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Role of Artificial Intelligence in Smart Building Design in Lagos State, Nigeria

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ABSTRACT

Our homes are evolving into hubs of connectivity and automation due to the proliferation of AI-driven gadgets, Internet of Things (IoT) sensors, voice assistants, and augmented reality (AR) applications. The research investigates the role of artificial intelligence in the design of smart homes in Lagos, Nigeria. The study employs a mixed-method approach, utilising quantitative and qualitative data collection instruments. A structured questionnaire was administered to architects via a Google form link the response rate provided a clear view of the current state of AI adoption in the study area. An in-depth interview was conducted on the phone with homeowners to validate the data. The study shows that most participants (80%) prefer AI-powered smart houses over conventional designs, and most respondents (90%) recognize the advantages of AI in improving comfort and leisure. Though to a lesser extent, AI is also acknowledged for its potential to optimize energy usage and boost property value. AI integration in smart houses is important for architects because it speeds up construction and improves design aesthetics. But architects also have to deal with issues like privacy and a greater need for outside expertise. AI-powered technologies make buildings more advantageous both financially and ecologically by optimising energy use, managing resources, and lowering running expenses. Despite these benefits, hefty upfront expenditures, a lack of technological know-how, and inadequate infrastructure prevent widespread application. To enhance construction professionals' comprehension of AI applications in smart building design, the study suggests holding workshops and providing training. It is also important to promote collaboration between architects, engineers, and contractors to facilitate the adoption of AI in building projects.

Keywords: *Smart home, Artificial Intelligence, Technology, Design, Internet of Things, augmented reality,*

Introduction

The way we live, work, and connect with the world has undergone a profound transformation in the 21st century due to an extraordinary technological revolution (Li, 2020; Rosenau, 2021). This shift is most clearly visible in the places we call home. A blend of technology, creativity, and architectural design, the "smart home" concept has arisen as a distinguishing trademark of our times and promises to transform our homes (Abubakar, Omeke, Ozturk, Hussain, & Imran, 2020). Our homes are evolving into hubs of connectivity and automation thanks to the proliferation of AI-driven gadgets, Internet of Things (IoT) sensors, voice assistants, and augmented reality (AR) applications (Abubakar, Omeke, Ozturk, Hussain, & Imran, 2020). These smart technologies can allow users to remotely control almost all devices in their house and precisely manage their use (Isyanto, Arifin, & Suryanegara, 2020). Maximising certain objective values while minimizing constraint values is the aim of smart home systems. Goal values include things like convenience, safety, and health, whereas constraint values include things like energy usage or legal requirements (King, 2018). Smart home designs are becoming more popular, which increases the need for various emerging technology and AI-based power solutions and opens up new prospects for innovation and growth, hence it is important to delve into their prospective benefits (Kumar, et al., 2021). Despite the versatile use of technology and data, people say it can be biased and its implementation can face drawbacks. Therefore, this research will also look into the challenges faced by integrating AI and emerging technologies in smart homes. Therefore, the study aims to investigate the role of artificial intelligence (AI) in the smart home design of residential buildings to understand its impact on users' quality of life. To achieve this aim, three objectives were set. They include:

i. To examine the potential benefits and limitations of incorporating artificial intelligence with smart home design technologies;

ii. To assess the extent to which Artificial Intelligence (AI) is employed in smart home design technologies in the study area; and

iii. To examine the impact of artificial intelligence on the performance of smart homes in the study.

Literature Review

Concepts of Smart Homes and AI

A smart home is a residence equipped with technologies that include sensors, wired and wireless networks, actuators, and intelligent systems (Taiwo & Zugwu, 2021). Equipped with highly advanced automatic systems, smart homes can monitor and control home activities for convenience, provide occupants with better comfort, and possibly reduce energy use. Smart home technology collects and analyzes data from the domestic environment. It also relays information to users and enhances the potential of managing different domestic systems. For easy understanding, we defined six core clusters of AI functions in smart homes, i.e., Automation and adaptability, Voice-Activated assistants, Energy efficiency, Security reinvented, Adaptive learning and predictive maintenance, Data privacy and ethical considerations (Guo, Shen, Zhang, & Wu, 2019).

Application of AI in Architecture and Building Designs

Artificial intelligence in architecture enables engineers and architects to design, plan, and build structures more efficiently (Rafsanjani & Nabizadeh, 2023). With this technology at hand, architects can optimize designs for sustainability and cost-efficiency and come up with never-before-seen design solutions. Currently, building information modeling (BIM) and the Internet of Things (IoT) as computer-based technologies are widely used in the AEC industry to help architects, engineers, and managers achieve the best practices of the aforementioned phases. BIM is predominantly utilized in the design and construction phase while IoT mainly manages the operation and maintenance process (Tang, Shelden, Eastman, N Pishdad-Bozorgi, & Gao, 2019). AI also helps with Rendering, Generative design, Integration with BIM, Immersive experiences, Parametric architecture, Planning, Construction & safety, and Home automation.

Parameters for Measurement of Smart Homes

Measuring the effectiveness and efficiency of smart homes involves assessing various parameters that span technological performance, user experience, security systems, energy management systems, health and safety systems, and residents' convenience (Aliero, Qureshi, Pasha, & Jeon, 2021). Technological performance is significant because it provides access to the technology underlying the home automation system's responsiveness, dependability, and general performance. The speed at which smart devices react to user requests, the effectiveness of communication protocols, and the smooth integration of devices are important factors (Al-Fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015). User experience, which includes how easily and naturally residents engage with the technology, is a critical metric for assessing the performance of smart homes (Kim, Oh, Cho, Lee, & Kim, 2013). It assesses the usability and design of interfaces, including control panels, voice commands, and mobile apps. One important factor to consider while evaluating the effectiveness of smart homes is their security system. The robustness of the safeguards in place to safeguard the home's digital and physical components is assessed by this parameter (Singh, Ra, Meng, Kaur, & Cho, 2019). An essential field of research for smart home applications is energy management. Four primary functions are offered by the energy management system presented by the research: home administration, real-time monitoring and control, energy profile, and energy optimization (Rathor & Saxena, 2020). The health and system a vital parameters for evaluating the effectiveness of smart homes. It encompasses features and technologies designed to enhance the well-being and safety of occupants. This parameter evaluates the integration of health-monitoring devices, air quality sensors, and emergency response systems with the smart home infrastructure. Monitoring factors like air quality, temperature, and occupancy contributes to a healthier living environment (Mshali, Lemlouma, Moloney, & Magoni, 2018).

Awareness of Smart Home Concepts among Stakeholders

In this case, governments, tech companies, homeowners, and service providers are all considered stakeholders. To make an informed decision about adoption, homeowners must be aware of the features, advantages, and possible cost savings of smart home systems (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013). Technology manufacturers need to make sure that the characteristics, usability, and compatibility of their products are effectively communicated. By enacting laws and offering incentives, policymakers can help to create an atmosphere that encourages the advancement and use of smart home technologies. To provide efficient help and upkeep, service providers—including installers and support staff—need to have a solid understanding of smart home ideas. All things considered, a knowledgeable stakeholder base is necessary for the effective acceptance of smart home ideas into everyday life, which will raise adoption rates and enable users to reap the potential advantages of these technologies.

Drivers and Barriers of Smart Homes

Smart homes embrace advanced technologies and the connectedness of devices that aim to increase consumers' life quality (Basarir-Ozel, Turker, & Nasir, 2022). They are based on data integration over shared platforms collected via sensors and wireless networks. The drivers of smart homes are multifaceted, encompassing concepts such as relative advantage, enjoyment, image enhancement, modern and multifunctional design, and consumers' technology innovativeness. Relative advantage is the idea that smart home technologies are better than traditional ones, which encourages adoption by offering advantages like increased convenience and efficiency (Wilson, Hargreaves, & Hauxwell-Baldwin, 2107).

Challenges and Opportunities in Implementing AI in Architectural Practices

At its core, AI in architectural design focuses on data-driven decision-making, automation of repetitive tasks, and providing predictive insights (Sarker, 2022). Some of the challenges and opportunities will be stated. Artificial Intelligence (AI) lacks human intuition, creativity, and emotional intelligence, but it can evaluate data and propose answers based on algorithms (Samsonovich, 2020). The caliber of the input data directly affects the caliber of the output. Biased or inaccurate data can result in poor design recommendations. The enormous volumes of data needed for AI operations give rise to issues with data management, storage, and privacy (Siddiqa, et al., 2016). The ethical dimensions of AI integration are vast. From potential job losses because of automation to concerns about who 'owns' the designs generated by AI tools, there's a plethora of ethical dilemmas to navigate. The architectural profession is diverse, with practitioners ranging from seasoned professionals who have been in the field for decades to fresh graduates. Integrating AI into everyday practice requires training and upskilling, a challenge, especially for those more accustomed to traditional design methods (Sofia, et al.,

2023). High-end AI software comes with a price tag. The investment in AI tools and the associated infrastructure can be significant for smaller architectural firms. There's also the recurring cost of software updates, training, and data management to consider. With the convenience and efficiency AI tools offer, there's a potential risk of over-reliance. Architects might be tempted to accept the first or most convenient solution offered by AI, leading to a decrease in critical thinking and exploration of alternative design solutions. Cultural and societal norms deeply influence architecture. AI, primarily developed and trained on datasets from specific regions or demographics, might not fully understand or incorporate these nuances, leading to designs that might not resonate with the local population (Kaur, Adar, Gilbert, & Lampe, 2022).

Methodology

This study to understand the role of artificial intelligence and emerging technologies in smart home designs was achieved by conducting a mixed method research which involved both qualitative and quantitative research approaches. Employing a mixed-method research approach combined qualitative with quantitative data collection techniques using interviews and structured questionnaires. To prevent participant's unfairness, an online survey was selected as the more effective data-gathering tool. The survey questions were constructed with the research's objectives in consideration, comprising four parts in its layout. Respondents for the questionnaire were Architects practicing in Lagos, Nigeria while interview participants were homeowners in Lagos, Nigeria. There were 104 responses questionnaire responses and the interview was conducted on the phone with 5 homeowners. The audio-recorded interview responses were transcribed to a text version by the researcher manually before being utilised for the analysis.

Findings and Discussion

The results obtained from the data-gathering phase are in two sections which include the questionnaire and interview analysis.

Questionnaire Response Analysis

A total of 104 questionnaires were adequately completed and used for the study. Table 1 below presents the demography of the respondents, 46.2% of the architects involved in this survey are diploma holders, while 44.2% are degree holders and 9.6% are other degrees as well, which implies that the responses cut across all degrees. This indicates that the responses are from individuals with significant educational backgrounds. The majority of the architects have a good understanding of the study focus with at least 6-10 years of experience and good familiarity with Artificial Intelligence in smart home design, showing a considerable level of expertise and familiarity with AI in smart home design.

Table 1. Profile of the Respondents

SN	Variables	Categories	Frequency (N = 104)	Percentage (N = 100%)
1.	Level of Education	Diploma	48	46.2
		Degree	46	44.2
		Others	10	9.6
2.	Respondents' Years of Experience	1-5	46	44.
		6-10	38	36.
		11-15	8	7.7
		16-20	-	-
		Above 20 years	12	11.50

Potential benefits and limitations of incorporating artificial intelligence with smart home design technologies

This section of the questionnaire was tailored towards identifying the benefits and limitations of using artificial intelligence and emerging technologies in smart home design. Figure 1 indicates that 88.5% of the respondents prefer AI-powered smart home devices over traditional ones for enhanced functionality. Table 2 shows some of the benefits of AI integration and how the respondents feel about them. The highest mean score (4.0) indicates that AI is perceived to significantly enhance leisure and comfort. Also, AI-enabled smart homes are believed to increase home values, provide convenience and comfort (mean score 3.67), AI contribute to energy efficiency (3.44), and enhance security and safety (3.40). AI is also perceived to contribute to cost savings in smart home operations (mean score 3.21), though it ranked lowest among the benefits. This implies AI technologies are perceived to substantially improve the quality of life for home users. This contends with a previous study on the benefits of AI (Chan et al., 2018; Zhou et al., 2020) Chan et al. (2018), found that AI's capacity to automate and optimize home surroundings results in enhanced comfort and convenience for consumers, supporting this current study. They contend that one of the main drivers of improved living situations is AI's predictive powers, which can change the lighting and temperature to user preferences. Zhou et al. (2020) discussed how AI algorithms can optimise energy consumption in smart homes through

the analysis of usage patterns and the modification of HVAC (heating, ventilation, and air conditioning) systems. They stress how AI can drastically cut down on energy waste, improving the sustainability of dwellings.

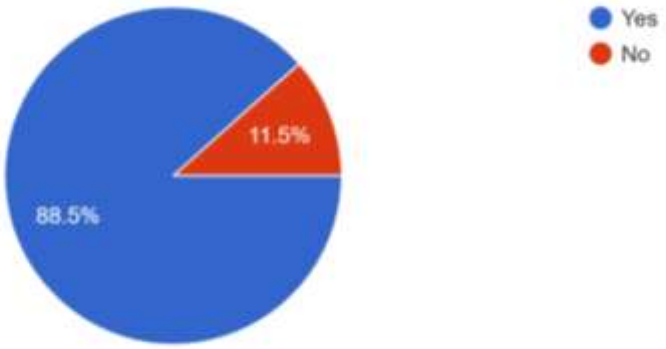

Figure 1: Preference of AI-powered smart homes over traditional ones

Table 2: Benefits of AI Integration

	Strongly Agree	Disagree	Neutral	Agree	Strongly Disagree	Mean	Rank
AI enhances security and safety measures in smart homes	12	6	14	36	36	3.40	5th
AI contributes to cost savings in smart home operations	10	16	40	18	20	3.21	6th
AI contributes to convenience and comfort in smart home operations	12	8	14	38	32	3.67	3rd
AI-enabled smart home increases home value	14	10	10	32	38	3.67	2nd
AI-enabled smart home increases energy efficiency	8	16	30	22	28	3.44	4th
AI enhances leisure and provides comfort	14	8	18	30	34	4.00	1st

Table 3: Limitations of AI Integration

	Strongly Agree	Disagree	Neutral	Agree	Strongly Disagree	Mean	Rank
There are compatibility issues when integrating AI devices with existing smart home systems	16	30	24	28	6	2.79	3rd
There are concerns about the potential job displacement due to the widespread adoption of AI in smart home technologies	14	18	32	30	10	3.04	2nd
AI smart homes make household members lazy	14	22	28	26	14	3.04	2nd
The integration of AI increases dependence on experts	10	10	26	40	18	2.77	4th
The integration of AI to monitor private activities	10	20	30	32	12	3.13	1st

Table 3 shows the limitations of AI integration into smart home design according to their mean and rank. The highest mean score (3.13) indicates significant concern over AI being used to monitor private activities while the lowest mean score was increased dependence on experts. Privacy issues are major concerns that may hinder the widespread adoption of AI in smart home designs. Malgieri and Comandé (2017) study, which emphasizes the ethical

and privacy issues of AI in smart homes, shares this concern. Their study shows that users need strong privacy rules because they contend that the gathering and processing of personal data by AI systems poses serious concerns to user privacy. Also, the dependence on experts and compatibility issues highlights the need for more user-friendly and integrable AI solutions. This finding is consistent with Yin et al. (2019) study that expert dependence would prevent widespread adoption, particularly in areas with little access to technical help. The study's conclusions highlight the significance of resolving privacy problems in AI applications. This implies that although AI has many advantages, these are outweighed by important ethical issues that must be resolved to win over users' confidence and acceptance.

Impacts of AI and emerging technologies on the design, construction, and maintenance of smart homes

This section of the questionnaire was tailored toward examining the impact of artificial intelligence and emerging technologies on the design, construction, and maintenance of smart homes based on respondents' perceptive. Figure 2 indicates that 36.5% of the respondents are neutral with the agreement that AI streamlines the design process of smart home designs and 30.8% of the respondents are in agreement. Figure 3 indicates that 51.9% of the respondents agree that AI technologies help in the reduction of construction time for smart home designs. Figure 4 indicates that 80.8% of the respondents believe that AI-driven maintenance increases the longevity of smart home systems. This implies that AI's capacity to streamline the design process, reduce construction time, and enhance maintenance efficiency demonstrates its potential to change the entire process of smart home design and construction. Figure 5 indicates that 44.2% are satisfied with the performance of AI-managed systems over traditional ones, implying respondents' preference for technologically advanced solutions.

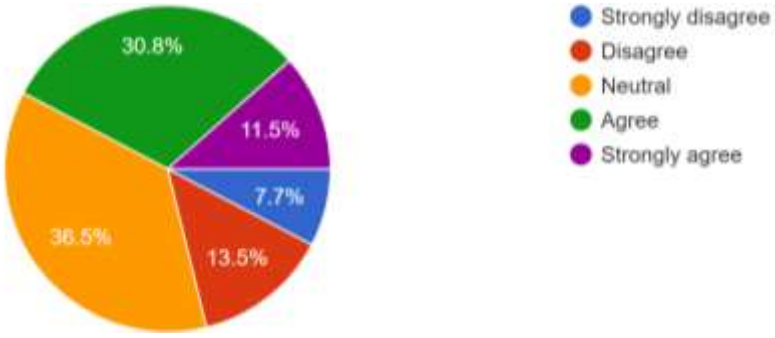

Figure 2: Agreement of AI streamlining the design process of smart homes

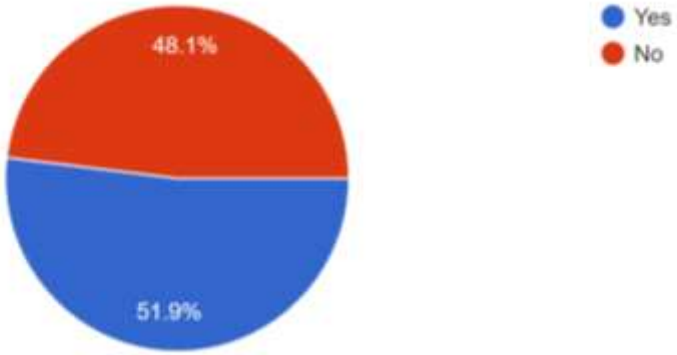

Figure 3: Reduction of construction time by AI technologies in smart home projects

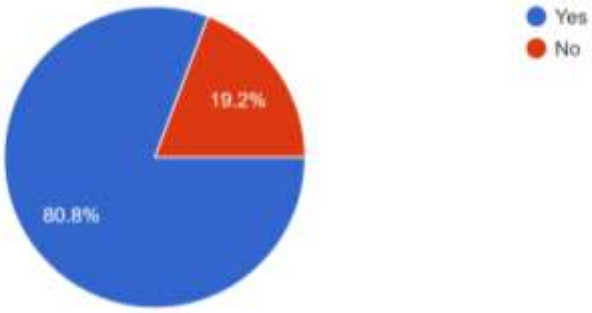

Figure 4: Longevity of smart home systems by AI-driven maintenance

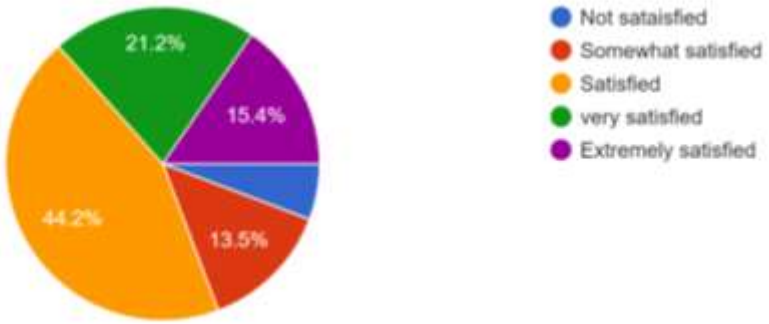

Figure 5: Satisfaction of performance of AI-managed smart home systems to traditional ones

Interview Analysis

The study also conducted interviews to validate the data gathered from architects, the interview data was used to make a discussion surrounding the extent to which homeowners have adopted artificial intelligence and emerging technologies in their smart homes. The interview was conducted among 5 respondents who were coded as R1, R2, R3, R4, and R5, this helps to keep the respondent anonymous and confidential. The interview participants were asked six questions each concerning the level of implementation of AI in smart homes, why AI is important, the benefits, and factors affecting its adoption. All participants have heard of AI in smart homes, but only two have implemented it in their home design. All participants attested that AI in smart homes helps enhance efficiency and functionality to a great or large extent, according to R1 AI is another way of having a functional and comfortable home. According to the respondents, reasons for the adoption of AI technology in smart homes include; comfortability, easy life for occupants, reduce the need for man-power, and promoting sustainability. Reluctance to the use of AI includes; financial constraints, lack of awareness among users, lack of technical know-how, and difficulty in handling. Lastly, participants were asked questions based on what they foresee as the future for the integration of AI in smart home design within Lagos. The respondents see it as a life-changing technological advancement and if all challenging factors are taken care of, its adoption level will be high. According to R1, more people will implement AI because of its great advantages, although it has to do with the use of power and connectivity. This also means the full introduction of electricity which could be the use of solar energy or a more sustainable power supply. R2 stated AI technology is a fast-growing trend and will be used if awareness increases and cost reduces. In summary, the use of AI in smart home design still needs some awareness and the limiting factors should be addressed.

Conclusion

The results show that the integration of AI in smart homes is very important in architecture because it improves the overall aesthetics of smart home designs and it also reduces the construction time of the buildings. However, these architects face challenges like fear of AI to monitor private activities and the integration of AI increases dependence on experts. Based on the study findings, the study recommends conduction of workshops and training sessions for construction professionals to enhance their understanding of AI applications in smart building design. It also encourages collaboration between architects, engineers, and contractors to promote the adoption of AI features in building projects. The study also recommends the incorporation of smart home technologies into building regulations and codes to ensure new homes are designed with the necessary infrastructure to accommodate home technologies.

Conflicts Declarations

The authors declare no conflict of interest

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