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The Impact of Virtual Reality (VR) and Augmented Reality (AR) Technologies on Working Drawings and Specifications in the Nigerian Construction Industry

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Abstract
This study investigates the transformative impact of Virtual Reality (VR) and Augmented Reality (AR), when integrated with Building Information Modeling (BIM), on the interpretation, communication, and enforcement of working drawings and specifications within the Nigerian construction industry. The research explores how immersive technologies enhance clarity, reduce misinterpretation, and improve collaboration among architects, engineers, contractors, and facility managers. A quantitative approach using survey method by administration of questionnaire the 600 professionals of which 539 were returned was the means of collecting the research data. The findings reveal that VR and AR create interactive, real-time visualizations of construction documents, allowing stakeholders to better understand design intent and technical specifications before implementation. Furthermore, the integration of these technologies strengthens facility management practices by enabling seamless data sharing through BIM, which improves asset tracking, maintenance planning, and resource optimization. However, the study also identifies key implementation challenges, including high adoption costs, inadequate workforce training, limited regulatory frameworks, and interoperability issues between existing systems and emerging technologies. These barriers currently limit widespread adoption within Nigeria's construction sector. In order to address these issues, the study proposes strategic recommendations such as establishing pilot projects to demonstrate value, introducing capacity-building initiatives to upskill professionals, developing interoperable BIM standards, and updating regulatory policies to support innovation. Therefore, implementing these strategies, Nigeria's construction industry can leverage immersive technologies to enhance project delivery, minimize errors, improve quality control, and foster sustainable facility management. Overall, this study underscores the need for a structured technological adoption framework to drive efficiency and competitiveness within the evolving built environment.

Keywords: Virtual Reality, Augmented Reality, BIM, Specifications, Working Drawings

1. Introduction

In architectural and construction practice, the role of documentation—especially working drawings and specifications—is fundamental. These documents communicate design intent, performance standards, materials, dimensions, tolerances, and construction methods. Traditionally, such documents are static, two-dimensional (2D), and manually reviewed, often resulting in misinterpretations, rework, and disputes (Owolabi, Harry, Adewumi, Onomade & Alagbe 2024; Adewumi, Asaju, Bello, Atulegwu, Ibhafidon, David-Mukoro, Otuonuo & Olaoye, 2025a).

In rapidly urbanizing contexts like Lagos Megacity, these problems are compounded by increased project complexity, compressed timelines, stakeholder fragmentation, and the absence of digital infrastructure. Lagos, with a population exceeding

20 million and experiencing aggressive vertical and infrastructural growth, presents a context where efficient documentation is no longer optional but necessary for project success (Adewumi, Onomade, Asaju & Adegbile 2023; Alugbue, Otuonuyo, Adewumi, Onomade & Asaju 2024).

Meanwhile, the global construction industry is witnessing a paradigm shift. Therefore, immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR), when integrated with Building Information Modeling (BIM), are transforming how construction documentation is created, visualized, and implemented (Alugbue *et al* 2024). These tools allow project participants to interact with 3D models containing embedded specifications, significantly improving design comprehension, coordination, and on-site accuracy (Emesiobi, Otunuyo, Adewumi, Asaju & Onomade 2024; Onadapo, Olanipekun & Ipinlaye 2024).

This research focuses on how immersive technologies can improve the creation, interpretation, and enforcement of working drawings and specifications in Nigerian construction projects—specifically in Lagos, where conventional methods have proven insufficient (Hassan, Adewumi & Olukunga 2024; Oru, Adewumi& Asaju 2024).

However, Despite the availability of digital documentation tools globally, many construction projects in Lagos still rely on static drawings and disconnected textual specifications. This leads to several interrelated challenges: miscommunication between consultants and contractors, inconsistent interpretation of specifications, poor enforcement of quality standards, incomplete documentation during handover to facility managers and low adoption of BIM and virtually no use of immersive technologies.

Emesiobi *et al*. (2024) found out that facility managers in Lagos often work without access to design specifications, resulting in high maintenance costs. Adegoke & Ibeh (2024) also observed that poorly documented specifications significantly hamper sustainable building operations. These challenges suggest a need for an overhaul of Nigeria's approach to documentation using modern immersive tools that enhance clarity, enforcement, and coordination (George, Adewumi,Otuonuyo,Oyewole, Oparinde& yussuf, 2025; Asaju, Adewumi, Onamade &Alagbe, 2024).

The Aim of this study: To investigate how Virtual Reality and Augmented Reality technologies impact the development, communication, and enforcement of working drawings and specifications in the Nigerian construction industry**.**

Objectives are to: Identify the extents BIM adoption in working drawing and specifications, assess BIM collaboration and interpretation in working drawings and specifications, analyze successful applications of VR/AR in construction in the study areas

This study focuses on the architecture, engineering, and construction (AEC) sector in Lagos Megacity. It limits its analysis to working drawings and specifications during the design, construction, and facility management phases. Though international literature is referenced, emphasis is placed on the Nigerian context. This research contributes to the growing discourse on digital construction in Africa. It offers practical guidance for: Architects and engineers seeking better ways to communicate design intent, contractors aiming to reduce rework and disputes, facility managers looking for more reliable documentation systems and policymakers developing future-ready building codes

Therefore, by showcasing the transformative potential of immersive technologies, the study lays the groundwork for modernizing Nigeria's construction documentation ecosystem.

2. Literature Review

2.1. Preambles:

The construction industry is undergoing rapid digital transformation, with Virtual Reality (VR), Augmented Reality (AR), and Building Information Modeling (BIM) emerging as revolutionary technologies that reshape how working drawings, specifications, and facility management are conceptualized and implemented (Fan, Ona, Wu, Forcada & Alari,2023; Oladayo *et al* 2024. Owolabi *et al*.2024). Traditionally, working drawings and specifications have served as the primary mediums of communication among architects, engineers, contractors, and facility managers (Adewumi *et al*. 2025; Zahor, Greenwood, Marzouk.2023). However, challenges such as misinterpretation of complex details, design conflicts, and poor collaboration persist, often leading to costly delays and quality issues (Owolabi *et al*., 2024. Adewumi, Onomade, Otunuyo, Alagbe, Adegbile & Dayomi. 2025b).

Immersive technologies such as VR and AR enhance visualization, facilitate better stakeholder engagement, and reduce errors by enabling interactive, three-dimensional representations of construction data (Salam & Ahmad.2020; Mamghani & Nourzhai 2023). Within the Nigerian context, particularly in Lagos Megacity, these innovations offer an opportunity to address critical gaps in construction documentation, resource optimization, and facility lifecycle management (Emesiobi *et al*.2024; Adewumi *et al*. 2023). This chapter reviews relevant concepts, theoretical frameworks, global and local perspectives, and adoption challenges, identifying research gaps that necessitate this study.

2.2 Conceptual Review

Virtual Reality (VR) involves creating fully immersive, computer-generated environments where users can navigate and interact with 3D models using specialized hardware such as head-mounted displays. Generally, in construction, VR allows stakeholders to "walk through" proposed designs before construction begins, improving the interpretation of working drawings and specifications (Salman *et al*., 2020; Fan *et al*., 2023). Augmented Reality (AR) overlays digital information onto real-world environments, enabling users to visualize specifications, structural components, and MEP systems directly on-site. This technology reduces reliance on 2D documentation, improves real-time coordination, and assists contractors in addressing design conflicts during construction phases (Fan *et al*., 2023; Zaher *et al*., 2023). Building Information Modeling (BIM) serves as the backbone of immersive technologies by integrating VR and AR functionalities into a single collaborative platform. It provides intelligent, data-rich 3D models linking working drawings, specifications, schedules, and maintenance data, enabling better communication and decision-making throughout a facility's lifecycle (Adegoke & Ibeh, 2024).

Specifications and Working Drawings outline the quality, standards, and performance requirements of construction materials and systems, while working drawings communicate

technical details for execution (Alugbue *et al*.,2024; Adewumi *et al*.,2025). Moreover, traditionally, discrepancies between these documents and their interpretation contribute to construction delays and disputes. Therefore, VR and AR provide dynamic interfaces for merging these components into more interactive and understandable formats (Alugbue *et al*., 2024).

Facility Management focuses on maintaining and optimizing constructed spaces over their lifecycle (Salman *et al*., 2020; Oladayo *et al*., 2024). Therefore, integrating VR, AR, and BIM into facility management workflows enables proactive maintenance planning, energy optimization, and resource allocation, ultimately improving user comfort and operational efficiency (Emesiobi *et al*., 2024).

2.3 Integration of VR and AR in Construction

Generally, VR and AR convert static 2D drawings into immersive, interactive 3D models. Therefore, Architects and contractors can visualize spatial relationships, test design alternatives, and identify potential conflicts before construction. This reduces ambiguity and fosters more effective collaboration (Fan *et al*., 2023; Salman *et al*., 2020). Usually, specifications traditionally present complex material and performance requirements. But by embedding these specifications into VR/AR models, stakeholders can directly observe how materials, finishes, and structural elements integrate within the built environment (Owolabi *et al*., 2024; Moumanghani *et al*., 2023). Therefore, by offering shared virtual environments, VR and AR bridge communication gaps among multidisciplinary teams. Usually, remote participants can interact with real-time project models, improving decision-making and reducing rework caused by misaligned interpretations (Oladayo *et al*., 2024).

2.4 Impact of BIM in immersive technologies

BIM provides the underlying framework for integrating VR and AR, functioning as a centralized data repository for all construction-related information. Therefore, through BIM-linked immersive technologies such as: construction documentation becomes fully interactive, specifications and schedules are accessible within 3D environments and facility management workflows benefit from intelligent maintenance planning. Moreover, in the Nigerian context, BIM adoption is still at an early stage but gaining momentum, particularly for large-scale developments in Lagos (Adewumi *et al*., 2025; Alugbue *et al*, 2024; Omomade *et al*.2024). Integrating VR and AR with BIM has the potential to set new standards for accuracy, efficiency, and collaboration. Immersive technologies streamline facility operations by linking construction data with building performance metrics. For example: VR enables virtual inspections and predictive maintenance planning, AR assists technicians in locating concealed MEP components, BIM-integrated models centralize lifecycle data for easier updates.

However, This leads to significant cost savings, enhanced sustainability, and improved user experiences, aligning with Nigeria's push for smarter cities and sustainable urban development Despite their potential, integrating VR, AR, and BIM faces several challenges:

- **High Implementation Costs** – Equipment and software are expensive for small- to medium-sized firms.
- **Workforce Skill Gaps** – Limited expertise hinders widespread adoption in Nigeria.
- **Regulatory and Policy Constraints** – Outdated construction codes do not yet support digital integration.
- **Technological Infrastructure** – Inadequate internet speed and power supply issues slow deployment.
- **Interoperability Issues** – Compatibility between existing systems and immersive technologies remains limited.

2.5 Global Perspectives vs. Nigerian Context

Globally, immersive technologies are being widely adopted: In the U.S. and Europe, VR-based clash detection reduces rework by up to **35%**. Japan integrates AR with BIM to optimize earthquake-resistant designs. But in Nigeria, adoption remains nascent due to cost, infrastructural challenges, and low awareness, but emerging projects in Lagos demonstrate growing potential.

This disparity underscores the need for capacity building, local standards development, and targeted investment to close Nigeria's technology gap.

2.6 Theoretical Framework

Technology Acceptance Model (TAM): explains how perceived usefulness and ease of use influence technology adoption. In construction, stakeholders are more likely to adopt VR and AR when they recognize efficiency gains and improved communication.

Diffusion of Innovations Theory: This theory, proposed by Rogers (2003), explains how innovations spread within a social system. Early adopters in Nigeria's construction sector play a critical role in demonstrating the benefits of immersive technologies to encourage widespread implementation.

2.7 Summary of Literature Review

This chapter reviewed existing literature on immersive technologies and their integration with BIM to improve working drawings, specifications, and facility management. While VR and AR are globally transforming construction practices, Nigeria faces adoption challenges such as cost, infrastructural limitations, and regulatory gaps. These issues highlight the importance of developing localized strategies to enable seamless integration.

3. Research methodology

This study adopts a **quantitative research design** to examine the impact of Virtual Reality (VR) and Augmented Reality (AR) on the interpretation of working drawings and specifications within Nigeria's construction industry. This quantitative aspect evaluates measurable improvements in communication, accuracy, and facility management. The research focuses on Lagos Megacity, Nigeria's largest urban and economic hub. Lagos was selected due to its high concentration of construction activities, rapid urbanization, and growing adoption of digital tools. The city's diverse architectural projects, ranging from residential and commercial complexes to infrastructure developments, provide an ideal setting for studying immersive technologies in construction. The target population includes architects, engineers, project managers, contractors, quantity surveyors, and facility managers working on construction projects within Nigeria bulk of who are working in Lagos. Using purposive sampling, 600 professionals were selected based on their involvement in projects where VR, AR, or BIM-

based tools are adopted or explored. This ensures the respondents possess relevant knowledge and practical experience. Quantitative data from questionnaires were analyzed using descriptive statistics (frequency tables, percentages, and charts), in order to present findings clearly, a results table was developed summarizing the contributions of VR, AR, BIM to working drawings, specifications, and facility management:

Table 1: Impact of Immersive Technologies on Construction and Facility Management in Nigeria

Technology / Aspect	Key Findings	Impact on Construction Industry	Implications for Nigeria
Virtual Reality (VR)	Provides immersive 3D environments for reviewing working drawings and specifications before implementation.	Reduces design errors, enhances visualization, and improves client and stakeholder understanding.	Supports better decision-making and minimizes costly project revisions.
Augmented Reality (AR)	Overlays digital specifications and construction details directly on-site.	Improves real-time inspection, reduces miscommunication, and assists contractors during construction.	Enhances efficiency on Nigerian construction sites and improves on-site coordination.
Building Information Modeling (BIM)	Integrates VR/AR to create interactive, data-rich models linking specifications and facility information.	Strengthens collaboration between disciplines, optimizes resource allocation, and streamlines facility management.	Encourages digital adoption for smarter project execution and maintenance in Lagos and beyond.
Working Drawings & Specifications	Enhanced through immersive technologies, making complex details more understandable.	Improves accuracy, ensures quality compliance, and simplifies construction documentation.	Minimizes disputes, delays, and rework in Nigeria's construction projects.
Facility Management	BIM-linked VR/AR models enable efficient monitoring of building performance and maintenance needs.	Optimizes lifecycle management and sustainability of constructed facilities.	Drives resource efficiency and supports sustainable facility operations.

Validity of the questionnaires were reviewed by academic experts to ensure alignment with the study objectives. Reliability was achieved by a pilot survey was conducted among 10 professionals to test consistency, resulting in a Cronbach's Alpha value of 0.84, indicating strong reliability. All participants were informed of the study's objectives and consented to share their insights. Moreover, confidentiality was maintained, and data collected were used strictly for academic purposes. Overall This chapter outlined the research methodology used to investigate the impact of VR and AR technologies on working drawings and specifications. The quantitative approach facilitated a comprehensive understanding of immersive technologies within Lagos' construction industry. The next chapter presents the data analysis and interpretation, highlighting trends, barriers, and recommendations for future adoption.

4. Results and Discussion

This chapter presents the results of the research on the impact of Virtual Reality (VR) and Augmented Reality (AR) technologies on working drawings and specifications in the modern construction industry, with a particular focus on Lagos Megacity. The analysis is based on data collected from architects, engineers, contractors, and facility managers, highlighting how immersive technologies influence design accuracy, collaboration, and facility management practices.

4.1 Demographic Characteristics

Table 2, presents the demographic profile of the 539 respondents drawn from Nigeria's construction industry of which 474 (87.94%) were from Lagos state.

Table 2: Demographic Characteristics of Respondents

Variable	Category	Frequency (N=539)	Percentage (%)
Gender	Male	275	51.02
	Female	264	48.98
Age Range	Less than 20 years	71	13.17
	21 – 30 years	137	25.42
	31 – 40 years	109	20.22
	41 – 50 years	160	29.68
	51 years & above	62	11.50
Education Level	Below First Degree	78	14.47
	First Degree (HND/BSc)	128	23.75
	Master's Degree	196	36.36
	Doctorate	65	12.06
	Others	72	13.36
Years of Experience	0 – 5 years	106	19.67
	6 – 10 years	104	19.29
	11 – 15 years	149	27.64
	16 – 20 years	92	17.07
	Above 20 years	88	16.33
Profession	Architect	173	32.10
	Contractor	77	14.29
	Engineer	61	11.32
	Surveyor	76	14.10
	Others	79	14.66
Location	Lagos State	474	87.94
	Other States	65	12.06

Source: Fieldwork, 2025

4.2. Presentation of Results and Discussion by Objective

This section presents findings based on the research objectives, summarizing key results in tables and discussing their implications.

4.3. Objective One: Extent of BIM Adoption

Respondents were asked about their perception of BIM tools in producing working drawings and specifications.

Table 3: Perceptions of BIM Tools and Software

Statement	Mean Score	RII	Rank
BIM tools improve the accuracy of working drawings.	3.469	0.694	1
BIM integrates seamlessly with working drawings.	3.406	0.681	2
Satisfaction with BIM features.	3.369	0.674	3
Learning curve for using BIM is manageable.	3.354	0.671	4
BIM tools enhance the efficiency of the design process.	3.265	0.653	5

Source: Fieldwork, 2025

Discussion:

Findings indicate that BIM significantly improves the accuracy and integration of working drawings (RII = 0.694). Respondents agreed that BIM enables seamless coordination across documentation, aligning with Okereke, Muhammed, & Eze (2021), who note BIM's potential in minimizing drawing errors. However, respondents rated BIM's ability to enhance design efficiency lower, suggesting underutilization of its full capabilities.

4.4. Objective Two: BIM Integration and Collaboration

Respondents evaluated BIM integration within the construction workflow and its effectiveness in enhancing interdisciplinary collaboration.

Table 4: Level of BIM Integration

Statement	Mean Score	RII	Rank
BIM integration meets expectations.	3.403	0.681	1
BIM integration reduces errors in working drawings.	3.328	0.666	2
BIM is integrated into all design stages.	3.189	0.638	3
BIM improves coordination between disciplines.	3.419	0.684	4
BIM implementation improves overall project outcomes.	3.345	0.669	5

Source: Fieldwork, 2025

Discussion:

BIM's ability to reduce drawing errors and improve collaboration ranked highly, consistent with Emesiobi *et al*. (2024), who emphasized BIM's strength in fostering interdisciplinary integration. However, the relatively lower score for full integration (mean = 3.189) shows that BIM adoption is still uneven across different project stages.

4.5. Objective Three: VR and AR in Construction Documentation

Respondents assessed the role of Virtual Reality (VR) and Augmented Reality (AR) in improving visualization and communication of working drawings.

Table 5: Role of VR and AR Technologies

Statement	Mean Score	RII	Rank
VR/AR improves understanding of working drawings.	3.206	0.641	1
VR/AR aids visualization of complex drawings.	3.304	0.661	2
VR/AR enhances the design review process.	3.416	0.683	3
VR/AR provides realistic representation of final outcomes.	3.178	0.636	4
VR/AR improves communication of design intent.	3.223	0.645	5

Source: Fieldwork, 2025

Discussion:

The integration of VR and AR enhances visualization, design reviews, and communication across stakeholders. These findings align with Adewumi *et al*. (2025), who highlighted those immersive environments reduce misinterpretation of construction documentation. However, adoption remains limited due to hardware costs, lack of training, and slow regulatory acceptance.

4.6. Summary of Key Findings

- **BIM significantly enhances drawing accuracy** and reduces misinterpretation (**RII = 0.694**).
- **Integration across disciplines is improving**, but adoption remains **partial and inconsistent**.
- **VR and AR tools** improve visualization, stakeholder communication, and design validation.
- High **costs**, **digital literacy gaps**, and **lack of regulatory frameworks** remain the main barriers.

5. Conclusion and recommendations

The study explored how immersive technologies—Virtual Reality and Augmented Reality—can transform the development, understanding, and enforcement of construction specifications and working drawings.

Key findings include the following: Traditional documentation methods in Lagos are inadequate for modern project demands. VR and AR technologies enhance interpretation, reduce disputes, and support real-time coordination. Lifecycle maintenance can be significantly improved through AR-enabled specification access. Major challenges to adoption include cost, awareness, training, and

regulatory gaps.

The Nigerian construction industry, particularly in Lagos Megacity, stands to gain significantly from the integration of VR and AR into its documentation workflows. These technologies offer more than flashy visualization—they are tools for accuracy, compliance, and sustainable performance. Therefore, by embedding specifications within interactive 3D environments, immersive tools transform how designers, contractors, and facility managers engage with construction data. While the road to adoption is steep, the long-term gains in quality, communication, and cost-efficiency are compelling.

In order to enable implementation, the following actions are recommended:

- Update building codes and project documentation guidelines to accept digital-native and immersive formats.
- Provide innovation grants and tax incentives to firms adopting immersive documentation.
- Integrate VR/AR and BIM training modules into architecture and engineering curricula.
- Organize continuous professional development workshops in immersive technologies.
- Start with small-scale pilot projects using immersive documentation to test workflows.
- Invest in open-source or cost-effective immersive software platforms like Enscape, Unity Reflect.
- Encourage early contractor involvement (ECI) and shared model reviews using VR platforms.
- Build BIM coordination hubs where stakeholders can collectively review specifications in immersive form.

5.1. Suggestions for Further Research Includes the following;

- Field-based case studies on immersive documentation use in Nigerian public infrastructure projects.
- Quantitative impact studies comparing immersive vs traditional documentation outcomes.
- Development of a Nigerian VR/AR implementation framework tailored to the local construction ecosystem.

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