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Exploring the Benefits of Virtual Reality Adoption for Successful Construction in a Developing Economy

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Abstract: Existing literature has shown that Virtual Reality (VR) is widely utilized in advanced economies to enhance sustainable construction practices. However, its adoption in developing economies remains limited. To this end, this study aims at exploring the potential benefits of implementing VR technology in a developing country. The study collected information on the beneficial aspects of VR from previous research and conducted questionnaire surveys to gather relevant insights from construction project experts in Nigeria. The collected data were analyzed using the Measurement of Alternatives and Ranking According to the Compromise Solution (MARCOS) method and Exploratory Factor Analysis (EFA). The MARCOS method revealed that the key potential benefits of VR include improved communication and collaboration, enhanced project performance, risk identification, digitalization, and safety planning. Furthermore, the study conducted an in-depth investigation of the beneficial areas of VR using EFA, which identified six component groups: pre-contract stage planning, post-contract stage planning, quality control and sustainability, design flexibility and reputation, resource management, and risk management and digitalization. The study provides a comprehensive discussion of the advantages of implementing virtual building methods in developing countries.

Keywords: construction innovation; construction revolution; digital construction; project performance; sustainable development; virtual reality

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1. Introduction

The construction industry is characterized by its diversity and competitiveness, encompassing a wide range of numerous and interconnected operations and materials. These factors have a significant impact on various aspects of society, such as culture, economy, and environment, throughout the entire lifespan of construction projects. It is worth noting that construction activities contribute to over 40% of global power consumption and approximately 30% of the total greenhouse gas emissions worldwide [1]. Furthermore, construction activities in Europe and USA consume approximately 40% of their total power supply [2,3]. Despite the vital role played by the construction industry in enhancing the quality of life in developing countries, there is a scarcity of research studies focusing on the sustainability performance of this sector in such countries [4]. Beach et al. [5] reported that the construction industry operates within a highly competitive market that relies heavily on data and is project-based. Throughout the life cycle of its primary products (i.e., buildings), there are stringent criteria for data sharing and processing. The industry encompasses various traditional disciplines, such as architecture, quantity surveying, structural engineering, mechanical engineering, and electrical engineering, necessitating efficient knowledge exchange and coordination among individuals. The introduction of technologies (e.g., cloud computing) has enabled construction stakeholders to enhance their productivity and achieve improved connectivity and coordination. Ahuja et al. [6] concluded that organized communication and knowledge exchange facilitates the seamless integration of different project phases. Utilizing widely accessible internet platforms and shared databases can promote the gathering and sharing of information among project stakeholders. The continuous technological development has made products, services, and electronic knowledge readily available on a global scale. In times of crisis, construction management faces significant responsibility in planning, implementing, and integrating technical solutions. Virtual Reality (VR) devices capture real-time data, which are then processed by cloud-based data centers to provide valuable customer insights and actionable recommendations [7]. Hence, it is essential to give due consideration to the techniques and impacts of VR advancements in the construction industry. As a result, it is necessary to develop plans that embrace the concept of sustainable development [8].

It is crucial to implement the concept of "sustainable construction" by enhancing the integration of fragmented data from all construction projects. This approach ensures that sustainability is prioritized, meeting present concerns while safeguarding the ability of future generations to meet their needs [9]. Kibert [10] postulated that the achievement of sustainable construction necessitates the establishment of an ecological ecosystem guided by principles of sustainability and the efficient utilization of energy. The concept of sustainable implementation often involves initiating practices before and after the involvement of construction firms in the project [11]. Wolstenholme et al. [12] recommended that the transformation of the building industry can be achieved through the adoption of efficient digital, innovative, and sustainable construction practices. Emphasizing environmental measures at the outset of the building process is actively promoted to ensure its advancement. The incorporation of VR technology contributes to this vision by providing remote access to computing resources via global Information and Communication Technology (ICT), thereby facilitating the pursuit of durable and environmentally conscious construction. Zhang et al. [13] highlighted areas in which VR could be applied as follows: construction project management, architectural and technical design, human perception, construction safety, engineering education, and construction equipment. All stakeholders involved in an enterprise must work together to implement VR technology in the building sector to opt-in and focus on managing time, cost, and quality through this mechanism, which are the key performance indicators for delivering any construction project [14]. Shi et al. [15] noted that VR head-mounted display technologies look promising and will significantly transform the interaction, communication, collaboration, and safety mechanism in the construction industry. This can be attributed to the VR ability to enable construction professionals interact, communicate, collaborate, and practice in an immersive virtual environment.

According to a research paper by Jingmond and Ågren [16], it was identified that organizational problems and inefficient knowledge transfer are the causes of defects in buildings during the construction stage. In addition, Aljassmi et al. [17] corroborated that any building project's performance can be greatly impacted by defects. Furthermore, a lack of necessary skills and inadequate supervision adds to the defects found in construction projects. Behzadi [18] researched the "use of augmented reality and VR technology in the construction industry". The study found that both technologies are beneficial for project scheduling, communication/information retrieval, safety management practices, and man-labor hours. Even though this research supports the use of VR in the construction sector, it is still crucial to evaluate the current state of VR applications in the Nigerian construction sector. While previous studies have examined the use of VR in various countries, there is a lack of research on its application in the construction sector of developing countries. Academic literature on VR in construction is limited, with only a few studies focusing on implementation strategies. This research aims to fill these gaps by exploring the benefits of VR technology in the Nigerian construction industry, thereby shedding light on its potential advantages. The findings will be valuable for stakeholders involved in sustainable construction projects as they strive to incorporate VR into their practices. The results may also influence the execution of building projects not only in Nigeria but also in developed countries that follow similar construction methods. The remainder of the paper comprises an extensive review of existing literature, followed by a description of the methodology and data analysis procedures employed in this study. The analyzed data are presented and discussed, and potential recommendations are proposed in the conclusion section.

2. Research Background

2.1. Application of Virtual Reality Practices

The integration of VR systems into the construction industry could be applicable in the whole life cycle of a construction project, which includes the design, construction, and post-construction phases. Behzadi [18] and Ahmed [19] asserted that VR is effectively utilized as a visualization tool, worker training technology, safety management, time management, cost management, design development and quality, and defects management tool. They also added that it could be used to recruit and preserve new workers and methods in cases of shortage of fit workforce.

2.1.1. Pre-Construction/Design Phase

VR has earned its relevance in the construction industry as a result of its numerous application areas in the whole life cycle of a construction project [20,21]. According to Ahmed [19], VR could be used for design development and clash detection, as it helps designers interact with real-world project and deal with any shortcoming of the design before it occurs. Bashabsheh et al. [22] asserted that the use of VR is worthwhile in the design phase of construction, as it increases the designer's realization of the building component assembly and correlates the relationship between the structural system and the architectural design. Wang et al. [23] also corroborated that VR helps the design team have a firm idea of the client's perspective and ascertain their commitment to the project, thereby reducing the time spent on unnecessary variations in design to accommodate the client's preferences. VR in connection with BIM could also help quantity surveyors to minimize the number of assumptions during taking off 2D drawings, as they could make automated measurements of work either from the immersive or the non-immersive systems.

2.1.2. Construction Phase

The construction phase of any project involves implementing the detailed design that was already planned during the pre-contract stage and proper performance monitoring [24]. The construction phase encompasses the diver's construction activities and process, which when put together under proper management and monitoring, helps achieve the sole aim of the construction [25]. This section will briefly review the important construction activities in which VR could be applied.

Sacks et al. [26] used 3D-immersive VR to train students on in situ concrete works. They found that using VR during training is more effective, as it helps to maintain the trainee's attention and concentration. They further encouraged the adoption of VR for safety training programs. Similarly, in a study conducted by Shi et al. [15], it was justified that VR is indeed effective in training students for cast-in-situ concrete works. Traditional masonry construction is characterized by its heavy reliance on labor and time, encountering challenges arising from the use of modern materials and construction methods [27]. In the past years, techniques were developed to meet these requirements and needs. Nevertheless, these techniques are still labor-intensive, which are scarce and expensive [28]. To this end, a mortarless masonry system has been introduced to improve the constructability and performance of masonry. Sampaio et al. [29] took advantage of the VR simulation capability to visualize the construction processes of a masonry cavity wall and a bridge in a learning environment. They further stated that VR is very effective in demonstrating the sequential construction processes of the cavity wall and bridge, thereby improving the learning of the students in the construction of cavity walls and bridges. According to Moynihan et al. [30], over one-quarter of steel produced annually is used in the construction of buildings, which climate change experts advise against. Yang and Chan (2018) also asserted that structural steel works for a building have grown worldwide, as the number of steel-framed buildings is less than 2% of all buildings. They further stated that cost has been the primary setback to the adoption of steel structures. Their research aimed at addressing the relevant cost issues concerning structural steel works. The researchers discovered that the expenses associated with constructing structural steel works are unavoidably expensive, and opting for steel-framed structures does not offer a notable advantage in terms of enhancing the construction timeline [31].

Interior finishing work often exhibits traits of uncertainty, instability, and inefficiency, with a tendency towards generating waste. It is not bound by technical limitations necessitating floor-by-floor execution, leading to multiple subcontractors being involved in its implementation [32]. Alrashed and Asif [33] revealed that there still exists a lack of awareness regarding glazing and thermal insulation, despite the improvement in the development of energy-efficient homes. To save energy in constructed or existing buildings, different measures could be taken into consideration, such as external insulation of the building. The utilization of glazed external walls can enhance the insulation of the building envelope by minimizing heat transmission losses through the outer walls [32]. Wall cladding in buildings is the application of insulation material over the building envelope. Cladding is employed in construction to offer thermal insulation and protection against weather conditions, as well as to enhance the aesthetic appeal of the buildings [34]. Their study focused on the environmental impact assessment of various chosen cladding materials and, importantly, the effect of the construction technique employed on the environment itself. Arif et al. [35] stated that cladding systems have the potential as substitutes for traditional systems, as they help reduce construction time and increase quality. Femi [36] emphasized the crucial significance of proper surface preparation and application techniques when it comes to paint, as inadequate preparation and technique are leading factors in paint failure. The study also highlighted that the primary objective of painting is to provide surface protection and decoration. However, this purpose can be undermined if the painting is executed improperly. Since the performance of a building project is evaluated based on maintenance costs, workmanship quality, and standards, it underscores the importance of ensuring these aspects are taken into account. Dadu et al. [37], in their research on "Quality Control in Abuja Mass Housing", revealed that an average of 98.5% of the buildings under Abuja mass housing had fading paints defect, followed by 82% of the mass housing buildings showed paint staining defects while 63% showed paint flaking defects.

In recent times, building with timber has become a huge trend in the construction sector around the world [38]. It is very evident now that the market is tilting to the use of wood as a structural material, as it is now understood that concrete and steel are energy-intensive and contribute significantly to the portion of global warming, and timber is becoming the obvious way to reduce it. Wiberg et al. [39] utilized VR to visualize the amount of timber used for building construction and also the number of virtual logs stacked. Khanzode et al. [40] opined that the use of virtual design and construction tools together with lean construction techniques can ease the complex process of Mechanical and Electrical (M&E) projects and other challenges, which include proper organization of the design team, technicality of logistics, and coordination of teams in a big room. M&E installations are essential components of construction projects, encompassing multiple trades involved in building services, including air-conditioning, fire services, plumbing, electrical wiring, and lift installations. However, the safety aspect of M&E works has not received the necessary attention it deserves. This is evident from the lack of easily accessible official accident statistics concerning M&E works in the public domain [41]. The authors further highlighted that the two primary types of fatal accidents in both new construction projects and repair, maintenance, alteration, and addition work fall from heights and electrocutions. These accidents can be attributed to inadequate safety management practices. Dadu et al. [37] revealed that low water supply, leakages in connections, and irregular pressure are the most frequent mechanical and water supply defects in Abuja mass housing.

Portman et al. [42] stated that the adoption of VR as 3D-immersive simulation software for landscape planning and architecture has increased over the years. They noted that the emergence of digital landscape visualizations occurred simultaneously with the initial phase of landscape planning and design. Since then, the application of VR has played a significant role in pushing the boundaries of the profession. Its impact extends to various aspects, such as site planning, landscape restoration, parks and recreation planning, green infrastructure planning, and residential landscape master planning, among others. Over the past few decades, digital landscape representations utilizing VR technology have evolved from basic, static depictions to highly realistic visualizations, enabling immersive exploration with real-time movement across multiple spatial and temporal scales. Berg and Vance [43] described VR as a technology that enables and enhances participants' complete immersive experience more like or beyond reality. They further stated that VR presents a peculiar way of interacting with the growing digital landscaping.

2.1.3. Post-Construction Phase

Shi et al. [15] argued that facility management is a critical component of building sustainability because a late response to the needs of facility management will lead to unnecessary waste of resources. They further stated that a lack of communication has been identified as an impediment to the mutual understanding of facility management requirements among the stakeholders. The recent development of VR in the design and construction of buildings has encouraged further research on the interpersonal relationship between VR and facility management through VR-immersive experience ability. Their research revealed that VR could help the stakeholders examine the requirement of facility management from their respective locations, thereby improving the efficiency of communication among the stakeholders. According to Carreira et al. [44], the objective of facility management is to establish and sustain an efficient built environment that facilitates the smooth operation of the industry. To navigate the complexities and professional demands of modern facilities management, practitioners have recognized the importance of employing specialized computerized tools. These tools serve to automate routine tasks, manage information, monitor the performance of buildings, and aid in decision-making processes. For the successful completion of any construction project, several back-office operations need to take place, such as project scheduling and planning as well as logistics planning. Alizadehsalehi et al. [45] highlighted that VR has been used effectively to tackle issues of project scheduling and planning over the years. Ahmed [19] also corroborated that VR is the future of construction as it is used in various important applications of the project, including project scheduling and logistics management.

Zhao et al. [46] asserted that safety management practices are critical for the construction industry. Additionally, they emphasized that effective training programs can have a direct influence on reducing human error, which accounts for over 50% of occupational incidents. Therefore, their research focused on the use of VR-based immersive simulations for safety training programs, where participants can easily practice their construction task in a hazard-free environment, thereby improving their consciousness when replicating such activities in the real-world environment. Getuli et al. [47] opined that VR technologies save cost during construction projects, as it enables workers to be trained and simulate real-world activity in a hazard-free environment, thereby saving the organization the cost of implementing the activity in the real-scale physical environment.

The fragmented nature of the construction industry resulted in the urgent need for a convenient communication mechanism to foster proper collaboration among the stakeholders throughout the life cycle of the construction project. VR-immersive features ensure proper dissemination of vital information about the construction project to the stakeholders, including the client in real-time, ensuring timely achievement of the shared objectives [18]. Getuli et al. [47] asserted that in practice, communication among professionals is often poor, and misunderstandings are common, resulting in inadequate support for workers. Due to the intricate nature of construction projects and the fragmented nature of their supply chains, it becomes extremely challenging for any individual stakeholder to possess all the required safety-related information and knowledge. Consequently, they argue that the implementation of VR technologies within the construction industry can enhance communication and collaboration throughout the project delivery process.

2.2. Benefits of Using Virtual Reality for Construction Projects

Given the enormous application areas of VR in the construction industry, this technology is beneficial to communication management, construction project delivery, design development, safety management, and risk management [19,22,48].

2.2.1. Pre-Contract Stage Planning

VR-immersive walkthrough experience allows the proper improvement in the efficiency of communication and collaboration among construction participants in an immersive virtual environment to achieve sustainable goals [15]. Similarly, Zhang et al. [13] asserted that inefficient communication between stakeholders has been the source of conflict in the construction industry. In this regard, VR has recently gained popularity for its capability to enhance proper communication and collaboration among stakeholders. According to Zhao et al. [46], the safety problem is becoming more urgent in the construction sector as a result of the anticipated risks and hazards. To this note, VR technologies have been adopted to ensure conducting of an adequate immersive safety training program in a hazard-free environment to enhance proper safety planning protocols within a construction site. Alizadehsalehi et al. [45] also stated that VR is effective for use in safety training and planning programs. Behzadi [18] claimed that the building industry has utilized VR technology to attract and retain new workers and approaches in the construction sector to address the scarcity of a fit workforce. VR technologies enhance and improve project performance, which improves organizational culture and overall productivity [49]. According to Wang et al. [23], VR increases the precision of the quantity take-off and reduces the number of assumptions made while taking off 2D drawings. Mutesi and Kyakula [50] and Vasista and Abone [51] revealed that the most beneficial aspect of VR is to help reduce mistakes in documentation.

2.2.2. Post-Contract Stage Planning

Getuli et al. [47] agreed that VR can be used to enhance construction scheduling, as it enables the participant to view the 3D model, thereby giving enough information on the requirements needed for the execution of the construction project. Similarly, Alizadehsalehi et al. [45] revealed that VR technologies are very effective in construction project scheduling. According to Zhang et al. [13], VR provides interactive data visualization of construction projects, which has a direct impact on how the projects are planned. Davila Delgado et al. [49] asserted that VR is utilized to enhance site planning. Vasista and Abone [51] emphasized that the adoption of VR practices brings about the advantage of reducing construction errors.

2.2.3. Quality Control and Sustainability

Vasista and Abone [51] asserted that the adoption of VR practices in the construction industry helps to ease complex tasks, improve productivity, and improve the quality of construction work. Moshood et al. [52] highlighted the benefits associated with the use of VR methods in the construction sector through the integration of workflow and the facilitation of sustainable building.

2.2.4. Design Flexibility and Reputation

Getuli et al. [47] and Alizadehsalehi et al. [45] identified that VR is very effective when utilized for design clash detections. This feature helps the design team to understand the relationship between the architectural components of the building in relation with the structural, electrical, and mechanical components of the building. Agrawal et al. [53] took advantage of the immersive capabilities of VR to conduct a hazard-free mitigation driving training program. Findings from their research identified that VR can help improve the driving skills of the participant and the capacity to deal with unanticipated hazards. Given the visualization capabilities of VR, Zhao et al. [46] and Alizadehsalehi et al. [45] stated that VR has been utilized to tackle design flaws before the construction phase. It is believed that every successful company must be a technology-developing company [49]. In this regard, strong motivators of VR technologies have begun to utilize VR to rebrand themselves as a smart engineering company, thereby improving their company's image.

2.2.5. Resource Management

Wang et al. [23], Ahmed [19], and Alizadehsalehi et al. [45] opined that when taking advantage of the immersive capabilities of VR for design review, design flaw detection, and clash detection, considerable cost and time could be saved, as poor design, errors, and resource wastage would be eradicated. Zhao et al. [46], Alizadehsalehi et al. [45], and Bashabsheh et al. [22] highlighted the enhancement of safety training as one of the areas, where VR is beneficial in the construction industry.

2.2.6. Risk Management and Digitalization

The immersive visualization capabilities of VR could help the participant identify potential risk zones since the construction site could be simulated in a virtual environment. In this regard, proper risk and safety protocols could be developed and adhered to by Getuli et al. [48]. Lew et al. [54] highlighted digitalization as one of the benefits of ICTs.

2.2.7. Summary of Literature on the Benefits of Virtual Reality

Table 1 gives a summary of the relevant works of literature review on the benefits associated with the adoption and practice of VR. A total number of 23 articles were reviewed in this section, as provided in Table 2.

Table 1. Variables and coded authors on the benefits of using VR practices.

S/N	Variables	[15]	[48]	[49]	[55]	[22]	[18]	[47,48]	[13]	[56]	[57]	[49]	[23]	[45]	[53]	[45]	[44]	[58]	[59]	[50]	[60]	[51]	[54]	[52]
1	Enhance communication and collaboration	*		*			*	*	*		*	*					*				*	*	*	
2	Reduce construction time	*		*			*	*			*		*			*		*		*	*	*		
3	Reduce construction cost	*					*	*			*		*			*		*			*	*		
4	Enhance workers' safety training		*	*		*			*		*	*	*		*		*	*						
5	Enhance construction scheduling		*				*									*								
6	Enhance design clash detection		*								*													
7	Safety planning		*	*			*	*			*			*		*			*					
8	Risk identification		*								*	*		*										
9	Enhance design efficiency		*		*	*		*																
10	Enhance construction planning		*						*		*	*			*									
11	Enable immersive visualization			*		*			*	*		*	*	*	*			*	*					
12	Overcome shortage of fit workforce			*			*																	
13	Avoid defects			*																				
14	Identify design flaws						*		*		*			*		*								
15	Improve project performance											*												
16	Improve company's image											*												
17	Enhance accurate quantity take-off												*									*	*	
18	Enhance maintenance			*			*		*		*													
19	Digitalization																						*	
20	Reduce mistakes in documentation																			*		*		
21	Enhance fast project delivery																							*
22	Reduce construction error																			*	*			
23	Ease complex task																			*	*			
24	Enhance sustainable construction																							*
25	Enable quality decision-making																					*		
26	Integrate workflow																				*	*		
27	Improve productivity																				*	*		
28	Improve quality																*			*		*		

Table 2. Summary of literature on benefits of virtual reality.

S/N	Topic	Year	Author	Methodology	Findings
A	BIM-based immersive virtual reality for construction workspace planning	2020	Getuli et al. [48]	Qualitative research design	The findings support that modern information technologies can be used to enhance both the safety protocols outlined in a project's health and safety plan and the configuration of workspaces in the project's site plan.

Table 2. *Cont.*

S/N	Topic	Year	Author	Methodology	Findings
B	Barriers and benefits of ICT adoption in the Nigerian construction industry. A comprehensive literature review	2020	Moshood et al. [52]	Review of literature	The ICT adoption process is viewed as an interaction between technology, a task, and an individual. Even though both practitioners and academics consider ICT as an opportunity, its sole application does not ensure success in the industry's approval. Companies can profit from ICT when users accept the technology and investigate its adoption difficulties.
C	Virtual reality applications for the built environment: Research trends and opportunities	2020	Zhang et al. [13]	Quantitative research design	Future study directions include user-centered adaptive design, VR information systems driven by human cognition, human factors-integrated construction training systems, occupant-centered facility management, and industry adoption.
D	Augmented and virtual reality in construction: Drivers and limitations for industry adoption	2020	Davila Delgado et al. [49]	Qualitative and quantitative research design	To effectively minimize the limiting factors and amplify the driving forces, the study categorized and grouped a wide range of limiting and driving factors. Additionally, it provided an approach with precise short- and long-term actions to boost adoption.
E	The application of virtual reality technology in architectural pedagogy for building constructions	2019	Bashabsheh et al. [22]	Quantitative research design	The three axes may be achieved more effectively using VR software than conventional teaching techniques. In conclusion, students benefit effectively from utilizing the VR program as a tool in building construction classes.
F	A study on the constraints of implementing Information and Communication Technology (ICT) in Malaysian construction industry	2019	Lew et al. [54]	Quantitative research design	The enhancement of measurement accuracy, the reduction in paper usage through digitization, and the facilitation of quick information exchange within the project team are the top three advantages of ICT adoption in the Malaysian construction sector.
G	Virtual reality for design and construction	2019	Alizadehsalehi et al. [45]	Review of literature	Students are better able to understand their learning plan following their virtual encounter. The three primary advantages of employing VR comprise visualizing complicated project designs, comprehending designs more quickly, and fostering innovation.

Table 2. *Cont.*

S/N	Topic	Year	Author	Methodology	Findings
H	A project framework to introduce virtual reality in construction health and safety	2018	Getuli et al. [48]	Review of literature	At the conclusion, review current suggestions in this area of construction health and safety as they relate to ICT technologies. A project structure will then be able to support future research and applications on the application of Building Information Modeling (BIM)-enabled VR.
I	A review on using opportunities of augmented reality and virtual reality in construction project management	2018	Ahmed [19]	Review of literature	Construction project scheduling, progress monitoring, employee training, safety management, time and cost management, and quality management all effectively use augmented reality.
J	Virtual reality headset training: Can it be used to improve young drivers' latent hazard anticipation and mitigation skills	2018	Agrawal et al. [53]	Experimental research design	The capacity of drivers to recognize and counteract latent 20 threats is improved by VR headset-based training programs.
K	Applications of virtual reality in construction	2018	Fernandes et al. [55]	Qualitative research design	The findings indicate a 50/50 split in favor of user-friendliness. While the office staff and senior levels urge technology to save time and, most crucially, money, seasoned field veterans had a difficult time adapting to the new software and altering their methods for accomplishing things.
L	Interactive virtual reality tool for BIM based on IFC	2018	Nandavar et al. [59]	Review of literature	This research offers original Open BIM-compliant solutions. It provides a wider variety of interactions and capabilities than the top-performing method for bringing IFC models into VR currently on the market. Nevertheless, it cannot handle extremely big BIM models, unlike the commercially available BIM-VR systems, and has not yet produced a high-quality representation of the model in VR.
M	Benefits, barriers and applications of information communication technology in construction industry: A contemporary study	2018	Vasista and Abone [51]	Qualitative research design	ICT may help construction projects succeed by satisfying the criteria related to time, cost, quality, scope, and customer satisfaction. It is therefore one of the major factors influencing a project's success.

Table 2. *Cont.*

S/N	Topic	Year	Author	Methodology	Findings
N	VR-embedded BIM immersive system for QS engineering education	2018	Wang et al. [23]	Qualitative research design	Utilizing VR walkthroughs to explore the virtual 3D building model might assist quantity surveying professionals and students in better comprehending architectural design, leading to more effective decision-making and accuracy in their job.
O	Towards interconnected virtual reality: Opportunities, challenges and enablers	2016	Bastug et al. [56]	Qualitative research design	This article emphasizes the significance of VR technology as a revolutionary use of 5G (and beyond), utilizing the most recent advancements in computer vision, artificial intelligence, storage/memory, fog/edge computing, and other fields.
P	Virtual reality as integration environments for facilities management	2017	Carreira et al. [44]	Qualitative research design	VR environments may boost efficiency in maintenance work. When compared to an old application interface, users without prior training show a high level of interest and performance. Eventually, reduced prices and higher quality will result from the possible reduction in user time and increase in involvement with a VR environment.
Q	A multiuser shared virtual environment for facility management	2016	Shi et al. [15]	Experimental design	Through the development of a shared immersive experience, this study reveals that interpersonal connection in a VR environment is a crucial component of effective communication in facility management.
R	Using augmented and virtual reality technology in the construction industry	2016	Behzadi [18]	Review of literature	VR could be used for scheduling, communication retrieval, labor hours, and safety.
S	Virtual reality-based cloud BIM platform for integrated AEC projects	2014	Goulding et al. [58]	Qualitative research design	Trainees may assess how decisions they make might impact their firm in a risk-free environment using a cloud-based VR building site simulator. Analyzing problems that arise on the building site, such as design, process, logistics, and supply chain, is one of the things that fall under this umbrella.

Table 2. *Cont.*

S/N	Topic	Year	Author	Methodology	Findings
S	Virtual reality-based cloud BIM platform for integrated AEC projects	2014	Goulding et al. [58]	Qualitative research design	Trainees may assess how decisions they make might impact their firm in a risk-free environment using a cloud-based VR building site simulator. Analyzing problems that arise on the building site, such as design, process, logistics, and supply chain, is one of the things that fall under this umbrella.
T	Virtual reality simulation for construction safety promotion	2013	Zhao et al. [46]	Review of literature	The suggested safety training program, which trains and tests personnel using VR simulation, may help to mitigate accidents and fatalities related to electrocution. VR simulations have been successfully employed in the construction sector for safety instruction.
U	Application of ICT in the construction industry in Kampala	2011	Mutesi and Kyakula [50]	Quantitative research design	The most commonly used software are Microsoft Word, MS Excel, and PowerPoint. AutoCAD, Master Bill, and Microsoft Project are popular for architectural/engineering design and drawing, quantity surveying, and project planning, respectively.
V	Adoption of virtual reality within construction processes: A factor analysis approach	2006	Fernandes et al. [55]	Quantitative research design	The study findings include a list of organizational, environmental, and project-related aspects that have to be taken into account. The champion inside a firm, top management support, internal demands, level of business competitiveness, coordination of organizational resources, and user engagement are important areas that demand special attention.
W	The impact of ICT on professional practice in the Nigerian construction industry	2006	Oladapo [60]	Quantitative research design	The findings show that while the majority of basic architectural, engineering, and quantity surveying tasks, such as drawing, engineering design, and bills of quantities, have been digitized, data and document management are still frequently handled manually.

3. Research Methods

A quantitative survey design was utilized to gather information pertinent to the study's goal, with questionnaires given to experts working in the Nigerian construction sector. The questionnaire was developed after researching the advantages of VR. The questionnaire is divided into many components: The first section was used to gather demographic data about respondents, including their occupation, years of experience, and educational background. The primary goal of this research which aimed to rate the benefits of VR practices in the construction industry was addressed in the other section. This was rated on a Likert scale of 1 to 5, with 5 denoting extremely high, 4 denoting high, 3 denoting average, 2 denoting low, and 1 denoting very low. The target demographics for this study were the builders, architects, engineers, quantity surveyors, and other construction industry professionals. A total of 83 questionnaires were retrieved with a 49% response rate. There are 33 architects, 15 builders, 12 engineers, and 23 quantity surveyors among these experts. Professionals in the study area were chosen using a convenience sample approach. The frequency was used to assess the respondents' demographic data and the Measurement of Alternatives and Ranking according to the Compromise Solution (MARCOS) method was utilized to determine how professionals responded to the questions. Factor analysis was used for its efficiency, classifications, and distribution of variables to a more suitable representation of the research.

3.1. MARCOS Method

As proposed by Stević et al. [61], the MARCOS method is a decision-making approach to evaluate and rank alternatives based on their compromise solutions. This method can be applied to explore the benefits of VR adoption for sustainable construction. By applying this method to explore the benefits of VR adoption for sustainable construction, stakeholders can make more informed decisions and select the most suitable VR strategies that align with their sustainability goals. The following stages make up the computational phases of this method. The first stage starts with identifying the relevant criteria in the context of VR adoption for sustainable construction. For each identified criterion, specific performance measures or indicators need to be defined. These measures should quantitatively or qualitatively capture the performance of the alternatives with respect to each criterion. The next step involves evaluating each alternative (i.e., different VR adoption scenarios or strategies) that can vary in terms of the level of VR integration, technology choices, implementation approaches, or other relevant factors. The best/ideal solution (AI) and the worst/anti-ideal solution (AAI) are determined as per Equations (1) and (2):

$$AI = \begin{cases} max(z_{ij}), \ for\ benefit\ criterion \\ min(z_{ij}), \ for\ cost\ criterion \end{cases} \tag{1}$$

$$AAI = \begin{cases} min(z_{ij}), \ for\ benefit\ criterion \\ max(z_{ij}), \ for\ cost\ criterion \end{cases} \tag{2}$$

where z_{ij} refers to the measure of performance of the ith alternative with respect to the jth attribute.

The second step comprises normalizing the decision matrix using Equation (3).

$$y_{ij} = \begin{cases} \frac{z_{ij}}{z_{aij}}, \ for\ benefit\ criterion \\ \frac{z_{aij}}{z_{ij}}, \ for\ cost\ criterion \end{cases} \tag{3}$$

where y_{ij} refers to the normalized measure of performance of the ith alternative with respect to the jth attribute.

The third step includes formulating the weighted matrix (c_{ij}) by multiplying the normalized values by the weights of the criteria (w_j) using Equation (4).

$$c_{ij} = y_{ij} \times w_j \quad (4)$$

The fourth step involves computing the utility functions ($f(Z_i)$) of the alternatives using Equation (5). Once the evaluation of alternatives is complete, the MARCOS method seeks to identify the optimal solution that represents an optimal trade-off or compromise between the different criteria. It is the solution that offers the best overall performance across all criteria, considering the relative importance or weights assigned to each criterion.

$$f(Z_i) = \frac{{Z_i}^{+} + {Z_i}^{-}}{1 + \frac{1 - f({Z_i}^{+})}{f({Z_i}^{+})} + \frac{1 - f({Z_i}^{-})}{f({Z_i}^{-})}} \quad (5)$$

where $f({Z_i}^{+}) = \frac{{Z_i}^{-}}{{Z_i}^{+} + {Z_i}^{-}}$ and $f({Z_i}^{-}) = \frac{{Z_i}^{+}}{{Z_i}^{+} + {Z_i}^{-}}$ represent the utility functions for the ideal and anti-ideal solutions, respectively. It is worth mentioning that the utility functions correspond to the overall benefits of VR adoption ranging from 0 to 1, denoting the least and most important, respectively.

3.2. Exploratory Factor Analysis

EFA is a statistical method employed in multivariate statistics to unveil the fundamental structure present within a substantial set of variables [62]. The main objective of EFA, a method used in factor analysis, is to discover the underlying correlations between measured variables. The appropriateness and factorability of the questionnaire responses for factor analysis have been investigated using two statistical metrics: Bartlett sphericity test and Kaiser–Meyer–Olkin (KMO) estimate of sampling adequacy [63,64].

4. Results and Discussion

4.1. Demographic Background Information of Respondents

Analysis in Table 3 shows the breakdown of data collected according to a questionnaire retrieved with information from built-environment professionals with architects with a frequency of 33 at 39.8% of the respondents, quantity surveyors with a frequency of 23 at 27.7% of the respondents, builders with the frequency of 15 at 18.1% of the respondents, and engineers with a frequency of 12 at 14.5% of the respondent's population. It could be observed that the professionals have an experience between 5 and 10 years with a frequency of 36 at 43.4% of the respondent's population, 6 and 10 years with a frequency of 35 at 42.2% of the respondents' populations, 11 and 15 years with a frequency of 3 at 3.6%, 16 and 20 years with a frequency of 6 at 7.2%, and above 20 years with a frequency of 3 at 3.6%. The respondent's level of education is given in Table 3, with the majority of respondents holding a bachelor's degree (frequency = 38 and percentage = 45.8%). Meanwhile, master's degree holders represent the second majority with a frequency of 31 and a percentage of 37.3%. Moreover, higher national diploma holders represent a frequency of 13 and a percentage of 15.7%, and the last is the doctorate holders with a frequency of 1 at 1.2%.

4.2. Benefits of Utilizing Virtual Reality

Table 4 displays the rankings of the factors indicating the benefits of VR practices in the construction industry. The following is a description of the MARCOS technique's computing processes: The best and worst options are determined, and the extended decision matrix is constructed. The ideal solutions (*AI*) and anti-ideal solutions (*AAI*) are the maximum and minimum measures of performance from the perspective of each expert, respectively. All the responses are assumed to be having equal importance of 1.20%. Considering the "enhance communication and collaboration", the extended decision matrix is then normalized, and the normalized values (y_{ij}) are multiplied by the weights of the criteria to determine the weighted matrix (c_{ij}). The S_I value is estimated as follows: $S_i = 1.20\% \times \left[\left(\frac{3.0}{4.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{5.0}{5.0}\right) + \left(\frac{1.0}{4.0}\right) + \left(\frac{4.0}{4.0}\right) + \left(\frac{5.0}{5.0}\right)\right] + \ldots = 0.88.$ The utility degrees of alternatives concerning the ideal (${Z_i}^{+}$) and anti-ideal (${Z_i}^{-}$) solutions can be computed as follows: $Z_i^+ = \frac{0.88}{1.00} = 0.88$ and $Z_i^- = \frac{0.88}{5.00} = 0.18$. Moreover, the utility functions for the ideal ($f\left(Z_i^+\right)$) and anti-ideal ($f\left(Z_i^-\right)$) solutions can be calculated as follows: $f\left(Z_i^+\right) = \frac{0.18}{0.88+0.18} = 0.17$ and $f\left(Z_i^-\right) = \frac{0.88}{0.88+0.18} = 0.83$. Finally, the utility function ($f(Z_i)$) of the first factor is estimated as follows: $f(Z_i) = \frac{0.88+0.18}{1+\frac{1-0.17}{0.17}+\frac{1-0.83}{0.83}} = 0.17$. The same procedures are repeated for the other factors.

Table 3. Demographic information of respondents.

Variable	Characteristics	Respondent No	Respondents (%)
Years of occupation	Less than 5 years	36	43.4
	6 to 10 years	35	42.2
	11 to 15 years	3	3.6
	16 to 20 years	6	7.2
	Above 20 years	3	3.6
Profession	Architect	33	39.8
	Quantity surveyor	23	27.7
	Builder	15	18.1
	Engineer	12	14.5
Education	HND	13	15.7
	BSc/BTech	38	45.8
	MSc/MTech	31	37.3
	PhD	1	1.2

Table 4. Benefits of employing virtual reality for construction projects.

S/N	Benefits of Virtual Reality Practices	$f(Z_i^+)$	$f(Z_i^-)$	$f(Z_i)$	Rank
1	Enhance communication and collaboration	0.167	0.833	0.170	1
2	Enhance design clash detection	0.167	0.833	0.164	5
3	Improve productivity	0.167	0.833	0.145	27
4	Improve quality	0.167	0.833	0.153	24
5	Reduce construction time	0.167	0.833	0.160	16
6	Risk identification	0.167	0.833	0.166	2
7	Digitalization	0.167	0.833	0.157	19
8	Enable immersive visualization	0.167	0.833	0.164	6
9	Enhance construction planning	0.167	0.833	0.162	11
10	Enhance design efficiency	0.167	0.833	0.162	10
11	Enhance fast project delivery	0.167	0.833	0.162	8
12	Improve company image	0.167	0.833	0.145	28
13	Help identify design flaws	0.167	0.833	0.147	26
14	Enhance sustainable construction	0.167	0.833	0.161	13
15	Enhance construction scheduling	0.167	0.833	0.160	17
16	Reduce construction error	0.167	0.833	0.162	9
17	Improve project performance	0.167	0.833	0.150	25
18	Enable quality decision-making	0.167	0.833	0.153	23
19	Safety planning	0.167	0.833	0.164	7
20	Ease complex task	0.167	0.833	0.154	22
21	Integrate workflow	0.167	0.833	0.161	12
22	Reduce mistakes in documentation	0.167	0.833	0.160	15
23	Enhance workers' safety training	0.167	0.833	0.157	20
24	Enhance maintenance	0.167	0.833	0.161	13
25	Enhance accurate quantity take-off	0.167	0.833	0.158	18
26	Help avoid defects	0.167	0.833	0.155	21
27	Overcome the shortage of fit workforce	0.167	0.833	0.165	3
28	Reduce construction cost	0.167	0.833	0.164	4

It could the concluded that the enhancement of communication and collaboration is the most beneficial aspect of VR practices with an index of 0.170, which means it is highly beneficial. Improved project performance, risk identification, and digitalization also indicate a high level of benefits of VR practices with indexes of 0.166, 0.165, and 0.164, respectively. The majority of the benefits of VR practices have an index value that is much above the average level, implying that these factors are also highly beneficial to the practice of VR for delivering construction projects.

4.3. Categories of Virtual Reality Benefits

The background effects, responsible for the correlation patterns of the set of variables, are found using EFA. According to Table 5, the acquired data are appropriate for conducting factor analysis, and Bartlett's test of sphericity is extremely significant for determining the degree of correlation between the variables. The results show that 88.5% of the collected data are suitable for factor analysis (KMO = 0.885). Additionally, Table 6 demonstrates that the p-value is less than 0.05, indicating that the data are adequate for factor analysis with degrees of freedom of 378 and a chi-square of 1466.29. Furthermore, Bartlett's test indicates that the correlation is an identity matrix (p-value = 0.000), indicating that exploratory component analysis is suitable since all the listed items have a significant correlation at the 5% level. According to Table 6, there are six components that each account for more than one-fifth of the variation, i.e., 15.9%, 12.8%, 12.8%, 10.2%, 10.2%, and 6.4%, respectively. Following the second component, the scree plot is broken upon closer examination. The number of considered components is indicated by the point where the slope of the curve levels off (Figure 1).

Table 5. KMO and Bartlett's test results related to virtual reality benefits.

Test		Value
Kaiser–Meyer–Olkin measure of sampling adequacy		0.885
Bartlett's test of sphericity	Approx. Chi-square	1466.29
	Df	378
	Sig.	0.000

Table 6. Benefits total variance explained.

Components	Initial Eigenvalues			Rotated Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.660	45.214	45.214	4.459	15.924	15.924
2	1.716	6.129	51.343	3.578	12.778	28.702
3	1.298	4.634	55.977	3.571	12.753	41.455
4	1.200	4.284	60.262	2.862	10.223	51.678
5	1.133	4.047	64.308	2.862	10.222	61.900
6	1.118	3.994	68.302	1.793	6.403	68.302
7	0.896	3.199	71.501			
8	0.776	2.773	74.274			
9	0.726	2.594	76.868			
10	0.672	2.401	79.269			
11	0.650	2.322	81.591			
12	0.575	2.053	83.643			
13	0.533	1.905	85.548			
14	0.515	1.839	87.387			
15	0.454	1.620	89.007			
16	0.424	1.516	90.523			
17	0.380	1.357	91.880			
18	0.335	1.196	93.076			
19	0.311	1.110	94.186			
20	0.269	0.960	95.146			
21	0.236	0.845	95.991			
22	0.233	0.833	96.824			
23	0.213	0.762	97.586			
24	0.200	0.715	98.301			
25	0.141	0.504	98.805			
26	0.126	0.451	99.256			
27	0.119	0.425	99.681			
28	0.089	0.319	100.000			
Extraction method: Principal component analysis						

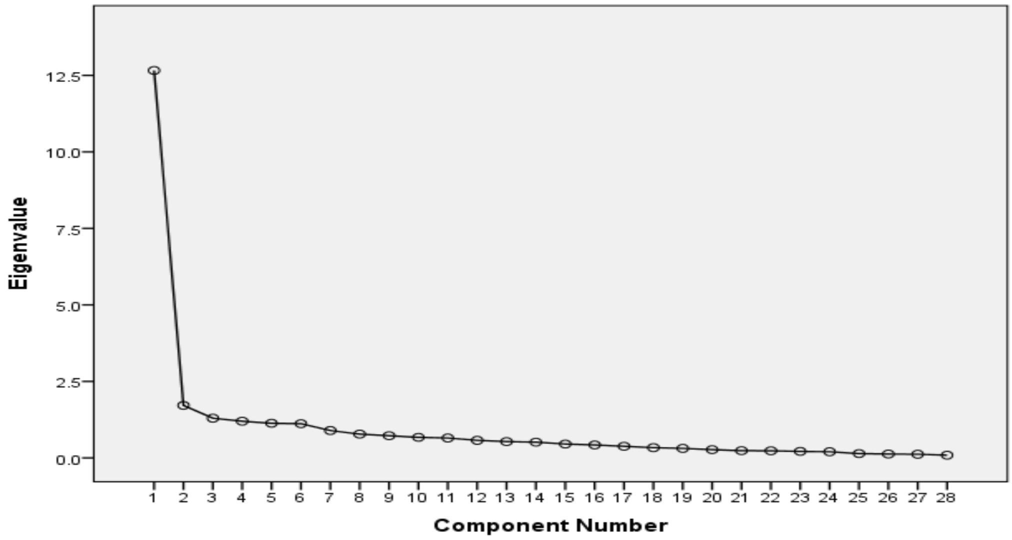

Figure 1. The scree plot of loading benefits of using virtual reality.

Table 7 reveals the rotated component matrix of the benefits associated with using VR for construction practices. All values below 0.40 are suppressed in Table 7, and the highest factor loading is chosen along the rows, which automatically falls under a group/column. Table 7 reveals that the variables are distributed into six groups of factor components. A model with six benefits groups may be adequate to represent the benefits of VR for delivering construction projects. Each variable only has a significant impact on one of the benefit groups, according to the factor grouping. As a result, it is vital to identify these groupings before outlining the six groups. Before the interpretation of the six benefits group, it is important to name these groups. Table 8 shows the naming of these groups, which is subjective because it relies on the common background and similarity of the variables.

Table 7. Benefits rotated components matrix.

S/N	Benefits	F1	F2	F3	F4	F5	F6
1	Enhance communication and collaboration	0.604					
2	Reduce construction time					0.726	
3	Reduce construction cost					0.831	
4	Enhance workers' safety training	0.423				0.647	
5	Enhance construction scheduling		0.559				
6	Enhance design clash detection				0.632		
7	Safety planning	0.578					
8	Risk identification		0.410				0.474
9	Enhance design efficiency	0.579					
10	Enhance construction planning		0.658				
11	Enable immersive visualization				0.515		
12	Overcome shortage of fit workforce	0.811					
13	Help avoid defects	0.421		0.400			
14	Help identify design flaws	0.423			0.582		
15	Improve project performance	0.428					
16	Improve company image				0.770		
17	Enhance accurate quantity take-off	0.572					
18	Enhance maintenance			0.553	0.450		
19	Digitalization						0.738
20	Reduce mistakes in documentation	0.694					
21	Enhance fast project delivery		0.559				
22	Reduce construction error		0.479				
23	Ease complex task		0.531	0.557			
24	Enhance sustainable construction			0.693			
25	Enable quality decision-making		0.798				
26	Integrate workflow	0.413		0.633			
27	Improve productivity	0.450		0.503			
28	Improve quality			0.648			

Table 8. Related component of the benefits of using virtual reality practices.

Factor Components	Variables	Factor Loading
Pre-contract stage planning	Enhance communication and collaboration	0.604
	Safety planning	0.578
	Enhance design efficiency	0.579
	Overcome shortage of fit workforce	0.811
	Help avoid defects	0.421
	Improve project performance	0.428
	Enhance accurate quantity take-off	0.572
	Reduce mistakes in documentation	0.694
Post-contract stage planning	Enhance construction scheduling	0.559
	Enhance construction planning	0.658
	Enhance fast project delivery	0.559
	Reduce construction error	0.479
	Enable quality decision-making	0.798
Quality control and sustainability	Enhance maintenance	0.553
	Ease complex task	0.557
	Enable sustainable construction	0.693
	Integrate workflow	0.633
	Improve productivity	0.503
	Improve quality	0.648
Design flexibility and reputation	Enhance design clash detection	0.632
	Enable immersive visualization	0.515
	Help identify design flaws	0.582
	Improve company image	0.770
Resource management	Reduce construction time	0.726
	Reduce construction cost	0.831
	Enhance workers' safety training	0.647
Risk management and digitalization	Risk identification	0.474
	Digitalization	0.738

5. Discussion

According to the findings of this research, enhancement of communication and collaboration, improved project performance, risk identification, digitalization, and safety planning are the most beneficial aspects of VR practices. The benefits of VR practices are grouped into six major groups based on the data analysis of this research work; pre-contract stage planning, post-contract stage planning, quality control and sustainability, design flexibility and reputation, resource management, risk management, and digitalization.

The first benefit group is pre-contract stage planning. This group accounts for 15.9% of the total variance with six benefits namely, enhancing communication and collaboration, safety planning, overcoming the shortage of fit workforce, avoiding defects, and improving accurate quantity take-off. The benefits that received higher factor loading are overcoming the shortage of fit workforce, improving communication and collaboration, and enhancing design efficiency and safety planning. This finding correlates with that of [8,12,16] which asserted that better collaboration among the professionals, safety training, design efficiency, overcoming the shortage of fit workforce, and reduction in mistakes during documentation are among the benefits associated with the practice of VR.

The second benefit group is post-contract stage planning. This group accounts for 12.8% of the total variance with five benefits, which include enhancing construction scheduling, enhancing construction planning, enhancing fast project delivery, reducing construction error, and enabling quality decision-making. The benefits that received higher loading are enabling quality decision-making, enhancing construction planning, enhancing construction scheduling, and enhancing fast project delivery [12]. Alizadehsalehi et al. [12] stated that VR has been utilized to address a range of difficulties, from design through building procedures to improve quick project delivery. Vasista and Abone [16] also revealed that VR helps a long way to improve decision-making through the integration of design teams and as a result enhance or foster fast project delivery.

The third benefit group is quality control and sustainability. This group accounts for 12.8% of the total variance with six benefits, which include enhancing maintenance, easing complex tasks, integrating workflow, improving productivity, and enhancing quality. The benefits that received higher loading are enabling sustainable construction, integrating workflow, and improving quality. One of the most significant advantages of adopting VR is the simplification of complex jobs as well as improved productivity and quality [15]. The results concur that simplifying difficult jobs and boosting productivity are two of the most important positive effects, but they differ when it comes to improving quality [18].

The fourth benefit group is design flexibility and reputation. This group accounts for 10.2% of the total variance with four benefits namely, enhancing design clash detection, enabling immersive visualization, identifying design flaws, and improving the company's image. Alizadehsalehi et al. [12] asserted that one of the most important benefits of VR is to enhance design clash detection and identify flaws in the design. This research could relate to the assertions, as enhancement of design clash detection and identification of design flaws are ranked among the most important benefits of VR. Delgado et al. [13] revealed that firms that adopt VR are viewed as successful firms, thereby improving their image and reputation.

The fifth benefit group is resource management. This group accounts for 10.2% of the total variance with three beneficial areas namely, reducing construction time, reducing construction cost, and enhancing workers' safety planning. The benefits that received higher loading are reduced construction cost and time. This agrees with Wang et al. [14] who reported the usefulness of VR to reduce construction costs and time. Through the immersive visualization of the building without being constructed using VR, the client can make changes easily, thereby reducing mockup costs.

The last benefit group is risk management and digitalization. This group accounts for 6.4% of the total variance with two benefits, which include risk identification and digitalization. This finding agrees with that of Getuli et al. [10] and disagrees with that of Lew et al. [20]. Getuli et al. [10] revealed that VR is a very important and useful tool in identifying potential risk areas or workspace during a construction project, as this helps to reduce the accident rate and provide a hazard-free construction site. Digitalization is not a significant advantage of VR in the construction business [20]. This conclusion contradicts the research's findings, which show that digitization is a big area where VR can be highly advantageous.

6. Conclusions

With the Nigerian construction sector serving as the foundation of research, the primary goal of this study is to analyze the possible advantages of VR utilizing the MARCOS and EFA approaches. The MARCOS identified the most advantageous application of VR in buildings. The five most significant benefits of adopting VR were the enhancement of communication and collaboration, improved project performance, risk identification, digitalization, and safety planning with indexes of 0.170, 0.166, 0.165, 0.164, and 0.164, respectively. The majority of the benefits of VR practices had an index value that was much above the average level, implying that these factors were also highly beneficial to the practice of VR for delivering construction projects.

The knowledge gained from this study could benefit the industry and the academic environment at large. It increases the awareness among construction professionals about the full benefits of adopting the technology, such as enhancing sustainability, productivity, and performance that indirectly curbs costs, time overruns, and poor quality. Thus, by implementing VR technology, the research's conclusions can enhance project sustainability and speedy completion. Furthermore, this study allows developing countries to explore the benefits attached to the adoption of VR technology to attain their sustainable goals.

This study could be used for further research on other areas of VR. Finally, the study was limited to Nigeria, one of the developing countries. However, further research on VR may be performed in developed countries, and it may also be possible to compare the use of VR in both developed and developing countries.

6.1. Managerial Implications

Reorganizing the benefits of VR implementation can yield important insights that can assist building stakeholders in effectively integrating VR into their projects. This reorganization can also serve as a benchmark, enabling construction players to systematically and efficiently adopt VR. Such a framework plays a crucial role in realizing the identified benefits highlighted in this study, ultimately enhancing productivity and sustainability in the Nigerian construction industry and other developing countries. By addressing these benefits, the Nigerian construction industry can achieve stability, sustainability, and efficiency. Furthermore, since many developing countries share similar construction practices, the findings presented in this study have the potential to accelerate the adoption of VR in other developing countries. Consequently, the implementation of VR can lead to reduced project time and costs, contributing to the overall success of the building industry. In addition to these advantages, this study offers specific contributions to the knowledge in the building industry:

- It presents a comprehensive database of the benefits of VR implementation and its various components.
- Building owners and other key industry players are provided with a robust platform for evaluating VR implementation to enhance the planning and execution of building projects.
- It provides scientific evidence and guidance for the adoption of VR in Nigeria and other developing countries.
- While most research efforts have focused on implementing construction cyber technology in developed countries, there is a scarcity of studies in developing countries like Nigeria.

Therefore, this study fills these gaps by assessing the benefits of VR implementation in Nigeria and highlighting its positive impact on local project quality. Additionally, the study emphasizes the benefits of VR in reducing construction costs and achieving efficient cost distribution for more profitable and successful projects.

6.2. Theoretical Implications

The utilization of VR to enhance project success is gaining popularity across numerous industries. In the context of the Nigerian construction sector, our study has successfully developed a model to evaluate the advantages of implementing cyber technology. Furthermore, we have analyzed the diverse benefits associated with the application of VR. Our study establishes a significant connection between the theoretical and practical implementation of VR. Hence, it is the first study to comprehensively analyze and assess the various benefits of VR implementation in the Nigerian construction sector. Moreover, this research serves as a valuable foundation for future studies investigating the benefits of VR adoption in similar developing countries. With its comprehensive theoretical and mathematical analysis, this study identifies the five most crucial components of these benefits. The findings of this study can assist policymakers in formulating strategies for incorporating robotics into construction, building upon the groundwork laid in this research.

6.3. Limitation and Future Research

One limitation of the study is its geographical scope. The research was conducted specifically in Nigeria, which is described as a developing country. This limited geographic focus may restrict the generalizability of the findings to other regions or countries with different contexts and construction industry dynamics. The benefits and challenges associated with the adoption of VR in construction could vary across countries with varying levels of infrastructure development, technological advancement, and cultural factors.

To overcome this limitation and provide a more comprehensive understanding of the benefits of VR in construction, further research could be conducted in developed countries. A comparison between developed and developing countries would allow for a broader analysis of the factors influencing the adoption and effectiveness of VR technology in construction projects. Additionally, the study's scope might be further limited by its reliance on specific methodologies, such as MARCOS and EFA. While these approaches offer valuable insights, other research methods or frameworks could provide alternative perspectives and contribute to a more comprehensive understanding of the benefits and limitations of VR in construction. Overall, while the study provides valuable insights into the benefits of VR in construction, its generalizability beyond Nigeria and its limited reliance on specific methodologies should be taken into account when interpreting and applying the findings to other contexts.

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