Evaluating the Drivers of Virtual Reality Applications for Facilities Management in the Construction Industry

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Abstract
Virtual Reality (VR) technology has emerged as a transformative tool in various industries, including construction and Facilities Management (FM). This study aims to evaluate the key drivers behind VR applications for facilities management within the construction industry. A field survey was conducted among construction professionals in Gauteng province, South Africa, to identify the drivers of VR applications for FM in construction. A random sampling method was used to collect data, and 127 questionnaire responses were received from the construction professionals within the study area. Data collected was computed using a descriptive statistical approach, and the valid mean item score was determined. The study findings identified and ranked the drivers, with the highest being to include quality improvement, reduced cost, productivity improvement, research and development improvement, safety enhancement, and delivery services efficiency as part of leading drive and mitigation of project safety risk and the lowest ranked being stakeholder curiosity. The study concludes that embracing VR technology through a better understanding of drivers for its application is a catalyst for advancing facilities management practices in the construction industry. It also established that with a proactive approach to integration and leveraging the diverse benefits offered by VR, facilities management in the construction industry can position themselves at the forefront of innovation and achieve sustainable growth within the industry.

Keywords
Virtual Reality, Construction Industry, Facilities Management, Drivers, South Africa

1. Introduction
The adoption of Virtual Reality (VR) technologies in the Facilities Management (FM) in the construction industry is driven by a compelling array of factors that promise transformative benefits. These drivers collectively contribute to the recognition that VR can revolutionize how FM professionals engage with the built environment, leading to improved outcomes and enhanced operational efficiency. VR is a transformative technology in different industries, including for FM in the construction industry. Despite promising potential, the widespread adoption of VR technologies in the construction industry faces obstacles that affect the drivers of this tool (Oke et al., 2022). The high cost of VR equipment presents a substantial challenge to Facilities Management (FM) in the construction industry, as documented by El-Mashaleh (2007) and Oladapo (2007). Financial constraints, maintenance costs, and the necessity for effective staff training are significant barriers, highlighting the multifaceted financial obstacles that impede widespread VR adoption. Addressing these challenges is essential for the successful integration of VR into FM practices. The need for specialized skills emerges as a critical challenge in applying VR for FM in the construction industry, echoing insights from Badamasi et al. (2022) and Hampson et al. (2014). Issues include a lack of expertise, resistance to cultural change, the cost of VR implementation, the complexity of application development, and broader technological immaturity. Additionally, the scarcity of skilled VR professionals, as noted by Hampson et al. (2014), complicates the integration of VR into FM activities, as professionals often seek opportunities in the entertainment and gaming sectors. Addressing these challenges is imperative for fostering the effective utilization of VR in the construction FM landscape.
Another major challenge in integrating VR applications for FM in the construction industry is the lack of standardization, as highlighted by Oke et al. (2018) and Lapierie and Cotep (2008). According to Oke et al. (2018),

key barriers to digital technology adoption in FM include insufficient training, high costs, inadequate adaptability of standards, and interoperability issues. These factors contribute to a complex landscape for effective VR implementation in FM. Lapierie and Cotep (2008) further noted that the absence of industry standards hinders the seamless incorporation of digital technologies in FM activities. Addressing this challenge is crucial to unlocking the full potential of VR in construction FM, necessitating efforts towards standardization and interoperability within the industry. The lack of awareness among facilities managers regarding VR is a significant impediment to its application in the construction industry, as elucidated by Badamasi et al. (2022). Other challenges include a shortage of skills and expertise, resistance to change, high implementation costs, complexity in application development, and broader issues of technological immaturity and inadequate awareness Badamasi et al. (2022). To fully realize the potential of VR for FM in construction, it is crucial to address these multifaceted challenges, with a particular emphasis on enhancing awareness and understanding among facilities managers. Hence, this study aims to explore the diverse drivers of VR application for FM in the construction industry, in view to bridging the productivity gap in FM in the construction industry, as elucidated by recent scholarly contributions.

2. Literature review

Strohanova (2019) and Miller (2020) emphasize the role of VR in enhancing quality standards for FM. By providing immersive visualization and simulation capabilities, VR enables stakeholders to identify and rectify potential issues early in the facility lifecycle, thereby improving overall project quality. Hegeman (2018) and Strohanova (2019) highlight VR's potential for cost reduction in FM. Through virtual prototyping and simulation, VR allows FM teams to identify cost-saving opportunities, optimize resource allocation, and minimize rework, ultimately leading to reduced management costs. Strohanova (2019) and Miller (2020) discuss how VR can drive productivity improvement and foster innovation through research and development. By facilitating virtual collaboration, experimentation, and prototyping, VR accelerates the pace of R&D activities and enhances productivity across FM teams. Hegeman (2018) and Miller (2020) underscore VR's role in enhancing safety in FM. Through immersive training simulations and hazard identification scenarios, VR equips FM stakeholders with the skills and awareness necessary to mitigate risks and ensure a safe working environment. Ramírez et al. (2015) explore VR's potential for improving delivery services efficiency and fostering better communication for FM teams. By enabling virtual walkthroughs and real-time communication, VR enhances coordination and collaboration among distributed stakeholders, leading to more efficient service delivery processes.

Ramírez et al. (2015) emphasize VR's capacity to facilitate stakeholder collaboration and enhance FM understanding. By providing stakeholders with immersive FM experiences and visualization tools, VR promotes alignment of objectives, fosters stakeholder engagement, and enhances overall comprehension of FM processes. Martínez et al. (2014) elucidate the benefits of VR-based 3D visualization techniques in driving stakeholder curiosity and engagement. By offering realistic and interactive FM representations, VR stimulates stakeholder curiosity, encourages exploration, and fosters a deeper understanding of FM concepts and complexities. Friedman (2017) and Haggard (2017) highlight VR's potential for improving project outcomes while minimizing resource wastage. Through comprehensive design changes, construction concept analysis, and complex process simulation, VR enables teams involved in FM to optimize resource utilization and enhance project deliverables. Castro-Lacouture (2009) discusses how VR can align FM activities with industry best practices and mitigate risks. By providing immersive training environments and scenario simulations, VR enhances FM teams' preparedness to address potential risks and adhere to established standards. Castro-Lacouture (2009) and Martínez et al. (2014) explore VR's potential for ensuring smoother facility operations and improving operational efficiency within FM activities. By simulating facility workflows and optimizing operational processes, VR enables FM stakeholders to enhance FM and streamline operations.

Friedman (2017) and Haggard (2017) emphasize the importance of technical expertise in leveraging VR effectively for FM. By providing training and upskilling opportunities in VR technologies, FM teams can harness VR's full potential and overcome technical challenges. Martínez et al. (2014) shed light on the role of VR in stimulating stakeholder curiosity in FM. By leveraging immersive 3D visualization and interactive experiences, VR fosters a sense of exploration and intrigue among FM stakeholders. Through virtual walkthroughs and interactive simulations, stakeholders are provided with opportunities to engage with FM concepts and explore various scenarios, thereby igniting curiosity and deepening their understanding of FM intricacies. Martínez et al. (2014) emphasize that by nurturing stakeholder curiosity, VR enhances engagement, promotes active participation, and ultimately contributes to the success of FM in construction industry.

In conclusion, this review underscores the multifaceted nature of VR as a driver of innovation and efficiency in FM. By applying VR for FM processes, organizations can enhance collaboration, improve decision-making, and achieve superior project outcomes in today's dynamic business landscape.

2.

Table 1. Drivers of Virtual Reality application for Facilities Management in the construction industry

DVR Variables	Authors
Quality Improvement	Strohanova 2019; Miller, 2020
Reduced Cost	Hegeman, 2018; Strohanova 2019
Productivity Improvement	Strohanova 2019; Miller, 2020
Research and development improvement	Strohanova 2019; Miller, 2020
Safety Enhancement	Hegeman, 2018; Miller, 2020
Delivery services efficiency	Ramírez et al., 2015
Better communication	Ramírez et al., 2015
Stakeholder Collaboration	Ramírez et al., 2015
Project 3D visualization	Martínez et al., 2014
Project outcome improvement	Friedman, 2017; Haggard, 2017
Less resources wastage	Friedman, 2017; Haggard, 2017
Alignment with best practices	Castro-Lacouture, 2009
Project understanding	Ramírez et al., 2015
Risks mitigation	Castro-Lacouture, 2009
Ensure smoother facility operations	Castro-Lacouture, 2009
Operational Efficiency	Martínez et al., 2014
Comprehensive design changes	Friedman, 2017; Haggard, 2017
Construction concept analysis	Friedman, 2017; Haggard, 2017
Complex process simulation	Friedman, 2017; Haggard, 2017
Technical expertise	Friedman, 2017; Haggard, 2017
Stakeholder Curiosity	Martínez et al., 2014

Source: Authors review (2023)

The study conducted by Badamasi et al. (2022) demonstrated that VR application for FM practices within the construction industry serves as a guiding force, ensuring that FM progresses in the intended direction. As depicted in Table 1 above, the drivers associated with VR application in FM play a pivotal role in enhancing project efficiency. This holds particular significance for FM within the construction sector, as it facilitates informed decision-making, ultimately leading to successful project execution (Martínez et al., 2014). Despite the concerted efforts of industry professionals in implementing VR for FM practices, there remains a need to establish a comprehensive understanding of its drivers among stakeholders. Furthermore, there is a scarcity of studies that delve into the drivers of VR application for FM practices within the construction industry, particularly in developing economies (Oesterreich and Teuteberg, 2016; Ogunbayo et al., 2023). Therefore, this study aims to evaluate the drivers of VR application for FM in the construction industry, focusing on the perspectives of professionals within the South African construction sector.

3. Methodology

This study was carried out within Guateng province in South Africa among Professionals working with digital technologies for facilities management in the construction industry. Respondents for this study were selected based on their involvement and experience with facility management processes in the construction industry. Guateng province was chosen for this study due to its numerous FM-driven construction projects and facilities. Through the systematic random sampling method 200 questionnaires were administered to the respondents, and 127 were retrieved. This study used random sampling method because it is easier and more direct and eliminated the possibility of clustering when adopted than cluster sampling, which breaks the population into different clusters and takes a simple random sample from each cluster (Rea & Parker, 2014). It also tends to cover all the elements evenly (Ogunbayo et al., 2023). The questionnaire was designed on a 5-point Likert scale and recorded a 64% response rate, using Strongly Disagreeing=1, Disagreeing=2, Neutral=3, Agreeing=4, and Strongly Agree=5. The data collected from respondents were screened and cleaned before the analysis. The respondents were asked questions about their, years of experience, profession, highest educational qualification, firm types they currently work for, number of construction projects they have been involved in, in the construction industry. Through the questionnaire, respondents were further asked about twenty-one drivers of VR application for FM in the construction industry identified from the literature.

The study conducted descriptive analysis, including percentage, frequency, mean item score, and standard deviation. This was conducted to examine the outcomes of the Likert inquiries about this research questionnaire. After computation, the drivers of VR application for FM in construction practices identified were sorted from the highest to lowest. The computation was based on the weighted responses from the survey participants for each question. It was also aligned with the scores chosen by the respondents that were deemed collectively as the analytically agreed indicators of comparative significance. This helped this study assess the drivers of VR application for FM in projects in the construction industry. The study adopted descriptive statistical tools to analyse how participants rated various questions in the survey questionnaire. According to Pallant (2020), means are significant in descriptive research since they reveal average participant scores on a given measure. The standard deviation explains the sample through a descriptive statistic that computes the numbers spread across the mean (Bell Bryman, 2011). The descriptive analysis conducted included percentage, frequency, and standard deviation.

4. Results

Respondents' highest level of education is presented in Figure 1. The findings indicate that 30.2% (38) of respondents had an honour’s degree, 24.6% (31) had a master’s degree, 23.8% (30) had a bachelor's degree, 18.3% (23) had a diploma degree, and 1% (1) with a Matric (grade 12).

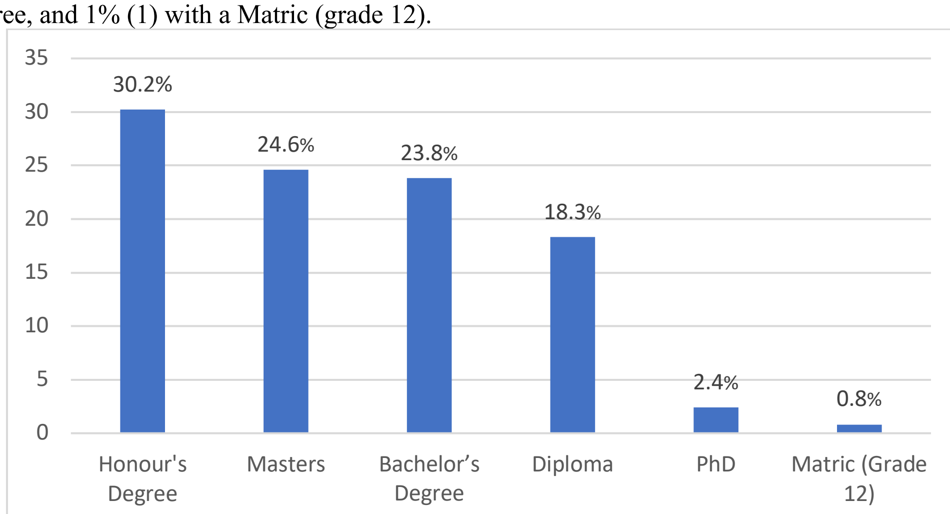

Figure 1. Respondents highest level of education

Figure 2. presents respondents' years of working experience in procurement processes in the South African construction industry. 38.1% (48) had 11-15 years of working experience, 34.1% (43) had 6-10 years of working experience, 13.5% (17) had 16-20 years of working experience, 6.3% (8) had 21-25 years of working experience, 5.6% (3) had 1-5 years of working experience, and 2.4% (3) had above 25 years of working experience.

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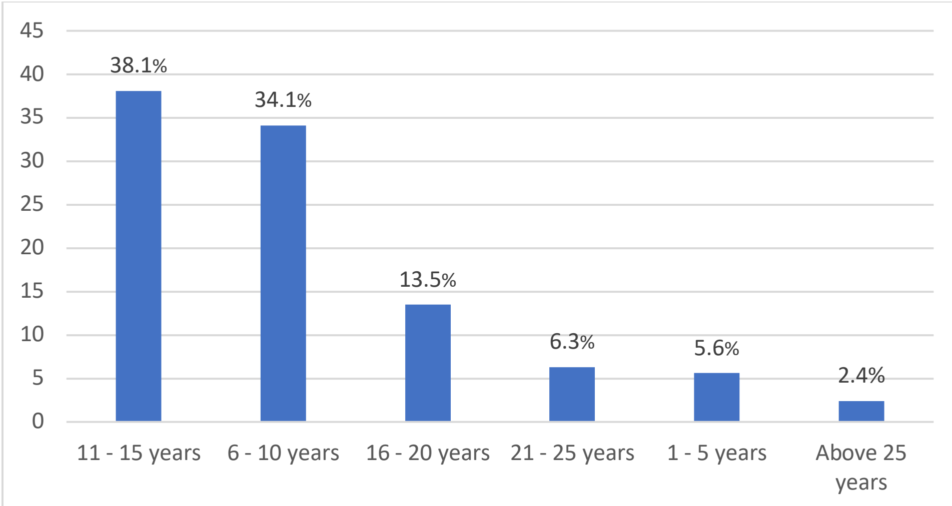

Figure 2. Respondents years of working experience

Figure 3. presents responses to the types of current firms that respondents work for in the South African construction industry. This comprises 46% (58) contracting firms, 34.9 consulting firms, and 19% (24) government parastatal.

Figure 3. Types of current firms respondents work for in the South African construction industry

Table 2. presents the results of descriptive statistics using Mean Score (MS) and Standard Deviation (Std. Dev.), ranking the drivers of virtual reality applications for FM projects in the South African construction industry. The responses to the twenty-one identified drivers of virtual reality application for FM projects using a five-point Likert scale of 5-point scale: 1= Strongly disagree (SD); 2= Disagree (D); 3= Neutral (N); 4= Agree (A); 5= Strongly agree (SA) to establish the rank of respondents scores.

Quality improvement ranked first with 3.56 MS and 1.092 Std Dev; reduced cost ranked second with 3.51 MS and 1.192 Std Dev; productivity improvement ranked third with 3.45 MS and 1.048 Std Dev; research and development improvement ranked fourth with 3.42 MS and 1.175Std Dev; safety enhancement ranked fifth with 3.33 MS and 1.058 Std Dev; Std Dev; delivery services efficiency ranked sixth with 3.28 MS and 1.164 Std Dev; better communication ranked seventh with 3.24 MS and 1.189 Std Dev; stakeholder collaboration ranked eighth with 3.21 MS and 1.148 Std Dev; project 3D visualization ranked ninth with 3.20 MS and 1.187 Std Dev; and project outcome improvement ranked tenth with 3.14 MS and 1.313 Std Dev. Similarly, virtual reality applications encourage less resource wastage with 3.09 MS and 1.213 Std Dev; alignment with best practices with 3.09 MS and 1.321 Std Dev; and project understanding with 3.09 MS and 1.252 Std Dev, ranked eleventh. Risk mitigation ranked fourteenth with 3.07 MS and 1.303 Std Dev; ensuring smoother facility operations ranked fifteenth with 3.03 MS and 1.245 Std Dev. The last six variables least ranked include operational efficiency, ranked sixteenth with 2.99 MS and 1.299 Std Dev; comprehensive design changes ranked seventeenth with 2.97 MS and 0.809 Std Dev; construction concept analysis with 2.87 MS and 0.829 Std Dev, and complex process simulation with 2.87MS and 0.889 Std Dev ranked eighteenth; technical expertise ranked twentieth with 2.83 MS and 0.980Std Dev; and stakeholder curiosity ranked fifteenth with 2.75 MS and 0.885 Std Dev, respectively.

Table 2. Drivers of virtual reality application for Facilities Management in the construction industry

DVR Variables	Mean	Std. Deviation	Rank
Quality Improvement	3.56	1.092	1
Reduced Cost	3.51	1.192	2
Productivity Improvement	3.45	1.048	3
Research and development improvement	3.42	1.175	4
Safety Enhancement	3.33	1.058	5
Delivery services efficiency	3.28	1.164	6
Better communication	3.24	1.189	7
Stakeholder Collaboration	3.21	1.148	8
Project 3D visualization	3.20	1.187	9
Project outcome improvement	3.14	1.313	10
Less resources wastage	3.09	1.213	11
Alignment with best practices	3.09	1.321	11
Project understanding	3.09	1.252	13
Risks mitigation	3.07	1.303	14
Ensure smoother facility operations	3.03	1.245	15
Operational Efficiency	2.99	1.299	16
Comprehensive design changes	2.97	0.809	17
Construction concept analysis	2.87	0.829	18
Complex process simulation	2.87	0.889	18
Technical expertise	2.83	0.980	20
Stakeholder Curiosity	2.75	0.885	21

5. Discussion

The study assessed VR application for FM in the South Africa construction industry. The result of the study indicated that quality improvement, reduced cost, productivity improvement, research and development improvement, safety enhancement, delivery services efficiency, and better communication were the highest ranked (1^{st} – 7^{th}) drivers of VR application for FM in the construction industry. The findings align with Strohanova (2019), Miller (2020) and Hegeman (2018) that the drivers of VR application for FM practices in construction are quality improvement, reduced cost, productivity improvement, research and development improvement, safety enhancement. It also aligns with the study of Ramírez et al (2015) that delivery services efficiency, and better communication are also drivers of VR application for FM in construction. The study findings imply that the drivers of VR for FM in construction will lead to, quality improvement, reduced cost, productivity improvement, research and development improvement, safety enhancement, delivery services efficiency, and better communication among stakeholders, if VR applications is well implemented in construction processes within the construction industry.

The findings also showed that stakeholder collaboration, project 3d visualization, project outcome improvement, less resources wastage, alignment with best practices, project understanding, risks mitigation was mediumly ranked (8^{th} – 14^{th}) drivers of VR application for FM in the construction industry. The study affirmed the findings of Ramírez et al (2015) of stakeholder collaboration and project understanding being some of the drivers while it agreed with the study of Martínez et al (2014) of Project 3D visualization being one of the drivers also. The study also agrees with Friedman (2017) and Haggard (2017) that, project outcome improvement and less resources wastage are drivers of VR application for FM in the construction industry. The findings further support Castro-Lacouture (2009) study that alignment with best practices will also be a driving force of VR application for FM in the construction industry. The study implies that the driving forces of VR application for FM in construction are very essential to improving project outcomes and enhancing visualization.

Furthermore, the findings indicated that ensure smoother facility operations, operational efficiency, comprehensive design changes, construction concept analysis, complex process simulation, technical expertise, stakeholder curiosity are least ranked (15^{th} – 21^{st}) drivers of VR application for FM in the construction industry. This supports Castro-Lacouture, (2009) that risk mitigation and ensure smoother facility operations will drive the VR application for FM in the construction industry. This also supports Martínez et al (2014) that operational efficiency and stakeholder curiosity are also drivers of VR application for FM in the construction industry. Friedman, (2017) and Haggard, (2017) study is supported in that, comprehensive design changes, construction concept analysis, complex process simulation, technical expertise will create a drive in VR application for FM in the construction industry. The study's findings suggest that while factors such as risk mitigation and operational efficiency are key drivers of VR application for Facilities Management (FM) in the construction industry, there is also potential for comprehensive design changes, construction concept analysis, complex process simulation, technical expertise, and stakeholder curiosity to play significant roles in driving VR adoption in FM practices.

6. Conclusions and Recommendations

The study assessed Virtual Reality (VR) application for Facilities Management (FM) in the South Africa construction industry. Specifically, this study assessed drivers of VR application for FM in the construction industry. The study identified quality improvement, reduced cost, productivity improvement, research and development improvement, safety enhancement, delivery services efficiency, and better communication as the major drivers of VR application for FM in the construction industry. The study established that the drivers of VR application for FM identified benefits the construction industry through the improvements and expansion and adoption of VR into more FM activities. Further, the study asserted the assistance for FM activities in construction to achieve a set of specific goals can be achieved by employing VR as a powerful technological tool that it is. The study suggested that more awareness is needed about the drivers of the VR technology to be made known to construction professionals in FM services to continue enjoying the advantages of VR application for FM in the construction industry.

Furthermore, organizing trainings on the drivers of VR application for FM activities in the construction industry for FM professionals is necessary. Trainings to enhance the understanding of stakeholders about the drivers of VR application for FM in the construction industry is also necessary. This study contributes to the existing body of knowledge by enabling FM professionals to recognise the vast drivers of VR application for FM in the construction industry to achieve a set of laid down FM objectives.

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