Sustainable Construction in the Era of the Fourth Industrial Revolution, Vol. 149, 2024, 43–49
https://doi.org/10.54941/ahfe1005273

Systematic Review of the Application Challenges of Virtual Reality for Facilities Management in the South African Construction Industry

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ABSTRACT

Amidst global disruptions in the construction industry, the adoption of innovative technologies is imperative for enhancing efficiency and productivity. Virtual Reality (VR) emerges as a crucial tool in transforming Facilities Management (FM) communication and providing immersive experiences. However, the South African construction industry faces specific challenges, including the cost of VR equipment, lack of standardization, specialized skills requirement, and limited awareness among facilities managers. Addressing these challenges is essential for unlocking VR's potential in construction FM. This study employs a systematic review methodology to shed light on these challenges, emphasizing the multifaceted nature of financial barriers, standardization issues, the need for specialized skills, and awareness gaps. Recommendations encompass cost reduction, standardized applications, training programs, and awareness campaigns. Despite challenges, VR presents opportunities to revolutionize South African construction FM, with advancing technology and successful implementations expected to drive accessibility and demand for tailored solutions in the future.

Keywords: Virtual, Technology, Facilities, Management, Construction, Industry, Applications, Challenges

INTRODUCTION

With global disruptions challenging the construction industry, innovative technologies offer a lifeline to boost efficiency, productivity, and resilience (Wyk et al., 2021). This surge in technology adoption is driven by escalating project complexity, mirroring a similar trend in Facilities Management (FM) (Easen et al., 2017; Fuchs et al., 2017). Sophisticated computer-based tools automate tasks, streamline information, and empower informed decision-making (Abel & Lennerts, 2005). At its core, FM aims to establish high-performing built environments for successful organizational operations (Cotts et al., 2010). This is where Virtual Reality(VR) emerges as a game-changer. Fuelled by recent advancements, interactive VR visualizations are

transforming FM communication by leveraging shared immersive experiences and interpersonal interaction (Shi et al., 2016). However, South Africa's construction industry faces unique challenges in optimizing FM (Ndlovu, 2021). Traditional methods are often slow, resource-intensive, and potentially risky, making VR's immersive, interactive capabilities even more attractive for tasks like training, maintenance, and inspection (Asgari & Rahimian, 2017; Sampaio et al., 2009, 2010; Fumarola & Poelman, 2011; Yang & Ergan, 2014; Maher et al., 2006). Despite its potential, VR adoption in South Africa faces hurdles like cost barriers, lack of standardized applications, specialized skills need, and limited awareness among facilities managers (Portman et al., 2015).

RESEARCH METHODOLOGY

This study delves into the challenges of applying VR for FM within the South African construction industry. Employing a rigorous systematic review method, we combed through peer-reviewed research on VR applications in FM across online databases like Google Scholar, ResearchGate, and Science Direct. Specific keywords, including "VR for FM," "VR adoption for FM," and "FM for construction," guided our search, ultimately yielding several relevant articles. By exhaustively analyzing these publications, we shed light on the current challenges of VR application for FM.

VIRTUAL REALITY APPLICATIONS FOR FACILITIES MANAGEMENT

FM, as a multidisciplinary field, strives to establish and maintain an efficient built environment crucial for organizational operations, leveraging the attributes of VR such as realism, interactivity, and visualization capabilities (Schultheis & Rizzo, 2001; Maher et al., 2006). In the realm of FM, VR applications provide transformative solutions, spanning asset visualization, space planning, training, maintenance, remote monitoring, collaboration, and data visualization, heralding a shift towards informed and sustainable practices (Carreira et al., 2018; Shamsudin et al., 2018). The integration of VR in FM communication, marked by its fully computer-generated environment, enables real-time manipulation, interaction, and navigation, empowering professionals to experiment with non-existent environments and optimize various facets of the built environment (Warwick, Gray, & Roberts, 1993; Sacks et al., 2013). These applications extend to construction safety training and various FM areas, including space modeling, interior design, lighting, HVAC, ergonomics, fire risk assessment, landscaping, site layout, and construction process planning (Bouchlaghem et al., 1996).

In summary, carefully planned and executed VR applications significantly enhance efficiency, collaboration, and decision-making throughout the construction project lifecycle, necessitating comprehensive integration into construction and FM processes (Korman & Johnston, 2010). Moreover, VR proves invaluable for FM and construction workers in familiarizing themselves with complex procedures, equipment operation, and safety protocols before reaching the construction site, offering a versatile tool for training,

maintenance, and inspection within the FM domain (Kunz et al., 2012). Additionally, VR aids stakeholders in exploring 3D models of planned facilities, providing insights into spatial relationships, layouts, and aesthetics, aligning with the broader goals of FM encompassing planning, design, construction, operation, and maintenance (Bouchlaghem, 2005; Kunz & Fischer, 2012).

CHALLENGES OF VR APPLICATION FOR FACILITIES MANAGEMENT

Despite promising potential, the widespread adoption of VR technologies in the construction industry faces obstacles that affect the benefits these tools offer (Oke et al., 2022). The cost of VR equipment poses a significant challenge to FM in the construction industry, as outlined by El-Mashaleh (2007) and Oladapo (2007). Financial constraints, maintenance expenses, and the need for effective staff training are identified obstacles, emphasizing the multifaceted nature of the financial barriers hindering widespread VR adoption. Efforts to address these challenges are crucial for successful integration into construction FM practices.

The second challenge in the integration of 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). Oke et al. (2018) emphasized that major impediments to digital technology usage in FM include the absence of adequate training, high costs, poor adaptability of standards, and interoperability challenges. These challenges contribute to a complex landscape for the effective implementation of VR in FM. Furthermore, Lapierie and Cotep (2008) specifically noted that the lack of standards in delivering industry products acts as a hindrance to the seamless incorporation of digital technologies in FM activities. Addressing this challenge is crucial to realizing the full potential of VR applications in construction FM, necessitating efforts towards standardization and interoperability within the industry.

The need for specialized skills emerges as a pivotal challenge in the application of VR for FM in the construction industry, echoing insights from Badamasi et al. (2022) and Hampson et al. (2014). Issues encompass a lack of expertise, resistance to cultural change, the cost of VR implementation, application development complexity, and a broader technological immaturity. Furthermore, the scarcity of skilled VR professionals, as highlighted by Hampson et al. (2014), exacerbates the complexity of integrating VR into FM activities, with professionals often opting for opportunities in the entertainment and gaming sectors. Addressing these challenges is imperative to foster the effective utilization of VR in the construction FM landscape.

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). Challenges encompass a dearth of skills and expertise, resistance to cultural change, high costs associated with VR implementation, complexity in application development, and a broader issue of technology immaturity and inadequate technological awareness. To fully unlock the potential of VR for FM in construction, there is a critical need to address these multifaceted challenges, with a particular focus on enhancing awareness and understanding among facilities managers.

RECOMMENDATIONS

VR's ability to create immersive and interactive 3D environments enables FM to observe and rehearse construction processes, leading to heightened awareness, reduced delays, and improved project outcomes (Nassereddine et al., 2022). Recognizing the importance of comprehensive training, Essop (2021) advocates for programs to bridge the skills gap and enhance confidence in VR usage among construction personnel. Additionally, strategies such as showcasing successful VR implementations through case studies, proposed by Nngidi (2023) and Essop (2021), aim to raise awareness and demonstrate the practical benefits of VR. These recommendations, encompassing cost reduction, standardized applications, training provision, and awareness campaigns, collectively position VR as a revolutionary tool for transforming FM practices in the construction industry.

FUTURE OPPORTUNITIES

Despite these challenges, VR holds immense potential to revolutionize South African construction FM (Nngidi, 2023). As technology advances and costs decrease, VR platforms will become more accessible and user-friendly. Additionally, as successful implementation stories emerge, awareness and demand will increase, driving further development of tailored VR solutions for the construction industry (Wong et al., 2018).

CONCLUSION

In conclusion, amid global disruptions in the construction industry, the adoption of innovative technologies is essential for increased efficiency and productivity. VR emerges as a pivotal tool, in transforming FM communication and offering immersive experiences. However, the South African construction industry faces specific challenges, including the cost of VR equipment, lack of standardization, specialized skills requirement, and limited awareness among facilities managers. Addressing these challenges is crucial for unlocking VR's potential in construction FM. The systematic review methodology employed in this study sheds light on these challenges, emphasizing the multifaceted nature of financial barriers, standardization issues, the need for specialized skills, and awareness gaps. Recommendations include cost reduction, standardized applications, training programs, and awareness campaigns. Despite challenges, VR presents opportunities to revolutionize South African construction FM, with advancing technology and successful implementations expected to drive accessibility and demand for tailored solutions in the future.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Sustainable Human Settlement and Construction Research Centre, Faculty of Engineering and the Built Environment, University of Johannesburg (CIDB Centre of Excellence).

FUNDING

This research was funded by the CIDB, Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa.

REFERENCES

Abel, J. and Lennerts, K., 2005 "Where does CAFM really help? Current fields of application and future trends according to system users", Proceedings of 22nd International Conference on Information Technology in Construction (CIB W78's), Volume 304 of CIB Publication, pp. 1–7.

Aghimien, D., Ngcobo, N., Aigbavboa, C., Dixit, S., Vatin, N. I., Kampani, S., & Khera, G. S. (2022). Barriers to digital technology deployment in value management practice. Buildings, 12(6), 731.

Almusaed, A., Yitmen, I., & Almssad, A. (2023). Reviewing and integrating aec practices into industry 6.0: Strategies for smart and sustainable future-built environments. Sustainability, 15(18), 13464.

Arain, F. M., & Burkle, M. (2011). Learning construction project management in the virtual world: Leveraging on second life. Journal of Information Technology in Construction (ITcon), 16(16), 243–258.

Asgari, Z., & Rahimian, F. P. (2017). Advanced virtual reality applications and intelligent agents for construction process optimisation and defect prevention. Procedia engineering, 196, 1130–1137.

Badamasi, A. A., Aryal, K. R., Makarfi, U. U., & Dodo, M. (2022). Drivers and barriers of virtual reality adoption in UK AEC industry. Engineering, Construction and Architectural Management, 29(3), 1307–1318.

Boton, C. (2018). Supporting constructability analysis meetings with Immersive Virtual Reality-based collaborative BIM 4D simulation. Automation in Construction, 96, 1–15.

Bouchlaghem, D., Shang, H., Whyte, J., & Ganah, A. (2005). Visualisation in architecture, engineering and construction (AEC). Automation in construction, 14(3), 287–295.

Bouchlaghem, N. M., & Liyanage, I. G. (1996). Virtual reality applications in the UK's construction industry. Cib Report, 89–94.

Briggs, J. C. (1996). The promise of virtual reality. The futurist, 30(5), 13.

Carreira, P., Castelo, T., Gomes, C. C., Ferreira, A., Ribeiro, C., & Costa, A. A. (2018). Virtual reality as integration environments for facilities management: Application and users perception. Engineering, Construction and Architectural Management, 25(1), 90–112.

Christiansson, P., Dalto, L., Skjaerbaek, J., Soubra, S. and Marache, M. (2002), "Virtual environments for the aec sector: The divercity experience", Proceedings of the International Conference, of ECPPM 2002 on eWork and eBusi-ness in Architecture, Engineering and Construction, Portoroz, pp. 1–8.

Cotts, D. G., Roper, K. O. and Payant, R. P. (2010), The Facility Management Handbook, Amacom, New York, NY.

Du, J., Zou, Z., Shi, Y., & Zhao, D. (2018). Zero latency: Real-time synchronization of BIM data in virtual reality for collaborative decision-making. Automation in Construction, 85, 51–64.

Easen, N., Buckland, D., McClelland, J. and Osborne, J. (2017), Future of Construction, RACONTEUR.net, London, available at: https://www.iirsm.org/sites/default/files/future-of-construction-special-report-2017.pdf (accessed May 2018).

El Ammari, K., & Hammad, A. (2019). Remote interactive collaboration in facilities management using BIM-based mixed reality. Automation in Construction, 107, 102940.

El-Mashaleh, M. S., Edward Minchin Jr, R., & O'Brien, W. J. (2007). Management of construction firm performance using benchmarking. Journal of management in engineering, 23(1), 10–17.

Essop, R. (2021). An assessment of virtual reality to enhance performance in the South African construction industry (Doctoral dissertation, University of Johannesburg).

Fuchs, S., Nowicke, J. and Strube, G. (2017), Navigating the Digital Future: the Disruption of Capital Projects, McKinsey & Company, Dallas.

Fumarola, M. and Poelman, R. (2011), "Generating virtual environments of real world facilities: Discussing four different approaches", Automation in Construction, Vol. 20, No. 3, pp. 263–269.

Hampson, K., Kraatz, J. A. and Sanchez, A. X., R&D Investment and Impactin the global construction industry. Abingdon, Oxford: Routlege, 2014.

Korman, T., & Johnston, H. (2010). Enhancing construction management education though the use of a virtual construction company simulation system. In The 2nd International Symposium on Engineering Education and Educational Technologies: EEET.

Kunz, J., & Fischer, M. (2012). Virtual design and construction: themes, case studies and implementation suggestions. Center for Integrated Facility Engineering, Stanford University, 1–2.

Lapierre, A. and Cote, P., Using Open Web Services for urban data management: A test bed resulting from an OGC initiative for offering standard CAD/GIS/BIM services, Urban and Regional Data Management: UDMS Annual 2007, Taylor and Francis: London, 381–395, 2008.

Maher, M. L., Rosenman, M., Merrick, K. and Marchant, D. (2006), "Designworld: a multidisciplinary collaborative design environment using agents in a virtual world", in Gero, J. S. (Ed.), Design Computing and Cognition, Springer, pp. 695–710.

Michell, K. A. (2010). A grounded theory approach to community-based facilities management: the context of Cape Town, South Africa. University of Salford (United Kingdom).

Nahm, A. Y., Vonderembse, M. A., & Koufteros, X. A. (2003). The impact of organizational structure on time-based manufacturing and plant performance. Journal of operations management, 21(3), 281–306.

Nassereddine, H., Hanna, A. S., Veeramani, D., & Lotfallah, W. (2022). Augmented Reality in the Construction Industry: Use-Cases, Benefits, Obstacles, and Future Trends. Front. Built Environ, 8, 730094.

Ndlovu, P. M. (2021). Examining issues influencing effective facilities management practice on selected public sector buildings in South Africa (Doctoral dissertation).

Nnaji, C., & Karakhan, A. A. (2020). Technologies for safety and health management in construction: Current use, implementation benefits and limitations, and adoption barriers. Journal of Building Engineering, 29, 101212.

Nngidi, A. A. An assessment of risk management in digitalization of facilities Management in South Africa (Doctoral dissertation, University of Johannesburg).

Oke, A. E., Aliu, J., Onajite, S., & Simeon, M. (2022). Success factors of digital technologies (DT) tools adoption for sustainable construction in a developing economy. Construction Innovation, (ahead-of-print).

Oke, E. A., Omoregie, A. D., & Koloko, A. C. O. (2018, March). Challenges of digital collaboration in the South African construction industry. In Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia (pp. 6–18).

Oladapo, A. A. (2007). A quantitative assessment of the cost and time impact of variation orders on construction projects. Journal of Engineering, Design and Technology, 5(1), 35–48.

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. Computers, Environment and Urban Systems, 54, 376–384.

Sacks, R., Perlman, A., & Barak, R. (2013). Construction safety training using immersive virtual reality. Construction Management and Economics, 31(9), 1005–1017.

Sampaio, A., Ferreira, M. and Rosário, A. D. (2009), "Interactive virtual application on building maintenance: the lighting component", Proceedings of the 3RD International Conference on Integrity, Reliability and Failure: Challenges and Opportunities Symposium Visualization and Human-Computer Interaction, Porto, pp. 221–222.

Sampaio, A. Z., Ferreira, M. M., Rosário, D. P. and Martins, O. P. (2010), "3D and VR models in civil engineering education: construction, rehabilitation and maintenance", Automation in Construction, Vol. 19, No. 7, pp. 819–828.

Schultheis, M. T., & Rizzo, A. A. (2001). The application of virtual reality technology in rehabilitation. Rehabilitation psychology, 46(3), 296.

Shamsudin, N. M., Mahmood, N. H. N., Rahim, A. R. A., Mohamad, S. F., & Masrom, M. (2018). Virtual reality training approach for occupational safety and health: a pilot study. Advanced Science Letters, 24(4), 2447–2450.

Shi, Y., Du, J., Lavy, S., & Zhao, D. (2016). A multiuser shared virtual environment for facility management. Procedia Engineering, 145, 120–127.

van Wyk, L., Kajimo-Shakantu, K., & Opawole, A. (2021). Adoption of innovative technologies in the South African construction industry. International Journal of Building Pathology and Adaptation.

Warwick, K., Gray, J., & Roberts, D. (1993). Virtual reality in engineering.

Whyte, J., & Nikolić, D. (2018). Virtual Reality and the Built Environment.

Wong, J. K. W., Ge, J., & He, S. X. (2018). Digitisation in facilities management: A literature review and future research directions. Automation in Construction, 92, 312–326.

Wong, J. K. W., Ge, J., & He, S. X. (2018). Digitisation in facilities management: A literature review and future research directions. Automation in Construction, 92, 312–326.

Yang, X. and Ergan, S. (2014), "Evaluation of visualization techniques for use by facility operators during monitoring tasks", Automation in Construction, Vol. 44, pp. 103–118.