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# ARCHITECTURE 5.0: OPPORTUNITIES AND CHALLENGES IN THE NIGERIAN CONSTRUCTION INDUSTRY

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**ABSTRACT:** *The rapid advancement of artificial intelligence (AI), robotics, and other digital technologies (DTs) has often lacked a focus on human-centrism. Industry 5.0 emerged as a response to Industry 4.0's digital revolution, emphasizing functional human-machine collaboration, sustainability, and resilience. However, the architecture, engineering, construction, and operations (AECO) sector, particularly in Nigeria, has been slow to seize the opportunities presented by Industry 5.0. This study investigates the opportunities and challenges associated with deploying Industry 5.0, specifically focusing on architecture within the Nigerian construction industry (NCI). A rapid literature review was conducted, analyzing relevant and indexed articles from reputable databases. The findings indicate that integrating AI into architectural design workflows can catalyze the adoption of other DTs, such as the Internet of Things (IoT), big data analytics, digital twins, cloud computing, blockchain, and augmented/virtual reality. These technologies can potentially transform planning, operations, end-of-life management, and visualizations during the design phase of architectural services. The study emphasizes the importance of architectural professionals acquiring relevant technical skills through education and awareness initiatives. It also stresses the need for policies and programmes implemented by the government, regulatory agencies, and industry firms to accelerate the adoption of DTs. Effective strategies for leveraging AI's potential are proposed to enhance design quality, speed, performance, and collaboration with allied design professionals. The findings offer valuable insights into adopting Architecture 5.0 within the NCI, particularly during the design stage.*

**KEYWORDS:** Digitalisation; Industry 5.0; Architecture; Construction; Nigeria.


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## INTRODUCTION

Technological advancements have been integral to global development, with transformative changes observed since the late 18th century (Almusaed *et al.,* 2023). The advent of Industry 4.0 marked a significant leap, characterized by the adoption of digital technologies (DTs) such as the Internet of Things (IoT), big data analytics, robotics, generative Building Information Modelling (BIM), augmented and virtual reality, smart systems, automation, cloud computing, and artificial intelligence (AI). These technologies have redefined operations, enhanced efficiency, and improved outcomes across various sectors globally. Mid-20th century thinkers like Herbert, Nash, and McCarthy introduced the idea that machines could possess intelligence, which evolved into AI, now encompassing applications such as expert decision support systems, algorithmic planning, gaming, and chatbots (Crawford *et al.,* 2023). Machine learning and neural networks have also become central to AI, aiding visual and audio recognition, outcome prediction, and forecasting tasks.

The development of AI, robotics, and other similar DTs has often lacked a focus on human-centric dimensions. For instance, Aljazeera reported approximately 400 auto crashes involving self-driving cars in 2020 due to insufficient human oversight. The rapid digital transformation and its associated limitations have spurred discussions among policymakers, practitioners, and academics, leading to the emergence of Industry 5.0. This new paradigm emphasizes human-machine collaboration, sustainability, and resilience, aiming to bridge the gaps left by Industry 4.0 (Alves *et al.,* 2023; Garrido *et al.,* 2024). Industry 5.0, which emerged in 2020, especially in Europe, is a much-anticipated revolutionary development based on the active engagement of human ingenuity and creativity with advanced DTs. This engagement facilitates efficiency, adaptability, flexibility, seamless communication, and collaboration between machines and humans. It also includes visualization, quality control, and real-time feedback systems in the productive and service industries, especially in design (Wolniak, 2023). According to Alves *et al.* (2023) and Garrido *et al.* (2024), Industry 5.0 was formally recognized by the European Commission in 2021 following extensive deliberations.

Digitalization is rapidly reshaping lives and professions, with implications across various industries. While there are concerns about the displacement of human workers by technology, studies indicate that Industry 5.0 enhances human value by making workers a digital asset (Panneerselvam, 2023). The human-centric approach of Industry 5.0 emphasizes the need to develop new skills for effective collaboration between humans and DTs, ensuring resilience and sustainability (Alves *et al.,* 2023). In contrast to Industry 4.0's tech-centric focus, Industry 5.0 prioritizes personalized and customized solutions, particularly in sectors like banking, defense systems, healthcare, manufacturing, and education (Baz *et al.,* 2023; Wolniak, 2023). Industry 5.0 can contribute to socially responsible, sustainable, and human-centered technological deployment, as inundated in the study by Panneerselvam (2023). The study further highlighted the opportunities in the sector with the deployment of Industry 5.0. These include enhanced operational efficiency, heightened quality control, sustainability initiatives, improved worker safety, elevated customer experience, cost-effectiveness, a competitive edge, heightened innovation, and positive contributions to social impact.

AI can significantly influence the construction sector's process optimization, creativity, and innovation. The sector contributes approximately 6% of the global gross domestic product (GDP), critical in sustainable development and national growth indices (Ikudayisi *et al.,* 2023). The sector has witnessed transformative shifts due to the integration of DT, such as AI (Rane,


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2023). This has enhanced construction processes, improved performance, and increased competitiveness (Owolabi *et al.,* 2022). AI, as a core component of *"Construction 4.0,"* helps address complex problems, reduce waste, improve design decision-making, and enhance site safety and project planning, as well as resulting in new spatial effects (Cudzik & Radziszewshi, 2018; Tunji-Olayeni *et al.,* 2022). While Industry 4.0 is still being adopted in many sectors, Industry 5.0 is seen as a natural extension of these advancements since its acknowledgment. This evolution is driven by the need to address the limitations of Industry 4.0, including its focus on the tech economy at the expense of human well-being and sustainability (Alves *et al.,* 2023).

In Nigeria, Industry 4.0 has been implemented in various sectors, such as small and medium enterprises, oil and gas, cybersecurity, transportation, finance, and agriculture (Lamptey *et al.,* 2020; Agubor *et al.,* 2021; Benjamin & Foye, 2022). However, its widespread adoption faces challenges due to inadequate infrastructure, regulatory barriers, and limited technological skills (Inuwa, 2022; Ukwandu *et al.,* 2023). In the Nigerian construction industry (NCI), the adoption of DTs is still in its infancy, with limited enthusiasm and capacity among professionals (Ezeokoli *et al.,* 2016). Despite the challenges, studies have highlighted the benefits of digital transformation in the NCI, including enhanced operational efficiency, improved productivity, and faster task execution (Aliu & Oke, 2023). Additionally, DTs can improve gender inclusion by automating hazardous tasks and creating more flexible work environments (Adepoju *et al.,* 2024). As the sector continues to grow in response to population expansion and urbanization, embracing Industry 5.0 offers significant economic, environmental, and social opportunities (Tunji-Olayeni *et al.,* 2023) in a sector with a low sustainability index.

Though research on Industry 5.0 is gaining traction in developed economies such as Sweden, Australia, and the United States, there is a paucity of studies focusing on its implementation in developing countries, particularly Nigeria (Tunji-Olayeni *et al.,* 2023). While AI applications in the NCI are recognized (Owolabi *et al.,* 2022), more research is needed to explore the broader opportunities and challenges associated with Industry 5.0. Specifically, the practice of architecture is integral to the sector's efficiency. Owolabi *et al.* (2022) recognized the design process as a major area of focus for technological deployment due to the capacity to enhance client satisfaction, performance, and productivity in the sector while contributing to economic, environmental, and social sustainability. Given the critical role of human capacity development in successfully deploying these technologies, collaborations between architectural firms and academic institutions will be essential for the sector's advancement (Dare-Abel *et al.,* 2014). In Nigeria, studies exist on deploying DTs, such as Building Information Modelling (BIM), AI, and virtual reality in architectural practices.

The quantitative study conducted by Owolabi *et al.* (2022) on AI applications in the NCI revealed a high awareness of AI in construction. The study further recommended the need to invest in more AI applications. However, enormous opportunities are inherent in effectively optimizing other digital tools in the design workflows of architectural firms in Nigeria. Dare-Abel (2013) noted that deploying DTs designed for individuals' ease of use can potentially enhance the efficiency, productivity, and quality of services rendered by architectural firms in Nigeria. Ibem *et al.* (2018) investigated the influence of BIM in architectural firms in Lagos, Nigeria. The outcome revealed a high level of BIM awareness and improved productivity. Tunji-olayeni *et al.* (2022) quantitatively assessed the critical success factors for the diffusion of AI in the NCI. The findings identified cost, behavioral, and institutional factors as the most significant. Furthermore, Ikudayisi *et al.* (2023) investigated the role of Industry 5.0 in


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integrated practices focusing on integrated project delivery, modular integrated construction, and integrated design processes. However, limited studies have specifically investigated the deployment of Industry 5.0 in the practice of architecture in Nigeria. This study aims to address this gap by investigating the opportunities and challenges of Industry 5.0 in the NCI, focusing on architectural practice. By doing so, it seeks to contribute to the growing body of knowledge on how digital transformation and human-centric technological integration can enhance performance and sustainability in the NCI.

## LITERATURE REVIEW

### *Architecture 5.0*

The architecture discipline has experienced significant transformation in its operations and services by integrating advanced DTs over recent decades. The emergence of AI has sparked revolutionary changes across various sectors, with the construction industry playing a pivotal role in advancing sustainable futures. AI and smart sensors have become integral in generating, processing, and analyzing data for assessments related to security, disaster risk management, building sustainability, and resilience. These technologies enhance project efficiency by facilitating simulations for acoustics, lighting, and ventilation and optimizing resources through circular economy (CE) strategies (Almusaed *et al.,* 2023). Architecture, inherently technology-driven, has long utilized such tools in its practice. While Industry 4.0 redefined workplace practices by integrating automation, its limited human oversight sometimes hindered creativity—an essential aspect of architectural work. In response, Industry 5.0 emerged, emphasizing human well-being, increased productivity, revenue growth, and job creation (Baz et al., 2023).

The adoption of Industry 5.0 within architecture, termed *"Architecture 5.0,"* represents a shift toward more skilled, human-centered practices. This transition places human intelligence and collaboration at the forefront of DT use in architecture, positively influencing operations, processes, and services. By promoting resilience, sustainability, and quality of life, Architecture 5.0 ensures a harmonious balance between technological innovation and human-centric design. This concept echoes the principles of Society 5.0 in Japan, which emphasizes individualization and personalization (Baz *et al.,* 2023). The architectural profession is crucial to the productivity and performance of the construction sector. With Architecture 5.0, the sector can benefit from cost-saving design iterations, enhanced decision-making through early stakeholder engagement, real-time feedback during operations, and visualization of building deconstruction and end-of-life scenarios.

CE has faced criticism in resource optimization for its limited large-scale application, especially in the construction industry. However, research suggests that DTs can be leveraged to expand CE practices within the architecture, engineering, construction, and operations (AECO) sector (Cetin *et al.,* 2021). Talamo and Bonanomi (2020) highlighted the strong correlation between adopting digitalization and productivity growth in the AECO sector, though the sector remains one of the least digitized globally. Despite recognizing DTs' role in CE by various industries, the opportunities for such technologies in the building design stage are often overlooked (Jia, 2021). Cetin *et al.* (2021) identified ten key DTs that support CE in the design of the built environment, including BIM, AI, Geographic Information Systems, Big Data and Analytics, Blockchain Technology, Additive/Robotic Manufacturing, Digital Twin,


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Internet of Things (IoT), Material Passports/Databanks, Cloud Technologies, and Digital Platforms/Marketplaces.

BIM, in particular, offers substantial benefits at the design stage, enhancing multidisciplinary collaboration and improving design information management across a building's lifecycle (Chen *et al.,* 2022). Its compatibility with various verification and performance simulation tools helps design professionals optimize building environmental performance (Ghanate, 2020). To further improve CE outcomes, BIM should focus on reuse, reduction, recycling, and resource efficiency (Rahla *et al.,* 2021). Computational BIM is recognized through visual programming for its cost-effective data management and extraction capabilities, aiding design iterations (Chen *et al.,* 2022). Additionally, adopting additive and robotic manufacturing can reduce waste, labor, and construction time, thus addressing environmental concerns in the construction sector. Other DTs, such as Big Data Analytics, digital twins, material passports, and blockchain technologies, offer promising CE benefits if studied further (Cetin *et al.,* 2021). Specifically, material passports help track materials throughout their lifecycle, promoting recovery, reuse, and resource efficiency while supporting environmental impact assessments, regulatory compliance, and market incentives (Munaro & Tavares, 2021).

Moreover, the Internet of Things and AI can provide detailed environmental impact assessments, helping architects minimize waste, reduce carbon emissions, and lower energy consumption while prioritizing human comfort and well-being through sustainable design solutions. Cross-disciplinary collaboration and applying green financing initiatives can further bolster the adoption of these DTs (Almusaed *et al.,* 2023; Dhayal *et al.,* 2023). According to Ikudayisi *et al.* (2023), integrated practices are becoming increasingly popular, with three critical approaches emerging: integrated project delivery, modular integrated construction, and integrated design process. Adopting Architecture 5.0 can facilitate merging these technologies with human intuition to create more efficient, sustainable, and personalized building designs. It emphasizes collaboration between human architects and intelligent machines, enabling more precise, adaptive, and eco-friendly construction processes. With tools like BIM, robotic manufacturing, and AI-driven design platforms, architects can push beyond automation to develop structures that respond to environmental challenges, user needs, and aesthetic goals. Architecture 5.0 can promote sustainable materials, energy efficiency, and personalized spaces that reflect both technological advancement and human values, paving the way for more innovative and responsible architectural practices.

### *Architecture 5.0 and the Nigerian Construction Industry*

The architecture discipline is vital to the operational efficiencies of the NCI. Nnaemeka-Okeke *et al.* (2020) emphasized that architects are integral in ordering, planning, preserving the built environment, and promoting sustainable development goals. The practice of architecture and the establishment of architectural firms in Nigeria have evolved significantly over the years, primarily due to the increasing adoption of information and communication technologies in management and design processes. Ezeokoli *et al.* (2016) noted that the NCI is still at the foundational implementation level of DTs. According to Oke *et al.* (2023), architectural design is one area in which DTs have been deployed. Dare-Abel *et al.* (2014) highlighted that Nigerian architectural firms have utilized technology since the 1980s. However, a reluctance among architects to fully embrace innovations, particularly AI, has created an auto-centric focus rooted in ignorance-driven fear of potential human replacement by AI. This concern stems from AI's ability to make human-like decisions, as Mrosla *et al.* (2019) pointed out. A study by Oyedele


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and Tham (2007), which assessed the performance of architects in Nigeria's building delivery process, emphasized the need for architects to enhance project integration and communication, develop stronger administrative and management skills, and improve design quality and buildability.

Architects in the NCI have employed various design tools. The rise of automated and computational tools has become increasingly integral to architectural design processes (Cudzik & Radziszewshi, 2018). The choice of tools often depends on the specificity of tasks. The growing deployment of AI tools in architectural firms has been hailed as a revolution, mainly due to the advent of computational design systems that assist in adaptive form creation and controls. Although efforts have been made globally to actualize the goals of the 2015 Paris Climate Agreement, the construction sector remains one of the highest contributors to carbon emissions. Unfortunately, previous industrial revolutions have done little to protect and conserve the world's natural systems. However, one of the primary goals of Industry 5.0 is to ensure environmental protection as part of a broader effort to achieve Society 5.0 within the sustainable development framework (Dhayal *et al.,* 2023). The embrace of Industry 5.0, as noted by Almusaed *et al.* (2023), will set the stage for Construction 6.0, which integrates advanced DTs such as cloud-based energy solutions, nanotechnology, and quantum computing to drive the sector forward more sustainably. In Nigeria, where the construction industry is rapidly expanding due to urbanization and population growth, integrating these cutting-edge technologies presents an opportunity for significant advancements in architectural practice, offering potential benefits in design efficiency, environmental sustainability, and overall project delivery.

## MATERIALS AND METHODS

This study adopted a non-quantitative research approach using a rapid literature review method to evaluate and synthesize published scholarly articles. The rapid literature review is a traditional literature review that seeks an overview of insights on a specific topic. This method involves a systematic literature search on reputable databases and selecting and screening relevant scholarly sources such as journal articles, conferences, and books. It also includes using inclusion and exclusion criteria, carefully reviewing the complete text, evaluating the reliability and quality, and organizing and synthesizing pertinent information. Many studies have used this method across several fields, especially to quickly examine the state of knowledge on an emerging research area or new intervention. For this study, the rapid literature reviews involved three stages. The first stage entailed searching on reputable databases. The second stage focused on literature screening and selection based on predetermined criteria. The final stage involved critical evaluation of the quality and reliability of the selected articles, data extraction, and synthesis of relevant information. Searches were conducted on ScienceDirect and Google Scholar databases using appropriate keywords and search strings. Other databases can also be used, but this study limited itself to these two reputable databases due to their broad spectrum of academic publications' coverage. Similarly, the data retrieval procedure on these databases is comparatively easy, especially for most recent publications.

The search strategy aimed to capture a broad range of relevant academic literature using specific keywords such as "Industry 5.0," "digital technologies," "architecture," and "construction." Boolean operators (AND, OR) were used to refine results, ensuring the


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selection of articles most relevant to the research. The focus was on peer-reviewed articles from the past decade to maintain information relevance. Inclusion criteria required that articles explicitly address Industry 5.0, digital technologies, architecture, and construction and their impact on the construction industry. Only English-language articles were considered, while studies outside this intersection or lacking substantive insights were excluded to keep the review focused. Data extraction involved thoroughly reviewing selected articles to identify key themes and findings aligned with the research objectives. These findings were categorized into thematic areas, enabling a structured synthesis that provided a comprehensive overview of current research, highlighting gaps and opportunities in Industry 5.0 and architecture in construction. A rigorous quality assessment was conducted based on relevance and journal credibility to ensure the reliability of the findings, and only articles meeting these standards were included in the final review.

## RESULTS AND DISCUSSION

### *Opportunities in the Deployment of Architecture 5.0 in NCI*

The deployment of Architecture 5.0, a human-centric, technology-driven approach that aligns with Industry 5.0 principles, presents several opportunities in the NCI in areas such as improving efficiency, sustainability and resilience, while addressing local challenges and enhancing the quality of the built environment.

### *Smart Working and Processes*

Adopting innovative working processes in architectural practices is increasingly important for improving operational efficiency and sustainability in the NCI. Wolniak (2023) highlighted that Industry 5.0 promotes social sustainability by optimizing supply chain management, minimizing project downtime, and enhancing operational efficiency, resulting in cost savings and competitive advantages. This is particularly relevant in Nigeria, where the construction sector often grapples with project delays, poor resource management, and frequent cost overruns. According to Ibem *et al.* (2018), Nigeria's push to improve service quality, productivity, and sustainability has led the construction industry to embrace DTs, particularly in executing procurement processes. Digital procurement streamlines operations and reduces manual errors, ensuring timely and successful project delivery. As the NCI continues to expand rapidly, adopting these technologies enhances competitiveness and helps companies to stay agile in a fast-paced sector.

Rane (2023) emphasized the value of co-creative and collaborative intelligence in the AECO sector. This intelligence is fostered through direct interactions between workers and machines, especially with AI tools like ChatGPT. In architecture, this collaboration between humans and machines is crucial in Nigeria, particularly for complex urban projects in cities like Lagos. Collaborative intelligence optimizes design processes, facilitates interdisciplinary coordination among architects, engineers and other stakeholders, and improves project efficiency. Intelligent technologies also allow real-time project tracking and feedback, providing insights enabling predictive analytics, risk assessments, and informed decision-making. In the NCI landscape, where project risks and uncertainties are often high, these capabilities are essential for making timely adjustments and ensuring successful project outcomes. By leveraging smart processes,


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architectural practices in Nigeria can reduce waste, improve resource utilization, and deliver projects more efficiently and sustainably.

***Enhanced Design Ideations and Iterations***

In the NCI, the adoption of Architecture 5.0 is poised to enhance design ideations and iterations. Cudzik and Radziszewshi (2018) highlighted two primary AI systems used in architectural design: symbolic and subsymbolic. The symbolic system enables the creation of non-hierarchical forms in autonomous design processes, navigating complex dependencies. In contrast, the subsymbolic system offers designers a more hierarchical approach with greater flexibility and freedom. This integration can significantly optimize building projects' planning and end-of-life stages. In the Nigerian context, where design challenges often include addressing diverse climatic and social conditions, the flexibility and personalization offered by Architecture 5.0 can empower architects to create contextually relevant, high-performance designs. Wolniak (2023) emphasized that Industry 5.0 allows for greater freedom in idea generation and product design, which can be facilitated through augmented and virtual reality for immersive design testing and visualization. This could revolutionize how Nigerian architects conceptualize and test sustainable and innovative design solutions.

Enormous opportunities are inherent for Nigerian architects in embracing Architecture 5.0. As AI continues influencing design thinking and creativity, it offers new benefits for personalized services, enhanced flexibility, and adaptability (Panneerselvam, 2023). The application of evolutionary algorithms, neural networks, and swarm intelligence, as explored by Cudzik and Radziszewshi (2018), shows how AI can facilitate the creation of complex geometries and spatial forms, offering greater design freedom. In a rapidly urbanizing environment like Nigeria, these advancements can amplify architectural conceptualization, pushing the boundaries of design and allowing for more innovative, sustainable, and resilient structures tailored to local needs.

***Circular Economy within the Sustainability Framework***

Adopting Architecture 5.0 in the NCI within the sustainability framework can be crucial in advancing the CE agenda. Wolniak (2023) highlighted that Industry 5.0 can drive responsible and efficient resource use, minimize environmental impact, and reduce waste generation, contributing to more sustainable manufacturing processes. This is particularly relevant in Nigeria, where construction waste and inefficient resource management have been significant challenges. By embracing Architecture 5.0, the NCI can enhance communities' environmental and social well-being while creating safer and healthier working environments. Almusaed *et al.* (2023) further emphasized that deploying human-centric technologies in the building industry promotes resilience and sustainable development. In Nigeria, where rapid urbanization and infrastructure needs put pressure on resources, integrating these technologies can ensure more efficient design processes and minimize the sector's carbon footprint.

Rane (2023) added that Industry 5.0 can enable resilient and sustainable design practices through AI-powered simulations and experimentation. This is crucial for NCI, where optimizing resource use and implementing eco-friendly construction techniques are vital for achieving sustainability goals. By adopting Industry 5.0 technologies, such as AI, the sector can shift toward more circular practices, reducing resource depletion and waste and promoting regenerative design solutions. Ikudayisi *et al.* (2023) also noted that DTs can support smart construction practices and resource efficiency. In Nigeria, adopting such technologies within


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the Industry 5.0 framework could enhance building lifecycle management, material reuse, and energy efficiency, aligning with the CE principles.

***Interconnectedness and Collaboration***

Adopting Architecture 5.0 in the NCI emphasizes the importance of interconnectedness and collaboration among stakeholders. Almusaed *et al.* (2023) highlighted vital benefits such as value-adaptive network dynamics, supply chain flexibility, and enhanced information exchange by effectively integrating relevant stakeholders in decision-making processes. These attributes of Architecture 5.0 can help to address the several challenges Ikudayisi *et al.* (2023) identified in the NCI, including supply and value chain fragmentation, linear workflows, environmental degradation, project cost, time overruns, and reduced productivity. Cudzik and Radziszewshi (2018) further underscored the role of AI in architectural practice, where DTs can serve as personal design assistants, especially in brainstorming and generating design solutions. This capacity for AI to assist in decision-making and idea generation has also been supported by Rane (2023), who found that collaborative tools like ChatGPT can enhance design workflows. This involves refining suggestions, exploring multiple design possibilities, offering client-specific customization, and providing real-time monitoring to reduce waste.

Integrating Architecture 5.0 in the NCI can promote more cohesive project management and improved collaboration between architects, engineers, contractors, and other stakeholders, driving the sector towards greater sustainability and efficiency. By leveraging AI and Industry 5.0 principles, the industry can overcome the traditional fragmentation and inefficiencies, resulting in better project outcomes and enhanced environmental stewardship.

***Promoting Problem-solving Capacities***

The successful implementation of Industry 5.0 within the architecture discipline in NCI can significantly enhance problem-solving capacities and critical appraisal among architects, ultimately boosting productivity and effectiveness. Integrating advanced technologies, Industry 5.0 can promote greater security and transparency in supply chain transactions through blockchain technology, offering architects and stakeholders a more reliable and efficient framework for managing projects (Wolniak, 2023). This shift is significant for Nigeria, where improving efficiency and transparency in the construction sector is crucial for addressing current infrastructural and operational challenges.

***Well-being and Job Satisfaction***

Wolniak (2023) emphasized human interaction and intuition inherent in Industry 5.0. This will enhance well-being and boost job satisfaction within the architectural discipline in the NCI. As this new paradigm encourages collaboration between human creativity and advanced technologies, architects and construction professionals in Nigeria may experience a more fulfilling work environment. This technology integration streamlines processes and allows for more significant personal input and creativity, which can significantly elevate job satisfaction. Furthermore, by prioritizing well-being through improved working conditions and a supportive atmosphere, Architecture 5.0 can contribute to a healthier workforce, ultimately benefiting individuals and the overall efficiency of architectural practices in Nigeria.


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***Renewable Energy Sources***

Adopting Architecture 5.0 in the NCI presents a significant opportunity to reduce carbon emissions by leveraging renewable energy sources. By integrating management systems, real-time energy monitoring, smart grids, and energy storage systems, the industry can effectively harness renewable resources like hydro, geothermal, wind, and solar power (Wolniak, 2023). In Nigeria, where access to reliable energy is crucial for both urban development and sustainable practices, embracing these renewable energy solutions can enhance the efficiency and resilience of architectural projects. This shift aligns with global sustainability goals and addresses local energy scarcity and environmental degradation challenges. Architects who incorporate these technologies into their designs and processes can create energy-efficient buildings and contribute to a greener, more sustainable future for Nigeria's rapidly growing urban landscape.

***Enhances Creativity***

Architecture 5.0 can significantly enhance creativity, AI, and machine learning in the NCI. These technologies can streamline data collection and analysis, enabling architects to tailor products and services to clients' specific perceptions and preferences, addressing their diverse and unique needs (Wolniak, 2023). Furthermore, this approach fosters resilient developments by integrating user feedback into the design process (Alves *et al.,* 2023). Rane (2023) emphasized that Industry 5.0 promotes interactive learning opportunities that contribute to capacity building, creativity, and the development of knowledge and skills through a more democratic approach to education and practice. This shift is particularly crucial in Nigeria, where fostering creativity and innovation in architectural practices can lead to more sustainable and contextually relevant solutions in response to the country's rapid urbanization and evolving infrastructure demands.

***Economic Savings***

According to Almusaed *et al.* (2023), adopting Industry 5.0 in the architecture discipline within NCI can lead to significant economic savings. Specifically, technologies like 3D printing and additive manufacturing systems like Apis Cor can reduce marginal costs while enhancing resource efficiency in building production. This advancement is particularly relevant in Nigeria, where the construction sector faces challenges related to rising material costs and inefficiencies. By integrating these innovative technologies, Nigerian architects and builders can streamline operations, lower expenses, and ultimately contribute to more sustainable construction practices, improving the overall economic viability of projects in a rapidly urbanizing landscape.

***Challenges of Architecture 5.0 in the NCI***

The deployment of Architecture 5.0 in the NCI faces several challenges. Addressing these challenges will require strategic investment in infrastructure, training, policy development, and incentives to encourage innovation in the NCI.


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***High Upfront Investment Cost***

The substantial upfront investment required for adopting Industry 5.0 poses a significant barrier to its early implementation within NCI's architectural discipline. Wolniak (2023) supported this notion, indicating that the economic costs associated with advanced technologies—such as virtual reality, blockchain, and robotics—can be discouraging for many firms. Almusaed *et al.* (2023) further emphasized that a highly digitized building construction sector will necessitate substantial technological, social, and economic investments to integrate these innovations seamlessly. In the Nigerian context, where the construction industry faces various challenges, these high initial costs can deter stakeholders from pursuing Architecture 5.0. Furthermore, Rane (2023) suggested that specialized education and training programmes focusing on critical and analytical thinking, oversight, evaluation, and technical aspects of Industry 5.0 deployment are essential. However, implementing such training initiatives would also add to local architectural firms' financial burden. This financial strain can hinder progress, limiting the ability of the sector to fully harness the potential benefits of Architecture 5.0 and impeding the overall advancement of the NCI. To overcome this barrier, multifaceted solutions are required. These include creating a long-term strategic framework that outlines training initiatives, funding mechanisms, and milestones. Also, incentivizing local production and innovation hubs, collaborative DTs development and open-source solutions, and partnerships with educational institutions on training will go a long way in resource sharing and establishing collaborative networks. Furthermore, phased implementation of technologies through leasing and subscription models limits the associated financial burden.

***Human Replacement by Technology***

Adopting Architecture 5.0 in the NCI raises concerns about potential job displacement and lean staffing. Wolniak (2023) has corroborated this in the study. The shift away from traditional processes could necessitate substantial economic investment in retraining staff to acquire specialized skills, mainly due to the complexities involved in communication with advanced digital systems (Almusaed *et al.,* 2023). This transition may lead to a significant reconfiguration of the workforce within the NCI, where many existing roles may become redundant as automation takes hold. However, Cudzik and Radziszewshi (2018) argued that, shortly, AI is unlikely to replace architects fully. The profession requires nuanced judgment to identify the most suitable solutions for design challenges, considering human aspirations, preferences, and evolving needs. In Nigeria, where cultural and contextual factors increasingly influence architectural practices, the human element remains crucial in the design process. Moreover, integrating AI and other advanced DTs can raise ethical concerns if not managed responsibly. Cudzik and Radziszewshi (2018) further noted that, despite the vast array of design tools available to architects today, many of these tools still have limitations in capabilities that do not fully meet the demands of contemporary architectural practice. Thus, while Architecture 5.0 offers transformative potential, it is imperative for Nigerian architectural firms to strategically navigate the balance between leveraging technology and maintaining the irreplaceable value of human creativity and insight in the construction industry.


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### *Digital Security Threats*

The adoption of Industry 5.0 within the architectural discipline of the NCI brings about increased interconnectedness among digital systems, which can elevate cybersecurity threats. Wolniak (2023) noted that this interconnectedness makes confidential information more vulnerable to data breaches. Additionally, Rane (2023) highlighted that integrating innovative systems under Industry 5.0 could lead to significant cybersecurity concerns, necessitating robust safeguards to ensure the integrity and confidentiality of sensitive data. The NCI has become unavoidably necessary to start paving the way for adopting these DTs; however, the risk of cyber threats has become a critical issue. As architectural firms adopt advanced digital tools and smart systems, they must be vigilant in implementing comprehensive cybersecurity measures. This is particularly important in a landscape where many firms may still develop their digital infrastructure and expertise, potentially exposing them to significant risks. Effective cybersecurity strategies are essential to protect sensitive information and maintain client trust, thereby ensuring that the benefits of Architecture 5.0 can be fully realized without compromising security.

### *Integration Complexities*

Integrating Industry 5.0 technologies into the existing processes of the NCI can present several challenges and obstacles. This integration demands adjustments and modifications to traditional systems, often necessitating external expertise, resources, and time for successful implementation (Wolniak, 2023). Additionally, Rane (2023) pointed out that the intricate nature of some DT algorithms can lead to interpretability issues, complicating their adoption within architectural practices. In Nigeria, these challenges are particularly pronounced due to several factors. The architectural discipline must navigate existing infrastructural limitations, varying levels of technological literacy among practitioners, and potential resistance to change from traditional practices. Moreover, the scarcity of skilled professionals who can effectively operate and interpret advanced technologies adds another layer of complexity to the integration process. Addressing these hurdles is essential for leveraging the benefits of Industry 5.0, which promises to enhance efficiency, sustainability, and innovation within Nigeria's architectural landscape.

### *Adoption Bottlenecks*

The initial implementation of Architecture 5.0 in the NCI may encounter several challenges, primarily due to unfavorable regulatory conditions stemming from the novelty of this approach. Traditional operational methods often resist change and lack the flexibility to adapt to new practices (Wolniak, 2023). To facilitate the smooth deployment of Industry 5.0, it is crucial to establish relevant policies and guidelines that address these bottlenecks. Collaborative efforts across the entire value chain are essential, particularly in intellectual property rights and the management of AI-assisted errors (Rane, 2023). In the Nigerian context, where the construction industry is still grappling with outdated practices and regulatory frameworks, this collaboration is vital for fostering an innovative environment. Policymakers, industry stakeholders, and academic institutions must work together to develop and implement comprehensive guidelines that support the integration of advanced DTs while safeguarding intellectual property. This collective effort can help mitigate the risks associated with AI and other emerging technologies, ultimately paving the way for a more sustainable and efficient architecture discipline in Nigeria's evolving construction landscape.


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***Over-reliance on Technology***

In the NCI, there is a growing concern that an over-reliance on technology in adopting Industry 5.0 may lead to a decline in critical thinking and problem-solving abilities among architectural professionals. If not addressed, this dependency on technology could hinder creativity and innovation within the discipline. Wolniak (2023) cautioned that integrating Industry 5.0 could diminish users' analytical skills without careful consideration. Similarly, Rane (2023) emphasized the importance of fostering awareness around human-AI collaboration; if not managed effectively, it could adversely affect the creative output of design professionals working on various projects. In the context of Nigeria, where the architecture sector is still evolving, striking a balance between leveraging advanced technologies and maintaining essential cognitive skills is crucial for enhancing design quality and ensuring that architects continue to innovate.

***Socio-economic Inequalities***

Almusaed *et al.* (2023) contended that Industry 5.0 could redefine workplace dynamics and potentially reduce job opportunities, particularly for professionals lacking hands-on expertise with emerging technologies. This is especially relevant in NCI, where the adoption of advanced technologies like AI, IoT, and robotics is still in its nascent stages. The socio-economic inequalities within the sector are likely to be exacerbated as skilled professionals proficient in these technologies will have a competitive edge. At the same time, those without the necessary skills may face marginalization or job loss. In Nigeria, where access to advanced technology education and training is often limited, the workforce may struggle to adapt to the demands of Architecture 5.0. To bridge this gap, fostering trust and clear communication about the benefits and opportunities of Architecture 5.0 will be essential. Encouraging a culture of acceptance and continuous learning within the NCI can help to mitigate skepticism and fear among the workforce. This will be crucial in ensuring that the adoption of Architecture 5.0 does not widen the socio-economic divide but instead creates opportunities for growth and innovation across all levels of the NCI.

## CONCLUSION

Through a rapid review of relevant articles, this study espouses the role of Architecture 5.0 and identifies the inherent opportunities and potential challenges in its deployment in the NCI. The study's outcomes provide valuable insights into the multifaceted dimensions of integrating AI within the design workflows of architectural practices in Nigeria. The study findings also underscore that the effective deployment of AI in design workflows could catalyze the adoption of other DTs, such as the Internet of Things, big data analytics, digital twins, cloud computing, blockchain technology, and augmented/virtual reality. These technologies are poised to transform the planning, operation, and end-of-life management and visualizations at the design stage of architectural services. It was emphasized that these call for concerted and collective efforts to maximize the inherent opportunities and address the impeding hindrances in this digital decade. The practical implications of these findings suggest the need for design practitioners, especially those in the architecture discipline, to equip themselves with requisite technical expertise through education and awareness. BIM can be promoted through policies and programmes by the government, regulatory bodies, and firms. Additionally, it was noted that government policies play a vital role in the affordability and accessibility of AI tools. The


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study recommends efficient ways of leveraging AI's capabilities and possibilities in architecture, ultimately improving design quality, speed, performance, and coordination with other allied design professionals in the industry. Although this study adopted a non-quantitative approach to exhume deeper and richer insights into the findings, there is a need for empirical studies in this context. The findings of this study improve knowledge on embracing Architecture 5.0 in the NCI, especially at the design stage.

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