Journal of Building Design and Environment
Science Exploration

Open Access Research Article

Insights and Issues of Implementing Virtual Reality (VR) for Supervision Training Purposes in SUBEB, Edo State, Nigeria

Osamwonyi Ada-okungbowa[1], Akinsanmi Akindeinde[2,*], Oluwafemi Adedeji[3], Colin A. Booth[4]

[1]Centre for Architecture and Built Environment Research, College of Arts, Technology and Environment, University of the West of England, Coldharbour Lane, Bristol BS16 1QY, UK.
[2]Department of Quantity Surveying, Federal University of Technology, Akure 340110, Nigeria.
[3]Department of Construction Project Management, Loughborough University, Loughborough LE11 3TU, UK.
[4]Centre for Architecture and Built Environment Research, College of Arts, Technology and Environment, University of the West of England, Bristol BS16 1QY, UK.

***Correspondence to:** Akinsanmi Akindeinde, Department of Quantity Surveying, Federal University of Technology, Akure 340110, Nigeria. E-mail: qssanmi@gmail.com

Received: December 30, 2024 **Accepted:** May 07, 2025 **Published:** May 17, 2025

Cite this article: Ada-okungbowa O, Akindeinde A, Adedeji O, Booth CA. Insights and Issues of Implementing Virtual Reality (VR) for Supervision Training Purposes in SUBEB, Edo State, Nigeria. J Build Des Environ. 2025;3:202448. https://doi.org/10.70401/jbde.2025.0008

Abstract

This study explores the adoption of Virtual Reality (VR) in the Nigerian construction industry, with a focus on its potential benefits and associated challenges. Purposive and snowball sampling techniques were employed to select 52 construction professionals from Benin, Edo State,an emerging urban center with extensive construction activity. Adopting a quantitative approach, the research utilized a five-point Likert scale survey to assess perceptions of the benefits and barriers to VR adoption. The survey was pretested for clarity and reliability, and data were collected via the Qualtrics platform. The findings indicate that the key benefits of VR include improved task-technology alignment, enhanced workplace safety through virtual training, and more effective remote collaboration. VR was also found to enrich user experience and learning engagement by simulating high-risk scenarios to aid hazard prevention. Nevertheless, the study identifies several critical barriers to adoption, such as uncertainty regarding learning outcomes, technical disruptions, and high implementation costs. Despite these limitations, VR holds considerable promise for transforming training and professional development in the construction sector. To maximize its impact, the study recommends the development of customized training modules, technological improvements to enhance system reliability, and government support to mitigate implementation costs. Overall, VR has the potential to significantly improve training effectiveness, safety standards, and operational efficiency in the Nigerian construction industry, provided that the identified barriers are adequately addressed.

Keywords: Adoption, barriers, benefits, construction industry, technology, training, virtual reality

1. Introduction

The infrastructure and construction sector plays a critical role in economic development, significantly contributing to employment and national prosperity[1,2]. In Nigeria, the construction industry is labor-intensive, involving multiple stakeholders, complex processes, and substantial financial commitments from project inception to completion. However, the widespread use of unskilled labor and inadequate supervision frequently leads to inefficiencies, cost overruns, and subpar quality[3]. Effective site supervision is essential for project success, as poor coordination and communication between supervisors and workers often result in rework, delays, and safety issues[4]. In responses to these challenges, emerging digital tools, such as Virtual Reality (VR) have been explored for their potential to enhance training, site supervision, and overall project performance in the Architecture, Engineering and Construction industry[5].

Despite the growing adoption of VR technology in the global construction industry, research on its implementation in Nigeria remains limited. Previous studies have demonstrated the benefits of VR in enhancing worker's engagement, skill development, and project efficiency within controlled environments[6]. Additionally, Zhang *et al.*[7] highlight the effectiveness of VR in training construction professionals, particularly in enhancing knowledge retention and practical skill acquisition. However, in Nigeria, VR adoption is still in its infancy, and empirical research examining its feasibility, advantages, and challenges remains scarce. The issue is especially evident in Edo State, where the local government, through the Edo State Universal Basic Education Board (SUBEB), constructs and renovates more than 120 schools annually[8]. Due to a shortage of qualified construction professionals, untrained local residents are often appointed as project monitoring officers, resulting in inadequate project oversight and declining construction quality. Given the growing demand for effective construction training solutions, this study seeks to assess stakeholder's perspectives on the benefits and barriers associated with VR adoption in the Nigerian construction industry.

This study offers critical insights into the potential of VR technology to enhance construction training and supervision in Nigeria. By evaluating the perspectives of key stakeholders, including government agencies, construction professionals, and policymakers, the research seeks to identify both the benefits and challenges associated with VR adoption in the industry. Moreover, the study contributes to the growing body of knowledge on digital transformation within Nigeria's construction sector by providing recommendations for effective VR integration in workforce training and project management. Ultimately, the findings aim to support policymakers and industry leaders in making informed decision regarding VR adoption to improve construction quality, safety, and operational efficiency.

2. Literature Review

2.1 VR in construction: evolution, applications, and workflow

VR is an advanced technology that creates immersive, computer-generated environments, enabling users to interact with 3D simulations in real-time[9]. The origins of VR can be traced back to the 19th century, with the development of stereoscopic imagery. This was further advanced by Morton Heilig's Sensorama in the 1960s and the introduction of head-mounted displays in the 1980s[10]. Charles Wheatstone's invention of the stereoscope is often highlighted as a foundational step towards the development of VR goggles. Helig's Telesphere Mask in 1960 marked significant progress in the field. The tern "virtual reality" was formally coined in 1989[11], establishing the field as an independent technological discipline. Since then, VR has evolved with advancements in motion tracking, artificial intelligence, and spatial computing, enhancing the immersive experiences and making it particularly relevant to the construction industry[12,13]. VR is described as a technology that simulates real-world scenarios by integrating 3D scenes with user interaction. It is also defined as a three-dimensional digital representation of real or imagined environments, allowing users to experience realistic visual and tactile sensations[14].

VR is increasingly being utilized in construction for design visualization, safety training, and project management. Through interactive simulations, construction professionals can experience building designs before construction begins, thereby reducing errors and enhancing decision-making[15]. Traditional design processes often rely on 2D drawings and static 3D models, which can limit stakeholders' understanding of spatial relationships. VR overcomes this limitation by enabling users to virtually walk through buildings, assess design elements in real-time, and make immediate modifications, significantly improving project accuracy[16]. Additionally, VR-based clash detection enhances the design review process by integrating with Building Information Modelling (BIM), enabling the identification of potential conflicts between architectural, structural, and mechanical systems prior to the start of construction begins[11].

Another major application of VR in construction is safety training and on-site worker education. Construction sites are inherently hazardous, with risks such as falls, equipment malfunctions, and structural failures. VR-based training programs allow workers to experience and respond to dangerous scenarios in a simulated environment, reducing the likelihood of real-world accidents[16]. Unlike traditional classroom-based training, VR immerses trainees in realistic construction site conditions, enabling them to practice emergency procedures, hazard identification, and equipment operation without any physical risks[17,18]. A structured VR experience workflow has been proposed in Figure 1, consisting of five stages: (1) collecting site data and technical documentation, (2) developing and optimizing 3D models of construction components, (3) creating a virtual environment and programming user interactions, (4) conducting usability testing and refining models, and (5) deploying VR for training and project coordination. This workflow ensures that VR applications remain accurate, efficient, and tailored to real-world construction challenges. VR-enabled site planning also improves logistics by simulating material delivery, equipment positioning, and worker movements, ultimately leading to reduced delays and optimized resource allocation[19].

Despite its transformative potential, the adoption of VR adoption in construction faces several challenges, including high costs, the need for technical expertise, and resistance to change[16]. Infrastructure limitations and issues related to software-hardware compatibility further hinder widespread implementation, particularly in developing regions[19]. However, advancements in AI-driven automation and cloud-based VR applications are gradually helping the construction industry overcome these barriers. As hardware costs decline and interoperability with BIM and digital twin technologies improves, VR is expected to become a mainstream tool for project visualization, workforce training, and real-time construction monitoring[20]. Future developments in haptic feedback and augmented VR interfaces will further enhance the realism and usability of VR applications in construction, positioning it as a critical component of digital construction workflows.

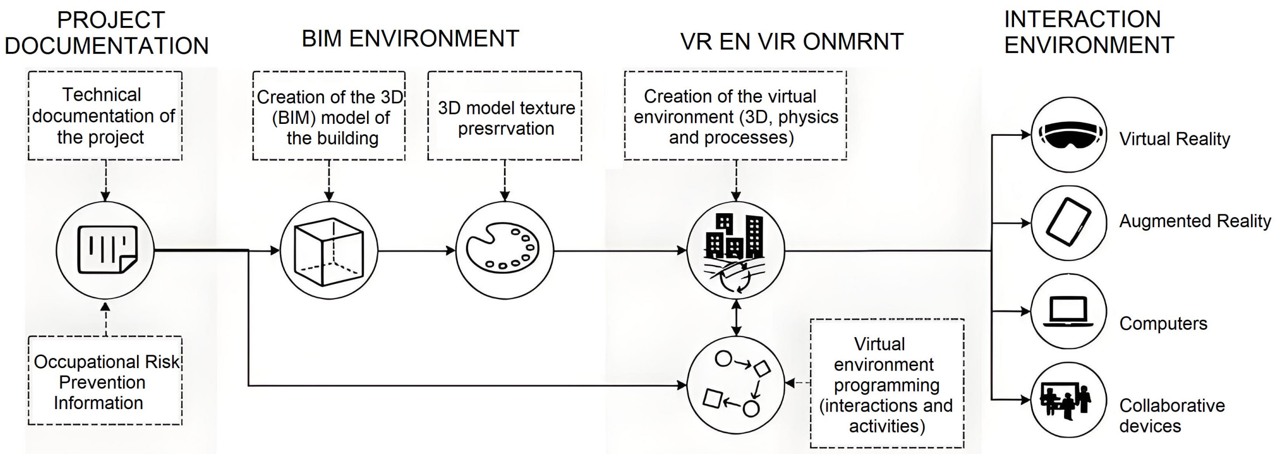

Figure 1. The virtual experience's creation workflow[18]. BIM: Building Information Modelling; VR: Virtual Reality.

2.2 VR for safety training and risk management

The construction industry is inherently high-risk, with workers exposed to various hazards such as falls, equipment-related injuries, and structural failures. As technological advancements continue to reshape the sector, the use of VR for safety training and risk management has gained significant momentum. VR-based safety training programs provide immersive and interactive experiences that enhance learning outcomes, improve hazard recognition, and reduce workplace accidents[21,22]. Unlike traditional safety training methods, which often rely on manuals, lectures, and videos, VR allows workers to engage with realistic construction site scenarios in a controlled virtual environment, thereby improving both engagement and knowledge retention[23]. This is consistent with previous findings, which suggest that conventional training approaches, such as computer-based learning, fail to equip decision-makers with the practical skills needed to address real-world safety challenges[9]. Additionally, Yu *et al.*[24] emphasize that VR training enhances both cognitive and behavioral learning, leading to a 40% increase in knowledge retention compared to conventional training methods. By offering a hands-on, risk-free learning environment, VR improves workers' ability to respond effectively to hazardous situations, ultimately contributing to safer construction sites[25].

One of the key advantages of VR in safety training is its ability to simulate high-risk scenarios without putting workers in actual danger. For example, VR-based modules can recreate hazardous events such as scaffolding collapses, electrocution risks, fire outbreaks, and heavy equipment accidents, allowing workers to practice emergency responses in a virtual environment[26,27]. These simulations provide real-time feedback and adaptive learning, helping workers develop critical thinking and decision-making skills under pressure[13]. VR technology can also be customized for specific construction projects, enabling site-specific safety training tailored to the unique risks present in each work environment. Previous studies have shown that VR training improves workers' hazard perception by 35% compared to traditional training methods, demonstrating its effectiveness in reducing workplace injuries[14,15]. Additionally, VR safety programs can be integrated with BIM to enhance risk assessment and mitigation strategies by visualizing potential hazard during project planning and execution[16]. By leveraging real-time data and predictive analytics, VR facilitates proactive decision-making, reducing the likelihood of costly accidents and project delays[26,27]. This is particularly beneficial for large-scale projects where monitoring multiple sites poses a significant challenging. Research by Han *et al.*[28] found that incorporating VR into safety audits led to a 28% reduction in onsite incidents and improved regulatory compliance. As construction firms increasingly recognize the value of VR for safety and risk management, its adoption is expected to expand, ultimately contributing to a safer and more efficient industry.

2.3 Benefits of VR adoption in construction

VR has emerged as a transformative tool for training across various industries, offering an improved task-technology fit and enhancing knowledge performance[6,28]. Its ability to provide informative feedback and support troubleshooting through remote instructions makes VR an effective management tool for skill development[13]. Additionally, VR foster motivational changes in performance by creating immersive environments that enhance employee engagement and allow for repeated practice without resource constraints[29]. The flexibility of VR-based training enables professionals to learn at their own pace and convenience, leading to improved learning outcomes and greater task execution efficiency[28]. Studies have shown that organizations implementing VR in their training programs experience increased productivity, faster task completion, and enhanced overall performance[28,30]. These advantages position VR as a valuable asset for modern workforce management, enabling businesses to optimize employee learning experiences while ensuring skill retention and application.

From a financial perspective, VR significantly reduces lifecycle costs by minimizing the need for physical training materials and on-site instructors[20]. The technology shortens training duration while simultaneously improving design review processes, enabling more intuitive and effective decision-making[14]. VR's capacity to deliver high-fidelity simulations ensures efficient training implementation, lowering production costs and overall expenditures on skill development[31]. For example, in the construction industry, integrating VR with BIM enhance visualization and project planning, thereby reducing errors and cost overruns[25]. Furthermore, virtual simulations offer financial benefits by decreasing travel expenses and optimizing training schedules, ultimately resulting in a higher return on investment[32]. These financial benefits underscore the long-term viability of VR in corporate training and workforce development.

The environmental benefits of VR-based training are also noteworthy. VR facilitates safer training by eliminating risks associated with real-world hazards, making it particularly valuable for high-risk industries such as construction and healthcare[33]. Training in realistic virtual scenario enables workers to familiarize themselves with complex tasks in a controlled environment, thereby enhancing their ability to identify hazards and assess risks effectively [34]. Studies have shown that VR improves the effectiveness of safety training by making invisible hazards visible, equipping workers with critical situational awareness before they engage in real-world tasks[13]. Additionally, VR serves as an effective platform for maintenance training, allowing professionals to simulate and practice critical repairs without disrupting actual operations[28,31]. These advantages underscore VR's role in promoting sustainability and minimizing environmental impact by reducing material waste typically associated with traditional training methods.

From a human-centered perspective, VR significantly enhances the user experience by increasing engagement and reducing cognitive load during training activities[34]. It promotes skill development and stimulates learning interest through interactive and immersive scenarios that improve knowledge retention[46]. Importantly, VR-based training helps overcome language barriers by providing visual and interactive cues, making it accessible to a diverse workforce, including non-native speakers[34]. Additionally, studies have shown that VR training increase concentration levels, ensuring that trainees remain focused throughout the learning process[28]. By integrating VR into training programs, organizations can improve workforce development and foster a culture of continuous learning and adaptability. The adoption of VR in professional training demonstrates its potential to revolutionize skill acquisition, equipping employees to handle real-world challenges more effectively. Several researchers have identified a range of benefits associated with VR, as summarized in Table 1 and categorized under four general themes: management, finance, environment, and human factors.

Table 1. Benefit of VR adoption in construction.

Theme	Key Variables	Summary of Findings	Citations
Management	More task-technology fitInstructions can be given remotely and can be used for troubleshootingProvides informative feedbackProduces better outcomeEffectiveness in knowledge performanceFlexible training timingFosters motivational change in performancePossibility of repeating training over and over againBetter employee engagement	VR enhances management efficiency by improving task-technology fit, allowing remote troubleshooting, and providing informative feedback	[6,13,25,28,30]
Finance	Fast delivery of tasksReduces lifecycle costsReduces training and production costsShortened training timeBest in design review (simplifies intuition making decision)	VR minimizes life cycle costs and streamlines decision-making in design reviews. Its significantly reduces training duration and costs	[14,20,25,31,32]
Environment	Safer method of trainingTraining in real-life scenario (more realistic presentation)Best for carrying spot (maintenance) trainingMakes invisible hazards visible	VR enhances environmental safety by providing realistic training scenarios that improve hazard recognition and risk assessment	[13,28,31,33,34]
People	Improved user experienceImproves skills and learning interestOvercoming language barriersReduces cognitive burdenIncreases concentration and engagements	VR improves user experience by making learning more interactive, reducing cognitive strain and fostering engagement	[25,28,34,46]

VR: Virtual Reality.

2.4 Barriers to VR adoption in construction

Despite the numerous benefits of VR systems, several notable limitations remain, as shown in Table 2. For example, a trial conducted by Joshi *et al.*[35] to evaluate the implement of VR in construction worker training identified simulator sickness as a potential drawback. Although previous studies suggest that such symptoms are common yet typically mild during VR sessions[36], they can still compromise the effectiveness of training and warrant careful monitoring. In contrast, another study found the occurrence of simulator sickness to be negligible among users, suggesting variability in its impact depending on the VR system and user profile[32]. Joshi *et al.*[35] also conducted a follow-up assessment to further examine the issue in their experimental design. Furthermore, as highlighted by Adami *et al.*[15], although the use of VR in construction worker training is expanding, many programs are not designed in accordance with adult learning theories. They argue that the training environments and modules often lack sufficient contextual flexibility, limiting the transferability of acquired knowledge and skills, an essential component of effective construction training. This misalignment may hinder post-training performance and the practical application of learned competencies.

Table 2. Barriers to VR adoption in construction.

Theme	Key Variables	Summary of Findings	Citations
Management	Uncertainty in proper learning outcomesLack of interoperability among systemsMore prone to disruption from technical issuesDifficulties in converting cad models to a virtual environmentDifficult for complicated trainingInability to adapt knowledge and skills in different scenariosLow accuracy in tracking and mappingTime consuming	VR faces challenges in ensuring learning effectiveness due to interoperability issues, technological disruptions, and difficulties in adapting knowledge across different scenarios	[32,35,36]
Finance	Requires substantial computing powerHigh cost of VR hardwareRequires technically skilled competenceRequires much cost to create the virtual environment	High setup and operational costs, along with the need for skilled personnel	[32,15]
Environment	Unfriendly interaction experienceDifficulties to author content for a specific purposeUsers aren't situationally aware (haptic feedback)Poor usability	VR system sometimes fails to provide intuitive and realistic interactions	[32,35]
People	Lack of awareness & reluctance to accept new tech. With usersUnwillingness to accept a virtual substituteMost consumers consider it as entertainment insteadSimulator sicknessUncomfortable hardware	User resistance, discomfort, and a perception of VR as merely an entertainment tool hinders its adoption	[23,35]

VR: Virtual Reality.

Another challenge is the development of a VR system that can effectively address maintenance difficulties in the industry. Guo *et al.*[5] argue that unfavourable climatic conditions stress the VR system's resilience, typically affecting the synchronicity and reliability of motion capture. They also emphasized that creating a VR maintenance application involves numerous preliminary tasks, and for developers to produce a high-quality system, they must master a wide range of multidisciplinary knowledge and skills, including kinematics simulation, digital modelling, process planning, and programming—challenges that can be particularly difficult for an underprepared team.

Gupta *et al.*[23] argued that creating and composing scenarios to simulate hazardous situations on active construction sites requires committed specialists who are familiar with real-world safety settings and possess the skills to translate this knowledge into the digital medium. According to their works, this introduces additional challenges, as the modeler's sense of reality is used to generate the environment, potentially resulting in a disorganized representation that may not be accurate.

3. Method

The study adopted a purposive sampling to select construction professionals in Benin, Edo State based on their expertise and direct involvement in construction activities. Benin, Edo State was chosen as the study area due to its importance as a major urban center with numerous ongoing projects, making it an ideal location for examining the role of VR in Nigeria's construction industry. The region's rapid development and the presence of a diverse range of construction professionals in southern Nigeria provided a rich context for examining the adoption of VR technology. In addition, key stakeholders such as the Edo SUBEB contributed to a well-rounded representation of perspectives from both the construction and educational sectors, offering valuable insights into how VR can influence training and professional development in the industry. To further enhance the diversity of perspectives, snowball sampling was also used, whereby initial respondents referred the questionnaire to other qualified professionals within their networks. To minimize potential sampling bias, referrals were carefully monitored to avoid clustering within homogenous groups. This combined sampling strategy addressed the challenge of an undefined sampling frame and ensured a broader representation of viewpoints[40]. As a result, the study was able to engage a more diverse group of professionals with relevant knowledge of VR in the Nigeria's construction industry, thereby increasing the reliability and depth of the findings.

A total of 82 questionnaires were distributed, of which 52 were deemed suitable for analysis, resulting in a response rate of 63.42%. This rate provides adequate representation of the target population and ensures that the findings reflect the expert insights of professionals directly involved in the construction industry. Moreover, the response rate aligns with standards observed in similar construction-related studies, indicating a reliable level of participant engagement and offering a solid foundation for the research conclusions. The study was guided by a positivist philosophical stance and employed a hypothetical-deductive methodology to establish casual and explanatory relationship between dependent and independent variables[38]. Comparable studies, such as Adami *et al.*[37], have also adopted quantitative approaches to examine emerging technologies in the construction sector. To systemically capture relevant data, the questionnaire was divided into three sections: (1) background information of respondents, (2) perceived benefits of VR implementation, and (3) challenges hindering VR adoption. A five-point Likert scale was used to allow respondents to express their level of agreement with the identified benefits and challenges, in line with the approach adopted by Owolana and Booth[39].

To ensure validity and reliability, the questionnaire was pretested with five industry experts, who provided feedback on its clarity, comprehensiveness, and relevance. Necessary adjustments were made based on their recommendation prior to the final distribution of the survey. Data collection was conducted using Qualtrics, a digital survey platform that automatically generated descriptive statistics such as mean weighted average score (WAS), response frequency, and standard deviation. The weighted average score, based on the Likert scale ranking (1 = lowest, 5 = highest), served as a key metric in analyzing the significance of the identified benefits and challenges. In addition, the study employed a further analytical method using the coefficient of variation, calculated by dividing the WAS by the standard deviation. This value was then added to the WAS to obtain an adjusted average score. According to Owolana and Booth[39], this method is sufficient for ranking the calculated factors. The adjusted average score for benefits is termed the Benefit Index Value (BIV). The formula used to calculate these index values is presented in Equation 1.

$$BIV_i = WAS_i + \frac{WAS_i}{\delta_i} \tag{1}$$

4. Result

4.1 Background information of respondents

The study sample, as presented in Table 3, comprised 52 respondents with diverse academic qualifications, including bachelor's degrees (50.00%), master's degrees (44.23%), and PhDs (3.85%). Professional affiliations varied, with the Nigeria Institute of Quantity Surveyors (NIQS) accounting for 38.46%, and others associations comprising 15.39%. Quantity surveyors constituted the largest professional group (32.69%), followed by engineers (25.00%). In terms of work experience, the majority of participants (51.92%) had between 1 and 5 years of industry experience. Regarding knowledge of VR, 46.15% reported having basic knowledge, 48.08% had moderate knowledge, and only 5.77% were experts in the field. These findings suggest that the sample represents a well-educated workforce with a range of professional experiences, although expertise in VR applications remains limited.

Table 3. Background information of respondents.

Variables	Classification	Frequency	Percentage (%)
Academic Qualification	Diploma Degree	0	0.00
	Bachelor's Degree	26	50.00
	Master's Degree	23	44.23
	PhD	2	3.85
	Others	1	1.92
Professional Bodies	NIQS	20	38.46
	NIOB	8	15.39
	NIA	4	7.69
	NSE	8	15.39
	RICS	2	3.85
	CIOB	2	3.85

	Others	8	15.39
Profession	Architect	6	11.54
	Builder	4	7.69
	Engineer	13	25.00
	Quantity Surveyor	17	32.69
	Project Monitoring Officer	2	3.85
	Others	10	19.23
Years of Experience	1-5years	27	51.92
	6-10years	15	28.85
	11-15years	6	11.54
	16-20years	2	3.85
	Over 20years	2	3.85
Knowledge of Virtual Reality	No Knowledge	3	5.77
	Basic Knowledge	24	46.15
	Moderate Knowledge	25	48.08
	Expert Knowledge	3	4.62

NIQS: Nigeria Institute of Quantity Surveyors; NIOB: Nigeria Institute of Builders; NIA: Nigeria Institute of Architects, NSE: Nigeria Society of Engineers, RICS: Royal Institute of Chartered Surveyors; CIOB: Chartered Institute of Building.

4.2 Benefits of adopting VR in Nigeria construction industry

Table 4 presents the G-factor, WAS, and the ranked BIV associated with the adopting of VR in the Nigeria construction industry. The G-factor reflects the level of agreement among respondents, categorized as follows: G-I: Strongly disagree; G-II: Disagree; G-III: Neither disagree not agree; G-IV: Agree; and G-V: Strongly agree. The table identifies fast delivery of tasks (BIV = 8.30) as the most influential benefit under the finance theme, followed by informative feedback (BIV = 7.90) and overcoming language barriers (BIV =7.92). Management-related benefits dominate the top rankings, highlighting VR's positive influence on process efficiency, training effectiveness, and the integration of new technologies. Conversely, better employee engagement (BIV = 6.52) and training repetition (BIV = 6.56) received the lowest scores. While VR demonstrates significant potential to enhance knowledge performance, decision-making, and safety, further emphasis should be placed on improving engagement and the long-term impact of training to fully realize its benefits within the industry.

Table 4. Benefit of adoption VR in the Nigerian construction industry.

Theme	Benefits	G-I	G-II	G-III	G-IV	G-V	WAS	SD	BIV	Group Rank	Rank
Management	Better employee engagement	6	3	9	19	15	3.65	1.27	6.52	9	21
	Flexible training timing	5	0	7	24	16	3.88	1.14	7.28	5	13
	Possibility of repeating training over and over again	5	6	7	12	22	3.77	1.35	6.56	8	20
	Effectiveness in knowledge performance	4	2	9	17	20	3.90	1.18	7.21	6	14
	Fosters motivational change in performance	5	2	8	18	19	3.85	1.23	6.98	7	16
	Produces better outcome	3	2	10	17	20	3.94	1.12	7.46	4	11
	Provides informative feedback	3	1	7	17	24	4.12	1.09	7.90	1	4
	Instructions can be given remotely	4	0	5	19	24	4.13	1.11	7.85	2	5

	can be used for troubleshooting										
	More task-technology fit	3	3	3	17	26	4.15	1.13	7.82	3	7
Finance	Shortened training time	4	5	9	21	13	3.65	1.17	6.77	4	18
	Best in design review (simplifies intuition making decision)	3	1	6	27	15	3.96	1.00	7.92	2	2
	Reduces training and production costs	4	7	10	16	15	3.60	1.24	6.50	5	22
	Fast delivery of tasks	2	1	8	15	26	4.19	1.02	8.30	1	1
	Reduces lifecycle costs	4	0	6	25	17	3.98	1.07	7.70	3	9
Environment	Training in real-life scenario (more realistic presentation)	4	4	5	16	23	3.96	1.24	7.15	2	15
	Makes invisible hazards visible	3	6	9	17	17	3.75	1.19	6.90	4	18
	Safer method of training	2	4	4	20	22	4.08	1.07	7.89	1	6
	Best for carrying spot (maintenance) training	4	4	8	18	18	3.81	1.21	6.96	3	17
People	Increases concentration and engagements	5	7	5	17	18	3.69	1.32	6.49	5	23
	Improved user experience	3	4	2	20	23	4.08	1.14	7.66	3	10
	Overcoming language barriers	3	1	6	23	19	4.04	1.04	7.92	1	2
	Reduces cognitive burden	3	2	11	20	16	3.85	1.08	7.41	4	12
	Improves skills and learning interest	2	4	5	18	23	4.08	1.09	7.82	2	7

VR: Virtual Reality; G-I: strongly disagree; G-II: disagree; G-III: neither disagree not agree; G-IV: agree; G-V: strongly agree; WAS: weighted average score; BIV: Benefit Index Value; SD: Standard Deviation.

4.3 Barriers of VR's adoption in Nigerian construction industry

Table 5 presents the analysis of barriers to VR adoption in the Nigerian construction industry. The most significant barrier identified is the difficulty in converting CAD models into virtual environments (BIV = 10.85), followed by the substantial computing power required (BIV = 10.69) and the uncertainty regarding proper learning outcomes (BIV = 10.56). These barriers underscore the technical challenges associated with adopting VR, particularly in adapting existing construction design models to immersive virtual environments and ensuring effective learning outcomes. In contrast, the least significant barrier identified is training in real-life scenarios (BIV = 5.49). This suggests that, although VR enhances the realism of training, it does not present a major challenge to its adoption.

Table 5. Barriers to VR's adoption in Nigerian construction industry.

Theme	Barrier	G-I	G-II	G-III	G-IV	G-V	WAS	SD	BIV	Group Rank	Rank
Management	Low accuracy in tracking and mapping	5	12	11	16	3	6.48	2.2	9.43	7	8
	More prone to disruption from technical issues	4	6	9	20	8	7.04	2.13	10.35	3	3
	Time consuming	7	14	13	7	6	6.15	2.41	8.70	8	9
	Difficulties in converting cad models to virtual environment	3	9	14	15	6	7	1.82	10.85	1	1

	Inability to adapt knowledge and skills in different scenarios	4	11	11	16	5	6.81	2.01	10.20	5	5
	Difficult for complicated training	5	5	12	16	9	6.98	2.25	10.08	6	7
	Lack of interoperability among systems	5	4	9	21	8	7.06	2.24	10.21	4	4
	Uncertainty in proper learning outcomes	4	6	10	18	9	7.13	2.08	10.56	2	3
Finance	Requires technically skilled competence	2	4	3	17	21	4.09	1.11	7.77	4	11
	Requires much cost to create the virtual environment	1	2	7	20	17	4.06	0.93	8.43	3	10
	High cost of VR hardware	0	2	2	20	23	4.36	0.76	10.10	2	6
	Requires substantial computing power	0	1	3	19	24	4.4	0.7	10.69	1	2
	Requires technically skilled competence	2	4	3	17	21	4.09	1.11	7.77	4	11
Environment	Training in real-life scenario (more realistic presentation)	7	8	14	12	6	3.04	1.24	5.49	4	21
	Makes invisible hazards visible	4	9	12	13	9	3.3	1.22	6.00	2	19
	Safer method of training	4	5	11	16	11	3.53	1.2	6.47	1	16
	Best for carrying spot (maintenance) training	5	8	11	15	8	3.28	1.23	5.95	3	20
People	Increases concentration and engagements	6	5	5	19	12	3.55	1.32	6.24	4	17
	Improved user experience	4	9	12	15	7	3.26	1.18	6.02	5	18
	Overcoming language barriers	2	6	16	16	7	3.43	1.03	6.76	3	15
	Reduces cognitive burden	3	3	5	26	10	3.79	1.05	7.40	1	13
	Improves skills and learning interest	2	6	4	21	14	3.83	1.12	7.25	2	14

VR: Virtual Reality; G-I: strongly disagree; G-II: disagree; G-III: neither disagree not agree; G-IV: agree; G-V: strongly agree; WAS: weighted average score; BIV: Benefit Index Value; SD: Standard Deviation.

Across different themes, notable barriers vary. In the management category, difficulties in converting CAD models into VR environments rank the highest, highlighting challenges in transitioning from conventional digital designs to interactive VR systems. In the finance category, the substantial computing power required emerges as the primary concern, reflecting the high technical and infrastructural demands of VR adoption. Within the environmental theme, ensuring safer training methods is identified as the most pressing issue, indicating that safety considerations in VR training simulations are of paramount importance. Among people-related factors, reducing cognitive burden ranks highest, emphasizing concerns about information overload when using VR for training and learning purposes.

5. Discussion

The study highlights "More technology task fit" as a major benefit of adopting VR in Nigerian construction industry. This aligns with the work of Guo *et al.*[5], who argue that VR offers a superior task-technology fit compared to traditional training methods, enabling workers to perform their tasks more effectively. Similarly, Adami *et al.*[37] support this view, starting that VR-based training enhances skill acquisition and safety behavior among construction workers. Moreover, the ability to provide remote instructions and facilitate troubleshooting ranked highly in this study, reinforcing the assertion by Sacks *et al.*[43] that VR improves individual training performance by offering real-time guidance. Additionally, Delgado *et al.*[41] found that multi-user VR applications in facility management enable experts in different locations to provide virtual instructions, thereby enhancing collaboration and operational efficiency.

Another significant benefit identified in this study is VR's ability to enhance workplace safety, with "safety training methods" ranking among the most notable benefits. According to Li *et al.*[11], VR provides an immersive learning environment that reduces training risks and improves cognition. Santamaría-Bonfil *et al.*[42] further emphasizes that VR is widely used for training in high-risk industries, such as maintenance and construction, where real-life scenarios can be simulated to improve hazard awareness and prevention. Additionally, VR enhances user experience, learning interest, and skill acquisition. Dhalmahapatra *et al.*[44] critique traditional training methods for their inability to promote long-term knowledge retention and engagement, advocating VR-based training as a more effective alternative for skill development and workplace safety. The adoption of VR training has implications beyond Nigeria, particularly in high-risk industries such as healthcare and manufacturing, where it can similarly enhance skill acquisition and safety behavior. Furthermore, as VR technology becomes more accessible, its cost-effectiveness and ability to provide remote training could offer significant advantages in regions with limited access to traditional training resources, potentially transforming global workforce development.

However, the study also identifies key barriers in VR adoption, particularly uncertainty regarding learning outcomes and technical limitations. Many respondents ranked "uncertainty improper learning outcomes" as a major concern, which aligns with the findings of Eiris, Gheisari, and Esmaeili[29], who argue that skills learned in a virtual environment may not always transfer effectively to real-world scenarios. In contrast, Rey-Becerra *et al.*[33] found that VR-based training improved hazard identification, emphasizing the importance of well-designed training modules. Another significant challenge is VR's susceptibility to technical disruptions, as complex rendering processes can degrade system resolution over time[45]. Additionally, the high cost of VR implementation remains a notable barrier. As highlighted in previous studies[5,37], the development of VR-based training materials and virtual construction environments requires significant financial investment. These challenges underscore the need for further technological advancements and cost-effective solutions to maximize the potential of VR in the construction industry.

6. Conclusion

VR presents a transformative opportunity for the Nigerian construction industry, offering notable benefits such as improved task-technology fit, remote collaboration, and safer training methods. It enhances instruction delivery, troubleshooting, and operational efficiency, while also improving user experience and learning engagement. However, challenges such as uncertainty in learning outcomes, technical disruptions, and high implementation costs continue to hinder wider spread adoption. Although VR is effective in simulating high-risk scenarios, concerns remain regarding the transferring of virtual skills to real-world applications.

To maximize the impact of VR, stakeholder should invest in customized training modules that reflect real-world scenarios to enhance skill transfer. Technical improvements should focus on optimizing rendering processes and ensuring system stability to reduce potential disruptions. Furthermore, government support, cross-sector collaboration, and cost-reduction strategies, such subsidies and grant programs, are essential to facilitating broader adoption.

Declarations

Authors contribution

Ada-okungbowa O: Conceptualization and methodology.
Akindeinde A: Writing-original draft and writing-review.
Adedeji O: Formal analysis.
Booth CA: Supervision.
All authors approved the final version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical approval

This research complies with ethical standards, ensuring voluntary participation, informed consent, confidentiality, and data protection. Ethical approval was obtained from the University of the West of England, Bristol, Faculty of Environment and Technology (No. 21025582), and participants were informed of their rights. The study adheres to relevant guidelines for responsible research conduct and data integrity.

Consent to participate

Informed consent statement was provided at the beginning of the questionnaire.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Funding

None.

Copyright

References

1. Oladinrin TO, Ogunsemi DR, Aje IO. Role of construction sector in economic growth: empirical evidence from Nigeria. FUTY J Environ. 2012;7(1):50-60. [DOI]
2. Oyewobi LO, Oke AA, Ganiyu BO, Shittu AA, Isa RB, Nwokobia L. The effect of project types on the occurrence of rework an expanding economy. J Civ Eng Constr Technol. 2011;2(6):119-124. Available from: https://academicjournals.org/journal/JCECT/article-full-text-pdf/3DF9DBB2948
3. Unegbu HCO, Yawas , D , Dan-asabe B. An assessment of the literature on the performance of construction projects in Nigeria. J Mek. 2023;46:27-38. [DOI]
4. Dalibi SG. Resultant effects of poor supervision in construction projects in Nigeria. In: 6th Building Construction Economics Round Table; 2016 Jul 14-15; Abuja, Nigeria. 2015. p. 1-22.
5. Guo Z, Zhou D, Zhou Q, Zhang X, Geng J, Zeng S, et al. Applications of virtual reality in maintenance during the industrial product lifecycle: A systematic review. J Manuf Syst. 2020;56:525-538. [DOI]
6. Howard MC, Rose JC. Refining and extending task-technology fit theory: Creation of two task-technology fit scales and empirical clarification of the construct. Inf Manag. 2019;56(6):103134. [DOI]
7. Zhang M, Shu L, Luo X, Yuan M, Zheng X. Virtual reality technology in construction safety training: Extended technology acceptance model. Autom Constr. 2022;135:104113. [DOI]
8. Azelama JU, Oviauyi PO, Alimi MK. Challenges of local governement administration in Edo State of Nigeria. Lwati J Contemp Res. 2008;5:215-226. [DOI]
9. Wang P, Wu P, Chi HL, Li X. Adopting lean thinking in virtual reality-based personalized operation training using value stream mapping. Autom Constr. 2020;119:103355. [DOI]
10. Paszkiewicz A, Salach M, Strzałka D, Budzik G, Nikodem A, Wójcik H, et al. VR education support systemA case study of digital circuits design. Energies. 2022;15(1):277. [DOI]
11. Li X, Wen Y, Chi HL, Wang X, Chan APC. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. Autom Constr. 2018;86:150-162. [DOI]
12. Hamma-Adama M, Kouider T. Causes of building failure and collapse in Nigeria: professionals' view. Am J Eng Res. 2023;6(12):289-300. Available from: https://rgu-repository.worktribe.com/output/247029
13. Zhou J. Virtual reality sports auxiliary training system based on embedded system and computer technology. Microprocess Microsyst. 2021;82:103944. [DOI]
14. Howard MC, Gutworth MB. A meta-analysis of virtual reality training programs for social skill development. Comput Educ. 2020;144:103707. [DOI]
15. Adami P, Rodrigues PB, Woods PJ, Becerik-Gerber B, Soibelman L, Copur-Gencturk Y, et al. Effectiveness of VR-based training on improving construction workers' knowledge, skills, and safety behavior in robotic teleoperation. Adv Eng Inform. 2021;50:101431. [DOI]
16. Zhang M, Shu L, Luo X, Yuan M, Zheng X. Virtual reality technology in construction safety training: Extended technology acceptance mode. Autom Constr. 2022;135:104113. [DOI]
17. Zhang Z, Pan W. Virtual reality supported interactive tower crane layout planning for high-rise modular integrated construction. Autom Constr. 2021;130:103854. [DOI]
18. Fernández A, Muñoz-la Rivera F, Mora-serrano J. Virtual reality training for occupational risk prevention: Application case in geotechnical drilling works. Int J Comput Methods Exp Meas. 2023;11(1):55-63. [DOI]
19. Musa A, Kibiya YM. Basic education in Nigeria: An appraisal of Kano State Universal basic education board, Nigeria. 2021. Available from: https://www.researchgate.net/publication/354863272_BASIC_EDUCATION_IN_NIGERIA_AN_APPRAISAL_OF_KANO_STATE_UNIVERSAL_BASIC_EDUCATION_BOARD_NIGERIA
20. Zhang J, Jiang S. VR for construction engineering and management: Review of user experience perspective. Internet Things.

2024;27:101275. [DOI]
21. Zhang Y, Liu H, Kang SC, Al-Hussein M. Virtual reality applications for the built environment: Research trends and opportunities. Autom Constr. 2020;118:103311. [DOI]
22. Li RYM. Virtual reality and construction safety. In: Li RYM, editor. An Economic Analysis on Automated Construction Safety. Singapore: Springer; 2017. p. 117-136. [DOI]
23. Gupta A, Varghese K. Scenario-based construction safety training platform using virtual reality. In: 2020 Proceedings of the 37th ISARC; 2020 Oct 27-28; Kitakyushu, Japan. IAARC; 2020. p. 27-28. [DOI]
24. Yu WD, Wang KC, Wu HT. Empirical comparison of learning effectiveness of immersive virtual reality-based safety training for novice and experienced construction workers. J Constr Eng. 2022;148(9):04022078. [DOI]
25. Scorgie D, Feng Z, Paes D, Parisi F, Yiu TW, Lovreglio R. Virtual reality for safety training: A systematic literature review and meta-analysis. Saf Sci. 2024;171:106372. [DOI]
26. Wolf M, Teizer J, Wolf B, Bükrü S, Solberg A. Investigating hazard recognition in augmented virtuality for personalized feedback in construction safety education and training. Adv Eng Inform. 2022;51:101469. [DOI]
27. Luo T, Feng Y, Wang X. Advancements in virtual reality-based emergency response training for construction workers. Autom Constr. 2024;146:104567.
28. Han Y, Yang J, Diao Y, Jin R, Guo B, Adamu Z. Process and outcome-based evaluation between virtual reality-driven and traditional construction safety training. Adv Eng Inform. 2022;52:101634. [DOI]
29. Eiris R, Gheisari M, Esmaeli B. Desktop-based safety training using 360-degree panorama and static virtual reality techniques: A comparative experimental study. Autom Constr. 2020;109:102969.
30. Ajah BO, Ajah IA, Obasi CO. Application of virtual reality (VR) and augmented reality (AR) in the investigation and trial of Herdsmen terrorism in Nigeria. Int J Crim Just Sci. 2020;15(1):1-20. [DOI]
31. Mechlih H. New employee education using 3D virtual manufacturing. In: 2016 13th Learning and Technology Conference; 2016 Apr 10-11; Jeddah, Saudi Arabia. Piscataway: IEEE; 2016. p. 1-3. [DOI]
32. Tseng KC, Giau DTN. A feasibility study of using virtual reality as a pre-occupancy evaluation tool for the elderly. Autom Constr. 2022;134:104037. [DOI]
33. Rey-Becerra E, Barrero LH, Ellegast R, Kluge A. The effectiveness of virtual safety training in work at heights: A literature review. Appl Ergon. 2021;94:103419. [DOI]
34. Vignoli M, Nielsen K, Guglielmi D, Mariani MG, Patras L, Peiro JM. Design of a safety training package for migrant workers in the construction industry. Saf Sci. 2021;136:105124. [DOI]
35. Joshi S, Hamilton M, Warren R, Faucett D, Tian W, Wang Y, Ma J. Implementing Virtual Reality technology for safety training in the precast/ prestressed concrete industry. Appl Ergon. 2021;90:103286. [DOI]
36. Jimoh R, Oyewobi L, Suleiman S, Isa R. Influence of supervision on labour productivity on construction sites in Abuja-Nigeria. Ind J Manag Prod. 2017;8(1):64-81. [DOI]
37. Odame-Amoabeng S, Akalin A, D'haenens F, Tricas-Sauras S, Chang YS. Immersive insights: A qualitative systematic review and thematic synthesis of views, experiences, health and wellbeing of students and educators using virutal reality in nursing and midwifrey education. Nurse Educ Today. 2025;150:106679. [DOI]
38. Park YS, Konge L, Artino AR. The positivism paradigm of research. Acad Med. 2019;95(5):690-694.. [DOI]
39. Owolana VO, Booth CA. Stakeholder perceptions of the benefits and barriers of implementing environmental management systems in the Nigerian construction industry. J Environ Eng Landsc Manag. 2016;24(2):79-89. [DOI]
40. Kirchherr J, Charles K. Enhancing the diversity of snowball samples: recommendations from a research project on anti-dam movements in Southeast Asia. PLoS One. 2018;13(8):e0201710. [DOI]
41. Delgado JMD, Oyedele L, Demian P, Beach T. A research agenda for augmented and virtual reality in architecture, engineering and construction. Adv Eng Inform. 2020;45:101122. [DOI]
42. Santamaría-Bonfil G, Ibáñez MB, Pérez-Ramírez M, Arroyo-Figueroa G, Martínez-Álvarez F. Learning analytics for student modeling in virtual reality training systems: Lineworkers case. Comput Educ. 2020;151:103871. [DOI]
43. Sacks R, Perlman A, Barak R. Construction safety training using immersive virtual reality. Constr Manag Econ. 2013;31(9):1005-1017. [DOI]
44. Dhalmahapatra K, Maiti J, Krishna OB. Assessment of virtual reality based safety training simulator for electric overhead crane operations. Saf Sci. 2021;139:105241. [DOI]
45. Xu Z, Zheng N. Incorporating virtual reality technology in safety training solution for construction site of urban cities. Sustainability. 2021;13(1):243. [DOI]
46. Chiang FK, Shang X, Qiao L. Augmented reality in vocational training: A systematic review of research and applications. Comput Hum Behav. 2022;129:107125. [DOI]

Publisher's Note