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Assessment of the Adoption of Smart Building Technologies in Nigeria: Implications for Sustainable Energy Management.

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Abstract

This study examines how smart building technologies (SBTs) are being used in Nigeria with an emphasis on how they affect sustainable energy management. The potential of SBTs to improve energy efficiency and lower operating costs is becoming more and more significant as energy needs increase and environmental concerns grow. Surveys and interviews with experts in design, development, and facility management around Nigeria were used to collect data using a mixed-methods approach. The results show that professionals are well aware of SBTs, but their complete acceptance has been slow, mostly because of high implementation costs, poor infrastructure, and a lack of experienced workers. Notwithstanding these difficulties, respondents stated that institutions that used SBTs saw notable improvements in operational efficiency and energy savings. Increased awareness has a beneficial impact on adoption rates, according to correlation research. The study comes to the conclusion that in order to remove current obstacles, supporting government policies—such as financial incentives—as well as focused industry training is crucial. Nigeria may get closer to sustainable energy practices and reap long-term economic and environmental rewards by implementing SBTs.

Keywords: *Nigeria, Sustainable Energy Management, Smart Building Technologies, and Adoption Barriers*

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1. Introduction

Energy efficiency and the use of smart technology across a range of industries have been given significant attention in the worldwide movement towards sustainable development. Buildings are essential to this transformation since they are large energy users. By optimizing resource utilization through automated systems that regulate lighting, HVAC (heating, ventilation, and air conditioning), and security operations, smart building technologies (SBTs) are a significant advance in attaining energy efficiency. These solutions enhance building comfort, safety, and productivity in addition to lowering energy consumption (Ghaffarianhoseini et al., 2016; Ahmed et al., 2020). Although smart buildings are widely seen as being crucial to reducing climate change and achieving energy efficiency goals, their uptake in developing nations, especially Nigeria, is still rather low.

Nigeria's energy industry confronts several obstacles, including a strong reliance on fossil fuels for energy production, inefficient electricity generation and delivery, and ongoing power shortages (Aliyu et al., 2018). Even though Nigeria is one of Africa's top oil producers, the country suffers from energy poverty, which limits access to reasonably priced and dependable electricity, particularly in rural regions. Outdated infrastructure, inadequate maintenance, and a lack of investment in renewable energy sources all contribute to the nation's energy inefficiency (Adenikinju, 2015). Adopting smart building technology might assist in minimizing energy waste, enhancing energy security, and promoting sustainable energy management, as buildings in Nigeria consume a significant amount of energy (Olaniyan et al., 2018). Nigeria is still in the early stages of adopting smart building technology, nevertheless. The broad adoption of SBTs is hampered by elements including exorbitant upfront prices, ignorance, a lack of technological know-how, and the absence of supportive regulatory frameworks (Olawumi& Chan, 2019). Additionally, poor infrastructure, including unpredictable power supply and restricted internet access, further impedes the successful adoption of smart building systems, which rely on real-time data and automation for energy management (Ihueze et al., 2022).

Notwithstanding these obstacles, the requirement to handle Nigeria's energy issues is propelling an increasing number of attempts to incorporate smart technology into the construction industry. Smart technologies have the ability to change Nigeria's urban landscape and support sustainable energy management, as evidenced by initiatives like the creation of green buildings and smart city projects like Lagos' Eko Atlantic City (Nduka et al., 2018). In addition to demonstrating the viability of smart building technologies in Nigeria, these initiatives emphasize how crucial it is to support policies, collaborate with stakeholders, and develop capacity to promote their adoption.The purpose of this research is to evaluate Nigeria's adoption of smart building technologies and investigate how they may affect sustainable energy management. It will look at how SBT adoption is going right now, the main forces behind and obstacles to it, and the possible advantages of these technologies in Nigeria. This study intends to add to the expanding corpus of research on sustainable energy solutions in developing nations and offer guidance to researchers, industry stakeholders, and policymakers on how to hasten Nigeria's adoption of smart building technology.

Objectives

1. To evaluate the level of awareness of smart building concepts by built environment professionals in the study area.
2. To examine the degree of adoption of smart building concept amongst built environment professionals in the study area

2. Review of Literature

The demand for better building management, sustainability, and energy efficiency has led to a recent surge in the use of smart building technologies (SBTs) worldwide. By optimizing space utilization, improving security, and lowering energy consumption, the integration of Internet of Things (IoT) devices, sensors, and automation systems has completely changed building operations in industrialized nations. Nonetheless, SBT use is still very low in poor nations like Nigeria. With an emphasis on global trends, the Nigerian context, and implications for sustainable energy management, this section examines the body of research on smart building technology.

2.1 Smart Building Technologies' Global Adoption

The capacity to include automated systems to regulate a building's lighting, HVAC (heating, ventilation, and air conditioning), security, and other operations is what distinguishes smart building technology. These systems optimize building operations in real-time by utilizing sensors, artificial intelligence (AI), IoT devices, and data analytics. Stricter environmental restrictions, rising energy prices, and the growing need for energy efficiency are some of the drivers driving the global usage of SBTs. Smart building technologies are a crucial part of contemporary sustainable architecture as they may cut energy use by up to 30%, claim Khan et al. (2021). Smart buildings are becoming a key component of the green building movement in industrialized nations. According to Ghaffarianhoseini et al. (2016), using SBTs in green building design improves occupant comfort, health, and well-being in addition to energy efficiency. Smart building technologies provide a method to meet environmental goals, as worldwide initiatives like the Paris Agreement press for reductions in carbon emissions (Dixon et al., 2016). According to Peng and Hong (2020), the use of renewable energy sources, including solar panels, into smart buildings further improves their sustainability. Adoption of smart building technology is still significantly hampered by their high upfront costs, particularly in low-income nations. Small enterprises and low-income homes may find the cost of sensors, IoT devices, and automation systems exorbitant. As a result, certain governments in industrialized nations have implemented incentives and subsidies to promote the use of SBTs (Ali et al., 2018). In nations like the US and Germany, where smart buildings are more common in urban settings, this strategy has shown promise (Berg & Magg, 2018).

2.2 Nigerian Smart Building Technologies

The use of smart building technology is still relatively new in Nigeria. The use of smart technology is still restricted to a small number of upscale buildings and commercial premises, despite increased awareness of the significance of sustainability and energy efficiency. According to Nduka et al. (2018), most buildings in Nigeria are built conventionally, with little focus on automation or energy efficiency. This is mostly because smart building technologies are expensive and there aren't many government incentives or laws that encourage them.According to Arc Tayo Christian Odefadehan (2022), Nigeria's construction industry confronts several difficulties, including antiquated building practices, lax regulatory monitoring, and inadequate infrastructure. The nation's adoption of smart building technology has been hampered by these obstacles. Odefadehan contends that a determined effort to modernize the building sector and bring it into compliance with international standards for sustainable construction is necessary if Nigeria is to fully adopt SBTs. This entails giving developers financial incentives to invest in smart technologies and revising building rules to include energy efficiency criteria. The absence of dependable infrastructure is one of the primary barriers preventing SBTs from being widely used in Nigeria. For smart technology-enabled buildings to work properly, energy and the internet must always be available. But

Nigeria's electrical supply is infamously unstable, with both urban and rural regions frequently experiencing power outages (Aliyu et al., 2018). Similarly, even if it is becoming better, internet access is still difficult, especially in rural regions. Implementing smart building systems that depend on automation and real-time data has proven challenging for developers due to this lack of infrastructure.

There are encouraging indications of advancement in Nigeria's construction industry despite these obstacles. Automated systems for energy management, water conservation, and security are among the components of smart building design that have started to be included in smart city projects like Lagos' Eko Atlantic (Onifade & Adeola, 2019). Even though they are still in their infancy, these initiatives show how SBTs have the power to change Nigeria's urban environment and support sustainable energy management.

2.3 Consequences for the Management of Sustainable Energy

Nigeria's sustainable energy management would be significantly impacted by the use of smart building technology. Buildings in Nigeria are among the biggest energy users, contributing significantly to the nation's electricity consumption, according to Ihueze et al. (2022). Smart buildings may lessen the burden on the national grid, cut greenhouse gas emissions, and minimize Nigeria's overall energy consumption by optimizing energy utilization. This is especially crucial in a nation where energy inefficiency is a significant problem. Renewable energy sources may also be more easily included in Nigeria's energy mix with the use of smart building technology. By optimizing the use of solar panels and other renewable energy sources, buildings with smart systems may lessen their need for fossil fuels. This is essential for Nigeria's shift to a more sustainable energy system, especially in light of climate change and the worldwide movement towards decarbonization (Odefadehan, 2022). However, a number of variables affect how well smart building technology supports sustainable energy management. To ensure the dependable operation of smart systems, a substantial investment in infrastructure is first required. Second, to encourage the use of energy-efficient technology, rules and regulations need to be revised. Third, the long-term advantages of smart building technology need to be better understood and taught to building owners and developers. The full potential of SBTs in Nigeria might not be achieved in the absence of these steps.

2.4 Adoption Obstacles

In Nigeria, a number of obstacles prevent smart building technology from being widely used. For many developers and property owners, the high cost of smart technology is a significant barrier, as noted by Afolayan et al. (2020). Sensors, automation systems, and IoT devices might be prohibitively expensive initially, especially for low-income families and small enterprises. Furthermore, the government does not offer enough financial incentives to promote the use of energy-efficient devices. The absence of technical know-how in Nigeria's construction industry is another significant obstacle. The skills required to develop and deploy smart building technologies are lacking, and many architects, engineers, and construction professionals are not conversant with them (Ihueze et al., 2022). Because developers are hesitant to engage in technology they do not fully understand, this skills gap has hindered the adoption of SBTs. Last but not least, Nigeria lacks laws and policies that encourage the use of smart building technology. According to Olawumi and Chan (2019), the majority of Nigerian building regulations do not provide requirements for smart technology or energy efficiency. Developers have found it challenging to defend the higher expenses of integrating smart technology into their projects due to this regulatory gap.

2.5 Nigeria's Prospects for Smart Buildings

Notwithstanding the difficulties, smart building technologies have a great deal of promise to revolutionize Nigeria's construction industry. There will be a growing need for energy-efficient structures that can lower power usage and advance sustainability as the nation's urban population continues to expand. Nigeria may overcome the obstacles to SBT adoption and profit from smart buildings for sustainable energy management if the proper laws, infrastructure, and awareness are in place.

3. Methodology

The adoption of smart building technologies (SBTs) in Nigeria and its implications for sustainable energy management are evaluated in this study using a mixed-methods approach that combines qualitative and quantitative research techniques. This approach makes it possible to fully comprehend the variables affecting SBT adoption as well as any potential obstacles in the Nigerian setting.

3.1 Research Design

The study uses a descriptive research approach to give a detailed account of how smart building technology is currently being used in Nigeria. Creswell & Creswell (2018) draw attention to the fact that descriptive research is appropriate for studies that aim to provide a thorough description of a particular occurrence. The level of SBT usage in Nigerian buildings, the reasons influencing acceptance, and the difficulties experienced by building owners and developers are all included in this design.

3.2 Collection of Data

Data was gathered using both primary and secondary sources. A systematic questionnaire was sent to a sample of building experts, architects, property developers, and facility managers in Lagos and Abuja, two significant Nigerian cities, in order to collect primary data. Because of their greater concentration of smart building initiatives and availability of contemporary technology, these cities were selected (Onifade & Adeola, 2019). The purpose of the questionnaire was to collect information on adoption rates, knowledge levels, and opinions on the advantages and difficulties of SBTs. To obtain a deeper understanding of the policy and infrastructure factors influencing the adoption of SBT, semi-structured interviews were conducted with key stakeholders, including government officials, industry experts, and representatives from technology companies, in addition to the questionnaire (Aliyu et al., 2018).

3.3 Analysis of Data

In order to evaluate the adoption rates of SBTs, quantitative data from the surveys were examined using descriptive statistics such as frequency distributions and percentages. To ascertain the correlation between factors, such as building type and the probability of using SBTs, chi-square tests were also utilized (Salkind, 2016). In order to find recurrent themes in the qualitative data, such as policy impediments and infrastructural issues, thematic analysis was employed (Braun & Clarke, 2016).

4. Result and Analysis

The results of the examination of the information acquired via surveys and interviews are shown in this section. SPSS was used to analyze the data, and the results were shown as tables, charts, and statistical interpretations.

4.1 Demographic Characteristics

100 respondents, mostly from Lagos and Abuja, who included architects, building professionals, property developers, and facility managers, provided the survey data. Table 1 displays the respondents' demographic characteristics.

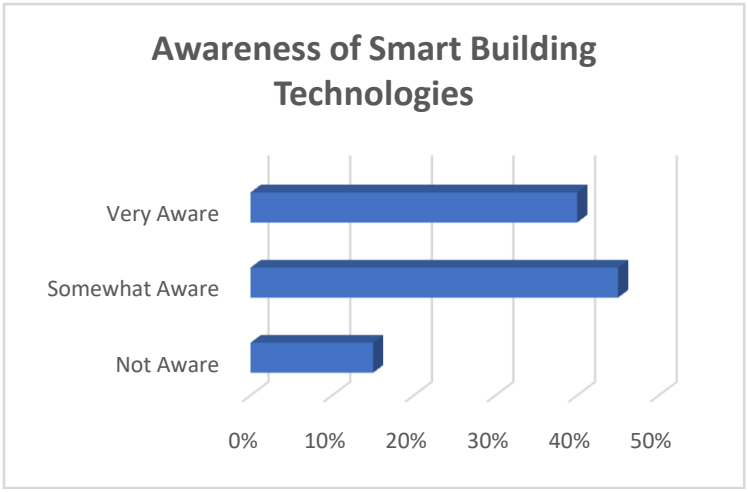
Table 1: Demographic Characteristics of Respondents

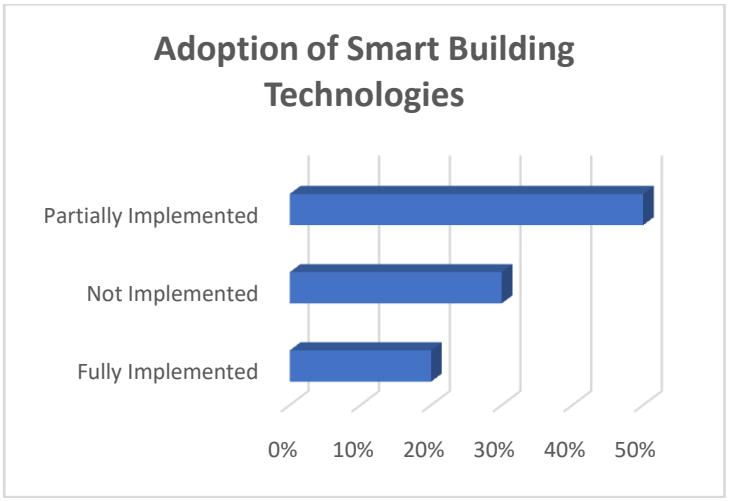
		Frequency	Percent	Valid Percent	Cumulative Percent
Sex					
Valid	Male	67	67%	67%	67.0
	Female	33	33%	33%	100.0
Age Group					
Valid	21–30	25	25%	25%	25.0
	31–40	48	48%	48%	73.0
	41–50	20	20%	20%	93.0
	51+	7	7%	7%	100.0
Education Level					
Valid	BSc/HND	60	60%	60%	60.0
	MSc/PhD	40	40%	40%	100.0
Profession					
Valid	Architect	35	35%	35%	35.0
	Developer	25	25%	25%	60.0
	Facility Manager	20	20%	20%	80.0
	Other	20	20%	20%	100.0

67% of respondents were men, and 48% of respondents were in the age range of 31 to 40. Furthermore, 60% of responders had at least a bachelor's degree.

4.2 Level of Awareness and Adoption of Smart Building Technologies (SBTs)

We asked respondents to rate their familiarity with smart building technology and adoption. The findings are displayed in Figures 1 and 2.





According to the study findings, 45% of respondents knew something about SBTs, and 40% knew a lot about them. Just 15% did not understand the idea.

While 20% of respondents claimed complete deployment, a sizable portion (50%) indicated partial implementation of SBTs in their facilities.

4.3 Barriers to the Adoption of Smart Building Technology

The respondents were asked to rank the obstacles to the adoption of SBT. The five biggest obstacles found are shown in Table 2.

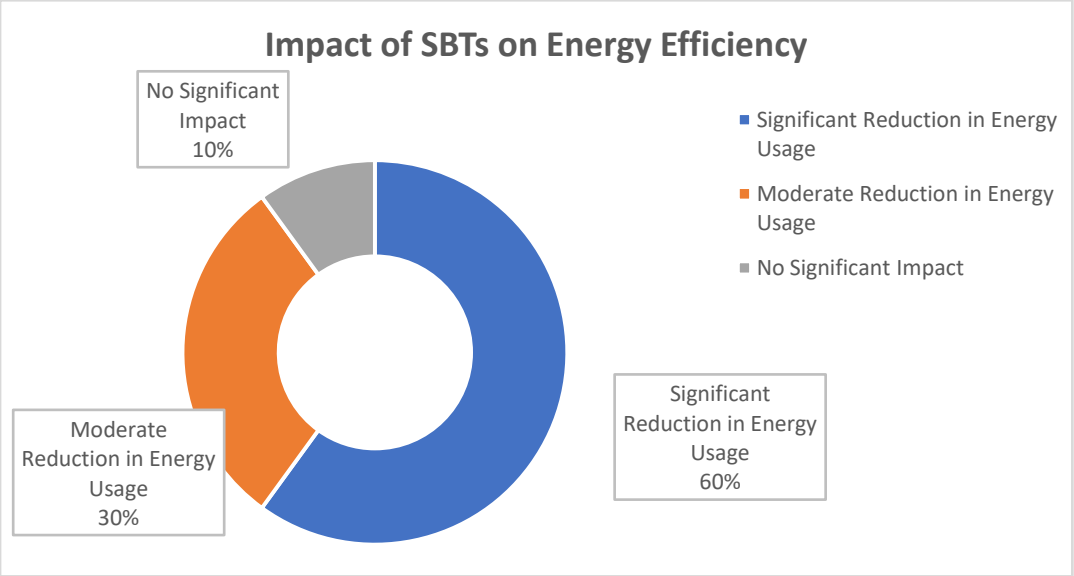
Table 2: Barriers to SBT Adoption

Barrier	Mean Score	Standard Deviation
High Cost of Implementation	4.5	0.6
Lack of Skilled Labor	4.2	0.72
Inadequate Infrastructure	4	0.81
Lack of Government Policies	3.8	0.85
Resistance to Change	3.6	0.9

The biggest obstacle, according to respondents, is the high cost of implementation (mean = 4.5), which is followed by a shortage of competent labor (mean = 4.2) and poor infrastructure (mean = 4.0).

4.4 Sustainability and Energy Management

Finding out how SBTs support sustainable energy management was another goal of the study. The perceived effect of SBTs on building energy efficiency was a question posed to the respondents. Fig.3 presents the findings.



The results show that 30% of respondents saw modest savings in energy use as a result of smart technology adoption, while 60% of respondents reported considerable reductions.

4.5 Inference-Based Statistics

A chi-square test was used to look at connections between demographic characteristics and SBT usage. The test assessed if the likelihood of adopting SBTs and occupation were significantly correlated.

Table 3: Chi-Square Test for Profession and Adoption of SBTs

Value	df	Asymp. Sig. (2-sided)
8.231	3	0.041

The chance of adopting SBTs and a respondent's occupation are statistically significantly correlated, according to the chi-square test ($\chi^2 = 8.231$, $p = 0.041$). This implies that some occupations are more likely to use smart technology than others, especially architects and facilities managers.

4.5.1 Analysis of Correlation

To ascertain the connection between adoption rates and SBT awareness, a Pearson correlation analysis was also carried out. Table 4 displays the findings.

Table 4: Pearson Correlation between Awareness and Adoption of SBTs

Variables	Correlation Coefficient (r)	Significance (p-value)
Awareness & Adoption	0.726	0.001

Awareness of smart building technologies and their adoption are strongly positively correlated, according to the Pearson correlation coefficient ($r = 0.726$, $p = 0.001$). This indicates that better adoption rates are typically linked to greater awareness.

4.6 Discussion of Findings

According to the data, only 20% of Nigerian construction professionals completely utilize smart building technology (SBTs), despite the fact that knowledge of SBTs is high among this group. High expenses, a shortage of competent labor, and poor infrastructure are major obstacles that highlight the necessity of industry training and government assistance. However, if these obstacles are removed, respondents reported large energy savings via SBTs, indicating tremendous potential for sustainable energy management. Furthermore, as awareness and adoption are correlated, focused educational initiatives may encourage increased adoption, and regulatory changes may improve infrastructure and accessibility to these technologies even more.

5. Conclusion and Recommendations

The study concludes that although professionals in Nigeria are well aware of smart building technologies (SBTs), the rate of complete implementation is still low. Significant obstacles to wider use include high implementation costs, a lack of competent labor, and inadequate infrastructure. However, the study demonstrates that SBTs may greatly improve energy efficiency, providing a sustainable route for the built environment in Nigeria. SBTs have the potential to solve some of Nigeria's most urgent energy management issues by lowering energy consumption and encouraging more effective resource use, which would benefit both operational cost reductions and environmental sustainability.The following suggestions are put out in an effort to increase the rate of SBT adoption:

Governmental Incentives and Policy Support: For real estate developers and organizations putting SBTs into practice, the government could offer incentives like tax breaks, subsidies, or low-interest loans. More stakeholders would be encouraged to embrace these technologies if clear policy frameworks supporting sustainable construction practices were established.

Industry-Specific Training Programs: Working with academic institutions and industry professionals, specialized training and certification programs should be created to address the lack of trained labor. This strategy would increase local knowledge of SBT installation and upkeep, decreasing dependency on outside knowledge and increasing the viability of smart technology adoption for Nigerian companies.

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