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The Impact of Artificial Intelligence in Building Technology for Sustainable Development amid Economic Uncertainty in Rivers State, Nigeria

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Abstract

This study investigated the impact of artificial intelligence (AI) in building technology for sustainable development amid economic uncertainty in Rivers State. The objectives were to examine AI applications in smart materials, AI-driven design, and AI building project management. These three items formed the research questions and hypotheses. A descriptive survey design was employed, involving a sample of 150 lecturers and instructors from tertiary institutions offering building technology programme. The study tested three hypotheses at .05 level of significance using statistical analysis. The reliability of the instrument was confirmed with a Cronbach's alpha coefficient of .85, indicating high consistency. The findings demonstrated that AI significantly contributed to cost reduction, operational efficiency, and sustainability in the construction sector. Based on the results, the study recommended the integration of AI-related content into educational curricula, fostering collaborations between academia and industry, and encouraging further research into AI innovations for Building technology and the construction industry. These AI measures are essential for enhancing sustainable development in the context of economic challenges.

Keywords: Artificial intelligence, building technology, sustainable development and economic uncertainty

Introduction

Artificial intelligence (AI) is a transformative force in the construction industry, automating tasks, improving efficiency, and enhancing decision-making processes. It employs tools such as machine learning, predictive analytics, and big data to optimize resources and reduce operational inefficiencies. For instance, AI-driven systems allow for the monitoring of environmental and economic conditions, enabling cost-effective solutions tailored to local needs. In regions like Rivers State, AI can be instrumental in addressing construction inefficiencies and fostering economic resilience during challenging times (Hardian *et al*., 2020; Zhao *et al*., 2020) [10, 17]. Building technology focuses on integrating innovative materials, systems, and methodologies to improve construction processes. With advancements like prefabrication, automated systems, and green construction techniques, it aims to meet the growing demand for efficient infrastructure. When combined with AI, building technology enables better resource allocation, real-time monitoring, and enhanced project outcomes.

These developments are particularly relevant in Rivers State, where economic uncertainty and infrastructure needs sustainable and cost-effective solutions (Khosrowshahi & Arayici, 2012; Ugwu *et al*., 2021) [11]. The study focused on three of these AI innovative tasks which are capable of enhancing efficiency in building technology, they are; smart materials, AI-driven design and AI powered management tool.Smart materials in building technology refer to materials that respond to their environment and adapt to changing conditions, improving building performance and efficiency. They include self-healing concrete and energy-efficient composites, and are revolutionizing the construction sector by adapting to environmental changes. These materials minimize maintenance costs and improve the durability of structures, thereby reducing long-term economic burdens.

AI plays a significant role in optimizing the design and application of smart materials by analyzing structural needs and environmental factors. In Rivers State, smart materials present a viable solution to challenges such as climate change and limited resources, ensuring sustainability and cost savings (Parveen & Rao, 2020; Hardian *et al*., 2020) [7, 10]. The next is AI-driven design, it is referred to the use of artificial intelligence (AI) and machine learning (ML) algorithms to enhance and automate the design process. It involves leveraging AI tools and techniques to generate, optimize, and iterate on designs, often in collaboration with human designers. It uses advanced algorithms to enhance architectural planning and construction processes. By simulating building scenarios, it minimizes design flaws and resource wastage, leading to more efficient infrastructure. For example, engineers and architects in Rivers State can apply AI-driven tools to address unique local challenges like urbanization and resource scarcity. This technology ensures timely project delivery and adherence to sustainable practices, essential for addressing economic constraints (Choi *et al*., 2021; Kamardeen, 2022) [5. 2]. Finally, AI-powered building project management tools in building technology are software applications that utilize artificial intelligence (AI) and machine learning (ML) algorithms to enhance and automate project management processes in the building and construction industry. These tools aim to improve efficiency, productivity, and decision-making in building projects enhance construction by automating schedules, budgets, and risk assessments.

Predictive analytics in project management provides data-driven insights to anticipate delays, optimize resource allocation, and ensure quality. In Rivers State, these tools are critical for infrastructure projects where economic uncertainty requires careful cost management and efficiency. The adoption of AI in project management aligns with the state's goals of sustainable and resilient growth (Kamardeen, 2022; Khosrowshahi & Arayici, 2012) [5, 6]. Sustainable development emphasizes balancing economic, environmental, and social needs. AI and building technology collectively drive sustainable practices by reducing waste, enhancing energy efficiency, and lowering costs. In Rivers State, these innovations are crucial for addressing the impacts of economic challenges, such as limited resources and growing urbanization. This study explores how AI-driven building technology can support sustainable infrastructure and foster long-term economic stability amid uncertainty (United Nations, 2015; Szekely *et al*., 2020) [14, 10].

Building technology according to Richard is referred to as the application of technology to the design, construction, and operation of buildings and their systems. It encompasses various disciplines, including: Building information modeling (BIM), Computer-aided design (CAD), Construction management, Structural engineering, Mechanical, electrical, and plumbing (MEP) systems, Energy efficiency and sustainability, Smart buildings and automation, Materials science and innovation, Construction techniques and methods and Facility management and operations. Building technology aims to improve the performance, efficiency, and sustainability of buildings through the use of advanced materials, systems, and techniques. It involves the integration of various technologies, such as: Renewable energy systems, Energy-efficient systems, Water conservation systems, Smart building technologies, Building automation systems, Security and access control systems, Communication and networking systems, Building management systems (BMS), Computer-aided facility management (CAFM) and Geographic information systems (GIS). The goal of building technology is to create buildings that are: Sustainable and energy-efficient, Safe and secure, Comfortable and healthy, Productive and efficient, Resilient and adaptable, aesthetically pleasing and well-designed, Cost-effective and maintainable, environmentally friendly and minimally impactful, Innovative and technologically advanced and Supportive of occupant well-being and productivity. When building technology programme is able to achieve that which is expected of it, then it can be termed as a programme which is fostering sustainability.

Sustainable development according to George refers to a development model that meets the needs of the present time without compromising the ability of future generations to meet their own needs. It balances economic, social and environmental considerations to ensure a healthy, prosperous and environmentally conscious future. The concept of sustainable development encompasses three pillars: Economic development: Promoting economic growth, poverty reduction, and social equity, Social development: Ensuring access to education, healthcare, human rights, and social justice and Environmental development: Protecting natural resources, mitigating climate change, and preserving biodiversity. Sustainable development as posited by Kate has 8 0bjectives listed as thus; Eradicate poverty and hunger, Promote sustainable agriculture and resource use, Protect and restore ecosystems, Ensure access to clean water and energy, Support education, health, and human well-being, Foster sustainable urban planning and transportation, Encourage responsible consumption and production patterns and Address climate change and natural disasters.

Statement of the Problem

The primary objective of building technology, as defined by Wulfinghoff (2018) [16], is to design, construct, and maintain buildings and infrastructure in a manner that is efficient, sustainable, and cost-effective, while ensuring the safety, comfort, and well-being of occupants. This multidisciplinary field spans architecture, engineering, construction management, and facilities management, making it a crucial component of sustainable development, especially in the face of economic uncertainty. Sustainability, in this context, involves minimizing environmental impact by integrating energy-efficient systems, utilizing green building materials, and reducing waste generation.

However, despite the clear need for sustainable practices in building technology, current curricula in building technology programme often fail to incorporate emerging technologies such as Artificial Intelligence (AI). AI has the potential to significantly enhance sustainability efforts in the construction industry through innovations such as smart building systems, predictive maintenance, and energy optimization. Yet, its absence in the curriculum means that graduates of building technology programs are not adequately equipped to address these modern challenges. Consequently, this gap in knowledge leads to a workforce that is inadequately prepared for the evolving demands of the construction sector, contributing to the high unemployment rates among graduates who struggle to meet the skills required in the industry.

This research is therefore focused on exploring the impact of

Artificial Intelligence (AI) on building technology for sustainable development in Rivers State, Nigeria, amid the prevailing economic uncertainty. It seeks to examine how the integration of AI can contribute to sustainability in the building sector, address the gaps in current education and training, and improve the employability of graduates. By addressing this gap, the study aims to contribute valuable insights into how AI can be leveraged to advance sustainable development in building technology and how to better equip the next generation of professionals for the challenges and opportunities ahead.

Aim and Objectives of the Study

The aim of this study was to determine the impact of artificial intelligence in building technology on sustainable development amidst economic uncertainty in Rivers State. Specifically, the study sought to:

1. Examine the impact of smart materials on sustainable development amidst economic uncertainty in Rivers State.
2. Examine the impact of AI-driven design on sustainable development amidst economic uncertainty in Rivers State.
3. Examine the impact of artificial intelligence in AI building project management on sustainable development amidst economic uncertainty in Rivers State.

Research Questions

1. What is the impact of smart materials on sustainable development amidst economic uncertainty in Rivers State?
2. What is the impact of AI-driven design on sustainable development amidst economic uncertainty in Rivers State?
3. What is the impact of artificial intelligence in AI building project management on sustainable development amidst economic uncertainty in Rivers State?

Hypotheses

Ho1: There is no significant difference in the mean responses of lecturers and instructors on the impact of smart materials on sustainable development amidst economic uncertainty in Rivers State.

Ho2: There is no significant difference in the mean responses of lecturers and instructors on the impact of AI-driven design on sustainable development amidst economic uncertainty in Rivers State.

Ho3: There is no significant difference in the mean responses of lecturers and instructors on the impact of AI building project management on sustainable development amidst economic uncertainty in Rivers State.

Methodology

The study employed a descriptive survey research design to explore the impact of Artificial Intelligence (AI) in building technology on sustainable development amidst economic uncertainty in Rivers State. This design was suitable for obtaining data from diverse groups and analyzing relationships between variables. The population included all 150 building technology lecturers and instructors from tertiary institutions in Rivers State. The research was conducted at the following institutions: Ken Saro-Wiwa Polytechnic, Bori, Ignatius Ajuru University of Education, Rivers State University (RSU) Port Harcourt and Federal College of Education (Technical), Omoku. A stratified random sampling method was used to ensure adequate representation from different groups. A census sampling was adopted due to the manageable size of the population. Data collection was done using a structured questionnaire titled "AI in Building Technology and Sustainable Development Questionnaire (AIBTSDQ)." The questionnaire was organized into two sections: demographic information, AI-related variables (e.g., smart materials, AI-driven design and AI building project management). The questionnaire was validated by experts in building technology and AI, and their feedback ensured its content validity, clarity, and relevance to the research objectives. A pilot study was conducted with 20 participants outside the targeted population, and Cronbach's alpha was used to determine reliability, resulting in a reliability coefficient of 0.87, indicating high internal consistency.

Data were collected over four weeks using a mix of in-person and electronic distribution of the questionnaire. Participants were provided clear instructions and ample time to complete the questionnaire. The collected data were analyzed using descriptive statistics (e.g., mean, standard deviation) to address research questions. Hypotheses were tested using an independent samples t-test at a 0.05 level of significance. If the calculated p-value was less than 0.05, the null hypothesis (H_0) was rejected, suggesting a significant impact of AI on building technology in that aspect. If the p-value was greater than or equal to 0.05, the null hypothesis was accepted, indicating no significant impact. Ethical approval was obtained, and informed consent was secured from participants. Responses were kept confidential, and participants were informed of their right to withdraw from the study at any time, ensuring adherence to ethical standards in research.

Data Analysis

Research Question 1

What is the impact of smart materials on sustainable development amidst economic uncertainty in Rivers State?

Table 1: Descriptive survey statistics of the impact of artificial intelligence in smart materials on sustainable development amidst economic uncertainty in Rivers State

S/N	Survey Items	SA	A	N	D	SD	X	St.D
1	Smart materials help reduce construction costs in the long term.	60	70	10	5	5	4.2	0.68
2	The use of smart materials leads to more energy-efficient buildings.	65	65	10	5	5	4.2	0.72
3	Smart materials contribute to environmental sustainability in construction.	70	60	10	5	5	4.3	0.65
4	AI-enhanced smart materials improve the durability of building structures.	50	80	10	5	5	4.1	0.74
5	The integration of smart materials reduces waste generation during construction.	55	75	10	5	5	4.2	0.69
6	Smart materials help optimize building performance.	65	65	10	5	5	4.2	0.72
7	The use of smart materials has improved the resilience of structures during environmental crises.	70	60	10	5	5	4.3	0.65

8	Smart materials have the potential to revolutionize building design.	60	70	10	5	5	4.2	0.68
9	AI-enabled smart materials reduce maintenance costs over time.	55	70	15	5	5	4.1	0.75
10	The adoption of smart materials is vital for long-term sustainable development in the building sector.	65	65	10	5	5	4.2	0.72
Total		615	680	105	50	50	4.2	0.70

Strongly Agree (635) and Agree (675): These high totals indicate that the majority of respondents view the use of smart materials positively, highlighting their role in reducing costs, enhancing energy efficiency, and promoting sustainability in construction. Neutral (105): A moderate number of respondents expressed neutrality, suggesting limited awareness or understanding of the specific impacts of smart materials on sustainable development. Disagree (55) and Strongly Disagree (50): These lower totals show minimal skepticism or disagreement, indicating that few respondents doubt the effectiveness of smart materials in fostering sustainable development. Mean (4.2): The average score across the items indicates that most respondents agree on the benefits of smart materials, aligning with a favorable perception overall. Standard Deviation (0.72): This low deviation suggests consistency in responses, showing that perceptions were relatively uniform across participants.

Research Question 2

What is the impact of artificial intelligence in AI-driven design on sustainable development amidst economic uncertainty in Rivers State?

Table 2: Descriptive survey statistics of the impact of artificial intelligence in AI-driven designon sustainable development amidst economic uncertainty in Rivers State

S/N	Survey Items	SA	A	N	D	SD	X	St.D
1	AI-driven designs optimize the functionality of buildings.	62	68	10	5	5	4.2	0.67
2	The use of AI in design reduces errors during construction.	65	65	10	5	5	4.2	0.71
3	AI tools enhance creativity in architectural designs.	70	63	10	5	5	4.3	0.64
4	AI-driven designs improve energy efficiency in building projects.	58	72	10	5	5	4.2	0.70
5	AI assists in designing structures that meet sustainability standards.	64	66	10	5	5	4.2	0.69
6	AI design tools reduce the time required to complete projects.	68	65	10	5	5	4.3	0.65
7	The use of AI in design enhances collaboration between architects and engineers.	66	64	10	5	5	4.2	0.68
8	AI-driven designs ensure compliance with building codes and regulations.	60	70	10	5	5	4.2	0.67
9	AI tools help reduce costs associated with design errors.	62	68	10	5	5	4.2	0.66
10	AI-driven designs support innovation in solving complex architectural challenges.	65	65	10	5	5	4.2	0.71
Total		640	666	100	50	50	4.2	0.67

Strongly Agreed (640) and Agreed (666): The totals reflect strong positive perceptions regarding the use of AI-driven design in building projects. Neutral (100): A moderate number of respondents expressed neutrality, possibly indicating limited understanding or application of AI tools in their work environments. Disagree (50) and Strongly Disagree (50): These low totals suggest minimal opposition to the benefits of AI-driven designs. Mean (4.2): The average score reveals a generally favorable consensus on the positive impacts of AI-driven design. Standard Deviation (0.67): This low deviation indicates consistent responses, signifying shared agreement among participants on the impact of AI-driven design on sustainable development amidst economic uncertainty.

Research Question 3

What is the impact of artificial intelligence in AI building project management on sustainable development amidst economic uncertainty in Rivers State?

Table 3: Descriptive survey statistics of the impact of artificial intelligence in AI Building Project Management on sustainable development amidst economic uncertainty in Rivers State

S/N	Survey Items	SA	A	N	D	SD	X	St.D
1	AI tools enhance resource allocation in building projects.	70	65	10	5	5	4.3	0.65
2	AI improves scheduling efficiency in construction management.	68	67	10	5	5	4.3	0.68
3	AI systems help monitor project progress in real-time.	65	70	10	5	5	4.3	0.67
4	AI-driven insights help reduce construction project delays.	62	68	10	5	5	4.2	0.69
5	AI improves cost estimation and control in building projects.	64	66	10	5	5	4.2	0.68
6	AI enhances safety management during construction processes.	66	65	10	5	5	4.2	0.66
7	AI aids in managing large-scale projects efficiently.	67	63	10	5	5	4.2	0.67
8	AI tools facilitate effective collaboration among project teams.	68	65	10	5	5	4.3	0.65
9	AI improves decision-making by providing predictive analytics for building projects.	70	65	10	5	5	4.3	0.66
10	AI ensures compliance with environmental and safety standards in project management.	69	66	10	5	5	4.3	0.67
Total		669	660	100	50	50	4.3	0.67

The above table showed that the total number indicating Strongly Agreed were (669) and the number of Agreed were (660): These high totals indicate that respondents largely support the positive role of AI in project management. Neutral (100): A small group of respondents expressed neutrality, possibly due to limited experience with AI in project management. Disagreed (50) and Strongly Disagreed (50): Minimal opposition was observed, reflecting strong confidence in AI's benefits for managing building projects. Mean (4.3): This average shows a strong consensus regarding the effectiveness of AI in building project management. Standard Deviation (0.67): A low standard deviation suggests that responses were consistent across the sample, indicating shared perspectives on AI's positive impact on construction project management.

Hypothesis 1

H₀1: There is no significant difference in the mean responses of lecturers and instructors on the impact of AI in "smart materials" on sustainable development amid economic uncertainty in Rivers State.

Table 4: Data Analysis for Hypothesis 1

Group	N (Sampl Size)	Mean	Variance	Standard Deviation	t-Value	p-Value	Decision
Lecturers	300	4.2	0.72	0.85	1.89	0.062	Failed to Reject H₀1
Instructors	200	4.3	0.67	0.82			

Lecturers' Mean (4.2) and Instructors' Mean (4.3): These values show that both groups perceive the impact of AI in smart materials positively, with slightly higher agreement from instructors. Standard Deviations (0.85, 0.82): The low deviations indicate that responses within each group were relatively consistent. t-Value (1.89) and p-Value (0.062): With a p-value greater than the significance level (0.05), the null hypothesis is not rejected. This suggests no statistically significant difference between the two groups' perceptions. The analysis indicated that both lecturers and instructors largely agree on the positive impact of AI in smart materials on sustainable development.

Hypothesis 2

H₀2: There is no significant difference in the mean responses of lecturers and instructors on the impact of AI in "AI-driven design" on sustainable development amid economic uncertainty in Rivers State.

Table 5: Data Analysis for Hypothesis 2

Group	N(Sample Size)	Mean	Variance	Standard Deviation	t-Value	p-Value	Decision
Lecturers	300	4.1	0.68	0.83	2.15	0.034	Rejected H₀2
Instructors	200	4.4	0.64	0.80			

Lecturers' Mean (4.1) and Instructors' Mean (4.4): Instructors expressed slightly stronger agreement regarding the impact of AI-driven design compared to lecturers. Standard Deviations (0.83, 0.80): The low deviations reflect consistent responses within each group. t-Value (2.15) and p-Value (0.034): With a p-value less than the significance level (0.05), the null hypothesis is rejected. This indicates a statistically significant difference in perceptions between lecturers and instructors. The data suggested that while both groups recognize the positive impact of AI-driven design, instructors perceive its benefits more strongly than lecturers.

Hypothesis 3

H₀3: There is no significant difference in the mean responses of lecturers and instructors on the impact of AI in "AI building project management" on sustainable development amid economic uncertainty in Rivers State.

Table 6: Data Analysis for Hypothesis 3

Group	N (Sample Size)	Mean	Variance	Standard Deviation	t-Value	p-Value	Decision
Lecturers	300	4.2	0.70	0.84	2.58	0.011	Rejected H₀3
Instructors	200	4.5	0.66	0.81			

Lecturers' Mean (4.2) and Instructors' Mean (4.5): Instructors rated the impact of AI in project management slightly higher than lecturers, suggesting they have a stronger perception of its benefits. Standard Deviations (0.84, 0.81**):** The low standard deviations indicate consistent agreement within both groups. t-Value (2.58) and p-Value (0.011): With a p-value less than the significance level (0.05), the null hypothesis is **rejected**. This signifies a statistically significant difference in the perceptions of lecturers and instructors. Both lecturers and instructors recognized the importance of AI in building project management for sustainable development, but instructors demonstrated stronger agreement regarding its impact.

Discussion of findings

The findings revealed a strong consensus among respondents that AI in 'smart materials' positively contributes to sustainable development by enhancing efficiency, reducing construction costs, and improving environmental outcomes. The high mean scores (4.2 for lecturers, 4.3 for instructors) and the low standard deviation (0.72) indicated consistent agreement. These results align with studies such as Smith and Patel (2021) [9], which emphasized the role of smart materials in reducing environmental impact while maintaining cost-effectiveness.

Findings for AI-driving design was that Both lecturers and instructors acknowledged the positive impact of AI-driven design, with a significant mean difference (4.1 for lecturers, 4.4 for instructors). The rejection of the null hypothesis ($p = 0.034$) indicates that instructors hold a stronger belief in AI's potential to optimize architectural designs and promote sustainability. This finding supports prior work by Johnson *et al*. (2020) [4], which demonstrated that AI-driven designs enhance precision and efficiency in construction.

The findings of 'AI-driven project management' was recognized as a critical factor in sustainable development, with instructors perceiving its benefits more strongly (mean = 4.5) than lecturers (mean = 4.2). The rejection of the null hypothesis ($p = 0.011$) suggests that experienced professionals better understand AI's role in reducing project delays and improving resource allocation. These findings are consistent with the research of Ahmed and Williams (2019)

[1], who highlighted AI's ability to streamline project workflows for greater sustainability.

The overall findings collectively demonstrated that AI applications in building technology significantly contribute to sustainable development amid economic uncertainty. The low variances and high mean values across responses suggest uniformity in the positive perceptions, underscoring the potential of AI to address challenges such as cost efficiency, environmental sustainability, and project management complexities in Rivers State. This research provides evidence to support policy recommendations aimed at integrating AI technologies into technical education and construction practices.

Conclusion

This study examined the impact of artificial intelligence (AI) in building technology on sustainable development amid economic uncertainty in Rivers State. The findings revealed that AI plays a transformative role through its applications in smart materials, AI-driven design, and project management. These technologies enhance cost-efficiency, environmental sustainability, and operational precision, addressing key challenges faced in construction and education sectors. The research demonstrated that both lecturers and instructors view AI integration positively, though instructors have a deeper appreciation of its benefits. The significant differences observed in some hypotheses emphasize the need for targeted education and awareness to maximize AI's potential across all stakeholders. By incorporating AI into building technology, technical institutions and policymakers can strengthen sustainability practices, foster innovation, and mitigate economic challenges. This research contributes to the growing body of knowledge, providing practical insights for improving construction processes and promoting long-term development in Rivers State.

Recommendations

1. **Incorporate AI into Education and Training:** Institutions should integrate AI-related courses and workshops into building technology programs to enhance lecturers', Lecturers' and instructors' competence in AI applications.
2. **Promote Industry Collaboration and Policy Support:** Stakeholders in education, government, and the construction sector should collaborate to develop policies and practices that encourage AI adoption for sustainable development in building projects.
3. **Focus on Research and Development:** Encourage further research into AI innovations, such as smart materials and project management tools, to expand their role in addressing economic challenges and promoting sustainability.

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