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Building information modelling (bim) and virtual reality (vr) integration for enhanced construction project management: collaboration and communication

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Abstract

The study sought to assess building information modelling (BIM) and virtual reality (VR) integration for enhanced construction project management: collaboration and communication in Delta State, Nigeria. Descriptive survey design was adopted for the study. The study was conducted in Delta State using some construction companies in the state (Monier Construction Company (Nigeria) Limited (MCC) and Setraco Nigeria Limited). The population of thestudy comprised of all the staff from the aforementioned two companies. Simple random sampling technique was used to select a total of 370 respondents for the study. The Instrument titled "building information modeling (bim) and virtual reality (vr) integration for enhanced construction project management: collaboration and communication questionnaire (bimvriecpmccq)" was used. Face validation of the instrument was carried out by an expert in civil engineering, statistics and architecture while Cronbach Alpha technique was used to determine the level of reliability of the instrument. The reliability coefficient obtained was 0.93 which was proved high enough to justify the use of the instrument. The researcher subjected the data generated for this study to percentage analysis which was used to answer the research questions and Pearson Product Moment Correlation Analysis for testing the hypothesis. The test for significance was done at 0.05 alpha levels. The study revealed that there is very high need of the integration of Building Information Modelling (BIM) and Virtual Reality (VR) has the potential to revolutionize construction project management by enhancing collaboration and communication among stakeholders. It was concluded that BIM offers a comprehensive digital representation of a construction project, while VR enables stakeholders to experience and interact with the model in a three-dimensional virtual space. The integration promotes a shared understanding among all parties involved, from designers and engineers to clients and contractors. Oneof the recommendations was that Construction firms should adopt platforms that seamlessly integrate BIM and VR technologies. These platforms should support real-time data synchronization, allowing team members to access and interact with up-to-date project models; and that Companies should invest in training programs to enhance the capacity of their workforce to use BIM and VR tools effectively.

Key words: Building Information Modeling (BIM), Virtual Reality (VR), Construction project management ,Collaboration and communication

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Introduction

In the last few decades, construction projects have become more and more complex. The industry has always known as traditional and less innovative, with a slow rate of productivity compared to other sectors. Construction companies still face challenges in delivering their projects at the scheduled time and in the budget. Securing a sufficient level of communication and collaboration within the project team is problematic. This complexity in construction projects which require tighter collaboration and an enhanced understanding about the processes call for further interactive tools and methods of teaching (Senescu, Haymaker and Aranda-Mena, 2013 cited in Abbasnejad, et al 2022; Arashpour, and Aranda-Mena, 2017). Design errors and poor collaboration and communication tools are considered the main reasons for project delays and cost overruns. Based on the fact that the interdisciplinary teams such as designers, engineers, and client involvement in the construction project require a proper communication and collaboration tool to increase the efficiency and interactivity of data exchange during the project duration (Hassanein, 2020 cited Lahdou, & Zetterman, 2011).

Building Information Modelling (BIM) has changed the shape of the construction industry dramatically in the last decade. BIM usage has a good impact on construction projects in providing a collaboration platform to project participants. Also, communication channels, visualization power to track issues and clarify uncertainties and increase the quality of the design process by detecting clashes at the early design stage and decrease rework. BIM is considered a centralized data repository and also a data pool that can be extended and interconnect with other emerging technologies like VR (Sampaio, 2018). However, adopting new technology in the construction field is a challenge. The BIM-VR extension creates new business opportunities to increase efficiency, agility, and productivity through digitalization and provide innovative solutions for problematic issues between project participants regarding time, cost, and quality (Du, et al., 2018).

Virtual Reality VR is an emerging technology that uses an artificially generated environment that is created with software and hardware. Virtual reality is experienced through sound and sight senses to achieve a higher level of perception. VR has been classified as one of the top 10 Gartner strategic technology trends for 2019. A study by Goldman Sachs estimate the size of the VR market will grow to reach 80 billion by 2025 (Bellini, 2016). VR aids the users to immerse themselves in a full-scale model, allow the users to walk through the project to check the detailed design before construction. In the design process, VR is a valuable tool in design review that helps to present and facilitate design components to clients who do not have an engineering background. Early Engagement of stakeholders in the design process through innovative tool increases the satisfaction degree and help to meet the project requirements. Also, provide a basis for the decision-making process at an early stage.

Statement of the Problem

Construction project management is inherently complex, characterized by a multitude of challenges that can impede project success. Among the most pressing issues are collaboration difficulties, communication breakdowns, and coordination problems. These challenges are often exacerbated by the involvement of multiple stakeholders, including architects, engineers, contractors, and clients, each with distinct interests and requirements (O'Connor, 2020). Gonzalez, (2019) argued that effective collaboration and communication are crucial for aligning these diverse stakeholders and ensuring that project objectives are met within the constraints of time, budget, and quality.

Several researches indicated that poor communication and collaboration are significant contributors to project delays and cost overruns. For instance, a study by Loosemore and Hsin (2018) found that

miscommunication between project participants was responsible for 30% of project delays. Similarly, issues related to coordination and information sharing have been linked to increased project costs and reduced quality (Gonzalez, 2019). Others suggest that while BIM improves data management and collaboration (Succar, 2015), its integration with VR for immersive visualization remains underexplored (Wang et al., 2018). Moreover, there is a lack of empirical evidence on how BIM-VR integration impacts project performance metrics such as time, cost, and quality (Deng et al., 2019). The problem lies in understanding how to effectively harness the combined potential of these technologies to enhance decision-making and reduce project risks. In light of the above this paper seeks to investigate building information modelling (BIM) and virtual reality (VR) integration for enhanced construction project management: collaboration and communication (A case study of Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC) in Delta state).

Objective of the Study

The primary purpose of this study is to explore how the integration of BIM and VR can enhance collaboration and communication within construction project management. Specifically, the study will address the following objectives:

1. To examine the effect of BIM and VR integration on collaboration in Setraco Nigeria Limited and MCC in Delta state.

2. To evaluate the impact of BIM and VR integration on communication in Setraco Nigeria Limited and MCC in Delta state.

3. To examine the relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco Nigeria Limited and MCC in Delta State.

Research Questions

Based on the above specific objectives, the following research questions were formulated to guide the researcher;

1. What is the effect of BIM and VR integration on collaboration in Setraco Nigeria Limited and MCC in Delta State?
2. What is the impact of BIM and VR integration on communication in Setraco Nigeria Limited and MCC in Delta State?
3. What is the relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco Nigeria Limited and MCC in Delta State?

Research Hypotheses

To answer the above research questions posed for the study this hypothesis was also formulated in a null form;

1. There is no significant relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco Nigeria Limited and MCC in Delta State.

Literature Review

Overview of Building Information Modelling (BIM)

The integration of Building Information Modeling (BIM) and Virtual Reality (VR) represents a transformative advancement in construction project management. Over the last few years, BIM has gained increasing attention as a new method for executing and managing construction projects. The central idea of BIM is to provide information on a shared database so that stakeholders can develop a virtual building information model collaboratively (Abbasnejad, et al., 2021). It is worth to note that BIM is more than just a technology providing unparalleled visualisation and intelligent models that enhance business capabilities in the Architecture, Engineering and Construction (AEC) industry (Aranda-Mena, et al., 2009). With BIM,

team members can upload, extract, update, or modify information in a common digital representation. Through this process, project members can reuse building information throughout the life cycle of a building. BIM has infinitesimal dimensions (nD) and has been used in the industry for many different applications such as three-dimensional (3D) visualisation and scheduling (also referred as 4D as adding the time or process dimension to 3D models), quantity take off, safety, clash detection, maintenance and facility management (Aranda-Mena, et al., 2005 cited in Hassanein, 2020).

Overview of Virtual Reality (VR)

Virtual Reality (VR) complements BIM by providing an immersive and interactive platform for project visualization. Chen et al. (2020) emphasize that VR allows stakeholders to experience and interact with project designs in a virtual environment, enhancing their understanding of spatial relationships and design concepts. This immersive experience can improve decision-making and reduce the likelihood of errors. VR's ability to simulate various scenarios and visualize changes in real-time is particularly valuable in construction project management. According to Wang et al. (2021), VR can be used to conduct virtual walkthroughs, which helps stakeholders to better assess design alternatives and construction processes.

Virtual reality's visual representation allows for integration of higher degree of freedom (DoFs) than traditional education and training approaches, such as static images and two-dimensional (2D) drawings [11]. The goal of immersive VR is to provide users with an immersive experience by using special hardware, such as the head-mounted display and sensor gloves to create an immersive environment. Using a VR headset, students can view project designs and site plans using their mobile devices or desktop computers. It empowers them to use their ingenuity to identify potential issues and resolve them in a simulated environment. As the user moves around in the virtual environment, their position also changes. This is even more crucial due to pandemic-related concerns about safety, since the AEC companies are looking for new forms of collaboration by using virtual reality that don't require everyone to be in the same room.

Integration of BIM and VR in Construction

BIM is used in the construction industry in many applications. Generating three dimensions (3D) visualization of the project (Azhar, 2011) is not the only use of BIM. It can be implemented in all phases of the project life cycle (Ahn, et al., 2016). As the construction projects are getting more sophisticated, the need for closer collaboration, more effective communication, and documentation is required (Eastman, et al., 2008). BIM improved the traditional paper-based tools in construction to a virtual environment, which increased efficiency, communication, and collaboration (Lee, 2008). It is viewed as the ultimate solution to the problems of coordination across the building supply chain (Howard, et al., 2017). When the schedule is added to the 3D model, time is introduced as the 4th dimension (4D). 4D models are essential in illustrating workflow and in creating a sequencing simulation that shows in 3D the building being built from start to finish. It will also provide early clash detection and identifying spatial conflicts in construction. (Azhar, 2011; Eastman, et al., 2008; Hardin & McCool, 2015). Clash detection is defined as an overlapping between components in the same space that occurs in 2D drawings, which can be easily identified in BIM. (Memon, et al., 2014).

Sampaio and his team created a project using virtual reality technology for construction planning (Sampaio, et al., 2012). A 4D model is created by linking the geometrical AutoCAD 3D model of distinct construction activity steps to the construction planning schedule. This application shows the construction process, eliminates inaccuracies and construction errors and improves coordination among construction partners. When the 4D model is extended to include the cost, the model becomes a 5D model. BIM minimizes the manual take-off, which reduces the time and efforts needed for cost estimation (Azhar, 2011; Nassar, 2012) by generating take-offs, counts, and measurements directly from a model (Eastman, et al., 2008). Bryde, et al., 2013 in their extensive research, found that project cost was the one influenced most positively by BIM implementation followed by time. McGraw-Hill (McGraw-Hill, 2012) reported that contractors listed reducing rework, reducing overall project duration, and reducing errors in documents as the top benefits of adopting BIM. Having all the information included in the model will help in prefabrication ordering and delivery of the building materials and will assist in coordinating material ordering and delivery. That will reduce the cost and duration of a project (Ahn, et al., 2016; Azhar, 2011; Eastman, et al., 2008). VR has

been used for safety training for construction workers by creating a set of safety training scenarios to examine and validate construction activities, and operations without being exposed to any risk (Shi, et al., 2006; Sacks, et al., 2013), and can help designers understand the effects of their designs on safety (Sacks, et al. ,2015).

Challenges Associated With the Implementation of VR in Construction

With the development of time, projects became more complex and the drawings harder to read and understand in two dimensions, especially for new workers in the field. Combining technologies together such as BIM and VR helps the workers at the worksite to read and understand the drawings more easily. According to Schiavi et al., (2022) VR technology has shown its relevance to assist in various construction activities. However, using VR technology requires further work in order to integrate it into the BIM process. It is mentioned by Schiavi et al. (2022) that activities and education relating to safety are not always applied at the worksite. The consequence is that the amount of research about how VR can be used to improve safety on construction projects are limited. Additional challenges with implementing the technology can be technical or practical, such as problems with data transformation and the need to adapt BIM data to fit VR environments.

Although VR technology which was first developed for entertainment purposes, has great potential in professional industries such as engineering and construction. However, its adoption in these fields is hindered by several key factors (Delgado, et al., 2020). One of the biggest challenges to widespread VR adoption in the construction industry is that many professionals believe VR technology is not yet completely developed for practical application, citing issues like battery limitations in the headgear. Additionally, the lack of a skilled workforce presents a significant challenge. The construction industry, in general, lacks adequately trained personnel and efforts toward upskilling have been limited (Delgado, et al., 2020). Technical requirements hinder VR integration into building procedures. VR systems require specialized equipment such as head-mounted displays, controllers and movement tracking sensors, in addition to powerful computational gear. Furthermore, the setup demands huge specialized spaces, which increases the logistical and financial strain, especially for smaller businesses with limited resources. Despite its potential, VR adoption within the AEC industry remains low, limited to specialized use cases. Challenges involving high hardware and training costs, power and battery limitations and a lack of market awareness all contribute to the limited uptake (Delgado, et al., 2020).

BIM-VR Impact on Collaboration and Communication

A construction project has the characteristics of temporary and openness, and the project team often involves numerous participants consisting of different departments in various organisations (Huang, et al., 2020). The complexities of the project itself and its organisational structure severely deepen the obstruction of information communication. This case can lead to a series of construction issues (e.g., design changes, re-work, quality defects, project delays, cost overruns, and safety incidents), which will seriously affect the project's performance (Hasan, et al., 2018). Therefore, the efficiency of communication among team members is essential in achieving the goal of the construction project performance. However, in traditional project management, information integration and real-time exchange to achieve efficient communication and collaboration among multidisciplinary team members remain challenging (Ahuja, Yang, & Shankar, 2010). Fortunately, the advent of building information modelling (BIM) offers an opportunity to address these issues more effectively in the architecture, engineering, and construction (AEC) industry (Manzoor, Othman, & Pomares, 2021; Oraee, et al., 2019).

BIM is an advanced and revolutionary technology for generating, visualising, and analysing architectural models, thus changing the way buildings are conceived, designed, built and operated (Azhar, Khalfan, & Maqsood, 2012; Sacks, et al., 2018). Moreover, BIM is considered a platform that encourages communication and participation of all participants throughout the lifecycle of the construction project, thus enabling the integration of organisations (Huang, et al., 2021). These are also the prerequisite for the rapid identification of project management problems and the efficient provision of immediate communication and responses in the new generation of construction project management. Thus, BIM is considered to be able to foster novel and creative alternatives to traditional AEC technology as well as organisation communication innovation in construction projects (Singh, & Holmstro¨m, 2015). However,

in practice, the effect of BIM has not been fully shown (Huang, et al., 2021; Awwad, Shibani, & Ghostin, 2020).

The construction project team involves different participating organisations and different departments within each organisation. Both internal and external communication activities exist in a construction project. Internal communication activities within an organisation are often known with fewer tasks compared with external communication, and their importance is often overlooked (Ali, et al., 2021). Effective internal and external communication by all participants is required for a project's goal achievement (Huang, et al., 2020). The impact of BIM on organisational communication in a construction project may be able to be shown by the structure change of communication network that integrates inter- and intra- organisational relationships when BIM use.

Communication Problems at Project Site

Communication is an ongoing and dynamic activity that involves many stakeholders throughout the project's life cycle. Mahmoud, et al., (2018) mentions that achieving and maintaining effective communication is critical as it directly affects project success. Throughout the project lifecycle, effective communication helps in successfully meeting various objectives and goals. While scientific knowledge and technical experience are necessary for creating a professional presence in the construction industry, communication skills are also required to round out this professional framework (Mahmoud, et al., 2018). The study mentions that poor communication can be understood as a failure in the effectiveness and success of the communication process. Many problems in the construction industry are caused by a lack of communication. It is a primary cause of disputes among project stakeholders. Poor communication negatively impacts critical elements of a project's success, such as the timeline, budget and stakeholder agreements (Mahmoud, et al., 2018). As a result, reworks are frequently required throughout the project lifecycle, leading to time delays and increased costs.

Causes of poor communication in construction projects: Poor communication is a fairly common problem in construction projects, and its impact can't be underestimated because it influences project success (Mahmoud, et al., 2018). Few causes of poor communication in the construction industry:

- Pressure can cause personnel to make mistakes. Personnel mistakes can be in a form of incorrect and inaccurate outcomes.
- Poor Feedback, where the timing and quality of feedback are critical to successfully completing a communication transaction successfully, is especially problematic when the requirement is urgent.
- Different levels of education are clear on the project site. Engineers, supervisors, project managers and workers interact with each other continuously during the execution of the project. Communication with workers can be quite difficult, as education plays a huge role in the capability of understanding technical tasks.
- Ineffective communication means that communication occurred, but the outcome or method was inadequate. Time and quality are the two key criteria that might lead to ineffective communication.

Empirical Review

Hassanein, (2020) carried out a research aims to analyze the implementation of modern technology like BIM (Building Information Modelling) and VR (Virtual Reality) in the construction industry and the challenges to convert the BIM models to a virtual model by using a virtual reality environment. The research focused on studying previous researches, former case studies, statistical treatment, and BIM software presenting benefits of using VR in the construction industry and an approach for using VR to work remotely during disasters. It was concluded that in a virtual environment, the client and the project team can easily understand the project when immersed in a virtual model. Also, the virtual reality model can be used to improve the coordination between different stakeholders, provide an agile and reliable source of information, simulate the construction process, and predict potential difficulties at different project phases. VR technology has the potential to provide a step-change in productivity. It can enhance the construction project during the design, planning, and execution phases. The virtual environment in the design phase would help the client and other participants understand the project without an engineering background. The findings of this research provide a business improvement plan to implement VR

technology in the construction industry in a wide range. A framework to adopt VR in a construction company.

Abbasnejad, et al., (2022) observed that The industry needs for integration of BIM-VR are not fully recognised by universities due to the lack of a guideline and cognitive dissonance between academia and industry. As a result, most universities do not have a rigorous strategy for developing BIM-VR teaching topics and plans. This study firstly aims to report on some of the employed processes by university lecturers and academics in an Australian University to integrate BIM-VR education into CM curriculum. The review on the secondary sources indicates that the integration of BIM/VR education requires the consideration of three aspects including: industry needs, course contents, classroom size and software and hardware selection. The second aim of this paper is to develop a decision support system by utilising the PROMETHEE method as one of the multi-criteria decision-making approaches. The findings of the secondary sources and development of the decision support system help the educational institutions and practitioners for their future BIM-VR implementation initiatives.

A study by Touma, (2024) highlights the importance of communication in the construction industry and its influence on project success. Traditional communication methods, such as 2D documents, are gradually being superseded by cutting-edge technology like Virtual Reality (VR) combined with Building Information Modeling (BIM). VR tools provide revolutionary capabilities by improving communication, visualization, and decision-making processes. The aim of this study is to identify the challenges associated with integrating VR technology with BIM in order to enhance communication in the construction industry. The study adopts a qualitative methodology with the research method as a case study. The study consisted of two main data collection methods, a documents' analysis and interviews with experienced engineers to delve deeper into the current situation of communication and the benefits of integrating VR technology with BIM. The results reveal several important findings. Communication challenges, such as language barriers and management issues at project sites, were identified by the respondents. Physical meetings were preferred for effective communication. Opinions on implementing VR varied among respondents, with some seeing VR as beneficial for task understanding and efficiency, while others favored traditional methods. However, some factors have contributed to the limited adoption such as the resistance to change, the use of traditional methods and the lack of experience about the VR technology. Therefore, the study recommended that integrating VR can enhance comprehension of blueprints and minimize errors, but its immediate necessity remains unclear compared to traditional methods.

Huang, et al., (2022) conducted a study to examine the impact of BIM on communication network from inter- and intra- organisational relationships in the construction project. First, the structures of the communication networks before and after the use of BIM in a project in China were determined based on the social capital perspective. Then, the social network analysis was adopted to measure the changes in network metrics (i.e., number of ties, density, centrality, centralisation, and clique). Results shows that the connections among nodes are denser, and all the values of the network centralisation decrease after BIM application compared with the situation before BIM use. Nevertheless, results also show that some construction project participants, who originally have interaction and communication needs, remain unable to establish effective connections among one another even after BIM use. Accordingly, some suggestions were proposed to solve the issues and deficiencies. This research contributes to (a) the state of knowledge by proposing social capital perspective that can identify inter- and intra-organizational relationships of the construction project from social interaction and common cognition to build communication network, and (b) the state of practice by identifying conditions and proposing strategies for strengthening organisational communication and collaboration in BIM-enabled network relationships.

Davidson, et al., (2019) carried out a Research into building information modeling (BIM) and virtual reality (VR) are combined and proposed as a potential solution that allows inclusion of the client into the design process. Following a literature review and precedent study, an experiment was carried out using this new process to simulate a client’s design decisions on window and interior furnishings. The choices made by the client using VR automatically updated a B/Q schedule built in Revit and allowed them to have a firm understanding of project costs. Besides giving the client more confidence in a pleasing final outcome, the technology also ensured an up-to-date, accurate, and easily understandable B/Q. The proposed method

features great potential savings in cost and time and gives the B/Q a newfound importance in future construction processes. The research case presented in this paper is a stepping stone in exploring new opportunities offered by VR and BIM and how they could improve the reliability and accuracy of traditional procurement within construction, specifically within the B/Q document.

Methodology

Descriptive survey design was adopted for the study. The study was conducted in Delta State using Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC) as the case study. The population of the study comprised of all staff in the two companies. Simple random sampling technique was used to select 370 respondents used for the study. The Instrument titled "Building Information Modelling (BIM) and Virtual Reality (VR) Integration for Enhanced Construction Project Management: Collaboration and Communication Questionnaire (BIMVRIECPMCCQ)" was used. Face validation of the instrument was carried out by two experts in civil engineering department and one expert in statistics while Cronbach Alpha technique was used to determine the level of reliability of the instrument. The reliability coefficient obtained was 0.93 which was proved high enough to justify the use of the instrument. The researcher subjected the data generated for this study to percentage analysis which was used to answer the research questions while Pearson Product Moment Correlation Analysis was used to test the hypothesis. The test for significance was done at 0.05 alpha levels.

Result and Discussion

Research Questions 1: The research question sought to find out the extent effect of BIM and VR integration on collaboration in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC). To answer the research percentage analysis was performed on the data, (see table 1).

Table 1: Percentage analysis of the extent effect of BIM and VR integration on collaboration in the two companies

EXTENTS	FREQUENCY	PERCENTAGE
VERY HIGH EXTENT	321	86.76**
HIGH EXTENT	49	13.24*
TOTAL	**370**	**100%**

**** The highest percentage frequency**
*** The least percentage frequency**
SOURCE: Field survey

The above table 1 presents the percentage analysis of the extent effect of BIM and VR integration on collaboration in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC). From the result of the data analysis, it was observed that the highest percentage (86.76%) of the respondents affirmed that the extent effect of BIM and VR integration on collaboration is very high, while the least percentage (13.24%) of the respondents stated that the extent effect of BIM and VR integration on collaboration is high in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC).

Research Questions 2: The research question sought to find out the extent impact of BIM and VR integration on communication in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC). To answer the research percentage analysis was performed on the data, (see table 2).

Table 2: Percentage analysis of the extent impact of BIM and VR integration on communication in the two companies

CONSIDERATION	FREQUENCY	PERCENTAGE
VERY HIGH CONSIDERATION	12	3.24*
HIGH CONSIDERATION	48	12.97
LOW CONSIDERATION	126	34.05
VERY LOW CONSIDERATION	184	49.73**
TOTAL	**370**	**100%**

** **The highest percentage frequency**

* **The least percentage frequency**

SOURCE: Field survey

The above table 2 presents the percentage analysis of the extent impact of BIM and VR integration on communication in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC). From the result of the data analysis, it was observed that the highest percentage (49.73%) of the respondents affirmed that the extent impact of BIM and VR integration on communication is very low, while the least percentage (3.24%) of the respondents stated that the extent impact of BIM and VR integration on communication in the two companies in Delta State is very high.

Research Questions 3: The research question sought to find out the relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC) in Delta State. In order to answer the research question, descriptive analysis was performed on the data collected as shown in Table 3.

Table 3: Descriptive statistics of the relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication

Variable	N	Arithmetic mean	Expected mean	r	Remarks
BIM and VR integration	370	16.00	12.5	0.90*	*Strong to perfect Relationship
collaboration and communication		17.56	12.5		

Source: Field Survey

Table 3 presents the result of the descriptive analysis of the relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication. The two variables were observed to have strong to perfect relationship at 87%. The arithmetic mean for building information modelling (BIM) and virtual reality (VR) integration (16.00) was observed to be greater than the expected mean score of 12.5. In addition to that, the arithmetic mean as regards collaboration and communication (17.56) was observed to be higher than the expected mean score of 12.5. The result therefore means that there is remarkable relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC) in Delta State.

Hypothesis One

The null hypothesis states that there is no significant relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in Setraco

Nigeria Limited and Monier Construction Company (Nigeria) Limited (MCC) in Delta State. In order to answer the hypothesis, Pearson Product Moment Correlation analysis was used to analyze the data (see table 4).

TABLE 4: Pearson Product Moment Correlation Analysis of the relationship betweenbuilding information modelling (BIM) and virtual reality (VR) integration and collaboration and communication in the two companies

Variable	∑x ∑y	∑x2 ∑y2	∑xy	r
Purposefulness in research (x)	5920	96524		
			105371	0.90*
Dependability of the results (y)	6496	115452		

***Significant at 0.05 level; df =368; N =370; critical r–value = 0.113**

Table 4 presents the obtained r-value as (0.90). This value was tested for significance bycomparing it with the critical r-value (0.113) at 0.05 levels with 368 degree of freedom. The obtained r-value (0.90) was greater than the critical r-value (0.113). Hence, the result wassignificant. The result therefore means that there is significant relationship between building information modelling (BIM) and virtual reality (VR) integration and collaboration and communication. The result is cognate to the research findings of Huang, et al., (2021) argue that BIM is considered a platform that encourages communication and participation of all participants throughout the lifecycle of the construction project, thus enabling the integration of organisations. Studies by Sacks et al., (2018) and Cheng et al., (2020) reveal that combining BIM with VR can increase project efficiency, reduce errors, and enhance overall project outcomes. The significance of the result caused the null hypothesis to be rejected while the alternative one was accepted.

Conclusion

The integration of Building Information Modelling (BIM) and Virtual Reality (VR) has the potential to revolutionize construction project management by enhancing collaboration and communication among stakeholders. Based on the findings it is therefore concluded that;

BIM and VR provide a dynamic and immersive environment that improves understanding, reduces errors, and facilitates more effective decision-making processes.

BIM offers a comprehensive digital representation of a construction project, while VR enables stakeholders to experience and interact with the model in a three-dimensional virtual space. This synergy allows for more precise visualization of project details, better coordination between teams, and the early detection and resolution of potential issues.

The integration promotes a shared understanding among all parties involved, from designers and engineers to clients and contractors.

It enhances transparency, ensuring that everyone is aligned with project goals and timelines, which ultimately leads to improved project outcomes, reduced costs, and minimized delays. As the construction industry continues to evolve, the adoption of BIM and VR technologies will likely become a standard practice, fostering a more collaborative, efficient, and innovative approach to project management.

Recommendations

The integration of Building Information Modelling (BIM) and Virtual Reality (VR) has the potential to revolutionize construction project management by enhancing collaboration and communication among stakeholders. The following recommendations are made as a result of the research findings that;

1. Construction firms should adopt platforms that seamlessly integrate BIM and VR technologies. These platforms should support real-time data synchronization, allowing team members to access and interact with up-to-date project models.
2. Companies should invest in training programs to enhance the capacity of their workforce to use BIM and VR tools effectively. This training should cover both technical aspects, such as software operation, and soft skills, like effective communication and collaboration in a virtual environment.
3. Regular virtual meetings should be scheduled to maintain open lines of communication among all parties.
4. Smooth collaboration and communication should be encouraged, it is essential to establish standard protocols and guidelines for BIM-VR integration. This includes defining the roles and responsibilities of team members, data exchange formats, and the frequency of model updates.
5. There should be feedback mechanisms within the BIM-VR environment to enable immediate communication and collaboration. Stakeholders should be able to annotate and comment directly on the virtual model, providing feedback that is instantly visible to all team members.

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