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Towards Industry 5.0 Application in the Construction Sector for a Sustainable Nigerian Built Environment

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Abstract

Despite garnering increasing attention, the fifth Industrial revolution (IR 5.0) remains unexplored in Nigeria. This study therefore evaluates IR 5.0 application in the Nigerian construction sector, with a view to strategizing pathways to enhance its application for a sustainable built environment. A qualitative research approach was applied to elicit response from professionals in Nigeria. Percentages and thematic analysis were used to analyze the result. The result shows that a foundational understanding of IR 5.0 exists. However, varied interpretations of the concept impedes its awareness. Key challenges were found to include poor infrastructure, high cost of technology, lack of sufficient training opportunities, and the absence of government policies and incentives. Altogether, this have resulted in a rather limited application of IR 5.0. Hence, the study strategizes that increased awareness, infrastructural and technological development, collaboration, and training programs can play a unique role in enhancing IR 5.0 application in the Nigerian construction sector. The paper's contribution to knowledge lies in providing a holistic insight on the emerging trends of IR 5.0 in Nigeria. Empirical evidence supports a promising foundation for IR 5.0 to build upon in sustainable materials, renewable energy systems and artificial intelligence towards a more sustainable built environment in Nigeria.

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Keywords: Built environment; Industrial revolution; Nigerian construction sector; Sustainable construction; Technological innovation.

1. INTRODUCTION

The importance of construction in the built environment and industrial revolution (IR) is evident in the way construction activities are vital to any country's environmental and socio-economic growth. As a matter of fact, not only does the construction sector provides infrastructure for the society, it also creates job opportunities for both skilled and unskilled workers [1]. This improves the quality of life in the built environment. The built environment is a hub of economic activities, individuals and families, and society's cultural heritage: It protects life and health, the inhabitants' psychological and social welfare, and sustains aesthetic and cultural values. However, despite the industry's contribution in bringing environmental and socio-economic changes, the built environment still faces certain country-specific construction related issues. For instance, in Nigeria as a developing country, there is a growing need for construction activities to adopt sustainable principles to reduce, reuse, and recycle with a view to ensuring that projects are economical, people oriented, environmentally friendly and technically appropriate. Economically, the Nigerian construction sector (NCI) contributes to the nation's growth through road, housing and other infrastructural developments. However, poorly managed construction projects often compromises cost and quality standards. The resultant effect in the Nigerian economy always manifests in wastage of resources, project failures and building collapse [2]. From a social perspective, construction activity affects the health and living standards of construction workers. Thus, the importance of a healthy and safety environment in pivoting a socially sustainable construction industry in Nigeria is important. Environmentally, the impact of waste generation, energy use, and excessive resource consumption has serious effects on sustainability. For example, not only does the NCI consumes high energy levels and resources, it also generates large amount of waste, emits hazardous gas, and relies heavily on traditional practices and older technologies whose consumption pattern and production system are adjudged unsustainable [3]. As a result, the NCI is affected. This emphasizes the need for built environment professionals to explore sustainable and innovative technologies that can revolutionize construction activities in the Nigerian built environment.

One of such smart technology is the IR. Over the years, the construction industry has gone through various revolutions from the pre-industrial age to the fourth industrial revolution. The first IR (IR 1.0) depended on steam engines for production. This was followed by the second IR (IR 2.0) which focused on mass production with the aid of electricity. Subsequently, IR (IR 3.0) was introduced with automation being its main feature. Eventually, the fourth IR (IR 4.0) evolved with digitalization in industrial processes, leading to increased productivity and economic growth being its main focus [1]. However, its implementation sometimes disregarded environmental and societal concerns, giving rise to discussions about the potential negative consequences of technological advancements on job displacement and social inequalities. This development gave rise to the emergence of the fifth IR (IR 5.0) as a societal-driven agenda, aiming to regulate the digital industrial transformation in a way that aligns with sustainability goals. In this context,

[4] noted that IR 5.0 seeks to align economic growth with environmental preservation and social well-being. Hence, the transformation to IR 5.0 extends beyond mere technological implementation, but rather encompasses a holistic paradigm, necessitating synchronized endeavors to govern and oversee the entire life-cycle of technological evolution, development, integration, and application within both corporate, industrial and construction domains. There have been several studies linking IR 5.0 to the construction sector.

As an example, [5] observed that IR 5.0 is starting to take shape and has the potential to drastically change the way construction is realized, its role in the construction industry being to execute a project with a human focus, adaptive to collaboration and focus on sustainability. [6] stated that IR 5.0 assesses the environmental effects and actions of the construction sector and collaborates to reduce environmental risks. Moreover, IR 5.0 is promising to use resources adjusted to the current requirements. For instance, waste along with overproduction is to be reduced to eliminate it. Hence, IR 5.0 supports technologies that make sustainable use of natural resources and can be applied in the construction sector. Understanding the definition of IR 5.0 in relation to sustainable construction (SC) is a vital component in enriching the knowledge base and enhancing its application. However, [7, 4] argued that a unanimous definition of IR 5.0 remains lacking. However, the most sustainable definition sees IR 5.0 as an industrial evolution led by humans based on the 6R (recognize, reconsider, realize, reduce, reuse and recycle) principles of industrial up-cycling, systematic waste prevention and logistics efficiency, designed to valuate life standard, innovate creations and produce high-quality custom products [8]. For [9], IR 5.0 aims to include human, social, and sustainability aspects. As such, construction projects under IR 5.0 are tailored towards environmental and socio-economic dimensions due to its strong priority on resource efficiency and design, reduction of waste, and minimal use of resources. Seen from these perspectives, IR 5.0 has the ability to enhance a sustainable built environment in the construction sector through sustainable practices, human-machine interaction, and innovative technologies. For IR 5.0 to work, there has to be an enabling technological environment. [10] posited key enablers of IR 5.0 to include human-centered approach and environmental impact awareness. The human-centered approach enables the avoidance of human job loss because of the intensive digitalization, while environmental impact awareness concerns the increase of energy efficiency and use of renewable energy sources.

However, IR 5.0 is not without its challenges. [11] stated that current challenges to IR 5.0 levitate towards security, privacy, lack of skilled workers, time-consuming process, and large budget. For example, regarding lack of skilled workers, development of technical, competency knowledge and skills to collaboratively work with smart machines is a necessary requirement. Thus, the adoption of advanced technology will also require more time and effort from the part of human workers. [12] observed that IR 5.0 is expensive as it requires investment, extra costs, regulatory compliance, security requirements, training human workers to use smart machines and highly skilled employees to increase productivity and efficiency. Adding to the challenge is the concern regarding the risk. Despite these challenges, IR 5.0 offers significant benefits to the socio-economic built environment. [11] explained that, with IR 5.0, corporate technologies leads to the emergence of sustainable policies, such as minimal waste generation and management that can make companies effective. Further to this, the work of [1] revealed that IR 5.0 in the construction sector results in health and safety, waste management, and forecasting environmental, social or financial outcomes.

[4] argued that there is currently no concrete empirical evidence showcasing the practical advantages of IR 5.0 for the economy, society, and the environment. This shows a significant gap in the practical application of IR 5.0 in the construction sector, especially in Nigeria where the concept is unexplored in literature. Thus, while several studies have contributed to IR 5.0 in developed countries, little or no scientific studies, with the exception of [1], have explored IR 5.0 within Nigeria's built environment. Therefore, our study bridges this gap by exploring the application of IR 5.0 in the construction sector, with a view to strategizing pathways to enhance its application for a sustainable built environment in Nigeria. Objectively, the study will:

I. Examine the understanding of IR 5.0 in the Nigerian construction sector by built environment professionals.
II. Assess the challenges hindering IR 5.0 application in the Nigerian construction sector.
III. Evaluate the application of IR 5.0 in the Nigerian construction sector by built environment professionals.
IV. Strategize pathways to enhance IR 5.0 application in the Nigerian construction sector for a sustainable built environment.

2. LITERATURE REVIEW

The construction industry plays an important position in any nation's economy. It pivots economic prosperity, fosters infrastructural development and creates job in the built environment. The importance of the built environment is unquestionable: It is where a nation's population lives, works and the national GDP are generated there-in. Hence, the built environment's design, planning, construction and operation is fundamental to the productivity and competitiveness of the economy, the quality of life of all citizens, and the ecological sustainability of the continent [13]. Construction work in the sector covers site acquisition, design, contract, site operation (construction), operations and management. The idea about sustainability in the construction sector refers to development or construction that protects the present socio-economic built environment without compromising the activities of future generations. In Nigeria, recent years have seen a surge in growing socio-economic and environmental problems such as waste generation, low productivity and safety concerns. Therefore, the pressure on the construction industry to become more sustainable requires new thinking and methods to be implemented. However, to achieve this, the built environment will need to embody significantly higher levels of innovation in its products and processes [3].

Over time, one of such massive innovations encountered by the construction sector is the IR transformation. According to [5], the evolution of IR from IR 1.0 - IR 5.0 shows that IR 1.0 evolved through the development of mechanical production infrastructures for water and steam-powered machines. Thus, IR 1.0 had a significant impact on society, transforming the way goods were produced and leading to increased productivity and economic growth. However, it also led to social and environmental problems such as poor working conditions and pollution. Eventually, IR 2.0 evolved with the concept of electric power and assembly line production. The IR 2.0 was a period of rapid scientific discovery, standardization, mass production, and industrialization. IR 2.0 focused primarily on mass production and distribution of workloads, which increased the productivity of manufacturing companies. Subsequently, IR 3.0 evolved with the concept of electronics, partial automation and information technologies. [14] explained that IR 3.0 utilized a newly recorded micro database for real advancement yield, the main impetuses, and mechanical interdependencies. Thus, the third industrial revolution (TIR) was led by high-tech innovations in manufacturing, distribution, and energy factors. In recent times, IR 4.0 evolved with the concept of smart manufacturing for the future, with the main objective of maximizing productivity, achieving mass production using emerging technologies, builds on the digital revolution, a realistic and sustainable production system. Currently, IR 5.0 is a future evolution designed to use the creativity of human experts working together with efficient, intelligent and accurate machines [12] to improve the efficiency of industrial processes.

Several studies have explored IR 5.0 in construction in developed countries. For example, discussions surrounding IR 5.0’s definition posits that the technological constituents, components, and functionality of IR 5.0 are ill-defined as scholars lack a consensus in differentiating this phenomenon from its predecessor [7]. Other scholars, such as [4] have postulated IR 5.0 as a novel concept that is continually evolving with literature not providing a detailed and widely accepted definition. Notwithstanding, attempts have been made by various industry practitioners and researchers to provide various definitions to aid its understanding. [15] viewed IR 5.0 as bringing back the human workforce to the factory, where human and machines are paired to increase the process efficiency by utilizing the human brainpower and creativity through the integration of workflows with intelligent systems. [8] defined IR 5.0 as an industrial evolution led by humans based on the 6R (Recognize, Reconsider, Realize, Reduce, Reuse and Recycle) principles. [16] saw IR 5.0 as the revolution in which man and machine are findings ways to work for improvement and efficiency. In the context of these definitions, it can be deduced that IR 5.0 has to do with human and machines co-working by using technologies in construction activities to enhance productivity for a sustainable built environment. Regarding the transformation to IR 5.0, [17] reasoned that IR 5.0 as a value-driven approach makes a bold shift from individual technologies to a systematic approach, which empowers the industry to achieve societal goals beyond jobs and growth, while placing the wellbeing of the industry worker at the center of the production process. In terms of the relationship between IR 5.0 and sustainable construction, socio-economic and environmental priorities such as responsible consumption and production, promoting renewables, inclusive growth, and social protection drives IR 5.0. [6] affirmed that IR 5.0 assesses the environmental effects and actions of the construction sector and collaborates to reduce environmental risks. Despite these potentials, IR 5.0 has some limitations. [18] noted that the acquisition of more advanced and sophisticated digital technologies is an additional financial burden to organizations. [19] stated that adopting IR 5.0 will require workers’ training on both technical and soft skills. Moreover, [12] was of the opinion that IR 5.0 also raises security and privacy concerns of authentication, integrity, access control and audit. In addition, [20] identified conflicting interests, lack of innovation, limited resources and a lack of political will as some of the challenges associated with the adoption of IR 5.0 in Sweden. In Nigeria, [1] observed that there is also the environmental burden that will arise from abandoning obsolete digital technologies and equipment for sophisticated infrastructure.

The benefits of IR 5.0 have been explored in various literature. For instance, the work of [21] showed that the adoption of IR 5.0 leads to higher employee and organizational performance in European firms. [4] affirmed that IR 5.0 brings about significant changes to address persistent and increasingly aggravated socio-economic and environmental challenges that poses a threat to the well-being of future generations on a larger scale. Among these are reducing waste and pollution in industries and pushing for circularity in supply chains, boosting prosperity, workforce productivity, employment growth and workplace safety and improving the working conditions for employees. [1] highlighted the uses of IR 5.0 in the construction industry to include: health and safety, collaborative working, waste management, measurement of environmental features in buildings and forecasting environmental, social or financial outcomes. Therefore, the above studies shows that revolutionizing the construction sector with IR 5.0 smart technology will secure long-term environmental and socio-economic developments in the built environment. However, while this review presents the position of academic literature on IR 5.0 and its sustainability implications in developed countries, there is little empirical evidence on the applicability of the concept in developing countries. To bridge this gap, our study explores the application of IR 5.0 in the Nigerian construction sector, it further strategizes pathways to enhance its application for a sustainable built environment in Nigeria.

3. METHODS

The study adopted the qualitative research design. This approach was deemed useful due to its ability to elicit in-depth response through interviews from the participants. Built environment professionals actively involved in the construction industry includes but are not limited to, Architects, Builders, Estate Surveyors and Valuers, Land Surveyors, Quantity Surveyors, Town planners, Civil, Electrical, Mechanical and Structural Engineers. To achieve the aim of this study, four of these professionals: Architects, Builders, Engineers (Civil, Electrical, Mechanical and Structural) and Quantity Surveyors were selected. These set of interviewees were chosen due to their understanding of IR 5.0 concepts and their active involvement in IR 5.0 related construction activities in Nigeria's built environment. [22] recommended between five and 25 participants for interviews in a qualitative study. To this end, 25 built environment professionals in Nigeria participated in the interview until the saturation point was achieved. In tandem with the research objectives, five questions were developed: (1). How do you understand the concept of industry 5.0? (2). What challenges hinders the application of Industry 5.0 in Nigeria's built environment? (3). Have you applied industry 5.0 in your construction projects? (4). How have you applied industry 5.0 in your projects? (5). What strategies can be applied to enhance Industry 5.0 application in Nigeria's built environment? Purposive sampling, which involves identifying and selecting individuals based on their knowledge or experience about a phenomenon under investigation [23] was employed for the study. This sampling technique allowed the participants to share their expertise and knowledge on IR 5.0. The participants were selected using contacts from Nigerian construction professional networks such as the Nigerian Institute of Architects (NIA), Nigerian institute of Building (NIOB), Nigerian Society of Engineers (NSE) and the Nigerian Institute of Quantity Surveyors (NIQS). The sample selection was focused on the Federal Capital Territory, Abuja, due to its ongoing housing and infrastructural developments in the country.

The collected data were analysed using percentages and thematic analysis. The thematic data analysis method was adjudged suitable due to the novel nature of IR 5.0 concept in the Nigerian construction sector, which requires validation of the factors and variables by experts using a qualitative research approach. The process involved in the thematic analysis followed the six-step process postulated by [24] and exemplified in the work of [3]: familiarization; coding; generating themes; reviewing themes; defining and naming themes; and writing up. In step 1, the authors familiarized themselves by reading the interview data thoroughly, and transcribed the audio and oral notes through repetitive listening. This was achieved by jotting the ideas of potential codes in a manual codebook. Inductive coding which create codes by allowing the data to determine the themes was used. This approach enabled the authors to apply a thorough and unbiased look at the themes. For Step 2 of the coding process, the authors transcribed the responses into short phrases or sentences that captured the meaning of the interview quotes. This assisted the authors in grasping the main point that emerged throughout the data, and to clearly discover reoccurring concepts that could be further refined.

In step 3, the themes were generated. Here, codes that were created were given a relook, patterns were identified, and this resulted in combining several codes into broad themes. In generating themes, the authors ensured that the themes captured important aspects of the data in relation to the research objectives. As a result, themes within themes (sub-themes) emerged, which improved the quality of the insights. For step 4, the themes were reviewed to ensure their usefulness and accurate representation of the data. This was achieved by reading the data excerpts and comparing the generated themes against each other to identify differences. In step 5, the themes and sub-themes were defined to put some meaning and understanding to the data. This culminated in step 6 where the analysis of the interview data was written down and the findings reported. The collected data was further analysed using the Nvivo software to solidify the patterns and themes that emerged from the analysis. Patterns, themes and nodes similar to the manual analysis carried out by the authors were formed. Nvivo software was used in order to improve the accuracy of the analysis carried out.

4. RESULTS

4.1 Participants' Description

As depicted in Table 1, the participants (P) comprised 40% of architects, 28% of builders, 16% of engineers, and 8% of quantity surveyors. This denotes that the professionals were from varying construction-related disciplines, with Architects representing majority of participants for the study. In terms of their educational qualifications, majority of the participants possessed a B.Sc degree, with professional registration spreading across Architects Registration Council of Nigeria (ARCON), Council of Registered Builders in Nigeria (CORBON), Council of Registered Engineering in Nigeria (COREN) and the Quantity Surveyors Registration Board of Nigeria (QSRBN). This indicates that all the built-environment professionals were adequately qualified to make informed inputs to this research. Moreover, the table also shows that 48% of the participants have 1–10 years of experience, 36% have 10–20 years, while 8% have over 20 years of experience. Overall, this statistic proves that the participants had enough industry experience to make knowledgeable contribution to this research. A detailed description of the interviewed participants is presented in Table 1.

Table 1: Description of the participants

ID	Profession	Education	Registration Status	Years of Experience
Participant 1	Quantity Surveyor	B.Sc	QSRBN	1-10
Participant 2	Architect	M.Sc	ARCON	1-10
Participant 3	Quantity Surveyor	B.Sc	QSRBN	Above 20
Participant 4	Architect	M.Sc	ARCON	1-10
Participant 5	Engineer	B.Sc	COREN	1-10
Participant 6	Builder	HND	CORBON	1-10
Participant 7	Architect	B.Sc	ARCON	10-20
Participant 8	Architect	HND	ARCON	10-20
Participant 9	Builder	HND	CORBON	10-20
Participant 10	Architect	M.Sc	ARCON	10-20
Participant 11	Builder	B.Sc	CORBON	10-20
Participant 12	Builder	B.Sc	CORBON	10-20
Participant 13	Builder	B.Sc	CORBON	10-20
Participant 14	Architect	M.Sc	ARCON	1-10
Participant 15	Architect	M.Sc	ARCON	1-10
Participant 16	Builder	B.Sc	CORBON	1-10
Participant 17	Architect	M.Sc	ARCON	1-10
Participant 18	Engineer	B.Sc	COREN	1-10
Participant 19	Architect	B.Sc	ARCON	1-10

Participant 20	Builder	B.Sc	CORBON	10-20
Participant 21	Engineer	B.Sc	COREN	10-20
Participant 22	Architect	M.Sc	ARCON	Above 20
Participant 23	Architect	M.Sc	ARCON	10-20
Participant 24	Engineer	B.Sc	COREN	1-10
Participant 25	Engineer	M.Sc	COREN	10-20

Source: Field survey, 2025

4.2 Thematic Analysis Interviews

This section delves into the research result and explores the key themes that emerged from the four research questions (RQ1, RQ2, RQ3 and RQ4) based on the thematic analysis conducted using Nvivo software. Table 2 summarises the main themes, sub-themes, and the frequency with which they were referenced across different sources. RQ1 examined the participants' understanding of IR 5.0. The analysis reveals several sub-themes, focusing on the basic understanding of IR 5.0, followed by themes such as sustainability**;** human-centered approach; and technological assistance. These result suggests that while a foundational understanding of the concept exists, certain areas, such as integration with existing industries and the sustainability of technological advancements, are still emerging. RQ2 assessed the challenges hindering IR 5.0 application. The result indicates that the challenges organisations face in its adoption are varied, with the most frequently discussed barriers being cultural and social barriers**;** infrastructure and technology; and cost and investment. These challenges underscore the complexity of integrating new technologies into existing systems, the resistance to change and the investment required for successful implementation. **S**kills and workforce readiness and research and development were highlighted as important factors less frequently mentioned.

RQ3 evaluated the current application of industry 5.0 technologies. The data indicates a limited application of IR 5.0 technologies. The extent of application is discussed across all 25 sources, highlighting the ongoing efforts to implement IR 5.0 principles. This suggests that organizations are actively exploring and applying these technologies but may still be in early or experimental stages of adoption. RQ4 explored the strategies for IR 5.0 adoption. The analysis reveals a strong emphasis on awareness and education, indicating that education and skill development are key drivers for overcoming adoption barriers. Infrastructure and funding were also frequently mentioned as necessary for supporting the widespread adoption of IR 5.0, followed by policy and regulation, highlighting the role of governmental and institutional support in enhancing IR 5.0 application in Nigeria. As shown in Table 2, these results provide a holistic and comprehensive overview of the current state of IR 5.0 in the Nigerian construction sector. The next section analyses the results in greater detail to answer the four research questions. A summary of the key themes and frequency in tandem with the research questions are captured in Table 2.

Table 2: Research questions and key themes

Name/Theme/Code	Files (Case Count)	References (Case Count)
RQ1 Awareness of Industry 5.0	**19**	**25**
Sustainable and efficient practices	13	13
Optimum use of resources for enhanced productivity	3	3
Sustainable practices	10	10
Technology driven resource optimization	12	12
Human and machine collaboration	11	11
Maximizing resource potential	1	1
RQ2 Challenges Hindering its Application	**24**	**45**
Barriers to Technological Advancement in Industry 5.0	21	35
Access to technology	10	10
Lack of awareness	15	16
Lack of stakeholder support for industry 5.0	8	9
Institutional and Infrastructure Gaps	7	10
Cultural and social barriers	2	2
Lack of collaboration between industry, academia and government	1	1
Poor government support	6	7
RQ3 Application of Industry 5.0	**9**	**13**
Digital Transformation in the Built Environment	3	3
Internet of things (IoT)	1	1
Use of AI in designs	1	1
Use of BIM	1	1
Innovative Tools for Modern Construction	2	2
Use of drones	2	2
Sustainable and Smart Design Approaches	7	8
Green design concepts	2	2
Renewable energy	4	4
Use of sustainable materials	2	2
RQ4 Strategies to aid Application of 5.0	**20**	**39**
Capacity Building/Stakeholder development	15	24
Creating awareness	12	14
Training stakeholders	9	10

Collaboration and investment in technology	2	2
Encourage partnerships for investment on technology	2	2
Policy and regulatory support for technological advancement	10	13
Adopting internal best standards	2	2
Government policies to encourage industry 5.0	9	11

Source: Field survey, 2025

4.2 Understanding of Industry 5.0 in the Nigerian Construction Sector

Table 3 focuses on how some of the selected participants understand IR 5.0. A cross-section of the responses shows varied interpretations, ranging from productivity, sustainability, to human-machine collaboration, providing insightful perspectives into the professionals' perception of this new paradigm. A summary of the understanding of IR 5.0 in Nigeria is presented in Table 3.

Table 3: Understanding of industry 5.0

ID	Profession	Understanding of Industry 5.0
P1	Quantity Surveyor	Optimum use of resources for enhanced productivity
P2	Architect	Sustainable practices in the built environment
P3	Architect	Collaboration between machine and people
P4	Engineer	Collaborative relationship between humans and machines
P5	Builder	Technology integrates human and machine operations
P6	Architect	Human-centred, sustainable, resilient production
P7	Architect	A new revolution of harnessing the power of human, machine and the environment towards a sustainable construction industry
P8	Architect	Industry 5.0 aims to create a more inclusive, sustainable, and resilient industrial ecosystem, where humans, technology, and the environment collaborate
P10	Builder	While Industry 4.0 focused on technologies such as the Internet of Things and big data, Industry 5.0 seeks to add human, environmental, and social aspects to the equation
P11	Builder	Revolutionary approach of human and machines in construction
P12	Architect	Sustainability
P13	Architect	Robots and smart machines operated by people
P14	Engineer	Industry 5.0 represents the next phase of industrial evolution, building on the advancements of Industry 4.0
P15	Architect	To promote sustainable construction

Source: Field survey, 2025

In light of this understanding, the study sought to gain further insight into the awareness of IR 5.0. The result in Table 4 reveals a generally low level of awareness among Nigeria's built environment professionals. For instance, while 70% of quantity surveyors were aware of IR 5.0 in some form, only 10% could explain its relevance to their projects. Engineers and architects displayed slightly higher awareness levels, with 30% of engineers providing insights into the potential of IR 5.0 technologies like Artificial Intelligence (AI) and collaborative robotics. A summary of the awareness of IR 5.0 among professionals in Nigeria is shown in Table 4. Figure 1 presents a chart of the awareness level of IR 5.0 among built environment professionals in Nigeria.

Table 4: Awareness of Industry 5.0 among Professionals in Nigeria

Professional Group	**Awareness of Industry 5.0 (%)**	**Comprehensive Understanding (%)**
Quantity Surveyors	70%	10%
Builders	65%	12%
Architects	55%	25%
Engineers	50%	30%

Source: Field survey, 2025

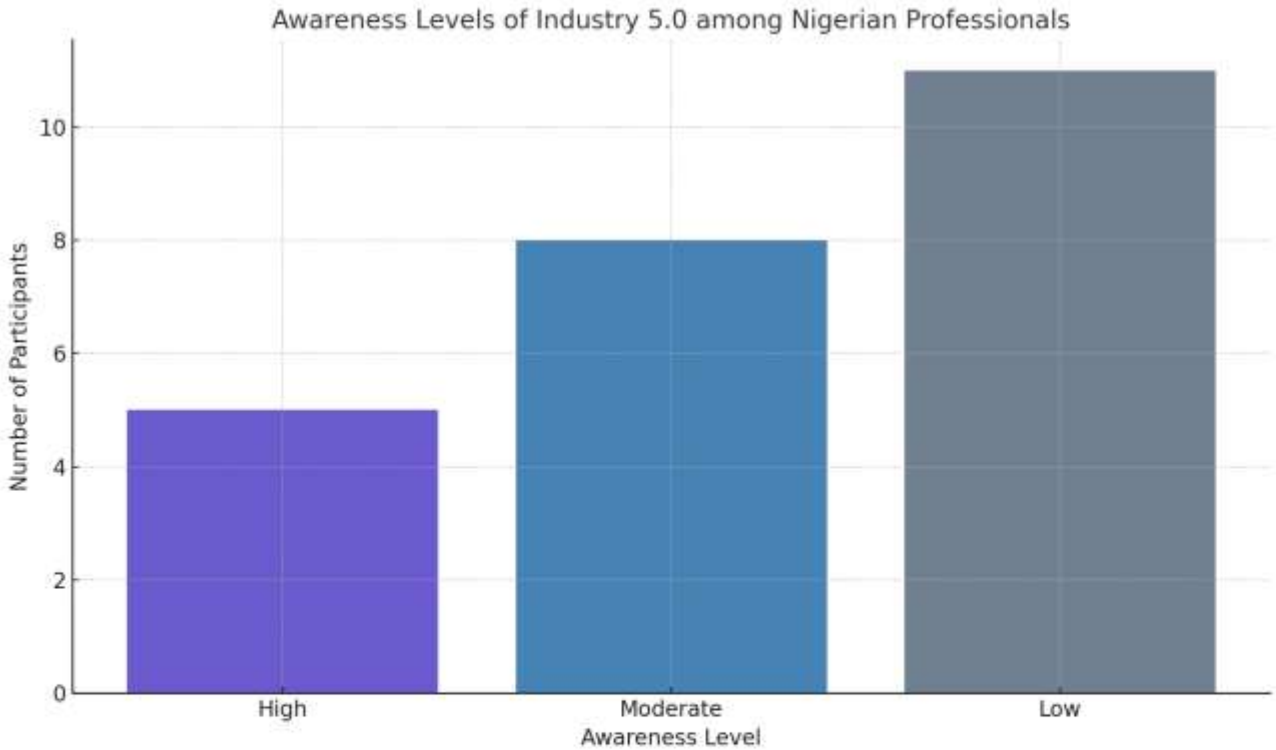

Figure 1: Bar chart showing the awareness level of IR 5.0 among professionals
Source: Author(s) findings

4.3 Challenges Hindering Industry 5.0 Application in the Nigerian Construction Sector

Table 5 highlights the varied challenges experienced by each participant in implementing IR 5.0 in their respective fields. Common themes among the professional groups include lack of awareness, financial constraints, and limited access to technology. A summary of the challenges facing the adoption of IR 5.0 among professionals in Nigeria is presented in Table 5.

Table 5: Challenges facing the adoption of industry 5.0 among professionals

ID	Profession	Challenges
1	Quantity Surveyor	Awareness and buy-in from stakeholders
2	Architect	Lack of awareness, lack of working proofs
3	Quantity Surveyor	Awareness and buy-in from stakeholders
4	Architect	Lack of technology access, steady power
5	Engineer	Skills gap, high cost of technology
6	Builder	Lack of awareness, high cost of technology
7	Architect	Funds, human intelligence, readiness to learn

Source: Field survey, 2025

Table 6 further highlights the key challenges faced by professionals in adopting IR 5.0 in the Nigerian construction sector. As identified by the participants, the study deduces multiple challenges that impedes the application of IR 5.0 in Nigeria. As shown in Table 6, one major issue is poor infrastructure, particularly unreliable power supply and inadequate IT networks, which significantly hinder the deployment of IR 5.0 technologies. Another recurring issue is high cost of adopting advanced technologies such as AI, Internet of Things (IoT), and robotics. For example, 65% of participants mentioned that these technologies are financially out of reach for small and medium-sized enterprises (SMEs). Participants also emphasize the lack of government policy and incentives to encourage IR 5.0 adoption, further complicating efforts to implement these technologies effectively. Additionally, the skill gaps among professionals was highlighted as a critical barrier, with 58% of participants noting insufficient training opportunities. A summary of the challenges hindering the application of IR 5.0 in Nigeria is presented in Table 6. Figure 2 presents a word cloud highlighting key challenges of IR 5.0 application in Nigeria.

Table 6: Key challenges hindering the application of industry 5.0

Challenge	**Frequency (No. of Respondents)**	**Percentage of Respondents**
High cost of technology	13	65%
Poor infrastructure	15	72%
Skill gaps	12	58%
Lack of government policies	13	60%
Resistance to change	9	45%

Source: Field survey, 2025

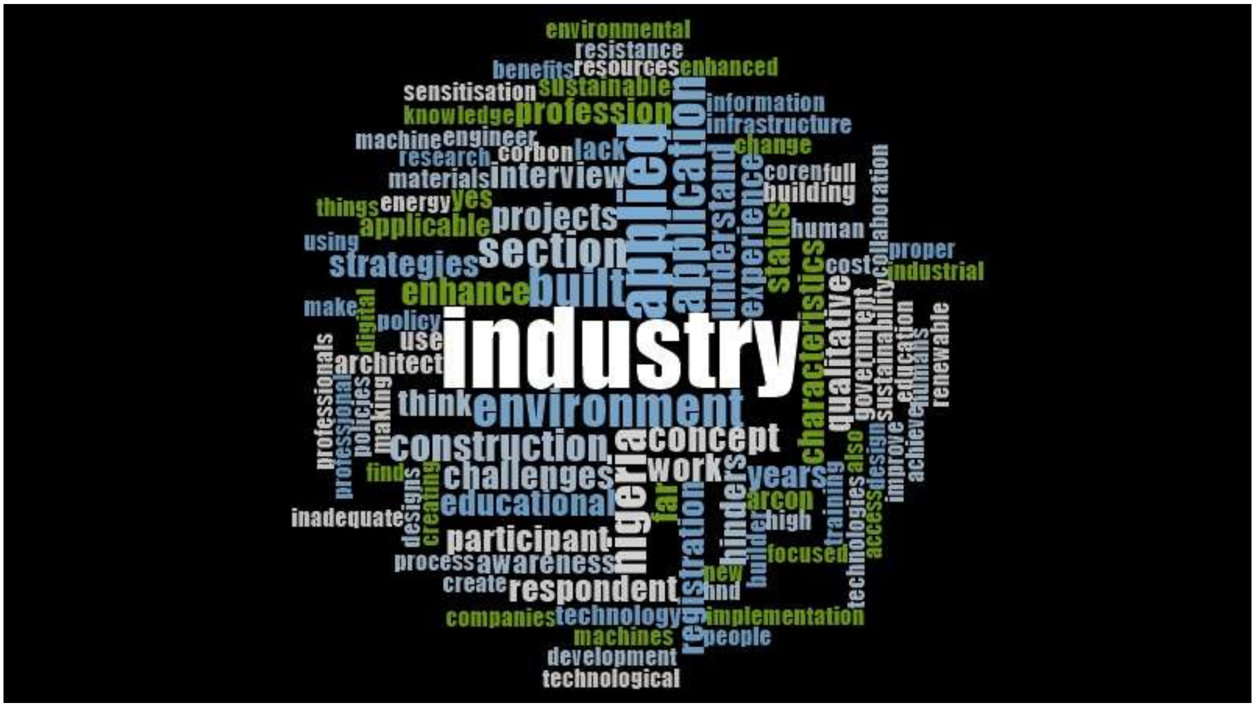

Figure 2: Word cloud highlighting key challenges of IR 5.0 application in Nigeria
Source: Author(s) findings

4.4 Application of Industry 5.0 in the Nigerian Construction Sector

Table 7 outlines whether or not the participant applied IR 5.0 concepts in their construction work. It further describes the specific applications, such as sustainable design, artificial intelligence (AI) integration, and the use of renewable energy systems. The application of IR 5.0 technologies in Nigeria's construction sector remains limited. As shown in Table 7, the most frequently reported technologies include sustainable materials and renewable energy systems, which were used in 40% and 35% of construction projects, respectively. Building Information Modeling (BIM) was another technology identified, though its adoption was limited to only 15% of projects due to its high implementation costs and technical complexity. Similarly, AI applications, such as design optimization and hazard identification, were used in 20% of projects but were mostly restricted to large-scale or high-budget developments. A summary of the current application of IR 5.0 technology is presented in Table 7.

Table 7: Current application of Industry 5.0 technology

Technology	Adoption Rate (%)	Example of Application
Sustainable materials	40%	Use of recycled waste in construction
Renewable energy systems	35%	Solar energy installations for buildings
Artificial Intelligence	20%	Design optimization and hazard detection
Building Information Modelling	15%	Collaborative planning and visualization

Source: Field survey, 2025

4.5 Strategies for Industry 5.0 Application in the Nigerian Construction Sector

Table 8 highlights the strategies proposed by participants to enhance the adoption of IR 5.0. These strategies range from awareness campaigns and training programs to partnerships and policy changes. The study also explores the potentials of applying IR 5.0 principles to Nigeria's construction sector. As shown in Table 8, the finding suggests strategies such as increasing awareness through education and publications, fostering collaboration between academia, government, and industry, and developing targeted training programs. A summary of the strategies for enhancing IR 5.0 adoption is presented in Table 8. Figure 3 presents a chart of the priority levels of the proposed strategies for IR 5.0 adoption in Nigeria.

Table 8: Strategies to enhance Industry 5.0 adoption

Strategy	Priority Level	Example of Implementation
Awareness campaigns	High	Workshops, professional training programs
Infrastructure development	High	Reliable power and IT infrastructure
Financial incentives	High	Tax breaks for adopting Industry 5.0 tech
Professional education	Medium	Curriculum focused on Industry 5.0
Stakeholder collaboration	Medium	Industry-wide partnerships

Source: Field survey, 2025

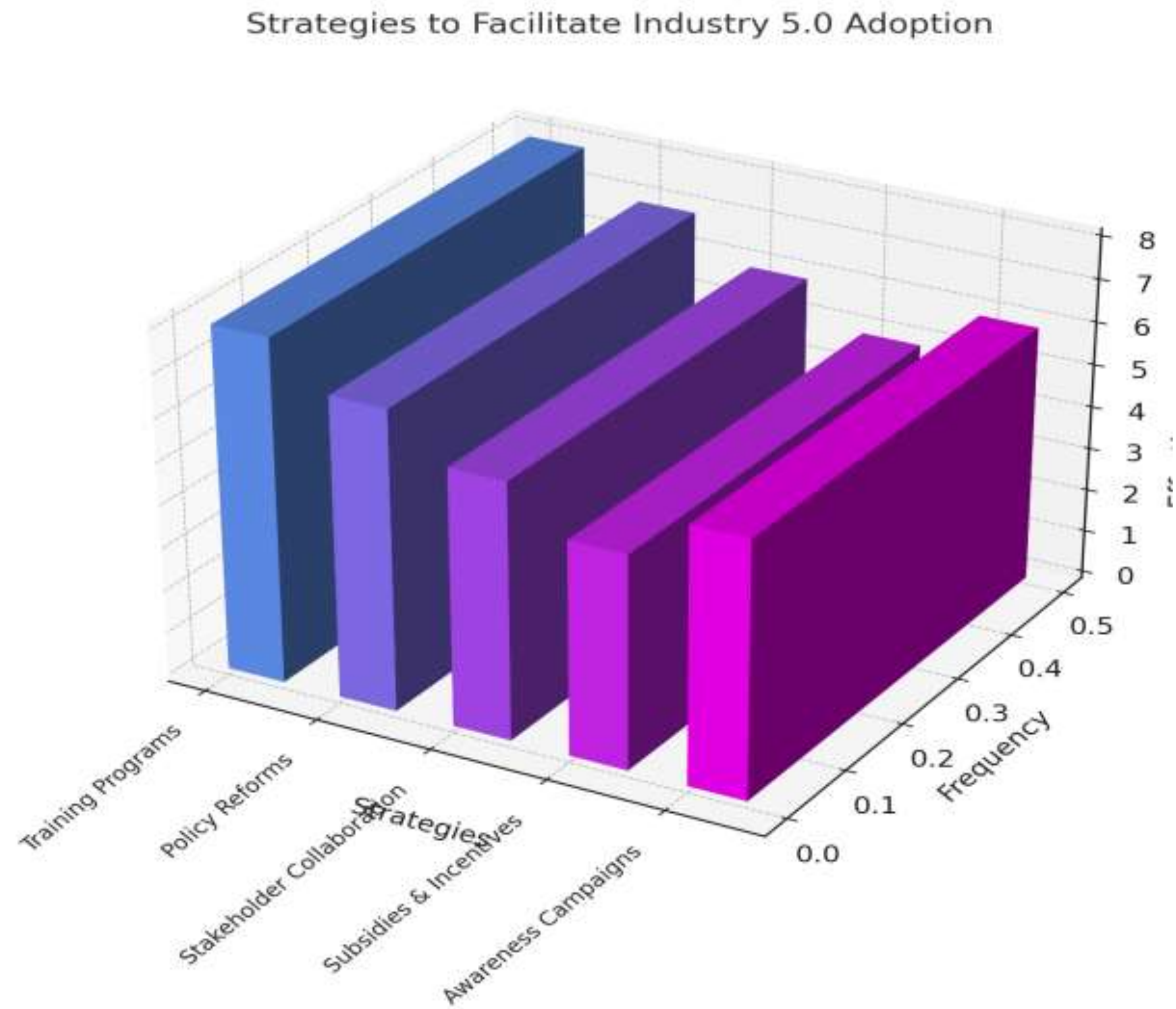

Figure 3: Chart showing priority levels of the proposed strategies
Source: Author(s) findings

DISCUSSION

IR 5.0 holds significant potential to transform Nigeria's construction sector, offering a more efficient approach for a more sustainable built environment. However, its application are hindered by multiple challenges. Regarding the depth of understanding and awareness, valuable insight drawn from the study shows that many professionals leaned towards associating IR 5.0 with automation, resource optimization, and human-machine collaboration. For instance, as disclosed by Participant P1, P3, P4, P5, P11, P3 and P14, *"industry 5.0 represents the next phase of industrial evolution, building on the advancements of*

Industry 4.0 such as optimum use of resources, and collaboration between machine and people for enhanced productivity." This is in stark contrast with few having a comprehensive understanding of its core principles, such as resilience, and sustainability. Altogether, it can be inferred that this variation in its understanding is an indication that IR 5.0 is still emerging in what can be termed 'its infant or experimental stage' in Nigeria. This result cements the position of [4, 7] that IR 5.0 is a novel concept that is continually evolving, with scholars lacking a unanimous definition and consensus in differentiating the phenomenon from its predecessor. Moreover, the result on the awareness of IR 5.0 revealed that its awareness level remains relatively low among built environment professionals in Nigeria. This is evidenced by few linking its relevance to their projects and a fair number providing insights into its potential, such as AI and collaborative robotics. In any case, it can be deduced that much effort is required to enhance the awareness of IR 5.0 in Nigeria.

Based on the thematic analysis interviews, the result indicates that the challenges hindering IR 5.0 are varied. Challenges such as poor infrastructure, high costs associated with technology adoption, lack of government policies/incentives, and insufficient training opportunities were highlighted among the key themes hindering IR 5.0 application in Nigeria's built environment. These underscores the complexity of integrating new technologies into existing systems, the resistance to change and the investment required for successful implementation. The result agrees with [12, 19, 18] that IR 5.0 is expensive as it requires investment, extra costs, training human workers to use smart machines and highly skilled employees to increase productivity and efficiency, and the acquisition of more advanced and sophisticated digital technologies which is an additional financial burden to organizations. The result also conforms to [20] that lack of innovation, limited resources and a lack of political are some of the challenges associated with the adoption of IR 5.0. In addition, a large proportion of the participants also identified the lack of exposure to IR 5.0 concepts during academic training as a major hindrance to its understanding. Ultimately, these challenges limits the rate and scale at which IR 5.0 technologies can be integrated into the Nigerian construction sector for a sustainable built environment.

Moreover, result from the study also showed that the application of IR 5.0 technologies in Nigeria's construction sector remains rather limited, but promising. This can be attributed to the technology still emerging. This is evident in the application of IR 5.0 technologies in areas such as sustainable materials, renewable energy systems, AI and BIM. As a case in point, sustainable materials were applied to recycle waste in construction projects. Renewable energy systems were also used for energy installations in buildings. Regarding AI, it was used to design optimization and hazard detection, while BIM was applied for collaborative planning and visualization. Altogether, these promising technologies reflect a growing emphasis on innovations and environmental sustainability which aligns with IR 5.0 principles. The result is consistent with [12] that potential applications of IR 5.0 can bring about innovative ecosystem, and green ecology. The result also lends credence to [6] that IR 5.0 assesses the environmental effects and actions of the construction sector and collaborates to reduce environmental risks. However, in Nigeria, these technologies have primarily been adopted in larger-scale projects, leaving smaller enterprises struggling to adopt them due to the financial and technical challenges. Despite this position, built environment professionals in Nigeria who have applied IR 5.0 concepts generally recognize its potential in improving the sector's productivity and sustainability. This suggests an underlying foundation on which the Nigerian construction sector can be built upon.

Furthermore, in exploring strategies that can enhance the adoption of IR 5.0 in Nigeria’s construction sector, the thematic analysis deduced 4 themes which includes awareness campaigns, infrastructure development, Government policies and collaborative partnerships. Regarding the importance of awareness, campaigns should be organized to educate stakeholders to be aware of the benefits of IR 5.0. For example, considering the challenges discovered, integrating these concepts into university curriculum and professional training programs can help bridge the gap between understanding, awareness and application. Additionally, investing in infrastructure development, particularly improving power supply and internet connectivity is another way in applying IR 5.0 in Nigeria’s construction sector. This demonstrates that its application in the construction sector can accelerate the industry’s transition into an environmentally friendly, socially responsible and economically viable sector. This lends credence to the submission of [17] that IR 5.0 as a value-driven approach can empower the industry to achieve societal goals beyond jobs and growth, while placing the wellbeing of the industry worker at the center of the production process. In addition, Government policies, such as provision of financial incentives, tax breaks and grants for technology adoption was also revealed as another key strategy that can enhance IR 5.0 application in Nigeria. This finding is consistent with [11, 3] that with IR 5.0, the emergence of sustainable policies, such as minimal waste generation and management can make companies effective. Furthermore, the study also highlighted collaborative partnerships between stakeholders as critical for sharing knowledge and resources to overcome common challenges. These findings conform to [3] that, competency knowledge and skills to collaboratively work with smart machines is a necessary requirement for IR 5.0 adoption. Hence, in the context of the Nigerian construction sector, emphasis should be placed on the importance of creating a supportive environment for innovation and leveraging IR 5.0 principles to enhance sustainability, human-centred solutions, and overall industry development.

6. CONCLUSION

The study evaluated the application of IR 5.0 in the Nigerian construction sector, with a view to strategizing pathways to enhance its application for a sustainable built environment. To enhance IR 5.0 application in the Nigerian construction sector, targeted strategies are therefore postulated to be adopted. For one thing, a strong emphasis on awareness and education, indicating that education and skill development should be placed in overcoming adoption barriers. This can be achieved by launching awareness campaigns aimed at educating professionals and stakeholders about the benefits of IR 5.0, as well as integrating these concepts into academic curriculum and professional development programs should be developed to enhance IR 5.0 application. In addition, infrastructure and funding are necessary for supporting the widespread adoption of IR 5.0. Substantial investments in infrastructure development and financial incentives are therefore required to ensure that necessary power supply and IT networks are available to support the adoption of advanced technologies. Hence, power supply should be reliable and internet connectivity should be adequate, this will boost the deployment of IR 5.0 technologies in Nigeria.

Moreover, policy and regulations by the government are also needed as key strategies to enhance IR 5.0 application. Therefore, sustainable policies, financial incentives and creation of a regulatory environment that supports IR 5.0 technologies should be prioritized. This will encourage the mobilization of advanced technologies such as AI and robotics to financially exist within the reach of SMEs. Furthermore, collaboration among stakeholders, including the private sector, government, and educational institutions, is essential to brainstorm ideas, share resources, expertise and expedite IR 5.0 application. This will help to address the missing skill gaps and ensure that built environment professionals in Nigeria are adequately trained to handle emerging technologies. Based on these recommendations, the study concludes on a strong note that, with the right governmental, institutional and stakeholders' support, Nigeria's construction sector has the potential and capacity to integrate IR 5.0 principles to become a more sustainable built environment. As a limitation, although all interviews were limited to Nigeria, the research and academic community will find the result analyzed in this paper applicable to other developing countries, and its findings can present unique discussions in developed countries. The strength of this paper lies in the emerging themes which forms the basis for the outcome of this study and validates the knowledge of existing literature. Future studies may consider applying the results of the study using a quantitative method.

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Isang, I. W; Ebiloma D. O: Writing-original draft, article conception.
Isang, I. W; Rimtip, M. N: Data collection.
Rimtip, M. N; Isang, I. W; Ebiloma D. O, Oke, A. E: Data analysis, supervision.
Ebiloma, D. O, Isang, I. W; Rimtip, M. N; Oke, A. E: Writing-review, validation.

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The author(s) declare no competing interests

References

[1] Tunji-Olayeni, P., Aigbavboa, C., Oke, A. and Chukwu, N. (2024). Research trends in industry 5.0 and its application in the construction industry. *Technological Sustainability.* 3 (1), 1-23. DOI: 10.1108/TECHS-07-2023-0029.

[2] Isang, I. W. (2011). Investigating the Factors Affecting the Performance of Construction Projects Akwa Ibom State. B.Sc Dissertation, University of Uyo, Nigeria. https://www.academia.edu/38808941.

[3] Isang, I. W., Ebiloma, D. O. and Ukpong, E. (2025). Stakeholders' engagement for advancing a sustainable Nigerian construction industry: A sustainable development goal-driven approach. *Smart and Sustainable Built Environment*. DOI: 10.1108/SASBE-08-2024-0283

[4] Ghobakhloo, M., Iranmanesh, M., Tseng, M., Grybauskas, A., Stefanini, A. and Amran, A. (2023). Behind the definition of Industry 5.0: A systematic review of technologies, principles, components,

and values. *Journal of Industrial and Production Engineering*. DOI: 10.1080/21681015.2023.2216701

[5] Musarat, M. A., Irfan, M., Alaloul, W. S., Maqsoom, A. and Ghufran, M. (2023). A Review on the Way Forward in Construction through Industrial Revolution 5.0. *Sustainability*. 15. https://doi.org/10.3390/su151813862

[6] Aheleroff, S., Huang, H., Xu, X. and Zhong, R.Y. (2022). Toward sustainability and resilience with Industry 4.0 and Industry 5.0. *Front. Manuf. Technol*. 2. https://doi.org/10.3389/fmtec.2022.951643

[7] Lu Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z. and Bao, J. (2022). Outlook on human-centric manufacturing towards Industry 5.0. *J Manuf Syst*. 62, pp. 612–627. https://doi.org/10.1016/j.jmsy.2022.02.001

[8] Rada, M. (2020). Industry 5.0 definition. https://michael-rada.medium.com/industry-5-0-definition-6a2f9922dc48

[9] Borchardt, M., Pereira, G. M., Milan, G. S., Scavarda, A. R., Nogueira, E. O. and Poltosi, L. C. (2022). Industry 5.0 Beyond Technology: An Analysis through the Lens of Business and Operations Management Literature. *Organizacija*, 55 (4). DOI: 10.2478/orga-2022-0020

[10] Trstenjak, M., Hegedic, M., Tošanovic, N., Opetuk, T., Đukic, G. and Cajner, H. (2023). Key Enablers of Industry 5.0 – Transition from 4.0 to the New Digital and Sustainable System. In: Kohl, H., Seliger, G., Dietrich, F. (Ed.s') Manufacturing Driving Circular Economy, GCSM, Lecture Notes in Mechanical Engineering, Springer, Cham, pp. 614–621. https://doi.org/10.1007/978-3-031-28839-5_69

[11] Ietto B., Ancillai, C., Sabatini A., Carayannis, E. G and Gregori G. L. (2022). The role of external actors in SMEs' human-centered industry 4.0 adoption: an empirical perspective on Italian competence centers. *IEEE Trans Engineering Management.* doi: 10.1109/TEM.2022.3144881

[12] Maddikunta, P. K. R., Pham, Q. V., Prabadevi, B., Deepa, N., Dev, K., Gadekallu, T. R., Ruby, R. and Liyanage, M. (2021), "Industry 5.0: A survey on enabling technologies and potential applications", *J. Ind. Inf. Integr*. 26. https://doi.org/10.1016/j.jii.2021.100257

[13] Newton, P., Hampson, K. and Drogemuller, R. (2009). *Transforming the built environment through construction innovation*. In: Newton, P., Hampson, K. and Drogemuller, R. (Ed.'s), Technology, Design and Process Innovation in the Built Environment. pp 3-28. Abingdon, Oxon: Taylor & Francis Group. http://hdl.handle.net/20.500.11937/12297

[14] Taalbi, J. (2019). Origins and pathways of innovation in the third industrial revolution. *Ind. Corp. Change,* 28, 1125–1148. https://doi.org/10.1093/icc/dty053

[15] Nahavandi, S. (2019), "Industry 5.0 - a human-centric solution", *Sustainability,* 11 (16), 4371. https://doi.org/10.3390/su11164371

[16] Imoize A. L, Adedeji O., Tandiya N and Shetty S. (2021). 6G enabled smart infrastructure for sustainable society: opportunities, challenges, and research roadmap. *Sensors*. 21 (5), 1709. https://doi.org/10.3390/s21051709

[17] Xu, X., Lu, Y., Vogel-Heuser, B. and Wang, L. (2021). Industry 4.0 and Industry 5.0 —Inception, conception and perception. *J. Manuf. Syst*. (61), 530–535. https://doi.org/10.1016/j.jmsy.2021.10.006

[18] Tripathy, H. P. and Pattanaik, P. (2020). Birth of industry 5.0: The internet of things and next generation technology policy. *International Journal of Advanced Research on Engineering and Technology*, 11 (11), 1904-1910.

[19] Narvaez Rojas, C., Alomia Penafiel, G. A., Loaiza Buitrago, D. F. and Tavera Romero, C. A. (2021). Society 5.0: A Japanese concept for a super intelligent society. *Sustainability*. 13 (12), 1-16. https://doi.org/10.3390/su13126567

[20] Srinadhuni, S. and Guo, T. (2023). Industry 5.0 Challenges in Sweden: Understanding the Power of Academia for Sustainability through Quadruple Helix Partnership. Master's thesis, KTH Royal Institute of Technology, Stockholm. https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-329142.

[21] Erro-Garces, A. and Aramendia-Muneta, M. E. (2023). The role of human resource management practices on the results of digitalisation. From Industry 4.0 to Industry 5.0. *Journal of Organizational Change Management*. 36 (4), 585-602. Doi: 10.1108/JOCM-11-2021-0354

[22] Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bernadette, B., Burroughs, H. and Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Qual Quant*, Vol. 52, pp. 1893-1907, doi: 10.1007/s11135-017-0574-8

[23] Isang, I. W. and Ebiloma, D. O. (2024). Exploring the Sustainable Benefits and Measures for Enhancing Quantity Surveyors' Involvement in Construction Projects: The Case of Nigeria. *East African Scholars Journal of Engineering and Computer Sciences*, 7 (9), 121-132. DOI: https://doi.org/10.36349/easjecs.2024.v07i09.001

[24] Braun, V. and Clarke, V. (2019). To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. *Qualitative Research in Sport, Exercise and Health*. 13 (2). doi: 10.1080/2159676X.2019.1704846