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IMPACT OF GEOGRAPHICAL INFORMATION SYSTEM ON SUSTAINABLE BUILT ENVIRONMENT

[1]TOSIN OMOTOSHO & [2]LUKUMAN MUSIBAU

[1]Department of Estate Management and Valuation, Ajayi Crowther University, Oyo, Nigeria. [2]Department of Estate Management and Valuation, The Federal Polytechnic, Ede, Nigeria.
osamueltosin@gmail.com

Abstract

This study provides platform to the utilization of Geographic Information Systems (GIS) in advancing sustainable development within the built environment vis-à-vis pivotal role of GIS in fostering sustainability in construction and urban planning through innovation, education, and training. The study investigates the pivotal role of Geographical Information Systems (GIS) in sustainable development, motivated by the increasing recognition of GIS as a transformative tool. The research aims to understand why GIS is crucial in shaping sustainable development initiatives, delving into its historical evolution, diverse applications, and contributions to achieving sustainable development goals. Employing a methodological approach that combines surveys, and literature analysis, the study meticulously explores GIS implementation in various contexts by distributing a structured questionnaire to the respondent from Federal School of Surveying, Oyo and staff of Environmental Studies, Federal Polytechnic Ede. Data gotten was analyzed using descriptive means of analysis and presented using table. The findings underscore GIS's significance in enhancing decision-making processes, resource management, and environmental conservation. Successful case studies in environmental conservation, disaster response, and urban planning exemplify GIS's positive impact, despite acknowledged challenges in

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Prof. A.I. Mteiye [MALAWI]

data accuracy, accessibility, and interoperability. The most crucial result identifies GIS as a transformative tool influencing sustainable development goals. The study recommends leveraging GIS for informed decision-making, urging policymakers to address challenges in data management to unlock GIS's full potential in sustainable development initiatives.

Introduction

The built environment plays a pivotal role in the pursuit of sustainable development, encompassing various aspects of construction, urban planning, and resource utilization. In recent years, the utilization of Geographic Information Systems (GIS) has emerged as a transformative force in enhancing sustainability within the built environment. GIS, a technology that integrates spatial data and analysis, offers unprecedented capabilities in decision-making, planning, and fostering environmentally conscious practices. This study delves into the dynamic interplay between GIS and sustainable development within the built environment, aiming to shed light on the multifaceted contributions of GIS to innovation, education, and training in construction and urban planning.

The escalating recognition of GIS as a powerful tool for shaping sustainable development initiatives underscores the need for a comprehensive investigation into its historical evolution, diverse applications, and its pivotal role in achieving sustainable development goals (Longley et al., 2015; Wang & Yang, 2016). This research seeks to bridge knowledge gaps and provide insights for practitioners, policymakers, and researchers by examining the intricate relationship between GIS and the built environment. As urbanization rises and environmental challenges intensify, understanding the transformative potential of GIS becomes increasingly critical for fostering resilient and sustainable built environments. The evolution of GIS technology has significantly influenced the trajectory of sustainable development in the built environment. GIS facilitates the integration of spatial and non-spatial data, enabling a holistic understanding of complex urban systems and environmental dynamics (Jiang, 2015; Nyerges, 2018). The capacity of GIS to provide real-time data, spatial analysis, and visualization has become instrumental in addressing the intricate challenges of contemporary urbanization and ensuring the efficient allocation of resources (Sui, 2018). Risk managers, however, need to have access to contact assistance for GIS devices in order to comprehend the terrifying character or hazard dimension, as Brumarová (2021) emphasized.

In the context of sustainable development, GIS contributes to informed decision-making by offering spatial insights that extend beyond traditional planning approaches (Albert & Lechner, 2019; Carver, 2017). This research seeks to elucidate how GIS acts as a catalyst for sustainability, fostering innovation through its applications in infrastructure

development, land-use planning, and disaster resilience (Davies & Shyu, 2019; Li et al., 2020). Additionally, GIS's role in education and training within the built environment is explored, recognizing its potential to cultivate a workforce equipped with the spatial literacy required for sustainable urban development (Obermeyer & Pinto, 2017; Wong, 2018).

Literature review

Historical Evolution of GIS in the Built Environment

The inception of Geographic Information Systems (GIS) in the built environment can be traced to the mid-20th century when technological advancements catalyzed a paradigm shift in spatial data management and analysis (Coppock & Rhind, 1991; Star & Estes, 1990). Early GIS applications emerged in the realm of cartography, focusing on digitizing maps to enhance their accessibility and usability (Foresman, 2019; Tomlinson, 2003). These foundational efforts laid the groundwork for integrating spatial data into decision-making processes, heralding the evolution of GIS as a transformative tool for the built environment.

The 1960s witnessed the advent of computer-based GIS, marking a pivotal moment in its historical trajectory (Longley et al., 2015). The development of Geographic Information Systems can be attributed to pioneers like Roger Tomlinson, whose groundbreaking work in Canada's Land Inventory initiated the systematic digitization of geographic information (Tomlinson, 2003). This digital transformation not only streamlined traditional cartographic processes but also paved the way for spatial analysis and modeling capabilities that would later become integral to sustainable development practices in the built environment. As GIS technology continued to advance, the 1980s witnessed the integration of satellite imagery and remote sensing data into GIS platforms, expanding the scope of applications beyond static maps (Goodchild, 2010; Star & Estes, 1990). This marked a critical juncture in GIS's evolution, allowing for a dynamic understanding of spatial phenomena and enabling more sophisticated analyses in areas such as land-use planning and environmental assessment. The subsequent decades witnessed the democratization of GIS technology, with increasing accessibility and user-friendly interfaces driving its adoption across various sectors (Longley et al., 2015; Nyerges, 2018). The development of open-source GIS software further accelerated its widespread use, empowering practitioners, researchers, and policymakers to harness spatial data for sustainable development within the built environment.

GIS Applications in Sustainable Development

GIS has become a linchpin in advancing sustainability within the built environment. Its applications are diverse, ranging from urban planning and infrastructure development to

natural resource management (Carver, 2017; Nyerges, 2018). In urban planning, GIS facilitates the analysis of land-use patterns, transportation networks, and environmental impacts, enabling informed decision-making for sustainable urban development (Albert & Lechner, 2019; Davies & Shyu, 2019). Moreover, GIS supports disaster resilience by providing real-time data for risk assessment, emergency response, and recovery planning (Li et al., 2020; Wong, 2018). According to Adeniyi and Ifeoluwa's (2021) study, the first step in creating an associate's degree emergency management curriculum is to look at the dangers and risks need to reduce exposure, react appropriately, and recover swiftly.

Spatial Analysis and Decision-Making

The core strength of GIS lies in spatial analysis, allowing for the integration of diverse datasets to derive meaningful insights (Jiang, 2015; Sui, 2018). In the built environment, this capability translates into optimized resource allocation, improved infrastructure planning, and effective land-use strategies (Obermeyer & Pinto, 2017; Tomlinson, 2003). GIS empowers decision-makers with tools to visualize spatial relationships, identify patterns, and simulate scenarios, contributing to sustainable urban development (Carver, 2017; Wong, 2018).

GIS in Education and Training for Sustainability

The role of GIS in education and training within the built environment is pivotal for cultivating a workforce equipped with spatial literacy and technological proficiency (Davies & Shyu, 2019; Obermeyer & Pinto, 2017). Integrating GIS into educational curricula enhances the understanding of spatial concepts, fosters critical thinking, and prepares professionals to address sustainability challenges in their careers (Li et al., 2020; Nyerges, 2018).

GIS Applications in Sustainable Development within the Built Environment

GIS Application in relation to Sustainable Development plays important role in the the Built Environment amongst which are:

Urban Planning and Land Use

GIS plays a pivotal role in urban planning and land use management, offering sophisticated tools for analyzing spatial patterns and facilitating informed decision-making (Carver, 2017; Albert & Lechner, 2019). By integrating demographic, economic, and environmental data, GIS enables planners to design sustainable urban environments, optimize transportation networks, and ensure efficient land allocation for residential, commercial, and green spaces (Davies & Shyu, 2019; Wong, 2018). This application fosters

comprehensive strategies for sustainable urban development, addressing challenges related to population growth, infrastructure demands, and environmental conservation.

Infrastructure Development

GIS contributes significantly to sustainable infrastructure development by optimizing the design, construction, and maintenance of essential facilities (Li et al., 2020). Through spatial analysis, GIS aids in identifying optimal locations for infrastructure projects, minimizing environmental impact, and enhancing resource efficiency (Carver, 2017; Wong, 2018). Whether planning transportation networks, energy distribution systems, or water supply infrastructure, GIS ensures that projects align with sustainability goals, promoting resilience and longevity in urban infrastructure.

Environmental Conservation and Natural Resource Management

GIS is a linchpin in environmental conservation, providing tools for monitoring and managing natural resources (Nyerges, 2018; Albert & Lechner, 2019). Through satellite imagery and spatial analysis, GIS facilitates the assessment of ecosystems, biodiversity, and land cover changes. This aids in designing and implementing conservation strategies, supporting sustainable resource utilization, and mitigating the impact of human activities on the environment (Davies & Shyu, 2019; Li et al., 2020).

Disaster Resilience and Emergency Response

GIS is instrumental in enhancing disaster resilience and emergency response within the built environment (Wong, 2018; Carver, 2017). By integrating real-time data on hazards, population density, and critical infrastructure, GIS allows for comprehensive risk assessments. This information is crucial for developing evacuation plans, optimizing emergency response routes, and mitigating the impact of natural disasters (Nyerges, 2018; Albert & Lechner, 2019). GIS's role in disaster management contributes to building resilient communities capable of withstanding and recovering from adverse events.

Community Engagement and Decision Support

GIS empowers community engagement and participatory decision-making in sustainable development initiatives (Obermeyer & Pinto, 2017; Wong, 2018). Through interactive maps and visualizations, GIS facilitates communication between stakeholders, fostering transparency and inclusivity in the decision-making process. This application ensures that community concerns are considered, promoting socially equitable and environmentally sustainable urban development (Carver, 2017; Davies & Shyu, 2019).

Benefits of GIS in Sustainable Development within the Built Environment

Within the Built Environment, below are some of the benefits of GIS in ensuring Sustainable Development:

Informed Decision-Making:

GIS empowers decision-makers with comprehensive spatial insights, facilitating informed choices in urban planning, resource allocation, and infrastructure development. By integrating diverse datasets, GIS enables a holistic understanding of complex urban systems, supporting sustainable decision-making processes (Carver, 2017; Albert & Lechner, 2019).

Optimized Resource Allocation:

One of the key advantages of GIS lies in its ability to optimize resource allocation. By analyzing spatial data, GIS aids in identifying optimal locations for infrastructure projects, minimizing environmental impact, and ensuring efficient land use. This optimization contributes to resource efficiency, reducing waste and promoting sustainable practices in construction and development (Wong, 2018; Davies & Shyu, 2019).

Environmental Conservation and Monitoring:

GIS facilitates environmental conservation by providing tools for monitoring and managing natural resources. From assessing biodiversity to tracking land cover changes, GIS supports the conservation of ecosystems. The ability to visualize and analyze environmental data aids in designing strategies for sustainable resource utilization and mitigating the impact of human activities on the environment (Nyerges, 2018; Li et al., 2020). High landslide hazard locations and frequency are located using GIS maps. When it comes to obtaining accurate results, GIS is among the most useful tools (Kapucu, 2020). The mapping assessment of landslide hazard zones is aided by the use of GIS tools such as ILWIS. In addition to being a quick and accurate tool for processing, evaluating, and displaying geographical data, it is a helpful tool for landslide risk analysis (Kirlin & Kirlin, 2020).

Resilience in Disaster Management:

GIS enhances resilience in disaster management by providing critical information for risk assessment and emergency response planning. The real-time data integration capabilities of GIS enable the identification of vulnerable areas, the optimization of evacuation routes, and the coordination of emergency services. This contributes to building disaster-resilient communities capable of adapting to and recovering from unforeseen events (Carver, 2017; Wong, 2018). Modern catastrophe management relies heavily on GIS, an advanced technology. This technology creates critical disaster-related decision-making information by fusing geospatial data with hardware and software capable of analyzing spatial, temporal, and attribute data (Sharma, Parkash, and Joshi, 2018).

Community Engagement and Social Equity:

GIS promotes community engagement and social equity by providing accessible and interactive platforms for communication. Through visualizations and mapping tools, GIS fosters dialogue between stakeholders, ensuring that diverse perspectives are considered in decision-making processes. This inclusivity contributes to socially equitable urban development, aligning with sustainability goals (Obermeyer & Pinto, 2017; Davies & Shyu, 2019).

Efficient Infrastructure Development:

GIS facilitates efficient infrastructure development by aiding in the selection of optimal locations and designs. Whether planning transportation networks, energy distribution systems, or water supply infrastructure, GIS ensures that projects align with sustainability goals. This efficiency extends the lifespan of infrastructure and reduces its environmental impact, promoting long-term sustainable development (Li et al., 2020; Wong, 2018).

Methodology

This study adopts a mixed-methods research design, combining qualitative and quantitative approaches to comprehensively explore the impact of Geographic Information Systems (GIS) on sustainable development within the built environment. The integration of both methods allows for a nuanced understanding of the multifaceted relationship between GIS applications and sustainability. The study focuses on participants from the Federal School of Surveying, Oyo, and the staff of Environmental Studies, Federal Polytechnic Ede. A purposive sampling method is employed to select participants with expertise in GIS, urban planning, environmental science, and related disciplines. This targeted approach ensures that participants possess the relevant knowledge and experience to provide valuable insights into the research questions.

Structured surveys are distributed to participants, gathering quantitative data on their experiences and perceptions regarding GIS applications in sustainable development. The survey includes questions on GIS utilization, challenges faced, and perceived effectiveness in fostering sustainability. In-depth interviews are conducted with key informants, including GIS practitioners, educators, and policymakers. These qualitative interviews aim to elicit detailed narratives, experiences, and expert opinions regarding the impact of GIS on sustainable development. Open-ended questions allow participants to elaborate on specific applications, challenges, and success stories. A comprehensive review of existing literature is conducted to supplement empirical findings. This involves analyzing scholarly articles, reports, and case studies related to GIS applications in sustainable development within the built environment. The literature analysis provides a theoretical foundation and context for the study. Survey responses are analyzed using

descriptive statistical methods, including frequencies and percentages. This quantitative analysis provides an overview of participants' perceptions and experiences with GIS applications.

Results

Quantitative Analysis

The quantitative analysis of survey responses provides valuable insights into the perceptions and experiences of participants regarding Geographic Information Systems (GIS) applications in sustainable development within the built environment. The survey, distributed to participants from the Federal School of Surveying, Oyo, and the staff of Environmental Studies, Federal Polytechnic Ede, aimed to capture quantitative data on GIS utilization, challenges faced, and perceived effectiveness in fostering sustainability. Data from 52 respondents, in the study areas, were analyzed as show in the table 1 below

Table 1: Demography and of the Respondents and their Usage of GIS

Description	Frequency **N = 52**	Percentage **(100%)**
Gender		
Male	36	69.2
Female	16	30.8
Education qualification		
OND	0	0
HND	8	15.4
B Sc	12	23.1
PGD	12	23.1
M Sc	16	30.8
PhD	4	7.7
Year of experience		
1-3years	20	38.5
4-6years	8	15.4
7-9years	8	15.4
10years and above	16	30.8
Usage of GIS in Professional Domain		
Yes	48	92.3
No	4	7.7

Source: Field Survey, 2024

The table 1 above shows the demographic response of the respondent from Federal School of Surveying and staff of Environmental Studies, Federal Polytechnic Ede . 69.2% of the respondent are male and the remaining 30.8% of the respondent are female. In determining the academic qualification of the respondent, it was gathered that none of

the respondent was OND holder, whereas 15.4% of the respondent are HND holder, 23.1%, 23.1%, 30.8% and 7.7% of the respondent are B Sc, PGD, M Sc and PhD holders respectively. Going by the year of experience of the respondent, it was gathered that 38.5% of the respondent have the experience of 1-3years, 15.4% of the respondent have 4-6years experience, 15.4% of the respondent claim they have 7-9years experience and the remaining 30.8% of the respondent have an experience of 10years and above. Also, response of the respondent as to the usage of GIS in their respective professional domain revealed and well evident that the higher percentage of respondent 92.3% claim they use GIS in their professional domain and this give the outcome of this research the validity as many respondent have experience on the subject matter.

On significance of GIS in Sustainable Built Environment, factors such as aiding decision making, resources management, environmental conservation, effective site analysis, disaster response and effective planning were analyzed on 4-Likert scale ranges from highly effective to not effective. The result is as indicated in table 2 below.

Table 2: Significance of GIS in Sustainable Built Environment

Factors	Highly Effective	Effective	Less Effective	Not Effective
Aid Decision Making	16 (30.8%)	32 (61.5%)	4 (7.7%)	0 (0%)
Resources Management	24 (46.2%)	28 (53.8%)	0 (0%)	0 (0%)
Environmental Conservation	12 (23.1%)	32 (61.5%)	8 (15.4%)	0 (0%)
Effective Site Analysis	28 (53.8%)	20 (38.5%)	4 (7.7%)	0 (0%)
Disaster Response	24 (46.2%)	20 (38.5%)	8 (15.4%)	0 (0%)
Effective Planning	24 (46.2%)	28 (53.8%)	0 (0%)	0 (0%)

Source: Field Survey, 2024

Table 2 above shows the various response of the respondent as regard the significance of GIS in sustainable Environment, 30.8% of the respondent claim that GIS is highly effective in making decision as regards sustainable built environment, 61.5% of the respondent claim it is effective, 7.7% of the respondent claim it is less effective. In determining if GIS is effective in resources management it was gathered that 46.2% of the respondent claim it is highly effective, 53.8% of the respondent claim it is effective, and none of the respondent select less effective and not effective respectively. Environmental

conservation as one of the significance of GIS in Sustainable Built Environment 23.1% of the respondent claim that GIS is highly effective in that regards, 61.5% of the respondent claim it effective, 15.4% of the respondent claim it is less effective.

Also in determining the impact of GIS in effective site analysis, it was gathered based on the response of the respondent that 53.8% claim it is highly effective, 38.5% of the respondent claim it is effective, 15.4% of the respondent claim it is less effective. Furthermore, 46.2% of the respondent claim that GIS is very significant in Disaster response, 38.5% of the respondent claim it is effective and the remaining 15.4% of the respondent claim it is less effective. Finally, the impact of GIS in effective planning, 46.2% of the respondent claim that GIS is highly effective, 53.8% of the respondent says it is effective and none of the respondent claim that GIS is less effective and or Highly Not effective respectively. This shows that GIS as advanced technological tools is effective and effective in Sustainable Built Environment by aiding decision making, allow for effective resources management, promote environmental conservation, ensure effective site analysis and aid in disaster response and as well allow for effective planning.

Moreover, data on challenges facing GIS in Sustainable Built Environment on factors such as data inaccuracy, accessibility, inadequate training and limited resources were analyzed on 4-Likert scale ranges from strongly agree to strongly disagree were analyzed, the result is as shown below in table 3.

Table 3: Challenges facing GIS in Sustainable Built Environment

Factor	Strongly Agree	Agree	Disagree	Strongly Disagree
Data Inaccuracy	12 (23.1%)	24 (46.2%)	12 (23.1%)	4 (7.7%)
Accessibility	12 (23.1%)	28 (53.8%)	12 (23.1%)	0 (0%)
Inadequate Training	12 (23.1%)	20 (38.5%)	16 (30.8%)	4 (7.7%)
Limited Resources	8 (15.4%)	32 (61.5%)	12 (23.1%)	0 (0%)

Source: Field Survey, 2024

This table 3 presents the challenges of GIS in Sustainable Built Environment and from the table, it was gathered that 23.1% of the respondent claim that data inaccuracy is one of the challenges facing GIS in built environment, 46.2% of the respondent also agree but 23.1% and 7.7% of the respondent have another view to that response by disagree and strongly disagree that data inaccuracy is one of the major challenges of GIS in built environment. Also, 23.1% of the respondent claim that accessibility is one of the challenges facing GIS in sustainable built environment, 53.8% of the respondent affirm this and agree to that statement but 23.1% of the respondent disagree to the fact that accessibility is one of the challenges facing GIS in Built Environment. 23.1% of the respondent claim that inadequate training on the use of GIS Software is one of the challenges facing GIS, 38.5% of the

respondent also affirm to this and 30.8% of the respondent disagree and 7.7% of the respondent strongly disagree. Going by the limited resources as on e of the challenges facing GIS in sustainable built environment, it was gathered that 15.4% of the respondent strongly agree, 61.5% of the respondent agree to that statement as negated by 23.1% of the respondent.

Qualitative Analysis

The qualitative analysis, based on in-depth interviews with key informants including GIS practitioners, educators, and policymakers, provides rich narratives and nuanced perspectives on the impact of Geographic Information Systems (GIS) on sustainable development within the built environment.

Innovative Applications:

Respondent highlighted innovative GIS applications in urban planning, infrastructure development, and environmental conservation. Case studies underscored the role of GIS in optimizing land use, improving transportation networks, and supporting sustainable architecture.

Educational Significance:

GIS's educational significance was emphasized, with educators noting its pivotal role in cultivating spatial literacy and analytical skills among students. GIS integration into academic curricula was seen as essential for preparing future professionals in the built environment.

Challenges and Limitations:

Respondent acknowledged challenges such as data accuracy issues, limited access to advanced GIS tools, and the need for continuous training. Despite challenges, GIS was perceived as indispensable for addressing complex urban challenges.

Interdisciplinary Collaboration:

The qualitative data highlighted the role of GIS in fostering interdisciplinary collaboration. Professionals from various fields collaborate using GIS platforms, contributing to holistic and sustainable solutions.

Expert Opinions:

Key informants provided expert opinions on the transformative impact of GIS. One Respondent stated, "GIS has revolutionized how we approach urban planning; it's not just a tool but a mindset shift towards more sustainable and data-driven practices."

Discussion

The perceived effectiveness of GIS in fostering sustainability, as indicated by the survey's average rating, aligns with participants' positive narratives during interviews. Innovative applications in urban planning, infrastructure development, and environmental conservation underscore GIS's transformative potential. However, challenges such as data accuracy issues and limited access to advanced tools are acknowledged, indicating the need for ongoing support and capacity building.

The educational significance of GIS emerges as a consistent theme. Educators emphasize its role in cultivating spatial literacy and analytical skills, aligning with the literature highlighting the importance of GIS integration into academic curricula. Moreover, the qualitative data underscores GIS's role in facilitating interdisciplinary collaboration, emphasizing its capacity to transcend disciplinary boundaries and foster holistic solutions to complex urban challenges.

The findings resonate with existing literature on GIS applications in sustainable development. The innovative use of GIS in optimizing land use, improving transportation networks, and supporting sustainable architecture aligns with established trends (Carver, 2017; Davies & Shyu, 2019). Challenges identified, such as data accuracy issues, reflect broader discussions in the literature on GIS implementation challenges (Goodchild, 2010; Nyerges, 2018).

The study identifies emerging trends, particularly the integration of GIS with emerging technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT). Respondent express optimism about the future potential of GIS in addressing evolving challenges. This aligns with the literature, which anticipates the continued evolution of GIS technologies to meet the dynamic needs of sustainable development (Li et al., 2020; Wong, 2018).

Conclusion and Recommendations

Conclusion

GIS emerges as a powerful instrument in navigating the complexities of sustainable development within the built environment. As urbanization accelerates and environmental challenges persist, GIS stands as a beacon for informed decision-making, innovation, and collaboration. This study contributes to the ongoing dialogue on GIS's transformative role, inviting stakeholders to embrace its potential and collectively shape a more sustainable and resilient future.

Recommendations

Practitioners can leverage GIS for innovative solutions, educators are encouraged to integrate GIS into academic curricula, and policymakers should consider the identified

challenges in formulating strategies for sustainable urban development. Addressing data accuracy concerns, enhancing accessibility to advanced GIS tools, and fostering interdisciplinary collaboration are crucial for unlocking the full potential of GIS in the built environment.

While this study provides valuable insights, it is not without limitations. The scope of participants is limited to specific institutions, and self-reported data introduces the potential for bias. Future research could expand the scope, delve into specific challenges, and assess the long-term impact of GIS on sustainable development.

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EDITOR-IN-CHIEF
Prof. A.I. Mteiye [MALAWI]