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Understanding Artificial Intelligence in Architecture and Construction

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Abstract

This study investigates the applications of Artificial Intelligence (AI) in the Architecture and Construction sectors, examines how Artificial Intelligence is integrated with Building Information Modeling (BIM) and its impact on the entire project lifecycle. A review of AI's pivotal role in modern architecture and construction. Artificial Intelligence is an engine that radically transforms project conception, alters the design, execution and management practices of infrastructure project. It brings significant advantages in all phases of the project, revolutionizing traditional methodologies in the Architecture and Construction by automating repetitive tasks, enabling faster design iterations through generative design, optimizing building performance through data analysis, improving collaboration with BIM integration and facilitating better decision-making with advanced simulations. The article delves into various critical applications of AI in the Architecture and the construction industry including optimized design achieved through automatic generation of innovative designs with generative design practices, advanced project management by predicting and optimizing resources, improvements in terms of safety at work, sustainable development, virtual and augmented reality applications, the creation of intelligent expert systems and finally explore the future of AI, AI's impacts on the design process and how it works with architectural-construction technologies and the associated benefits and challenges.

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Introduction

In 1956, the phrase “artificial intelligence” was first used in a Dartmouth, United States, symposium attended by the leading scholars. Therefore, it has been possible to discuss the existence of artificial intelligence for over fifty years. In recent years, however, the usage of artificial intelligence has become widespread due to advancements in processing power, the availability of huge amounts of data, and the creation of new algorithms [1]. Basing on the latest estimates provided by the United Nations, the global population is projected to experience significant growth over the coming years. By 2030, it is expected to reach approximately 8.5 billion, followed by an increase to 9.7 billion by 2050. The anticipated demand for infrastructure in the near future exceeds the capacity of the current construction sector to meet such requirements. The challenges of the architecture and construction sectors are often linked to inadequate technological expertise and a low level of technology adoption. These issues have been associated with cost inefficiencies, project delays, subpar quality performance, uninformed decision-making, low productivity, and shortcomings in health and safety outcomes. As a response to the slow performance growth in the construction sector, organizations are initiating the investigation and adoption of AI (Artificial Intelligence) to optimize procedures and drive productivity [2]. Architecture and construction has changed as the use of AI and robotics to boost productivity, creativity, and supply chain alignment is being employed. Even though the Industry is still developing, this alignment has created Supply Chain. This hybrid approach allows architects and engineers (architectural and construction firms) to pioneer sustainable structures and shape future environments [3]. AI's integration has transformed current practices, introducing innovative methodologies and tools that optimise various facets of the construction lifecycle [4].

AI deals with the science of inventing intelligent machines and computer systems that can learn and help to solve problems. It is playing a significant role in the era of digitalization, driving the digital transformation of many industries and sectors, including Architecture and construction. In the Architecture and Construction industry, AI provides advantages to deal with a diversity of difficult, complex construction-engineering and management of problems that defy conventional computational methods-based solutions [5].

The increasing need for sustainable, intelligent and durable infrastructure has hastened the integration of AI and other technologies where AI has advanced swiftly, finding applications across various fields. In this, AI systems can emulate human thought processes and handle repetitive tasks with extensive data [6]. Artificial Intelligence (AI) was in 1955 defined by emeritus Stanford Professor John McCarthy as, “the science and engineering of making intelligent machines.” Artificial intelligence (AI) is a set of technologies that enable computers to perform a variety of advanced functions, including the ability to see, understand and translate spoken and written language, analyze data, make recommendations, and more.

Artificial intelligence in architecture and construction has changed the field, transforming the industry by enhancing project conception, design, and execution, but its effectiveness still depends on the user's expertise. While AI-powered generative design tools rapidly explore possibilities and optimize layouts, their true potential is unlocked when asked the right questions and the right

scenarios posed. Architects, designers and engineers guide the AI, ensuring that designs are efficient, sustainable, and aligned with the project vision. This collaboration between AI and the professionals/users in the architecture and construction accelerates creativity and streamlines project development. As projects advance, AI plays a critical role in management and execution where project management teams use AI to possibly spot anomalies before they disrupt project progress.

Enhanced BIM with AI capabilities provides real-time updates and predictive maintenance, ensuring meticulous planning and monitoring. AI assists in scheduling, resource allocation, and risk management, keeping projects on track and on budget. AI advancements also improve collaboration by integrating data from various sources, facilitating better stakeholder communication. AI-driven VR and AR technologies provide immersive visualizations, enabling clients to experience and give design feedback before construction begins. These developments highlight AI's pivotal role in modern architecture and building construction, driving innovation and efficiency from concept to completion.

2- IMPACT OF AI ON THE DESIGN AND CONSTRUCTION PROCESS

With AI-powered generative design tools, architects, structural and construction engineers can swiftly generate numerous design alternatives by setting specific parameters, optimizing layouts, and selecting materials for innovation and practicality. These tools also leverage environmental data to recommend sustainable materials and optimal building orientations, boosting energy efficiency and project sustainability. This accelerated and refined design approach speeds up the process and elevates the quality of the final designs driving efficiency, innovation, and sustainability. Advances include generative design tools, real-time BIM updates, and streamlined workflows that optimize projects and enhance project management, collaboration, and sustainability.

AI in architectural design and construction transforms project conception, design, and execution. By optimizing layouts, structures, and materials with generative design tools, AI enhance BIM, project management, and visualizations to improve collaboration and decision-making, enhances design efficiency, creativity and precision. Generative design tools improve sustainability and quality while Immersive virtual reality (VR) and augmented reality (AR) visualizations give clients unparalleled experiences of their future spaces while predictive data insights drive informed decisions and personalized solutions. Architects and construction engineers can explore countless design possibilities in seconds with AI-powered generative design and push the boundaries of creativity while optimizing every aspect of a project. From automated drafting to real-time updates in building information modeling (BIM) to energy-consumption analysis, AI streamlines workflows, allowing to focus on creating visionary designs.

AI revolutionizes traditional methodologies in Architecture and construction engineering, “[The transformative impact of Artificial Intelligence on efficiency, design innovation, and sustainability]”, by automating repetitive tasks, enabling faster design iterations through generative design, optimizing building performance through data analysis, improving collaboration with BIM integration and facilitating better decision-making with advanced

simulations, ultimately leading to more efficient and innovative project delivery while minimizing errors and costs.

AI promotes sustainability with energy-efficiency insights and eco-friendly material recommendations.

Project management is also evolving with AI, ensuring timely and budget-friendly completion through intelligent scheduling, resource allocation, and risk prediction. Enhanced collaboration and seamless data integration improve communication among architects, engineers, contractors, and clients, resulting in smoother project execution and deliver superior projects more efficiently, showcasing AI applications in the industry [7]. As this technological revolution continues, the future of architectural design and construction will continue to evolve and embrace innovation.

3- KEY WAYS AI IMPACTS ARCHITECTURE AND THE CONSTRUCTION INDUSTRY

3-1- DESIGN OPTIMIZATION

- i. **Generative Design:** AI algorithms can generate a wide range of design options based on parameters, allowing architects to explore more creative and optimized solutions quickly.
- ii. **Site Analysis:** AI can analyze large datasets like environmental factors, traffic patterns, and local regulations to inform design decisions.
- iii. **Building Performance Simulation:** AI can simulate energy consumption, lighting conditions, and indoor air quality to optimize building design for sustainability.

3-2- CONSTRUCTION MANAGEMENT

- i. **BIM Integration:** AI can analyze vast amounts of data within Building Information Models (BIM) to identify potential issues, optimize scheduling, and improve cost estimations.
- ii. **Construction Monitoring:** AI-powered cameras and sensors can monitor construction progress, detect safety hazards, and identify potential delays in real-time.
- iii. **Resource Optimization:** AI can optimize resource allocation by predicting material needs and scheduling deliveries efficiently.

3-3- COLLABORATION AND VISUALIZATION

- i. **Virtual Reality (VR) and Augmented Reality (AR):** AI-powered VR and AR experiences allow clients and stakeholders to virtually walk through designs, facilitating better communication and decision-making.
- ii. **Data-driven Insights:** AI can analyze large datasets to provide valuable insights for design teams, enabling better collaboration and informed decision-making.

3-4- SUSTAINABILITY AND RESILIENCE

- i. **Energy Modeling:** AI can analyze energy usage patterns and suggest design modifications to optimize energy efficiency.

- ii. Climate Change Adaptation: AI can help design buildings that are resilient to extreme weather events by analyzing climate data.

4- HOW AI WORKS WITH ARCHITECTURAL AND CONSTRUCTION TECHNOLOGIES

AI is enhancing architectural technologies like BIM, digital twins, extended reality (XR), and the Internet of Things (IoT). In Building Information Modeling (BIM), AI facilitates real-time updates, predictive maintenance, and automated clash detection, streamlining the construction process and ensuring accurate and up-to-date models. AI in the realm of design and BIM with the integration of cutting-edge technologies, notably Generative Adversarial Networks (GANs) and models like ChatGPT, has also profoundly transformed how architects, engineers, and construction professionals conceive, plan and execute projects [8]. Recent studies using Large Language Models (LLMs) to solve construction-related problems demonstrate the long-term opportunities of GenAI in the industry.

In 2023, Zheng and Fischer developed a BIM-GPT integrated framework to retrieve, summarize, and answer questions from the BIM database, overcoming the challenges due to the extensive engineering required to automate complex information extraction from rich BIM models. By prompting the LLM appropriately, BIM-GPT shows how advanced integration can extract value from construction data assets [9]. Digital twins benefit from AI's ability to simulate scenarios, predict outcomes, and optimize building performance for more efficient, sustainable operations. AI is also transforming XR technologies, including VR and AR, by providing more immersive and interactive design experiences. This allows to visualize and modify designs in real time, leading to better decision-making. AI enhances IoT by analyzing data from connected devices to optimize building management systems, improving energy efficiency, security, and occupant comfort.

Real-time monitoring through IoT sensors provides invaluable insights into the structural health of buildings and infrastructure, allowing for proactive maintenance and reducing the likelihood of unexpected failures [10]. Looking at building construction being the most diverse sub-sector in construction, it is a complex and dynamic process that involves multiple stakeholders, such as owners, architects, engineers, contractors, subcontractors, suppliers, and regulators. The process requires coordinating and integrating various activities, such as design, planning, scheduling, procurement, fabrication, installation, inspection, and maintenance. The process also generates and consumes vast data, such as drawings, specifications, contracts, reports, invoices, and photos. Building construction's quality, efficiency, and sustainability depend primarily on how well these activities and data are managed and utilized. Each of these aspects involves complex and dynamic processes that require coordinating and integrating various resources, disciplines, and stakeholders and considering and managing various constraints, uncertainties, and changes. These challenges pose significant difficulties and risks for this industry, resulting in low productivity, high cost, long delays, poor quality, and high environmental impact. Addressing these challenges and improving the performance and productivity requires innovative and disruptive solutions that can leverage the power of data and technology. The most promising and emerging solution is Generative Artificial Intelligence (GenAI), a branch of AI that aims to create novel and realistic data or content, such as text, image, video, audio, or code, based on some input or prior knowledge. Generative AI can be seen as the opposite of discriminative AI, which aims to classify or recognize

data or content, such as identifying objects in an image or translating text from one language to another. Generative AI can also be seen as a form of creative AI, which aims to produce data or content that is not only realistic but also original, diverse, and expressive. Generative AI also relies on large language models (LLMs), which are neural network models that can generate natural language text based on a given prompt or context. LLMs are trained on massive amounts of text data from various sources, such as books, articles, websites, and social media. They can capture natural language's semantic and syntactic patterns and relationships [11]. The AI models and techniques for smart and sustainable architecture and construction also include, AI-enhanced project management, AI-driven safety monitoring, generative Design, AI-driven energy optimization, materials selection and recycling, AI for green certifications, affordable housing solutions, disaster resilience and response, inclusive urban planning and social impact assessment [12]. The integration of AI with these technologies enhances the entire building/structure lifecycle, making structures smarter, more efficient, and adaptable to future needs. The influence of construction materials on the building structure has various aspects in addition to the traditional expectations of high strength and durability, such as construction timelines, energy consumption, carbon emission, aesthetics, and thermal comfort. As a result, the contribution of many influencing factors to the optimization of construction materials makes it difficult for traditional approaches to finding the efficient material recipe. Additionally, traditional methods need numerous trial-and-error cycles on experiments and simulations, which are laborious, time consuming, and resource intensive, even for improvements on a single property. The explosive development of artificial-intelligence (AI) techniques can drastically alter and improve the role of computers in science and engineering.

Machine learning (ML), especially deep learning (DL), is one type of the key branch of AI, which derives mathematical models that can directly execute out specific tasks (e.g., generation, prediction, improvement, clustering, and dimension reduction) from acquired data (e.g., data tables, graphs, and images) utilizing computer algorithms. These technologies are well suited for solving complex problems involving a large number of combinatorial spaces or nonlinear processes that cannot or can only be solved at a higher computational cost through traditional approaches [13].

5- BENEFITS OF USING AI IN ARCHITECTURE AND CONSTRUCTION

The construction industry as well as architecture faces numerous challenges, such as optimizing project planning, design, resource allocation, and risk management. The integration of AI technologies has the potential to address these challenges and improve overall performance [14]. Integrating AI into architectural and construction engineering practices brings a host of transformative benefits that enhance every stage of the design and construction process. From optimizing resources and automating repetitive tasks to improving project management and client interaction, AI is revolutionizing how architects, construction engineers and project managers work and how buildings are conceived and maintained.

In summary here are key benefits of using AI in architecture, construction and engineering in general each contributing to more efficient, innovative, and sustainable built environments; enhanced design exploration, optimization of resources, automation of repetitive tasks, improved

project management, Real-time collaboration, enhanced visualization and client interaction, Predictive maintenance and management, energy efficiency, Increased precision and reduced errors, data-driven decision-making and finally safety and quality control which are the AI's significant advantages to the architectural and construction industry to ensure effective task and time management.

Artificial Intelligence (AI) technology not only optimizes processes but also improves efficiency for traditional building design. AI's evolution from rule-based systems to large-scale models is accelerating the digital intelligent transformation of the sector [15]. AI with its capacity to analyze extensive datasets, make informed decisions and simulate complex scenarios, complements the dynamic and real-time data acquisition capabilities of IoT [16]. Despite the transformative potential of AI in architecture, several challenges hinder its widespread adoption. A significant barrier is the initial investment required for AI technologies and infrastructure. Another obstacle is the learning curve associated with AI tools, requiring training and upskilling and resistance to change remains prevalent in the industry, as some professionals accustomed to traditional methods may be slow to embrace new technologies. However, these challenges are not insurmountable. Adoption of a phased approach, starting with smaller projects to gradually integrate AI and build confidence in its capabilities.

Collaborative partnerships between AI providers and users can tailor solutions to specific needs, reducing costs and complexity. Investing in robust training and sensitization programs will create awareness and equip the workforce with essential skills, fostering a culture of innovation and adaptability.

Cloud-based AI services can mitigate the need for heavy in-house infrastructure, making advanced AI tools more accessible. By strategically addressing these challenges, the architectural and construction industry can fully leverage AI's potential, paving the way for a more efficient, innovative, and sustainable future.

6- CONCLUSION

As AI technology advance as well as AI user awareness, it will enhance the capabilities and efficiency of architects, engineers, and construction professionals instead of replacing them. While AI can perform so many tasks, the creative and complex nature of design and analysis requires the creative thinking and intuition that only human can provide. Designers bring a unique blend of creativity, experience, and emotional intelligence to design spaces that resonate on a deeply human level through Human centered AI.

Human-centered AI is an essential need to help the machines understand and utilize human input for amplifying human abilities and reflecting realistic conceptions in Architecture, construction and engineering in general. Human-centered AI, mainly via natural language processing and machine reading comprehension, can understand and learn from human interests, preferences, languages, and behaviors for providing human-centered environments, systems, and approaches that satisfy human interests and preferences. The first approach includes a surrogate modelling process for replacing conventional time-consuming modeling processes by an economical computational predictive model based on several intelligently simulation results. The surrogate

model process can properly detect patterns from historical data in real time or near real time that enable making quick decisions.

The second approach is considered design-assist modelling which is integrated into the intuition of designers to facilitate architectural processes having no analytical explanations (e.g. optimizing the spatial layout of furniture within a space) [17]. The ability of AI to generate and evaluate numerous design options quickly a process known as generative design, a subset of artificial intelligence that uses algorithms to explore and generate various design options based on a set of constraints and parameters provided so designers and engineers can apply their expertise to selecting and refining the best solutions. It allows designers and engineers to focus on the more creative and strategic aspects of their work. By analyzing customer data, generative AI can identify patterns and create product designs that are more likely to be successful. The collaboration between AI and users through Intelligent Expert systems leads to more innovative, efficient and sustainable designs. AI expert systems that specifically aim to replicate human expertise and decision making processes within specific domains, leverage knowledge bases, rules sets and inference mechanisms to provide recommendations or make decisions, imitating the problem solving capabilities of human experts.

Overall, AI empowers architects, engineers, and construction professionals to move beyond traditional design methods by leveraging data analysis, advanced simulations, and automation to create more efficient, sustainable, and innovative buildings while improving project outcomes. The future of AI in the Architectural-construction engineering industry is interesting as advanced algorithms and real-time data analysis ensure that buildings are designed and constructed with the highest safety standards, predicting potential risks and mitigating issues before they arise as well as cost efficiency is significantly improved by AI's optimized resource allocation, reduced material waste, and streamlined project timelines. Additionally, AI's ability to analyze environmental data and recommend sustainable materials and practices leads to greener and more energy-efficient buildings. As AI integrates into the fabric of built cities and communities, it enables smarter and safer structures and paves the way for a sustainable future.

7- References

1. Bolek B., Tural O. and Ozbasaran H., 2023. "A systematic review on artificial intelligence applications in architecture."
2. Datta S.D., Islam M., Sobuz M.H.R., Ahmed S. and Kar M., 2024. "Artificial intelligence and machine learning applications in the project lifecycle of the construction industry: A comprehensive review."
3. Amjad A., Ibrahim Y., Asaad A, 2023. "Reviewing and Integrating AEC Practices into Industry 6.0: Strategies for Smart and Sustainable Future-Built Environments."
4. Massimo Regona, Tan Yigitcanlar, Carol Hon, Melissa Teo, 2024. "Artificial intelligence and sustainable development goals: Systematic literature review of the construction industry."

5. Amos Darko, Albert P.C. Chan, Michael A. Adabre, David J. Edwards, M. Reza Hosseini, Ernest E. Ameyaw, 2020. “Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities.”
6. Damilola Onatayo, Adetayo Onososen, Abiola Oluwasogo Oyediran Hafiz Oyediran, Victor Arowoia and Eniola Onatayo, 2024. “Generative AI Applications in Architecture, Engineering, and Construction: Trends, Implications for Practice, Education & Imperatives for Upskilling—A Review.”
7. Jon Holmes, 2024. “How AI in architecture is shaping the future of design and construction.
8. Rane N., 2023. Role of ChatGPT and Similar Generative Artificial Intelligence (AI) in Construction Industry.”
9. Prashna Ghimire, Kyungki Kim, Manoj Acharya, 2023. “Generative AI in the Construction Industry: Opportunities & Challenges.”
10. Nitin Rane, Saurabh Choudhary, Jayesh Rane, 2023. “Artificial Intelligence (AI) and Internet of Things (IoT) – Based Sensors for Monitoring and Controlling in Architecture, Engineering, and Construction: Applications, Challenges, and Opportunities.”
11. Ridwan Taiwo, Idris Temitope Bello, Sulemana Fatoama Abdulai, Abdul-Mugis Yussif, Babatunde Abiodun Salami, 2024. “Generative AI in the Construction Industry: A State-of-the-art Analysis.”
12. Nitin Rane, 2023. “Integrating Leading-Edge Artificial Intelligence (AI), Internet of Things (IoT), and Big Data Technologies for Smart and Sustainable Architecture, Engineering and Construction (AEC) Industry: Challenges and Future Direction.”
13. Xing Quan Wang, Pengguang Chen, Cheuk Lun CHOW, Denvid Lau, 2023. “Artificial-intelligence-led revolution of construction materials: From molecules to Industry 4.0.”
14. Ke Wang, Ziyi Ying, Shankha Shubhra Goswami, Yongsheng Yin and Yafei Zhao, 2023. “Investigating the Role of Artificial Intelligence Technologies in the Construction Industry Using a Delphi-ANP-TOPSIS Hybrid MCDM Concept under a Fuzzy Environment.”
15. Yangluxi Li, Huishu Chen, Peijun Yu, Li Yang. “A Review of Artificial Intelligence in Enhancing Architectural Design Efficiency.”
16. Nitin Rane, Saurabh Choudhary, Jayesh Rane, 2023. “Artificial Intelligence (AI) and Internet of Things (IoT) – Based Sensors for Monitoring and Controlling in Architecture, Engineering, and Construction: Applications, Challenges, and Opportunities.”
17. Hamed Nabizadeh Rafsanjani, Amir Hossein Nabizadeh, 2023. “Towards human-centered artificial intelligence (AI) in architecture, engineering, and construction (AEC) industry.”