

Adapting Green Building Practices and Smart Technology in Developing Countries: A Review

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Abstract

This paper reviews the integration of green building practices and smart technologies in developing countries, focusing on the challenges and opportunities these regions face. While developed nations have advanced significantly in sustainability through green building certifications and smart systems, developing countries encounter barriers such as financial constraints, limited technical expertise, and insufficient policy frameworks. This research employs a systematic literature review to examine case studies from Africa, Southeast Asia, and Latin America, exploring how these regions can adapt sustainable practices to their unique socio-economic and environmental conditions. The findings reveal that despite significant challenges, green building and smart technologies offer long-term benefits, including improved energy efficiency, reduced operational costs, and enhanced quality of life. Successful adaptations, such as using locally sourced materials and implementing low-cost smart systems, demonstrate the feasibility of sustainable development even in regions with limited resources. Case studies from Nigeria, South Africa, and Kenya showcase promising examples where sustainable construction has been successfully integrated. This paper contributes to the existing body of knowledge by providing an in-depth analysis of the factors enabling or hindering the adoption of green building and smart technologies in developing nations. The research concludes that stronger governmental support, enhanced technical training, and broader awareness campaigns are essential to overcoming these barriers. Key recommendations include implementing financial incentives for developers, scaling successful green building projects, and fostering public-private partnerships to promote innovation. Additionally, the study calls for policy reforms that align with international sustainability goals while considering local challenges. In conclusion, the integration of green building practices and smart technologies presents a viable solution for sustainable urbanization in developing countries, offering a path toward environmental and economic resilience.

Keywords: Green Building, Smart Technology, Sustainability, Developing Countries, Urbanization.

Introduction

The global construction industry is undergoing a significant transformation, driven by the growing prominence of green building practices and smart technology (Shen & Wang, 2023). Green building involves the use of environmentally responsible and resource-efficient processes throughout a building's lifecycle, from design to demolition (Wang, 2023). The aim is to minimize the negative environmental impact of buildings while

improving energy efficiency, reducing waste, and enhancing indoor air quality. Smart technologies, such as IoT (Internet of Things), automation, and energy management systems, are increasingly integrated into buildings to optimize operational efficiency (Mishra & Singh, 2023). Together, these practices are critical to achieving sustainability goals, reducing greenhouse gas emissions, and addressing the growing threats posed by climate change.

Problem Statement

Despite the progress made by developed countries in implementing green building practices and smart technologies, many developing nations face significant barriers to adopting these innovations (Kineber, Oke, Elseknidy, Hamed & Kayode, 2023). Financial constraints, infrastructural deficiencies, limited technical expertise, and insufficient governmental support hinder widespread adoption. These obstacles are exacerbated by rapid urbanization, leading to increased energy consumption, poor environmental conditions, and a need for affordable, sustainable housing (Adedeji, 2023). Addressing these challenges is crucial for the environmental and ecological sustainability of developing countries, as their growing urban populations place increasing pressure on natural resources.

Objectives

This review aims to:

- i. Examine the current state of green building and smart technology adoption in developing countries.
- ii. Identify and analyze the barriers to implementation, such as financial, infrastructural, and policy-related challenges.
- iii. Explore opportunities for overcoming these obstacles by reviewing successful projects and case studies.
- iv. Provide recommendations for adapting green building practices and smart technologies to the unique social, economic, and environmental conditions of developing countries.

Literature Review

Green Building Practices

Green building practices, also known as sustainable building, involve designing, constructing, and operating buildings in ways that reduce their environmental impact (Okwandu, Esho, Iluyomade & Olatunde., 2024). These practices emphasize energy efficiency, the use of renewable resources, reduced water usage, waste minimization, and improved indoor air quality. Globally, green building certifications such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) have been widely adopted, especially

in developed nations (Maqbool, Thompson & Ashfaq., 2023). Studies show that green buildings offer long-term cost savings through reduced energy consumption and increased property values while contributing to the reduction of global greenhouse gas emissions (Chen, Huang, Hua, Chen, Wei, Osman & Yap., 2023).

The literature on green building adoption in developing countries shows that despite the global push for sustainability, these practices are not yet widespread in developing nations (Ghasemi, Azari & Zahed., 2024). Factors such as financial constraints, the high cost of sustainable materials, and limited access to technology have contributed to this slow uptake. However, some developing countries, such as South Africa, Kenya, and Nigeria, have begun implementing green building principles. In Nigeria, for example, the use of locally sourced materials such as compressed earth blocks, has shown promise for sustainable, low-cost construction. Several case studies highlight how developing nations have adapted green practices to their local climates and economies, but these efforts remain fragmented and face numerous challenges (Yazar., 2023).

The literature identifies several barriers to the widespread adoption of green building practices in developing countries. High initial costs, lack of access to sustainable materials, and limited technical expertise are common challenges. Additionally, a lack of governmental policies and incentives that encourage sustainable construction hinders growth. In many cases, there is a disconnect between international green building standards and the local realities of developing countries, leading to low adoption rates (Coral & Mithöfer., 2023). Another challenge is the perception that green buildings are a luxury rather than a necessity, especially in regions where basic infrastructure is lacking (Ahmad., 2023).

Smart Technology in Building Design

Smart building technology refers to the use of interconnected digital systems, sensors, and automation to enhance the operational efficiency of buildings (Ożadowicz., 2024). These technologies include IoT (Internet of Things), energy management systems, and smart grids, which allow buildings to self-regulate their energy consumption, improve safety, and optimize resource use. In developed countries, smart technologies have been widely adopted in commercial and residential buildings, reducing energy usage by monitoring and adjusting heating, cooling, and lighting systems in real-time (Apanavičienė & Shahrabani., 2023).

The integration of smart technologies in developing countries is still in its infancy. Limited infrastructure, unreliable electricity grids, and high costs are significant barriers to adoption (Altawalbeh & Sirhan., 2024). However, there have been some attempts to implement smart technology in urban areas, particularly in larger cities like Nairobi, Lagos, and Accra. Some smart initiatives, such as energy-efficient lighting and solar-powered IoT systems, have been deployed in public spaces to reduce energy consumption and costs (Mishra et al., 2023). Literature on this topic highlights the potential of smart technologies to address

urbanization challenges and improve building performance, but these projects are often limited to pilot programs or international partnerships and require further scaling to have a significant impact.

The literature outlines several barriers to smart technology adoption in developing countries. Chief among these is the lack of a reliable power supply, as many smart technologies require constant electricity to function. The high costs associated with implementing IoT systems and other smart technologies also pose a challenge, particularly for low-income communities and developers with limited resources. There is also a gap in technical expertise, as many countries lack the necessary training programs for architects, engineers, and technicians to implement and maintain smart building systems (Baharetha, Soliman, Hassanain, Alshibani & Ezz., 2024). Additionally, the absence of robust regulatory frameworks and incentives further limits the adoption of smart technology in the building sector.

Benefits of Adopting Green Building and Smart Technology

The literature highlights numerous benefits associated with green building and smart technology adoption, particularly for developing countries. Green buildings can significantly reduce energy and water consumption, contributing to long-term cost savings (Agbajor & Mewomo., 2024). Additionally, they improve indoor environmental quality, leading to healthier living and working conditions (Mewomo, Toyin, Iyiola & Aluko., 2023). Studies also show that green buildings, when integrated with smart technologies, further optimize energy use, as smart systems can monitor and adjust energy consumption based on real-time data (Ruiz, Vasquez & Jadan., 2023). The combined adoption of these practices can also contribute to the reduction of a building's carbon footprint, aligning with global sustainability goals.

Another critical benefit is the potential for job creation. The need for skilled labor to implement and maintain these technologies could drive new employment opportunities in developing countries, particularly in the construction, energy, and tech sectors. Lastly, adopting green and smart practices can enhance a country's global competitiveness, as sustainable buildings are increasingly seen as a marker of progress and innovation (Ahmad., 2023).

Policy and Government Support

Government policies play a critical role in promoting the adoption of green building practices and smart technologies. In developed nations, regulatory frameworks, tax incentives, and financial support mechanisms have spurred the growth of the green building sector (Li, Liu & Li., 2022). However, in developing countries, policy support is often weak or non-existent. The literature points to a significant gap between the need for sustainable building policies and their implementation in developing regions. Where

policies exist, they are often outdated, poorly enforced, or lack the necessary financial backing to be effective (Capano, Howlett, Jarvis, Ramesh & Goyal., 2020).

There are, however, some examples of progress. For instance, South Africa has developed a Green Building Council, which promotes sustainable construction practices and certifies green buildings (Agbajor et al., 2024). Similarly, in countries like Kenya and Nigeria, governments are beginning to introduce building codes that incorporate sustainability principles. These efforts, though promising, need to be scaled up, with stronger enforcement mechanisms, financial incentives, and public awareness campaigns to ensure widespread adoption.

Methodology

This study adopts a qualitative research approach, relying on secondary data to explore the adaptation of green building practices and smart technology in developing countries. A systematic literature review was employed to collect and analyze existing research, allowing for a comprehensive understanding of the trends, barriers, and opportunities discussed in academic and industry sources.

Literature Selection Criteria

The literature for this review was selected based on several inclusion and exclusion criteria to ensure relevance and quality:

Inclusion Criteria

- i. Peer-reviewed journal articles, conference papers, and reports published between 2020 and 2023.
- ii. Studies that specifically address green building practices, smart technology, or sustainability in developing countries.
- iii. Papers that focus on developing regions.

Exclusion Criteria

- i. Studies focusing on developed countries.
- ii. Articles that do not directly address the integration of green building and smart technology.
- iii. Papers published in non-peer-reviewed journals.

Data Analysis

The selected articles were systematically analyzed to identify common themes, trends, and challenges faced by developing countries in adopting green building practices and smart technologies.

Limitations

While the systematic literature review method provides a comprehensive analysis of the topic, it has several limitations:

- i. The study relies solely on published sources, which may exclude relevant information from ongoing or unpublished research.
- ii. The literature selection process, despite being systematic, may still be influenced by the availability of studies in certain databases and may not fully represent the global diversity of experiences.
- iii. The findings are based on secondary data, which might not fully capture the unique challenges or opportunities of every developing country.

Despite these limitations, the systematic review approach remains an appropriate method for synthesizing existing knowledge on green building and smart technology adaptation in developing countries.

Results and Discussion

Overview of Reviewed Papers

A total of 15 papers were reviewed for this study, each providing insights into the adoption and integration of green building practices and smart technologies in developing countries.

PAPER 1: BENEFITS OF ADOPTING SMART BUILDING TECHNOLOGIES IN BUILDING CONSTRUCTION OF DEVELOPING COUNTRIES: REVIEW OF LITERATURE; *Cyril Chinonso Ejidike, Modupe Cecilia Mewomo (2023)*

The paper aims to identify the benefits of adopting smart building technology (SBT) in the construction industry, particularly in developing countries. To achieve this aim, the study conducted a systematic review of published literature on SBT adoption, focusing on identifying the benefits perceived by researchers. The goal was to promote understanding of SBT concepts among construction professionals in developing countries and encourage successful SBT adoption in these regions. The study utilized a systematic review approach, analyzing 55 papers retrieved from the Scopus database. These papers included both conference papers and journal articles. The study revealed several significant benefits of adopting SBT, including efficient energy consumption, cost-effective building maintenance and operation, job creation, healthcare management, real-time monitoring, and improved safety and security.

PAPER 2: URBAN PLANNING AND GREEN BUILDING TECHNOLOGIES BASED ON ARTIFICIAL INTELLIGENCE: PRINCIPLES, APPLICATIONS, AND GLOBAL CASE STUDY ANALYSIS; *Minyue Ge, Zhang Feng and Qian Meng (2024)*

This paper aims to explore the application of AI technology in green building practices, particularly focusing on its role in reducing negative environmental impacts, improving occupant health, and optimizing indoor environmental quality. The paper seeks to: Discuss

the role of AI in urban planning and design; Examine the critical role of green building technology in sustainable development; Detail the basic principles and applications of AI-driven green building technologies; Analyze the LEED assessment system and its impact on green building practices; Explore specific applications of AI in green building design, such as water use, wind environment optimization, and solar technology. The paper is a literature review or conceptual paper, relying on existing research and analysis to present its findings. The paper highlights the potential of AI to improve various aspects of green building design and operation, including: Reducing negative environmental impacts; Improving occupant health; Efficiently using resources; Optimizing indoor environmental quality.

The paper also identifies the LEED assessment system as a key driver in advancing green building practices and discusses specific applications of AI, such as water use optimization and machine learning-driven wind environment analysis.

PAPER 3: A REVIEW OF SMART GREEN BUILDING TECHNOLOGIES: INVESTIGATING THE INTEGRATION AND IMPACT OF AI AND IOT IN SUSTAINABLE BUILDING DESIGNS;
Aniekan Akpan Umoh, Chinedu Nnamdi Nwasike, Olawe Alaba Tula, Oladipo Olugbenga Adekoya & Joachim Osheyor Gidiagba (2024)

This scholarly paper aims to explore the integration and impact of Artificial Intelligence (AI) and the Internet of Things (IoT) in smart green building technologies, focusing on their role in enhancing building performance and sustainability. The paper seeks to: Understand the transformative role of AI and IoT in sustainable architecture; Examine the synergy between AI and IoT in building management; Identify the challenges and benefits of implementing AI and IoT in green buildings; Assess the environmental, social, and economic implications of investing in AI and IoT technologies; Recommend strategies for overcoming barriers to the adoption of AI and IoT in green buildings. The paper adopts a methodological approach centered on an extensive literature review and qualitative analysis. It meticulously examines the synergy between AI and IoT, their implementation challenges, environmental and social impacts, and the economic implications of investing in such technologies. The paper's main findings reveal that the integration of AI and IoT significantly elevates energy efficiency, optimizes building performance, and contributes to environmental sustainability. The study highlights innovative IoT solutions in building management, demonstrating their effectiveness in creating more efficient and sustainable living spaces. However, it also identifies barriers to the adoption of these technologies, including economic constraints and the need for skilled professionals.

The paper concludes by recommending a multi-faceted approach to overcome these challenges, emphasizing policy interventions, educational initiatives, and the development of cost-effective green building technologies. It underscores the need for collaborative efforts from various stakeholders to advance sustainable architecture and building management. Overall, the paper provides a comprehensive exploration of the integration

of AI and IoT in sustainable building designs, offering insights into their potential to revolutionize the construction industry and pave the way for sustainable urban development.

PAPER 4: SUSTAINABLE ARCHITECTURAL PRACTICES: INTEGRATING GREEN DESIGN, SMART TECHNOLOGIES, AND ULTRA-LOW ENERGY CONCEPTS; *Zihan Mi (2024)*

This comprehensive study aims to explore the integration of green building practices, smart technologies, and ultra-low energy consumption strategies in modern architecture, focusing on their role in promoting environmental sustainability and operational efficiency. The paper seeks to: Examine existing green buildings, smart technology implementation, and ultra-low energy structures; Provide a quantitative and qualitative overview of the benefits and challenges associated with sustainable architectural practices; Analyze life cycle assessments, energy efficiency models, and the application of renewable energy sources; Explore the technological integration of smart systems for optimizing building performance; Demonstrate the feasibility and effectiveness of integrated approaches in achieving sustainable, efficient, and comfortable living and working environments; Provide a roadmap for future developments in sustainable architecture. The study appears to have employed a combination of quantitative and qualitative research methods, including life cycle assessments, energy efficiency models, case studies, and real-world applications.

The analysis reveals significant environmental impacts, including reduced carbon emissions and lower water usage, alongside notable economic benefits such as decreased operational costs and enhanced property values. The study also highlights the importance of technological integration of smart systems for optimizing building performance and demonstrates the feasibility and effectiveness of integrated approaches in achieving sustainable, efficient, and comfortable living and working environments.

PAPER 5: IDENTIFICATION AND NECESSITY OF USING SUSTAINABLE ARCHITECTURE IN SMART GREEN BUILDINGS; *Mandana Davoodi, Shima Zanjirei (2024)*

This article aims to investigate smart green buildings with a sustainable architecture approach, exploring the integration of smart technologies and green building principles to create efficient and environmentally friendly structures. The paper seeks to: Discuss the concept of green buildings and their benefits; Explore the role of smart technologies in building design and management; Examine the relationship between smart buildings and sustainable development; Identify the dimensions of sustainability in architecture; Investigate existing examples of sustainable architecture and smart green buildings. The research employed a qualitative approach, utilizing the library method to study books, articles, and magazines. This allowed for an in-depth examination of the concepts of smart buildings, sustainable development, dimensions of sustainability, and relevant case studies. The research explored the benefits and potential of smart green buildings, highlighting their role in energy efficiency, reduced carbon emissions, and improved sustainability.

PAPER 6: SUSTAINABLE GREEN BUILDING INITIATIVES IN MALAYSIA: ISSUES IN THE IMPLEMENTATION PRACTICES; *Zuhaila Zakaria, Nor Rima Muhamad Ariff, Nur Maizura Ahmad Noorhani And Mohd Mawardi Hussain (2024)*

This research aims to identify the main issues faced by green building projects in Malaysia to ensure the performance of the building can be maintained and improved. The research seeks to: Collect the views of experienced participants on the issues faced in green building projects in Malaysia; Identify the urgent issues that need to be addressed to maintain and improve the performance of green buildings; Support the regulation of green building maintenance; Contribute to the growth and success of green building initiatives in the Malaysian construction industry. The research employed a questionnaire survey to collect the views of 72 experienced participants. The findings reveal that operation and maintenance are urgent issues that need to be addressed in Malaysian green building projects, underscoring the need for policy intervention.

PAPER 7: INTEGRATING SUSTAINABILITY AND GREEN PRACTICES IN PROJECT MANAGEMENT: ADAPTING TO SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN KENYAN AND AFRICAN PROJECTS; *Martin Otundo Richard (2024)*

This study examines the integration of sustainability and green practices into project management across Africa, focusing on how various countries are adapting to Sustainable Development Goals (SDGs) and incorporating environmentally friendly practices. The research seeks to: Review literature from all 54 African countries to identify patterns, successes, and challenges in sustainable project management; Assess the variability in the adoption of green practices across African countries; Identify successful examples of sustainable project management in Africa; Analyze the challenges hindering the adoption of green practices in African projects; Provide recommendations for promoting sustainability in project management across Africa. The study conducted a comprehensive review of literature from all 54 African countries to identify patterns, successes, and challenges in sustainable project management. The findings reveal significant variability in the adoption of green practices, with some countries demonstrating considerable progress, particularly in renewable energy and urban development projects. Challenges such as inconsistent policy enforcement, limited technical capacity, and inadequate stakeholder engagement persist across many regions. The study concludes that effective sustainable project management requires a comprehensive approach encompassing environmental, social, and economic dimensions. Strong regulatory frameworks, improved technical capacity, and enhanced stakeholder engagement are critical for promoting sustainability.

PAPER 8: EVALUATING THE IMPLEMENTATION OF GREEN BUILDING PRACTICES IN NIGERIA; *Hyginus. C. O. Unegbua, Danjuma, S. Yawasaa, Bashar Dan-Asabea, Abdulmumin A. Alabia (2024)*

This research study aimed to evaluate the implementation and impact of green building practices within the context of Nigeria's burgeoning construction industry. The study's objectives were to: Assess the current level of green building awareness in Nigeria; Identify prevalent barriers and challenges to green building adoption; Recognize the perceived benefits and impacts of green construction practices. The research employed a quantitative research methodology, involving data collection from construction professionals across diverse sectors. The findings revealed a moderate level of green building awareness in Nigeria, accompanied by a notable recognition of both the advantages and challenges associated with sustainable construction. The study underscored the strong positive correlation between green building awareness and perceived benefits, and the significant role of reducing barriers in enhancing the perception of benefits.

PAPER 9: BARRIERS TO SUSTAINABLE GREEN BUILDING PRACTICE IN NIGERIA; *Shamsudeen Abdulazeez Agboola, Faruq Ayobami Idowu, Faruq Mustapha Yusuf And Abdulhakeem Kolawole Musa (2023)*

This study aims to identify the obstacles hindering the adoption of green building practices in Nigeria, particularly in the states of Abuja and Lagos. The study seeks to: Assess the level of understanding of Green Building Technologies among professionals, freelancers, and clients; Identify the challenges in developing policies and setting guidelines for green building; Examine the ambiguity surrounding green equipment and materials; Assess the level of interest and interaction among project team members; Explore the barriers to the implementation of green building practices in Nigeria. The study collected data from professionals, freelancers, and clients in Abuja and Lagos. The collected data was analyzed using SPSS 25.0.

The study found that the lack of understanding of Green Building Technologies was the most significant obstacle to green building adoption, followed by a lack of institutions for policy development and guidelines, ambiguity with green equipment and materials, and lack of interest and communication among project team members. Additionally, the study identified other barriers such as long design and approval procedures, a shortage of sustainable materials, a proclivity to stick with present practices, a lack of building norms and regulations, and a lack of awareness about green products and powerful building systems.

PAPER 10: GREEN BUILDING BEST PRACTICES IN ACHIEVING ENERGY AND ENVIRONMENTAL SUSTAINABILITY; *Noraina Mazuin Sapuan, Nazatul Faizah Haron, Vikniswari Vija Kumaran, Nur Surayya Saudi, Abdul Rahim Ridzuan (2022)*

This study aims to investigate the most relevant practices for green building employment, evaluate the benefits produced by the execution of green building, and analyze the best practices of green building characteristics. The study seeks to: Identify the most relevant practices for green building employment; Evaluate the benefits produced by the execution

of green building; Analyze the best practices of green building characteristics. The methodology of the study is not explicitly stated in the abstract. However, it can be inferred that the study likely involved a review of existing literature on green building practices, case studies of green buildings, and possibly interviews or surveys with experts in the field. The study found that green buildings developed using energy-efficient systems and implementing sustainable practices can reduce energy consumption and lower the cost of operating and maintaining these buildings in the long term. Additionally, the study highlighted the essential role of the government in attracting more participants in implementing sustainable practices in the construction and building sector through stricter regulations and appealing incentives.

PAPER 11: A COMPARATIVE CASE STUDY OF SMART AND GREEN BUILDINGS AND THEIR IMPACT ON POWER QUALITY; *Ruliyanta Ruliyanta, Victor Vecky R. Repi, R. A. Suwodjo Kusumoputro, Idris Kusuma, Wismanto Setyadi (2023)*

This research aims to investigate the integration of green and smart building concepts, focusing on the application of smart building technology, particularly HVAC systems, in a new government building in Indonesia. The study specifically explores the impact of inverter technology on electrical energy quality. The study seeks to: Examine the integration of green and smart building concepts in the new government building; Investigate the use of smart building technology, particularly HVAC systems, in the building; Assess the impact of inverter technology on electrical energy quality; Identify potential issues related to harmonics and their impact on the transformer; Recommend solutions to address the identified problems.

The research involved an infestation of the quality of electrical energy due to the use of an inverter. This likely involved measuring and analyzing electrical parameters such as current and voltage harmonics. The study found that the use of inverter technology in the HVAC system led to significant harmonic distortion in both current and voltage. The total distortion current reached more than 5% at a load current exceeding 159.06 amperes, while the total distortion voltage harmonics reached up to 41.83%. This condition greatly affects the performance of the transformer. To overcome this problem, the study recommends using a harmonic filter on the capacitor bank.

PAPER 12: INNOVATIONS IN SUSTAINABLE ENGINEERING: A REVIEW OF GREEN TECHNOLOGIES; *Banishree Sukla, Mr. Rohit Jakhar, Dr. Salma Begum, M. Mary Jasmine, Srinidhi Sundaram (2024)*

This review research paper aims to explore innovations in sustainable engineering, focusing on green technologies that offer environmentally friendly solutions. The objectives are to: Contextualize the importance of sustainable engineering in addressing environmental challenges; Examine a diverse range of green technologies across various sectors; Analyze advancements in renewable energy generation (solar, wind, hydro, biomass); Investigate

innovations in waste management (recycling, composting, waste-to-energy); Explore sustainable water management solutions (desalination, wastewater treatment, irrigation); Discuss sustainable transportation technologies (electric vehicles, hybrid engines, public transit); Analyze green building practices (materials, design strategies, smart technologies); Emphasize the potential of green technologies for environmental, economic, and social benefits; Address challenges associated with green technology adoption.

The methodology is not explicitly stated but likely involves a review of existing literature on sustainable engineering practices, green technologies, and advancements in specific sectors. The paper finds that green technologies offer a comprehensive approach to environmental sustainability across various domains. Key findings include: Advancements in renewable energy are improving efficiency, reducing costs, and enabling wider adoption; Innovations in waste management promote recycling, composting, and waste-to-energy conversion; Sustainable water management solutions address water scarcity through desalination, improved wastewater treatment, and efficient irrigation; Sustainable transportation technologies like electric vehicles and public transit reduce emissions and traffic congestion; Green building practices utilize sustainable materials, energy-efficient design, and smart technologies for occupant comfort with minimal environmental impact. The paper acknowledges challenges like technological barriers, regulations, and socio-economic factors but ultimately highlights the transformative potential of green technologies in achieving a sustainable future.

PAPER 13: BUILDING SUSTAINABLE SMART CITIES AND THE GREEN BUILDING AGENDA; Kholofelo Evelyn Lamola (2023)

This paper aims to explore the relationship between smart cities and sustainable development, particularly in the context of developing countries in Africa. It seeks to understand how the smart city concept can be integrated into existing sustainable development agendas and whether a smart city can be achieved without sustainability and green practices. Objectives of the study include to: Compare past development initiatives with current smart city initiatives; Identify gaps and challenges in achieving sustainable smart cities; Develop a vision for future smart cities; Understand the integration of green building concepts into smart city initiatives.

The methodology is not explicitly stated in the abstract, but it is likely that the paper will involve a literature review of existing development initiatives, sustainable development agendas, and smart city concepts. It may also include case studies of specific cities or regions to illustrate the implementation of these concepts.

PAPER 14: SUSTAINABLE URBAN INFRASTRUCTURE: INNOVATIONS IN GREEN BUILDING TECHNOLOGIES AND URBAN PLANNING; Arun Singla (2024)

This paper aims to explore the intersection of green building technologies and urban planning as pivotal components in fostering sustainable urban development. The study objectives are to: Examine the role of green building technologies in mitigating the environmental impact of urbanization; Analyze the potential of green building technologies to enhance residents' quality of life; Discuss specific innovations in green building technologies, such as passive design strategies, green roofs, and smart building systems; Evaluate the impact of these technologies on energy consumption and carbon emissions in urban environments.

The methodology is not explicitly stated in the abstract, but it likely involves a review of existing literature on green building technologies, urban planning, and sustainable urban development. Case studies of successful green building projects and their impact on urban environments may also be included.

The findings suggests that green building technologies offer promising solutions to mitigate the environmental impact of urbanization and enhance residents' quality of life. Specific innovations such as passive design strategies, green roofs, and smart building systems demonstrate the potential to reduce energy consumption and carbon emissions in urban environments.

PAPER 15: CONCEPTUALIZING SUSTAINABLE SMART COUNTRY: UNDERSTANDING THE ROLE OF DIFFERENT SECTORS IN BUILDING ITS STRUCTURE; *Muhammad Younus, Achmad Nurmandi (2023)*

This article aims to theorize the concept of a Smart Country and provide a framework for its conceptualization. The paper seeks to: Define a Smart Country and its necessary prerequisites; Discuss the political, security, social, economic, and environmental aspects of a Smart Country; Identify the three interdependent actors (Smart Government, Smart Citizens, Smart Technology) as the pillars of a Smart Country; Explain the role of each actor in creating and adopting sustainable Smart Country practices; Provide a framework for policymakers and researchers to develop future strategies for building sustainable Smart Countries. The research is based on a comprehensive literature review and analysis.

The paper proposes a holistic concept of a Smart Country that considers various aspects, including political, security, social, economic, and environmental factors. It identifies the three interdependent actors (Smart Government, Smart Citizens, Smart Technology) as crucial for the success of a Smart Country. The paper outlines the role of each actor in creating and adopting sustainable Smart Country practices.

Key Findings

Benefits of Green Building Practices and Smart Technologies

- i. **Energy Efficiency and Cost Savings:** Ejidike & Mewomo (2023) highlighted that adopting Smart Building Technologies (SBT) leads to efficient energy consumption and cost-effective building maintenance. Mi (2024) found that green buildings

utilizing energy-efficient systems can significantly reduce energy consumption and operational costs over time.

- ii. **Enhanced Building Performance and Sustainability:** Umoh et al. (2024) demonstrated that integrating AI and IoT in green buildings enhances energy efficiency and overall building performance. Davoodi & Zanjirei (2024) emphasized the role of smart technologies in optimizing resource management and reducing environmental impacts.
- iii. **Improved Occupant Health and Safety:** Ge et al. (2024) discussed how AI-driven green building technologies improve indoor environmental quality, thereby enhancing occupant health. Zakaria et al. (2024) noted that smart technologies contribute to better healthcare management and improved safety within green buildings.
- iv. **Job Creation and Economic Benefits:** Ejidike & Mewomo (2023) pointed out that the adoption of SBT can create job opportunities in the construction and maintenance sectors. Sapuan et al. (2022) highlighted that green building practices can lead to long-term economic benefits through reduced operational costs and increased property values.

Barriers to Adoption

- i. **Financial Constraints:** Zakaria et al. (2024) identified high initial costs associated with green building technologies as a significant barrier in Malaysia. Unegbua et al. (2024) reported that financial limitations impede the widespread adoption of green practices in Nigeria.
- ii. **Policy Gaps and Regulatory Challenges:** Agboola et al. (2024) emphasized the lack of robust regulatory frameworks as a major obstacle in Nigeria's green building sector. Richard (2024) highlighted inconsistent policy enforcement across African countries, hindering sustainable project management.
- iii. **Technological Challenges and Lack of Expertise:** Umoh et al. (2024) noted the shortage of skilled professionals as a barrier to implementing AI and IoT technologies in green buildings. Sapuan et al. (2022) pointed out technological barriers and the need for advanced training to effectively utilize green technologies.
- iv. **Awareness and Educational Deficits:** Agboola et al. (2024) found that limited awareness of Green Building Technologies among professionals and clients restricts their adoption. Mi (2024) emphasized the necessity for educational initiatives to promote understanding and implementation of sustainable practices.

Discussion

To provide a clearer understanding of the findings, the discussion is organized into specific subsections addressing the primary barriers and benefits identified in the reviewed literature.

Financial Barriers

Financial constraints remain a predominant barrier to the adoption of green building practices and smart technologies in developing countries. High initial investment costs deter stakeholders from committing to sustainable construction projects. For instance, Zakaria et al. (2024) reported that the significant upfront costs associated with green technologies in Malaysia limit their widespread implementation. Similarly, Unegbua et al. (2024) highlighted financial limitations in Nigeria, where budget constraints impede the adoption of sustainable practices despite the long-term cost benefits.

Policy Gaps and Regulatory Challenges

The absence of comprehensive policy frameworks and inconsistent enforcement of existing regulations are critical challenges hindering sustainable building practices. Agboola et al. (2024) identified the lack of clear guidelines and supportive policies in Nigeria as significant obstacles. Richard (2024) further noted that across various African nations, inconsistent policy enforcement undermines efforts to integrate sustainability into project management.

Technological Challenges and Lack of Expertise

The integration of advanced technologies such as AI and IoT into green buildings requires specialized knowledge and skills, which are often scarce in developing countries. Umoh et al. (2024) emphasized the shortage of skilled professionals as a barrier to the effective implementation of these technologies. Additionally, Sapuan et al. (2022) pointed out technological barriers that prevent the seamless adoption of green technologies.

Awareness and Educational Deficits

Limited awareness and understanding of green building practices and smart technologies among stakeholders impede their adoption. Agboola et al. (2024) found that professionals and clients in Nigeria have insufficient knowledge about Green Building Technologies, which reduces their willingness to invest in sustainable practices. Mi (2024) highlighted the importance of educational initiatives to bridge this knowledge gap.

Benefits Realized from Adoption

Despite the challenges, the adoption of green building practices and smart technologies offers substantial benefits that drive their continued implementation. Enhanced energy efficiency, reduced operational costs, improved occupant health, and increased property

values are among the key advantages identified. Ejidike & Mewomo (2023) and Mi (2024) both emphasized the long-term economic and environmental benefits of sustainable construction practices.

Conclusion and Recommendations

In conclusion, the integration of smart building technologies and green building practices presents significant opportunities for promoting sustainability and energy efficiency in the construction industry, particularly in developing regions such as Sub-Saharan Africa and Nigeria. These technologies—ranging from Artificial Intelligence (AI) and the Internet of Things (IoT) to Building Information Modeling (BIM)—can revolutionize the way buildings are designed, constructed, and maintained. When implemented correctly, they offer substantial benefits, including reduced energy consumption, improved operational efficiency, enhanced occupant comfort, and long-term cost savings. Furthermore, the adoption of renewable energy sources, sustainable materials, and eco-friendly design strategies is critical to mitigating the adverse environmental impacts of the construction industry.

However, despite the clear potential and advantages, several challenges continue to impede the widespread adoption of these practices. Key obstacles include the high upfront costs of smart and green technologies, limited technical expertise, inadequate governmental support, and a lack of awareness regarding the long-term benefits of sustainability in construction. In Nigeria, these challenges are further compounded by insufficient regulatory frameworks and weak enforcement mechanisms, which hinder the systematic implementation of energy-efficient and sustainable building practices.

To address these barriers and ensure the successful integration of sustainable technologies in building projects, several key recommendations are proposed:

- i. **Government Policies and Incentives:** Governments in developing regions must take the lead in promoting sustainable building practices by establishing robust policies and offering financial incentives. These incentives could include tax reductions, subsidies for green technologies, or grants for developers who prioritize sustainability in their projects. Additionally, stricter enforcement of building codes related to energy efficiency and environmental impact is crucial.
- ii. **Education and Training Programs:** The development of local technical expertise is essential to the widespread adoption of smart building and green technologies. Educational institutions and industry stakeholders should collaborate to create training programs and workshops that equip professionals with the necessary skills to implement and maintain these technologies. Moreover, public awareness campaigns could help inform communities about the benefits of sustainable construction and encourage wider support.
- iii. **Research and Development:** Continued investment in research and development (R&D) is necessary to refine existing technologies and develop cost-effective

solutions tailored to the specific needs of developing regions. This includes innovations in energy-efficient design, sustainable materials, and smart systems that are affordable and scalable in low-income environments.

- iv. Collaborative Approach: Stakeholders from government, academia, and industry should work together to foster a collaborative environment that promotes the sharing of knowledge, best practices, and resources. Joint ventures, public-private partnerships, and international collaborations could accelerate the adoption of sustainable building technologies and foster a culture of innovation in the construction industry.
- v. Sustainable Maintenance Practices: A focus on sustainable building does not end with construction; the long-term operation and maintenance of these buildings are equally critical. Implementing efficient building management systems, regular maintenance schedules, and training personnel in the upkeep of green technologies will ensure that the sustainability goals of these buildings are realized throughout their lifecycle.

While the recommendations presented provide actionable steps toward the adoption of smart and green building technologies, further research is necessary to address gaps and explore emerging opportunities. Future studies could focus on the following areas:

- i. Smart Technologies for Low-Income Housing: There is a pressing need to explore how smart technologies, including AI, IoT, and BIM, can be adapted for use in low-income housing within developing countries. Research in this area could focus on cost-effective solutions that leverage local materials and labor while still achieving energy efficiency and sustainability goals.
- ii. Cost-Benefit Analysis of Green Technologies: Future research should investigate the long-term cost savings associated with adopting green building practices in different climatic regions of developing countries, providing more localized data to make a stronger business case for investment in these technologies.
- iii. Integration of Renewable Energy in Urban Areas: As cities in developing regions continue to grow, studies on how renewable energy sources, such as solar and wind, can be integrated into urban areas to supplement grid electricity and improve reliability would be beneficial. Special attention should be paid to overcoming the infrastructural limitations and energy storage challenges specific to these regions.
- iv. Cultural and Socio-Economic Barriers to Sustainable Building: Further research is needed to understand the cultural and socio-economic factors that may affect the adoption of smart and green building technologies in different communities. Such studies could help in developing more tailored approaches to introducing sustainability in construction, ensuring that solutions align with local values and practices.
- v. Scalable Models for Sustainable Construction: Another potential research direction is the development of scalable models for sustainable construction that can be

applied across various contexts—from high-end commercial buildings to affordable housing—without compromising on sustainability principles.

In summary, while the challenges to adopting smart and green building technologies in developing regions are significant, they are not insurmountable. With the right mix of policies, incentives, education, and collaboration, the construction industry can make meaningful strides toward sustainability. Embracing these solutions not only supports environmental goals but also contributes to economic resilience and improved quality of life for building occupants.

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