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

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Abstract
Virtual Reality (VR) has emerged as a revolutionary technological asset across multiple sectors, including the construction and Facilities Management (FM) industry. This study aims to evaluate the level of VR applications for facilities management in the construction industry. A field survey was conducted among construction professionals in Gauteng province, South Africa, to identify the level of virtual reality applications for facilities management in construction projects. 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 level of VR application, with the highest being space modelling, planning of construction processes, virtualisation of buildings, site layout planning, fire risk assessment, and site landscaping, and the lowest ranked being promoting information among users. In conclusion, this study highlights the growing utilisation and varied applications of Virtual Reality (VR) for Facilities Management (FM) within the construction industry, providing valuable insights for advancing operational efficiency and decision-making processes. Furthermore, it was established that by proactively integrating VR and harnessing its different advantages, facilities management within the construction industry can lead to innovation and attain sustainable growth in its level of applications.

Keywords
Virtual Reality, Construction Industry, Facilities Management, Application, South Africa.
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1. Introduction

According to Pitt et al. (2005), Virtual Reality (VR) is a groundbreaking technology with vast potential across various industries, offering novel approaches to enhance operations, efficiency, and innovation. In the construction sector, VR holds promise for Facilities Management (FM), presenting opportunities to revolutionise traditional practices and improve project outcomes (Pitt et al., 2005). VR as a technology for FM projects encompasses a wide array of applications, ranging from space modelling and site layout planning to fire risk assessment and virtual site inspections (Bouchlaghem et al., 1996; Ogunbayo et al., 2022).

In the construction industry of developing countries, VR applications for FM are increasingly employed for more efficient outcomes and cost and timely savings on FM practices (Bouchlaghem, 2005; Kunz & Fischer, 2012). To achieve this, stakeholders must push for the expansions of VR applications to cover a much broader range of FM activities in a facility lifecycle (Pitt et a., 2005; Wang et al., 2019; Mozaffari et al., 2005). VR was introduced to FM of the building and construction process, allowing contractors to design, construct, and operate based on a comprehensive model (Kunz et al., 2012). However, it is worth noting that virtual prototyping in the manufacturing sector has advanced significantly compared to its adoption in construction (Abina et al., 2023). A key concern for construction planners is determining the most suitable digital technology tools for FM in the construction industry (Huang et al., 2007). Facility management can virtually inspect the construction site and facilities, identify potential issues, and provide feedback without being physically present (Bamgbose et al., 2024).

The study by Pratama and Dossick (2019) highlighted several applications of VR for FM in the construction industry, such as space modelling, planning of construction processes, site layout planning, fire risk assessment, site landscaping, monitoring of construction processes, and space selling. Also, the studies of Kunz and Fischer (2012) and Abina et al. (2023) indicated that although the applications of VR for FM can be extended to virtual site inspection, design simulation, interior designing, construction planning, designing driving simulators, simulating architectural structures, operational safety training, and promoting information among users are the VR applications for FM that they identified.

The study by Wolfartsberger (2019) suggested that Space modelling, planning of construction processes, virtualisation of buildings, and site layout planning were areas through which VR can be used for FM in the construction industry. The studies of Huang et al. (2007) posit that VR in FM can be used for fire risk assessments, Landscaping, virtual site inspection, and Design Simulation. Its application can also aid in air conditioning design, interior design, and lighting design for FM (Liu & Seipel, 2018; Huang et al., 2007). The studies of Elmualim and Gilder (2014), Boston (2018), and Wolfartsberger (2019) informed that the application of VR for FM in monitoring construction processes, heating ventilation designing, construction planning, and designing driving simulators. Also, Syberfeldt et al. (2015), Whyte and Nikolic (2018), and Pratama and Dossick (2019) noted that the VR applications for FM in the construction industry include simulating architectural structures, Operational safety training, Space selling, and Promoting information among users. Bouchlaghem (2005) stated that visualisation in virtual design applications serves a purpose beyond mere visual representation, as it should be an iterative process where insights gained through visualisation inform and influence subsequent versions of the design for facilities.

Thus, FM, Architects, engineers, and stakeholders can use VR to explore 3D models of the planned facility before construction begins, gaining a better understanding of spatial relationships, layouts, and aesthetics (Whyte & Nikolic, 2018). It can also be used for real-time design adjustments, allowing for on-the-fly modifications and iterations, leading to more informed decisions (Kandi et al., 2020). Virtual reality offers a valuable avenue for the construction industry to enhance productivity, address process-related challenges, and draw insights from manufacturing sectors (Elmualim & Gilder, 2014; Abina et al., 2023). The process of virtual prototyping (VP) involves utilising computer-aided design to construct digital models, known as virtual prototypes, and creating realistic graphical simulations that encompass aspects such as physical layout, operational concept, functional specifications, and dynamic analysis in diverse operating conditions (Elmualim & Gilder, 2014; Ogunbayo & Aigbavboa, 2022).

The study of Carreira et al. (2018) established that understanding the level of VR application for FM ensures that facilities will have broader applications to the FM processes. As shown in Table 1 above, VR applications are valuable in improving FM and giving efficiency in the construction industry. It is significant to the construction industry's performance as it facilitates strategic decision-making for successful FM toward management capacity expansion (Owolabi et al., 2023; Kunz & Fischer, 2012). Despite efforts made by construction professionals and facility managers to improve the VR application for FM in the construction industry, understanding the different levels of its application in FM among stakeholders needs to be established. Also, few studies have established the level of VR application for FM within the construction industry (Pratama & Dossick, 2019; Wolfartsberger, 2019; Abina et al.,2023). Hence, this study evaluates the level of VR applications for FM in the construction industry with the aim of bridging the productivity gap in FM through the application of VR , drawing upon a rich body of literature, empirical evidence, and quantitative results. By synthesising insights from diverse sources, it aims to provide valuable perspectives that inform future research directions, industry practices, and policy decisions in leveraging VR technologies applications for FM within the construction sector.

2. Methodology

This study was carried out within Gauteng 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. Gauteng 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 the random sampling method because it is more straightforward and more direct. It also eliminates the possibility of clustering when adopted, unlike 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, and number of construction projects they have been involved in in the construction industry. The questionnaire further asked respondents about nineteen levels of VR application for FM in the construction industry identified from the literature.

2.

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 level of VR application for FM practices in the construction industries identified was 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 level 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.

3. Survey Results

The highest level of education of the respondents 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).

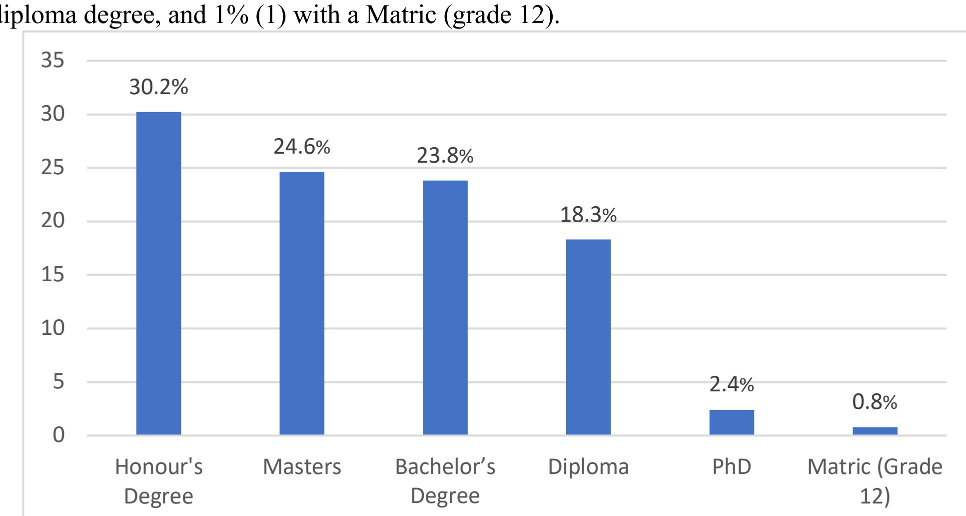

Figure 1. Respondents highest level of education

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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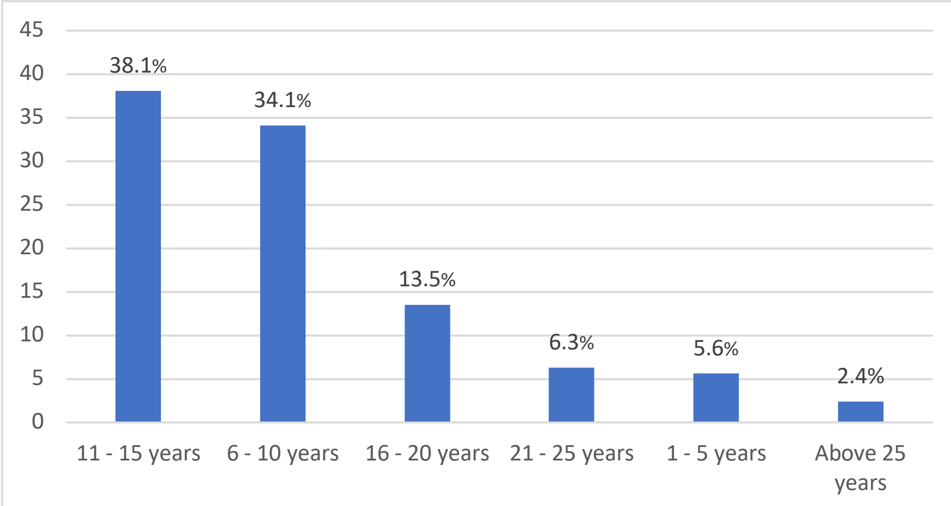

Figure 2. Respondents years of working experience

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.

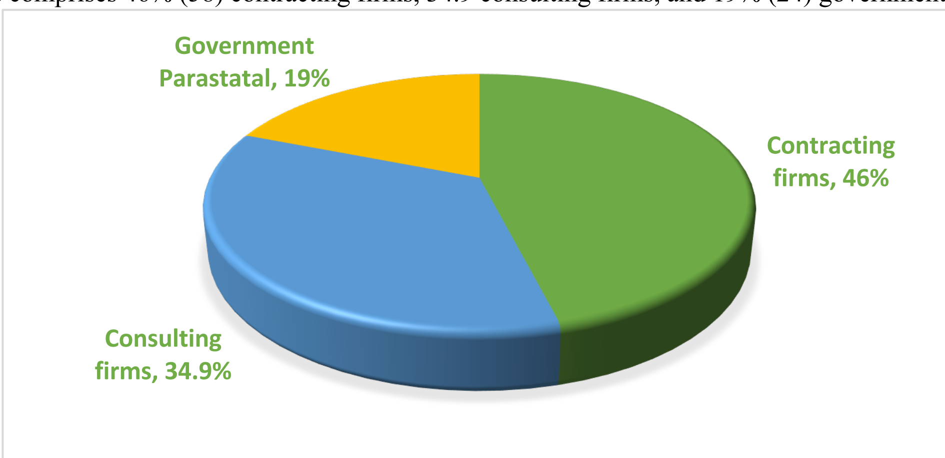

Figure 3. Types of current firms respondents work for in the South African construction industry

Table 2. Level of Virtual Reality application for Facilities Management in the construction industry

Level of VR application for FM	Mean	Std. Deviation	Ranking
Space modelling	4.70	0.707	1
Planning of construction processes	4.50	0.713	2
Virtualisation of buildings	4.50	0.616	2
Site layout planning	4.48	0.690	4
Fire risk assessment	4.44	0.699	5
Site Landscaping	4.31	0.687	6
Virtual site inspection	4.30	1.037	7
Design Simulation	3.30	1.334	8
Air Conditioning designing	3.09	1.220	9
Interior Designing	3.03	1.245	10

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Lighting Designing	2.92	1.383	11
Monitoring of construction processes	2.83	1.251	12
Heating Ventilation designing	2.82	1.422	13
Construction planning	2.81	1.355	14
Designing driving simulators	2.72	0.909	15
Simulating architectural structures	2.69	0.950	16
Operational safety training	2.57	1.015	17
Space selling	2.57	0.925	17
Promoting information among users	2.41	0.957	19

Table 2. presents the results of descriptive statistics using Mean Score (MS) and Standard Deviation (Std. Dev.), ranking the level of virtual reality application for FM of projects in the South African construction industry. The responses to the nineteenth identified level of VR application for FM of 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.

Space modelling ranked first with 4.70 MS and 0.707 Std Dev; planning of construction processes with 4.50 MS and 0.713 Std Dev; and virtualisation of buildings with 4.50 MS and 0.616 Std. Dev ranked second; site layout planning ranked fourth with 4.48 MS and 0.690 Std Dev; fire risk assessment ranked fifth with 4.44MS and 0.699 Std Dev; site landscaping ranked sixth with 4.31MS and 0.687 Std Dev; virtual site inspection ranked seventh with 4.30 MS and 1.037 Std Dev; design simulation ranked eighth with 3.30 MS and 1.334 Std Dev; air conditioning designing ranked ninth with 3.09 MS and 1.220 Std Dev; and interior designing ranked tenth with 3.09 MS and 1.245 Std Dev. Likewise, lighting designing ranked eleventh with 2.92 MS and 1.383 Dev; monitoring of construction processes ranked twelfth with 2.83 MS and 1.251 Std Dev; heating ventilation designing ranked thirteenth with 2.82 MS and 1.422 Std Dev; construction planning ranked fourteenth with 2.81 MS and 1.355 Std Dev; and designing driving simulators ranked fifteenth with 2.72 MS and 0.909 Std Dev. The four least ranked variables were simulating architectural structures, ranked sixteenth with 2.69 MS and 0.950 Std Dev; operational safety training, with 2.57 MS and 0.909 Std Dev; and space selling, with 2.57 MS and 0.925 Std Dev, ranked seventeenth; and promoting information among users ranked fifteenth with 2.41 MS and 0.957 Std Dev.

4. Discussion

The study assessed VR application for FM in the South African construction industry. The result of the study indicated that space modelling, planning of construction processes, virtualisation of buildings, site layout planning, fire risk assessment, site landscaping, and virtual site inspection were the highest ranked (1st – 7th) in the level of VR applications for FM in the construction industry. The findings align with Bouchlaghem et al. (1996) and Pratama & Dossick (2019) that the level of VR application for FM can be used for space modelling, planning of construction processes, site layout planning, fire risk assessment, and site landscaping in the construction industry. It also aligns with the study of Elmualim and Gilder (2014) and Boston (2018) that the VR application level for FM is applicable in the virtualisation of buildings and virtual site inspection levels in the construction industry.

The findings also showed that design simulation, air conditioning designing, interior designing, lighting designing, monitoring of construction processes, and heating ventilation designing were mediumly ranked (8th – 13th) in levels of VR applications for FM in the construction industry. The study affirmed the findings of Whyte and Nikolic (2018) and Pratama and Dossick (2019) that design simulation and air conditioning designing are included in the level of VR application in the construction industry. The study also agrees with Liu and Seipel (2018) and Huang et al. (2007) that the VR application level for FM in the construction industry includes interior and lighting design. The findings further support the studies of Kunz and Fischer (2012), Elmualim and Gilder (2014) and Abina et al. (2023) that monitoring of construction processes and heating ventilation designing were other levels of application of VR for FM in the construction industry. It also emphasises VR's role in facilitating various design and monitoring aspects within construction FM practices.

Furthermore, the findings indicated that construction planning, designing driving simulators, simulating architectural structures, operational safety training, space selling, and promoting information among users are the least ranked (14th – 19th) in levels of VR applications for FM in the construction industry. This supports Carreira et al. (2018) and Bouchlaghem (2005) that construction planning, designing driving simulators, simulating architectural structures, operational safety training, and promoting information among users are all inclusive of the levels of VR application for FM in the construction industry. It also agrees with the study of Pratama and Dossick (2019), Abina (2023), and Bamgbose et al. (2024) that space selling is also one of the levels of VR application for FM in the construction industry.

5. Conclusions

The study assessed the level of VR application for FM in the South African construction industry. It provided valuable insights into the level of VR applications for FM within the construction industry. The study identified space modelling, planning of construction processes, virtualisation of buildings, site layout planning, fire risk assessment, site landscaping, and virtual site inspection as the significant applications of VR for FM in the construction industry.

The study findings established that VR applications significantly enhance visualisation, collaboration, and decision-making for FM in the construction industry. The study also indicated that VR technologies hold immense potential for revolutionising FM processes in construction projects. If applied properly, they offer immersive and interactive experiences that can facilitate better planning, design, maintenance, and operation of facilities being managed within the construction industry. The study suggested that to continue enjoying the benefits of VR applications for FM in the construction industry, construction professionals should be more aware of the possibilities of VR applications. It is essential to organise training sessions on the potential applications of VR for FM within construction activities for industry professionals to enhance their understanding of VR applications for FM practices within the construction sector. The study also suggests constant evaluations of VR applications within the industry among professionals to assess the effectiveness and usability of VR applications for FM and to gather their experience in its application.

Further research should be conducted on the potential application of VR for FM within the construction industry, focusing on addressing existing challenges that help stakeholders unlock new opportunities for improving efficiency, productivity, and sustainability.

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