AI-Driven Building Architecture. Ethics, Sustainability and Optimization

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Abstract. The architectural sector is seeing a boom in the integration of artificial intelligence (AI), motivated by its promise to improve sustainability and building efficiency. However, there is a scarcity of studies on ethical problems in AI-driven architectural methods. Data for this study were acquired from practising architects using a mixed methods approach that included questionnaires and interviews. The findings revealed an increased understanding of AI's potential but also prompted worries about its ability to replace human creativity and talent. The research also emphasized the need to carefully consider ethical concerns such as prejudice, transparency, and responsibility. Respondents were also concerned that AI might exacerbate current biases in the industry, notably regarding gender, race, and socioeconomic status. The research indicates that the incorporation of AI in the process of designing and building can enhance sustainability and building performance optimization in the architectural domain, regardless of these limitations. Architects can use the issues highlighted in the study to incorporate AI into their practice, ensuring ethical standards in technological advancements.

Keywords: artificial intelligence (AI), architecture, ethics, sustainability, building performance optimization

Introduction

AI is playing an increasing role in architectural design, integrating artificial intelligence methods in design, analysis, and fabrication (Wei 2019). AI, machine learning, and the Internet are more and more being used in building architecture to increase efficiency, grid flexibility, and occupant well-being (Ntafalias 2022). AI technology in smart buildings is growing, offering benefits such as energy consumption reduction, improved automation control and reliability, and enhanced safety and comfort for occupants (Panchalingam & Chan 2019). Artificial intelligence is integrated to create self-learning buildings that can adapt to future challenges, thereby contributing to a more sustainable world (Maksoud et al. 2022). AI in architectural design may create new jobs and replace existing ones, but it requires specialized field diversity and controlled flexibility for success (Lin & Xu 2021).

LITERATURE REVIEW

AI, Sustainability and Building Performance Optimization

Artificial intelligence-enabled smart buildings can potentially contribute to sustainable cities by reducing energy consumption costs and improving occupants' comfort, productivity, and safety (Sleem & Elhenawy 2023). AI-based decision support systems are primarily focused on early-stage project prediction, with economic sustainability being the most considered goal, although environmental and social goals are receiving increasing attention (Smith & Wong 2022). AI's integration into urban services can potentially enhance the sustainability of cities, but policymakers, planners, and citizens must make informed decisions about its adoption (Yigitcanlar & Cugurullo 2020): multi-zone optimization of high-rise buildings using artificial intelligence for sustainable metropolises (Ekici et al. 2021) AI is increasingly being used in the design process to save labour, accelerate implementation, and optimize building performance for construction, prefabrication, and energy efficiency (Furmanek 2021). Artificial intelligence, specifically machine learning, is being used to optimize energy performance in buildings through a rapid energy performance estimation engine (Seyedzadeh et al. 2020, 17). Advanced analytics methods can be deployed in real-time or near-real-time to analyse the Building Automation System (BAS) data for building performance optimization (Misic et al. 2020, 2-4). Artificial intelligence algorithms, including hybrid neural networks and decision trees, can effectively enhance the accuracy of objective functions used in building energy prediction and optimization problems (Banihashemi et al. 2017). AI, specifically the Particle Swarm Optimization (PSO) model, is effective in optimizing the strength, energy, and cost of building materials in construction management engineering (Ronghui & Liangrong 2021). Artificial intelligence, specifically machine learning methods, has been employed to forecast building energy consumption and efficiency (Tabrizchi et al. 2019, 1). AI techniques, such as the Firefly and Genetic Algorithms, are being used for optimizing energy consumption and maximizing user comfort in smart buildings (Wahid et al. 2019, 5, 6, 22). AI control systems and cloud-building energy and environment monitoring systems can improve building management, equipment, and system optimization and reduce CO2 emissions (Bumpei & Yashiro 2019, 12). Boosted regression trees, an artificial intelligence technique, are used to accurately predict the level of comfort in office buildings, providing substantially superior predictive performance (Sajjadian et al. 2018, 8, 1).

AI, Ethics and Architecture

Since using AI technologies might have unintended consequences, we should think about the ethical ramifications (Sciarretta et al. 2022, 66, 71). Tzachor et al. (2020, 2) emphasize the need for robust ethics and risk assessment processes when deploying AI technologies rapidly, which can be extrapolated to other fields, including architecture. Regona et al. (2022, 2) identify significant challenges, including ethical considerations, associated with integrating AI into the construction industry. While not explicitly addressing these ethical issues, the research highlights the complexities of implementing AI technologies in this sector, such as data acquisition, labour constraints, and site variability, which implicitly raise ethical questions concerning safety and optimal utilization. Shazly et al. (2020, 2, 3) discuss how the use of AI in building architecture presents ethical questions about data collection, applications, and conversion to commodities across the life cycle of data. An ethical framework ensures human control in building architecture while maximizing the promise of AI and minimizing the hazards (Taddeo and Floridi 2018, 2, 3). Green (2018, 2) listed a number of ethical issues with integrating AI technology, including reliance, rights, moral automation, robot awareness, evil and good uses, bias, unemployment, socioeconomic injustice, and spiritual and social psychological repercussions. AI deployment can be ethically justified using design techniques in algorithms, data sets, and applications, even in sensitive applications like national security (Carter 2022, 2, 5, 9).

METHODOLOGY

Using a mixed-methods approach, this study investigates the ethical implications of AI adoption in architecture. Architects and members of the construction sector participated in an online survey, and architects, artificial intelligence experts, and sustainability consultants participated in semi-structured interviews to gather qualitative data. Correlations, trends, and patterns are found through analysis. By integrating quantitative and qualitative data, the triangulation approach offers a thorough understanding of AI deployment and perspectives. The research draws attention to the particular moral issues architects and other building construction stakeholders encounter in technology-powered contemporary practice.

DISCUSSION OF FINDINGS

Demography

A total of 1011 out of 1500 questionnaires were completed, with a response rate of almost 67%. The data for this study were gathered from a sample of 1011 people working in the Nigerian construction business. Respondents were picked using a non-probability convenience sampling approach. The poll was sent electronically to industry experts such as architects, engineers, and contractors. The survey data shows men as a substantial majority of respondents (81.8%), while women were merely 18.2%. Some participants were under 25 years old (10.1%), but the biggest group fell between 31 to 35 accounting for 40.1%. This is closely followed by those who fall within the age bracket of 26-30, which makes up 34.9% of all respondents. As such, it seems that most professionals are in their early to mid-career stages and few are experienced beyond twenty years. Respondents' education level was high, with postgraduate degree holders dominating at 60% and only 35% having bachelor's degrees. For instance, this research also highlights potential barriers to entry into the profession facing younger architects as well as an increasing absence of women and older professionals even though they do not represent all architects practicing in Nigeria. However, it should be noted that these findings may be biased due to potential limitations associated with self-reported surveys.

RESULTS

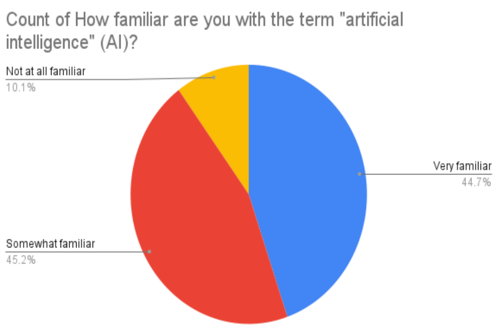

Fig. 1: Respondents' familiarity with Artificial Intelligence.

As per the graph, 10.1% of participants are completely ignorant of the term "artificial intelligence" (AI), whereas 44.7% and 45.2% of them have some knowledge of it. This demonstrates how artificial intelligence's reputation is growing quickly despite the fact that it is still young and evolving. The study's findings indicate that people's ability to identify intelligence increases with age and educational attainment. Increased interest in technology has also been linked to cognitive decline, according to research. All things considered, the data indicates that artificial intelligence (AI) is a quickly taking off trend that is becoming more and more popular, particularly among youth and tech aficionados.

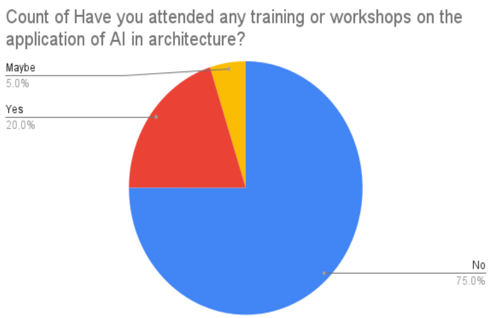

Fig. 2. Respondents' attendance at training/technical workshops on Artificial Intelligence and Architecture.

75% of respondents said they had not attended a skills development session or workshop, with "No" being the most common response. 20% of survey respondents said they had attended an AI development workshop or training, with a "yes" answer being the second most popular option. 5% of survey respondents said they were considering attending an AI development training or workshop, with "maybe" being the least likely option. Research shows that there is an urgent need for architects to be trained in these skills. This seems logical because artificial intelligence is still a very young field. However, it should not be forgotten that artificial intelligence has the power to change the planning, construction and operation of buildings. Architects and other partners must therefore develop knowledge and skills necessary for the fair and responsible use of intellectual skills.

The survey results showed that 554 out of 554 participants had at least heard of the use of skills in construction. Of a particular app, a small percentage (303 people) are not aware of that app. The number 152 suggests they may have heard of some specific practices. This demonstrates awareness of the potential of AI to

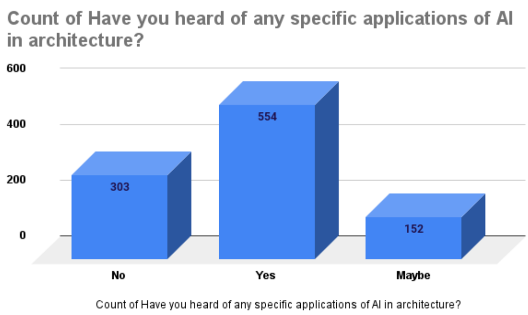

Fig. 3. Respondents' familiarity with Artificial Intelligence applications in Architecture.

improve the design, optimization and sustainability of the built environment. A number of AI devices have been used for architectural projects as reported by the respondents.

Some of the most popular ones are:

Coolhom: A design-focused 3D smart tool used to optimize building designs.
Midjourney: An AI platform that generates real-life images from texts.
Bing Image Generator: This search engine is designed specifically to generate visual content.

Other than these tools, architects also use other AI-based solutions to improve their design work, and notable options are:

Autodesk Generative Design Tools: Uses AI to explore different design alternatives given certain parameters.
Rhino.ai: Uses AI for 3D modelling, analysis, and visualization.
Archilogic: It makes 3D models and interactive floor plans from 2D drawings.
Autodesk Construction Cloud: Employs artificial intelligence (AI) for project management planning and coordination purposes.
Karamba: uses artificial intelligence (AI) to perform structural optimization and analysis.
ANSYS: provides AI-powered simulation and analysis capabilities for structural engineering.

IES VE: incorporates Artificial Intelligence (AI) into the building performance simulation and energy analysis activities it performs.

Survey results show that the most positive attitudes towards the potential impact of AI are in the following areas: architecture, understanding its role in streamlining workflows, automating repetitive tasks, streamlining production, and aiding conceptualization and user communication. However, artificial intelligence also has great potential in the field, such as fulfilling the needs of architects or creating unique models and designs.

There are however concerns about financial risk and reliance on wisdom, leading to the possibility of laziness. Ethical issues and the fear that architects will become careless and lazy due to the pooling of expertise are recurring themes. Overall, analysis of the responses shows that a balanced approach is needed to reap the benefits of AI while tracking its progress.

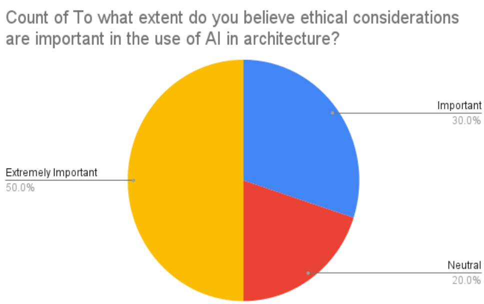

Fig 4. Respondents' perspective on the importance of ethical considerations in the integration of Artificial Intelligence in Architecture.

The research raises ethical questions about the use of artificial intelligence in architectural design. Some claim that artificial intelligence (AI) may be used to prevent panic in real estate education, while others are concerned that AI would provide uninteresting, unsophisticated and useless models. The necessity to restrict human participation in design and decision-making processes is stressed. The report advises against depending on the same AI algorithms over the world since this might lead to a lack of architectural change. The study also underlines the necessity to recognize creative inspiration and the value of human aid in the design process.

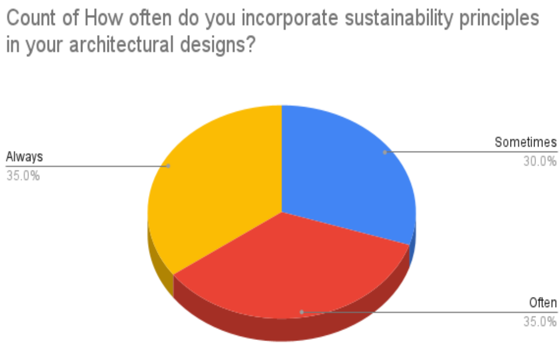

Fig 5. Respondents' frequency of application of sustainability principles in Architectural Design.

The survey responses suggest a range of perspectives on how AI can contribute to sustainable architectural practices. Some respondents express uncertainty or doubt about AI's ability to grasp environmental design problems effectively. However, there is a prevalent acknowledgement that AI can enhance sustainable practices by providing access to data, automating model checking against sustainability principles, optimizing resource use, and offering insights for better analysis of conditions related to sustainability. The idea that AI algorithms can generate numerous design variations, allowing architects to choose the most sustainable and efficient options, is highlighted.

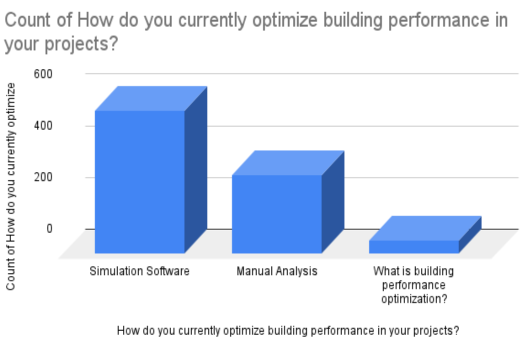

Fig 6. Respondents' level/method of optimizing building performance.

Architects encounter a number of challenges when it comes to achieving sustainability and building performance optimization, including the sourcing and pricing of sustainable materials, knowledge and competence in contemporary environmental technology, time restrictions, project limits, and the availability of sustainable materials. AI may solve these difficulties by automating repetitive operations, improving designs for sustainability and performance, and allowing for design simulation and automation. AI can mimic building performance in terms of energy consumption, carbon emissions, and occupant comfort, allowing architects to make more informed decisions and guarantee that structures fulfil sustainability targets. It may also offer sustainable materials that suit project needs and budgets, as well as analyse massive volumes of data on buildings and their performance to find patterns and areas for improvement.

AI can produce novel concepts for sustainable and high-performance buildings, challenging conventional wisdom and exploring new possibilities. It may assist architects in closing knowledge gaps by giving access to a variety of information about sustainable building materials, technology, and design solutions *via* AI-powered databases, knowledge graphs, and expert systems. AI may also assist architects locate resources for learning about sustainability and building performance optimization, such as training courses, workshops and conferences, as well as link them with specialists in these domains. Furthermore, AI can mimic and automate zoning rules, building ordinances, and floodplain restrictions, providing greater knowledge of how different regulations affect building design and performance, which may help guide policy choices and enhance urban environmental sustainability.

Data, cybersecurity, and programming are some of the issues that AI encounters when used to optimize building performance. Input accuracy, confusing information, data privacy, and upkeep are all major challenges. AI systems may also disregard human control and preferences, emphasizing the importance of striking a balance between efficiency and human touch. A dearth of trained experts may impede the deployment and maintenance of AI-powered systems. Cost and accessibility are other important considerations. The initial cost of installing AI-powered systems might be considerable, possibly impacting some businesses or organizations. Access to electricity, computer capacity, and connection may restrict the usage of AI in specific places or buildings.

Technology-related ethical issues in architectural projects are not uncommon. Examples include designing for the future and attaining transcendent design in building. It is out-of-date to make irrelevant designs that do not take into account the context and demands of the present. This raises moral questions regarding the architect's duty to offer designs that are responsive, sustainable, and relevant. The quest for inventive and aesthetically beautiful designs must coexist with financial and practical limits in order to achieve a transcendent design in building. A comprehensive approach to problem-solving that takes into account aesthetics, functionality, and environmental effects was stressed by respondents. They also emphasized the significance of lifelong learning and expert advice in order to successfully negotiate moral conundrums, underscoring the necessity of a comprehensive approach to design and advancement.

CONCLUSION AND RECOMMENDATION

The study highlighted the necessity for a balance between ethical considerations and human touch as it examined the possible advantages and hazards of AI in architecture. AI can speed up sustainable practices by automating, optimizing, and gaining access to data. Regarding AI's ability to improve building performance, respondents were cautiously optimistic. Before AI is extensively used in the field, there are obstacles that must be overcome. Although there are many ethical conundrums with the use of technology in architectural projects, these problems may be solved in a way that upholds moral standards. The study suggests eliminating prejudices against the use of AI in performance optimization and sustainability. Architects may overcome their initial reluctance and promote inquiry by receiving education and being aware of the AI potential. Training and skill development can help the shift go more smoothly and boost confidence while integrating AI. Building confidence and promoting broader acceptance may be achieved by showcasing the efficacy of AI applications in architecture through successful case studies. A defined set of rules for the moral application of AI in design might help allay worries about accountability, transparency, and bias. A more controllable transition can be achieved by implementing integration in phases to reduce disturbances. Software engineers, AI specialists, and architects working together can make it easier to create AI solutions that are specifically suited to the requirements of the architectural sector.

The report suggests doing a larger-scale study to get more representative data from a diverse group of architects. It also proposes looking at AI's present use in architecture to uncover potential applications and problems. A framework for ethical AI use in architecture should be created to overcome bias, transparency, and accountability challenges. Collaboration among architects, AI specialists, and software developers helps speed up the creation of AI solutions adapted to the architectural industry's requirements. A collection of successful AI implementation case studies may highlight the practical benefits of AI while also encouraging wider use. These guidelines are intended to guarantee that the findings are generalizable and relevant to the larger architectural community.

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