainability; a well-implemented smart city infrastructure becomes the backbone for different initiatives relating to efficient resource management, reduced consumption of energy, and better handling systems of waste. The likelihood of high rates of approval will also reflect that the residents are probably harvesting tangible fruits from such implementations, possibly translating into environmental gains.

Its adoption in terms of the use of smart technologies, smart grids, and smart lighting, is quite different and positive, with 46.9 percent reporting high and the other 36.5 percent being characterized by a moderate diffusion. This means that an accumulation of 83.4 percent of positive responses is where smart technologies are deeply penetrating. The relatively lower percentage of the respondents in the very low or low rates of adoption: 9.9% and 6.7%, respectively, might suggest those places that have implementation problems or groups of people who cannot adopt technologies due to some hindrances. It is also crucial that a high level of smart technology adoption shows environmental sustainability. Smart grids and smart lighting technologies have a direct outcome on the reduction of energy use and better efficiency in resource consumption. This adoption at mass would go to show that Banana Island is set in an advantageous position to realize its goals in environmental sustainability through technological solutions.

Factually, the level of integration of smart city services is very effective, with 42.4% feeling that the integration is effective and 40.8% rating the integration as very effective, thus giving a total of 83.2% positive responses. This relatively high satisfaction entailing from the integration of the services would support the belief of successful coordination between the various components of a smart city, especially in key areas such as waste and water management. The relatively low percentage of dissatisfied responses- 8.3 percent very ineffective and 8.5 percent ineffective reflect areas of service for which improvement or better integration is desired. Such services are crucial integrations toward environmental sustainability in that they allow better resource use, management of wastes, and conservation of water. A high effectiveness rating suggests integrated systems are working in concert toward environmental goals.

This leads to the findings from within Banana Island, which reflects an extreme positivity towards innovation diffusion thus: 41.6% agree and 41.3% strongly agree, hence, a total of 82.9%, that new smart solutions are continually being introduced. This would mean an extreme output on the perceived innovation level and, therefore, a dynamic and progressive way of implementing smart city solutions. Therefore, fairly low levels of disagreement-7.7% strongly disagreed, and another 9.3% disagreed-may provide greater insight into areas where innovation implementation has not reached its full potential or has been communicated poorly. More significantly, in terms of environmental sustainability, this strong positive perception of innovation diffusion suggests that there is a fertile environment for the adoption of new, more efficient technologies and solutions. This may enable environmental management systems and sustainability initiatives that are increasingly sophisticated to be gradually introduced.

Table 3 Environmental Sustainability

S/N	Statements	Responses	Frequency	Percentages
1	Energy Efficiency Analysis	Very Poor	133	35.5
		Poor	134	35.7
		Neutral	46	12.3
		Good	52	13.9
		Excellent	10	2.7
		Total	375	100.0
2	Waste Management Effectiveness Analysis	Very Ineffective	150	40.0
		Ineffective	143	38.1
		Neutral	37	9.9
		Effective	39	10.4
		Very Effective	6	1.6
		Total	375	100.0
3	Environmental Quality Assessment Analysis	Very Poor	132	35.2
		Poor	145	38.7
		Neutral	44	11.7
		Good	47	12.5
		Excellent	7	1.9
		Total	375	100.0
4	Resource Conservation Impact Analysis	Not at all	130	34.7
		Slightly	152	40.5
		Moderately	31	8.3
		Significantly	48	12.8
		Extremely	14	3.7
		Total	375	100.0

The energy efficiency of Banana Island projects presents a very different and quite distressing picture, with an alarming 71.2% of the respondents describing it as negative: 35.5% very poor and 35.7% poor. This is an overwhelming vote of no confidence and points to serious deficiencies in the implementation or effectiveness of energy-efficient systems in buildings and infrastructure. The few positive ratings that came in, with only 13.9%

rating it as good and a mere 2.7% as excellent, underline a big gap between smart city aspirations and real energy performance. The neutral response of 12.3% might indicate areas where energy efficiency initiatives are in transition or partly implemented. This candid assessment raises key questions as to how well the current smart city initiatives are doing concerning their energy sustainability objectives and indicates the urgent need for a whole-of-island infrastructure, and comprehensive energy efficiency improvements. The negative high rating percentage may be due to reasons such as outdated systems within buildings, poor energy management practices, or ineffective use of smart energy solutions.

The problem of using the waste management facilities in Banana Island is very big, as 78.1% of respondents assessed it negatively, according to this research (40% very ineffective and 38.1% ineffective). This strong negative predisposition to assessment of the reviewed waste management infrastructure and processes implies that, notwithstanding the smart city initiatives existing, there are substantial problems with the current waste management infrastructure and processes. The extremely low positive ratings, with only 10.4% finding it effective and an extremely low rating of 1.6% as very effective, show signs of an implementation failure in effective waste management. Neutral responses of 9.9% might belong to the area where waste management systems are either under development or showing mixed results. This data shows a serious disconnect between the ambitions of smart city waste management and the real implementation, or it might also mean that there is a flaw in the recycling infrastructure, systems of collection, or ways of disposal. Overwhelming negativity indicates that the basic problems of waste management have not been resolved by current smart city initiatives.

It is strikingly discouraging that the perception of general environmental quality is considered negative by 73.9% (35.2% very poor and 38.7% poor), in which the contribution of different environmental elements increases, such as air quality, water quality, and noise levels. Only a small percentage reported positive perceptions: 12.5% perceived it as good and 1.9% as excellent, which means that smart city initiatives undertaken so far have failed in solving problems related to environmental quality. The neutral responses, which account for 11.7%, might show improvements that are ongoing but have not reached an appreciable level. This data therefore suggests a wide chasm between the ideals of environmental sustainability in smart city projects and the actual environmental conditions as felt by the residents. For instance, the high share of negative ratings could be due to poor pollution control measures, poor treatment of water systems, or an inadequately implemented noise management program.

The level of contribution that smart city initiatives make to resource conservation is rated as alarming, as 75.2% of the respondents answered that they either do not help or help a little. This is a negative assessment since current smart city initiatives have not led to significant influence on the way of living, especially about resource conservation-particularly for water and energy management. The low positive responses from 12.8% with a significant impact and 3.7% extreme indicate a severe shortfall in the realization of resource conservation goals. The 8.3% who reported a moderate impact may reflect isolated successes or partial implementations. This information reflects a critical gap between the intended and realized resource conservation impact of smart city initiatives. The high percentage of negative responses seems to indicate that current smart technologies and systems may not be designed or implemented in a manner that could effectively attain the goal of resource conservation.

Table 4 Implementation Effectiveness

S/N	Statements	Responses	Frequency	Percentages
1	Policy Compliance Effectiveness Analysis	Very Ineffective	142	37.9
		Ineffective	125	33.3
		neutral	47	12.5
		Effective	48	12.8
		Very Effective	13	3.5
		Total	375	100.0
2	Stakeholder Engagement Analysis	Not Engaged	123	32.8
		Slightly Engaged	150	40.0
		Moderately Engaged	44	11.7
		Highly Engaged	48	12.8
		Fully Engaged	10	2.7
		Total	375	100.0
3	Technical Efficiency Analysis	Very Ineffective	125	33.3

		Ineffective	141	37.6
		neutral	43	11.5
		Effective	57	15.2
		Very Effective	9	2.4
		Total	375	100.0
4	Performance Outcomes Analysis	Very Ineffective	135	36.0
		Ineffective	137	36.5
		neutral	49	13.1
		Effective	45	12.0
		Very Effective	9	2.4
		Total	375	100.0

The data on policy compliance regarding smart city technologies shows that the majority, 71.2%, rated them negatively-37.9% very ineffective and 33.3% ineffective. This means that the gap between laid-down policy and actual implementation on the ground is huge. There was minimal positive rating, with only 12.8% finding it effective and 3.5% finding it very effective, which indicates serious deficiencies in the enforcement of policies and their adherence. The neutral response of 12.5% may point to transitional or partially effective policy implementation areas. This low rating for policy compliance holds serious implications for environmental sustainability, as effective policies are indispensable to ensure that smart city technologies make a meaningful contribution to environmental goals. The high responses of 'No' reflect the possible reasons for flaws in policy design, mechanisms of enforcement, or involvement of stakeholders in smart city initiatives that might be badly acting in achieving environmental sustainability goals.

The stakeholder engagement is very alarming, standing at 72.8%, with 32.8% not being engaged and 40% slightly engaged. It is indeed a serious cause for alarm over critical stakeholder involvement on the part of the government, residents, and developers in any smart city initiative. The extremely low positives in engagement levels -12.8 % highly engaged and 2.7% fully engaged to a failure in creating effective partnerships and collaboration amongst various stakeholders. The moderate level of engagement of 11.7% might reflect isolated pockets of successful collaboration among the stakeholders. This is particularly dangerous for environmental sustainability efforts since the successful implementation of smart city initiatives calls for active participation and coordination among all stakeholders. This may suggest that the data indicates a further need for more participatory and inclusive approaches to stakeholder involvement in environmental sustainability initiatives.

The technical efficiency of the smart city systems shows evident weakness, as 70.9% of the respondents rated it negatively-33.3% very ineffective and 37.6% ineffective. This high negative rating regarding system speed and reliability does indeed imply a substantial number of technical challenges in the implemented smart city infrastructure. With low positive ratings at just 15.2%, finding it effective and 2.4% very effective, this does indeed indicate that the technical infrastructure is failing to meet the expected standards of performance. The 11.5% neutral response may reflect areas where technical systems function at acceptable but less-than-optimal levels. Poor technical efficiency in light of environmental sustainability does directly imply that an unreliable or inefficient system would compromise the effectiveness of monitoring the environment, management of resources, and other initiatives necessary for sustainability. It is indicative from the data that major upgrading is essential for the technical infrastructure if goals of environmental sustainability are to be supported.

This makes for grim reading: 72.5% of the respondents rated smart city initiatives for desired performance outcomes as negative, with 36% being very ineffective and 36.5% rating it as ineffective. The high negative reviews depict how the respondents are greatly disappointed that smart city initiatives have failed to achieve proper improvement in living conditions and sustainability. This is further enhanced by the very low positive ratings in the forms of 'effective' at 12%, and 'very effective' at 2.4%, which indicate a gap between what should have been achieved and what has been achieved from these programs. A neutral response of 13.1% could represent points where some improvement has occurred but not to the level desired. This poor performance regarding the desired outcome has serious implications for environmental sustainability, given that it would seem to suggest current smart city initiatives are not effectively contributing toward environmental improvements. The findings hint at the need for an overall review and probable redesign of the smart city initiatives for them to be aligned with the goals of sustainability and community expectations.

These analyses together suggest major barriers in each of the dimensions of implementation effectiveness, which again reflects a deficiency in potential smart city initiatives in Banana Island to contribute toward environmental sustainability. The high negative grades in all the dimensions consistently indicate systemic impediments that must be addressed to enhance the overall effectiveness of those initiatives.

3.1 Smart City Technologies

Smart cities are transforming the way we live, work, and interact with each other. Smart governments use digital technologies to enhance public services, governance, and citizen engagement. E-governance initiatives allow citizens to access government services remotely, improving convenience and transparency. Mobility/Wi-Fi is crucial for connectivity infrastructure and mobility solutions, ensuring residents have seamless access to digital services.

Figure 1: Smart city component. Source: TechTarget.com (2024)

Smart/Digital Citizens actively participate in smart city services, sharing data and adopting digital tools. Open data is essential for transparency and innovation, empowering developers to create applications to address urban challenges. Smart Health uses digital technologies to improve healthcare delivery, such as telemedicine and wearable health monitors. Smart agriculture uses IoT devices, drones, and data analytics to optimize farming operations. Smart grids use digital communications to optimize electricity production, distribution, and consumption, supporting renewable energy integration. Smart buildings use sensors and automated systems to manage lighting, heating, and security. Smart transportation systems, such as autonomous vehicles and intelligent traffic management, improve mobility by reducing traffic congestion and pollution.

3.2 Environmental sustainability principles and indicators

Environmental sustainability in smart cities involves many interrelated dimensions, and recent literature emphasizes the importance of measurable indicators and clear sustainability goals. Research shows that effective environmental management strategies should include technical and social dimensions (Chatfield & Reddick, 2015). The main sustainability indicators identified in the literature include carbon reduction, energy efficiency, waste management, and resource conservation indicators. Current research shows the importance of establishing sustainable development goals that are compatible with international standards such as the United Nations Sustainable Development Goals. Ringenson and Höjer (2016) emphasize that ecological stability requires analytical methods that can monitor multiple indicators simultaneously. These books also emphasize the importance of sustainable policies that take into account local conditions and maintain international environmental standards.

3.3 Global use of Smart city and sustainability development evidence

Global case studies provide valuable insights into smart city development in Lagos. The Korean City Smart Project, reviewed by Lima et al. (2024), demonstrates the benefits and potential problems of urban planning. This research shows the importance of human interaction and technological advancement, an important lesson for the development of Banana Island.

The "Technologies for Smart Cities" image by the Federal Ministry of the Republic of Austria highlights the development of smart cities by 2030, focusing on key areas such as energy, mobility, environment, and digital infrastructure. Key climate and energy goals are outlined, highlighting the need for cities to adopt sustainable practices to reduce their carbon footprint. Smart energy and smart grids are crucial for achieving energy efficiency and sustainability in urban environments. Intelligent mobility, including electric vehicles and autonomous vehicles, is a prominent component, in reducing traffic congestion and emissions.

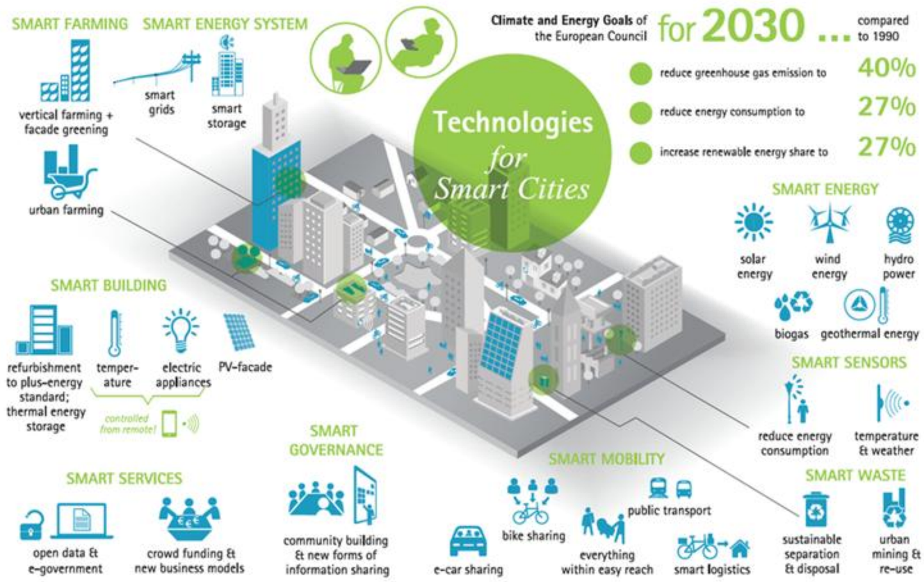

Figure 2: Smart cities technologies. Source: Researchgate.net (2024)

Digital infrastructure and high-speed connectivity such as 5G networks, are essential for a smart city, enabling real-time data collection and analysis for applications such as traffic management, public safety, and environmental monitoring. Smart environmental solutions, such as waste management and pollution control, are also highlighted, allowing cities to manage resources efficiently and maintain a clean environment. Green buildings and sustainable infrastructure are also critical components of smart cities, using energy-efficient technologies to reduce their environmental impact. The image highlights the importance of a collaborative approach between technology, governance, and citizen engagement for creating the cities of the future.

Ma's (2024) study of Zhenjiang documents China's experience and provides important economic lessons for urban development. This research shows that successful urban planning requires a strong integration between economic, social, and environmental objectives. Comparison with other examples around the world shows that Banana Island development could benefit from taking a consistent integrated approach and maintaining an interest in local development.

3.4 Urban planning in Lagos (focus on Banana Island)

As a major residential development in Lagos, Banana Island offers unique opportunities and challenges for building a beautiful community. Dharma (2023) identified several key initiatives for smart city development in Lagos, including waste management systems, renewable energy installations, and smart transportation networks. The study specifically pointed out that Banana Island could serve as a model for sustainable urban development in Nigeria due to its well-developed infrastructure and rich population. Banana Island is a highly developed residential and commercial area in Lagos, Nigeria, and its urban environment provides various opportunities for attractive urban planning. Smart cities integrate information and communication technologies (ICT) to effectively manage resources and improve the quality of urban life, with a focus on sustainable development (Allam & Dhunny, 2019). Based on this image, some of the modern urban technologies that Moose Island may have adopted might include:

Figure 3: Google image of Banana Island Source: Google.com (2024)

Efficient energy systems: - Smart energy management systems can be implemented to monitor and optimize electricity consumption, especially given the large number of residential buildings with high energy demands. Renewable energy solutions such as solar buildings and public lighting can reduce dependence on non-renewable energy sources and reduce environmental impact (Bulkeley & Castán Broto, 2013). Water Management: - Since the island is surrounded by water, it is essential to integrate smart water systems. Technologies such as real-time monitoring of water use, wastewater treatment, and flood prevention help ensure environmental sustainability. Because of their proximity to water bodies, river management practices that prevent pollution and erosion are important to protect surrounding water resources (Deakin, 2014). Sustainable transportation: - Beautiful cities emphasize environmentally friendly transportation options. The image shows a road network that offers the possibility to connect electric vehicle (EV) stations and promote the use of electric vehicles or bicycles to reduce carbon emissions. Intelligent traffic management systems also help to reduce congestion and promote a smooth transportation system (Ygitcanlar, 2015). Waste management: - As shown in the picture, Banana Island Village allows for the implementation of a smart waste system that uses sensors to optimize the waste disposal and recycling process. This reduces the environmental impact of garbage trucks by reducing their carbon footprint and increasing productivity (Soltani et al., 2015). Impact on environmental sustainability: - The environmental sustainability of Banana Island can be improved through these smart city technologies. For example, reducing carbon emissions through smart transportation and efficient energy systems is consistent with global sustainable development goals. In addition, smart water management is important for surrounding waters to ensure the efficient use of natural resources without harming the environment (Zhao et al., 2017). In addition, smart waste management contributes to sustainable development by increasing the efficiency of waste treatment and encouraging recycling. This is consistent with environmental policies that support reducing land waste and emphasize the importance of clean and energy-efficient technologies (Glaeser & Kahn, 2010).

3.5 Discussion of findings

The results of the Banana Island case study display a variety of interesting alignments and divergences to established theoretical smart city frameworks. The high implementation rates regarding smart infrastructure (86.2% positive response) and technology adoption (83.4% positive response) are in tune with what has been emphasized under technological aspects in the smart city frameworks. However, this conflicts with the poor environmental sustainability outcomes; a point observed by Ramli, Azizi, and Thurairajah (2024) emphasizes the fact that technological implementation is not going to be effective without proper user participation in behavioral change. This study found this trend of discontinuation where high smart technology adoption does not affect the environmental indicators; energy efficiency at 71.2 percent negative, waste management at 78.1 percent negative, and conservation of resources at 75.2 percent minimal impact.

These findings by the study in terms of low stakeholder engagement-72.8% showing minimum engagement-align with Khansari, Mostashari, and Mansouri (2013) in emphasizing the importance of inclusive governance in smart cities. Poor policy compliance metrics-71.2% of the responses from the sample recorded negative compliance-along with the stakeholder engagement metrics, reflect what Chatfield and Reddick (2015) argue about the need for citizen-centered approaches to governance. This is in line with the theoretical frameworks, which suggest that the challenges of implementation in Banana Island might not be due to technological barriers but rather an output of the little attention to social and governance aspects of smart city development.

The results on environmental sustainability have also agreed with observations made by Darma (2023) to a large extent, regarding the challenges of urbanization in Nigeria and barriers to the implementation of smart cities. Poor ratings regarding environmental quality in the research area, for instance, 73.9%, and inadequate systems for waste management, are good examples of infrastructural and policy framework challenges as stated in the literature. This also corresponds with the critique of Ringenson and Hojer (2016) that not all smart city initiatives correspond effectively to sustainability goals, since a big gap exists between smart technology implementation in Banana Island and real environmental outcomes.

These findings agree, to some extent, with the study on economic factors in the adoption of smart cities undertaken by Min Ma (2024). While Banana Island presents high technological adoption, the poor environmental and social outcomes mean that economic factors alone are actual drivers of implementation without sufficient attention to environmental sustainability, just as the findings in the Zhenjiang Chinese city were. That relates to Lima, Edelenbos, and Gianoli (2024) emphasis on balancing technological progress with social integration.

The study's findings indicate that there are essential issues to implementation, which also find support from several theoretical frameworks in terms of holistic smart city development. The poor technical efficiency at 70.9% negative and performance outcomes at 72.5% negative reflect Aik Wirsbinna and Grega, (2021), who ensured that systems should be regulated to ensure resources were distributed equitably. The information provided shows that smart city technologies have been implemented on Banana Island but lack the regulatory and governance frameworks to ensure effective outcomes for environmental sustainability.

This study reveals a critical disconnect between smart city implementation and environmental sustainability outcomes in Banana Island, Lagos. Despite impressive technological adoption rates (83.4% positive) and robust infrastructure implementation (86.2% positive), the environmental impact metrics demonstrate concerning failures in achieving sustainability goals. The research identifies three key areas of disconnect:

Firstly, the technological-environmental gap is evident in the stark contrast between high smart technology adoption and poor environmental outcomes. While smart infrastructure deployment has been successful, the environmental metrics show alarming deficiencies in energy efficiency, waste management, and resource conservation. This suggests that merely implementing smart technologies without proper integration into environmental management systems is insufficient for achieving sustainability goals.

Secondly, the implementation-outcome disparity is reflected in the poor performance of key environmental quality indicators, despite high levels of service integration. This indicates that while smart city services are technically integrated, they are not effectively contributing to environmental improvements. The gap between implementation and actual environmental impact highlights the need for better alignment between smart city solutions and sustainability objectives.

Thirdly, the governance-sustainability gap manifests in weak policy compliance and limited stakeholder engagement. These findings indicate that current smart city initiatives lack the necessary governance frameworks and community participation to drive meaningful environmental improvements. The poor technical efficiency ratings further suggest that existing systems are not optimized for environmental sustainability outcomes.

To bridge the implementation-outcome disparity, the Lagos State Government, through the Ministry of Urban Development, should establish a Smart City Environmental Management Office (SCEMO). This office should implement a comprehensive performance monitoring system that tracks the real-time environmental impacts of smart city initiatives. The implementation process should include: monthly environmental performance reviews, quarterly stakeholder feedback sessions, and continuous monitoring of key environmental indicators through smart sensors and data analytics. Success metrics should be tied to specific environmental outcomes rather than just technological deployment rates.

To resolve the governance-sustainability gap, BIPORAL (Banana Island Property Owners and Residents Association) should partner with the Lagos State Government to create a Smart City Sustainability Governance Board (SSGB). This board should implement a structured stakeholder engagement framework that includes: bi-monthly community forums, quarterly environmental performance reviews, and annual sustainability planning sessions. The implementation should follow a participatory approach where all stakeholder groups have representation in decision-making processes. The board should establish clear environmental performance targets and ensure policy compliance through regular audits and enforcement mechanisms.

4.0 Conclusion

The research, having identified the key bridges that disconnect smart city initiatives fair conceptualization, massive implementation, and poor outcomes, especially on the environment calls for adequate sensitization to ensure that the populace and key stakeholders carried along to be part of the driving force to propel an actualization of the positive environmental outcome desired of the schemes and initiatives applied. Every applied initiative must therefore be adequately integrated into existing environmental management systems that have been proven to work with the people, thereby achieving sustainability goals. To address the technological-environmental gap, the Lagos State Environmental Protection Agency (LASEPA) should establish an Integrated Environmental Technology Framework (IETF) in collaboration with BIPORAL (Banana Island Property Owners and Residents Association). Implementation should follow a four-phase approach: First, conduct a comprehensive audit of existing smart technologies to assess their environmental impact potential. Second, develop performance metrics that directly link technological implementations to environmental outcomes. Third, deploy IoT-based environmental monitoring systems integrated with existing smart infrastructure. Lastly; ensure that all subsequent initiatives to be introduced must be community-oriented (ie; an initiative that will be for the people and to be powered by the people) This framework should be reviewed quarterly with environmental performance dashboards and undergo annual technological-environmental alignment assessments.

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