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INTEGRATION OF BUILDING INFORMATION MODELLING (BIM) AND VIRTUAL REALITY (VR) FOR COLLABORATIVE DESIGN REVIEW: A COMPARATIVE STUDY

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Abstract: The increasing complexity of Architecture, Engineering and Construction (AEC) projects necessitates more effective communication among various stakeholders, and places high demands on streamlining the design information and workflows. This research aims to conduct a comparative study by integrating Building Information Modelling (BIM) and Virtual Reality (VR) into the design phase of construction projects using two VR platforms: Arkio and Vrex To this end, a framework consists of three main components has been developed: (1) the BIM model component, which contains the geometry, semantic and orientation data of building elements; (2) the data transformation component, which transfers the data from the BIM model to VR ; and (3) the collaborative design review component, which integrates BIM with VR, and provides several functions for facilitating collaborative design review. The developed framework was applied to a case study to demonstrate its validity and practicality, and analyze various capabilities of Arkio and Vrex. The results show the potential of BIM-VR integration for improving cross-disciplinary collaboration and informed decision-making in the design phase. This research assists practitioners in incorporating BIM and VR in their design review workflow, which will reduce the design time and its associated cost, and eliminate design errors caused by lack of collaboration or inefficient communication.

Keywords: Virtual Reality, Building Information Modelling, Collaboration, Design Review

1 INTRODUCTION

In the Architecture, Engineering, and Construction (AEC) industry, communication among stakeholders is vital, particularly in complex projects, which necessitates effective collaboration to enable successful completion of the projects. Design reviews are essential in the design processes where reviewers assess work, make critical decisions, set objectives, and plan further actions to guarantee the efficacy and quality of the design (Horvat, Kunnen, et al., 2022; Yu et al., 2022; Howie et al., 2023). The lack of data transmission, and low level of understanding among the multidisciplinary stakeholders during design and construction phases are the primary problems that contribute to the failure of projects in meeting their requirements (Tea et al., 2021). Collaboration during the design stage can lower the chances of failures and the cost of reworks in the later stages. The performance of construction projects can be improved by interactive communication between the project's stakeholders on the core project requirements. Effective communication between stakeholders can enhance the quality of the design and by reducing ambiguities and design flaws.

Numerous studies noted VR) as one of the innovative and promising technological developments to support collaborative designs (Wen and Gheisari, 2020; Menegon and da Silva Filho, 2022; Adriana Cárdenas-Robledo et al., 2022). VR enhances collaboration by offering shared visualizations and immersive settings that enable interaction between distant engineers, stakeholders, and clients. This eliminates the need for physical presence during design reviews thus eliminating geographical barriers of remote stakeholders. The rise of BIM practices in the AEC industry has promoted BIM-based VR applications in the projects. Data visualisation in the BIM-based immersive virtual environment could assist and enhance design collaboration; in particular, visualisation of data in such environment during the design process could lead to a deeper understanding among collaborators (Yu et al., 2022; Prabhakaran et al., 2021). Despite the increasing demand for BIM and VR in design review, engineering teams are lagging in adopting these technologies due to the lack of knowledge for incorporating it into the design workflow (Howie et al., 2023). Thus, this research aims to develop a framework for incorporating BIM-VR integration in the current design workflows to enhance virtual collaboration and communication. The developed framework intends to connect remote project participants in a common virtual setting for a collaborative design review. A background literature study was carried out to summarise the results of studies related to collaborative design using VR in the AEC industry. Then, a conceptual framework for utilising BIM and VR is proposed to improve collaborative design review. A case study was used to demonstrate the implementation of the framework and its applicability in real-life projects. Finally, a discussion of the results is provided, and a conclusion offering summary of the research, and recommendations for future research is presented.

2 LITERATURE REVIEW

This section reviews the literature related to the design review, and the applications of VR and BIM-VR integration that can improve design review process, along with the existing VR technologies and their challenges in the AEC industry.

2.1 Traditional Design Approaches

Traditional design review processes in the AEC industry have long relied on static 2D drawings, fragmented document exchanges, and in-person coordination meetings that require all stakeholders to interpret complex information independently. These reviews often occur through disconnected channels such as email threads, markups on printed plans, and siloed software platforms, making it difficult to maintain a single source of truth or ensure that everyone is working from the latest design iteration. As a result, design intent is frequently communicated in ways that are slow, inconsistent, and highly dependent on individual interpretation. Ineffective communication among project stakeholders is one of the key issues in the AEC industry, particularly in assuring shared perspectives across geographically distant stakeholders. Poor stakeholders' communication frequently leads to misconceptions, misinterpretations, and lack of knowledge that can negatively impact the quality, timeliness, cost, and safety of a construction project (Du et al., 2018; Zhang et al., 2020; Osorto Carrasco and Chen, 2021). Effective communication between coworkers and other specialists is crucial for final project design and delivery, as insufficient coordination can cause discipline-based conflicts (Safikhani et al., 2022; Prabhakaran et al., 2020). Another issue with the use of 2D designs for project communication is that it limits end-user input, which hinders innovative design and entail long-term dissatisfaction (Potseluyko et al., 2022; Davidson et al., 2019). This is because technical drawings and 2D pictures are not intuitive enough for clients without sufficient background in architecture and engineering to visualise their future developments and choose the specifics and additions they need. Therefore, efficient information and data visualisation is essential for lowering complexity and increasing efficiency in complicated projects.

2.2 Collaborative Design Using VR and Integration of BIM with VR

Early collaboration in the architectural and engineering design process decreases risks of costly changes and rework in the later phases of the projects. Design reviews, when effectively conducted, increase the likelihood of producing a product with the necessary reliability, quality, performance, and safety as well as the possibility of cutting project delivery cost and time (Wolfartsberger, 2019; Prabhakaran et al., 2020). The issue of fragmentation between design and construction disciplines, which leads to ineffective work practices and expensive late adjustments in the construction phase, can be directly addressed by early collaboration in the right environment (Heydarian et al., 2015). Building Information Modelling (BIM) is one of the most useful technologies to assist design review. Integrated information management using BIM enables the AEC industry to model, interact, collaborate, and integrate sustainable design and construction needs and actions throughout the entire project lifecycle (Wang et al., 2022; Wang et al., 2023; Getuli et al., 2020). Despite the growing applications of BIM in the design review, BIM still faces some challenges due to the complexity of collaborative design changes such as real-time visualization and communication for redesigning 3D models and design updates (Omrany et al., 2023; Panya et al. 2023). BIM integration with VR can enhance collaborative design by blurring the boundaries between the real and virtual worlds, thereby supporting end users' decision-making processes (Cheng, Chen and Chen, 2020; Aref Maksoud et al., 2023).

VR is a sophisticated communication platform that supports numerous aspects such as synchronous chat, audio chat, and a shared virtual workplace for oral and visual communication (Podkosova et al., 2022; Boton, 2018). VR enables an immersive exploration, facilitating communication and understanding among participants, regardless of professional background or expertise. Visualizing data in immersive BIM-based virtual environments can enhance design collaboration, fostering deeper understanding among collaborators during the initial design stages (Yu et al., 2022; Prabhakaran et al., 2021). VR aids in visualising the comprehensive information available in a BIM model and produces real-time interactive project visualisation for a reliable shared understanding among the main project stakeholders (Berg and Vance, 2016; Schiavi et al., 2022). Visualizing data in immersive BIM-based virtual environments can enhance design collaboration, fostering deeper understanding among collaborators during the initial design stages (Yu et al., 2022; Prabhakaran et al., 2021). Users can have safe, immersive, and realistic experiences in VR, some of which are challenging to replicate in actual environments. Immersive virtual reality (ImVR) is an advanced type of VR that provides users with a deep level of immersion and more seamless and realistic experience (Ehab and Heath, 2023; Horvat, Kunnen, et al., 2022). Using head-mounted displays (HMD), which allow users to see the designed environment, and immersive walkthrough at a 1:1 scale, has also become more practical in recent years (Roupé et al., 2020; Zhang et al., 2023). An immersive virtual environment enhances user perception, memory, problem identification, and collaboration, encouraging creative problem-solving techniques among design partners (Ehab and Heath, 2023).

BIM-based VR has enormous potential for design visualisation to improve communication and better grasp design complexity, while cloud-based multi-user VR systems have attracted interest for distant stakeholder engagement (Truong et al., 2021). Wolfartsberger (2019) proposed a virtual reality tool “VRSmart” that visualises CAD data, facilitating decision-making, and increasing workflow effectiveness by intuitively checking for design flaws and fostering improved communication. Du et al. (2018) introduced CoVR, a cloud-based virtual reality headset system that gathers BIM design data and generates a multiuser collaborative virtual environment for distant project stakeholders. Lin et al. (2018) developed a Database-supported VR/BIM-based Communication and Simulation (DVBCS) system to improve the communication and simulation performance integrating BIM, game engine, and VR technologies for healthcare facility design in the semi-immersed VR environment. VR-assisted design review attempts towards increased presence to enhance user experience, discover design flaws, and improve visual perception.

3 PROPOSED FRAMEWORK

The proposed framework for collaborative design review consists of three main components: (1) BIM Model, (2) Data Transformation, and (3) Collaborative Design Review using integrated BIM-VR Model, as shown in Figure 1.

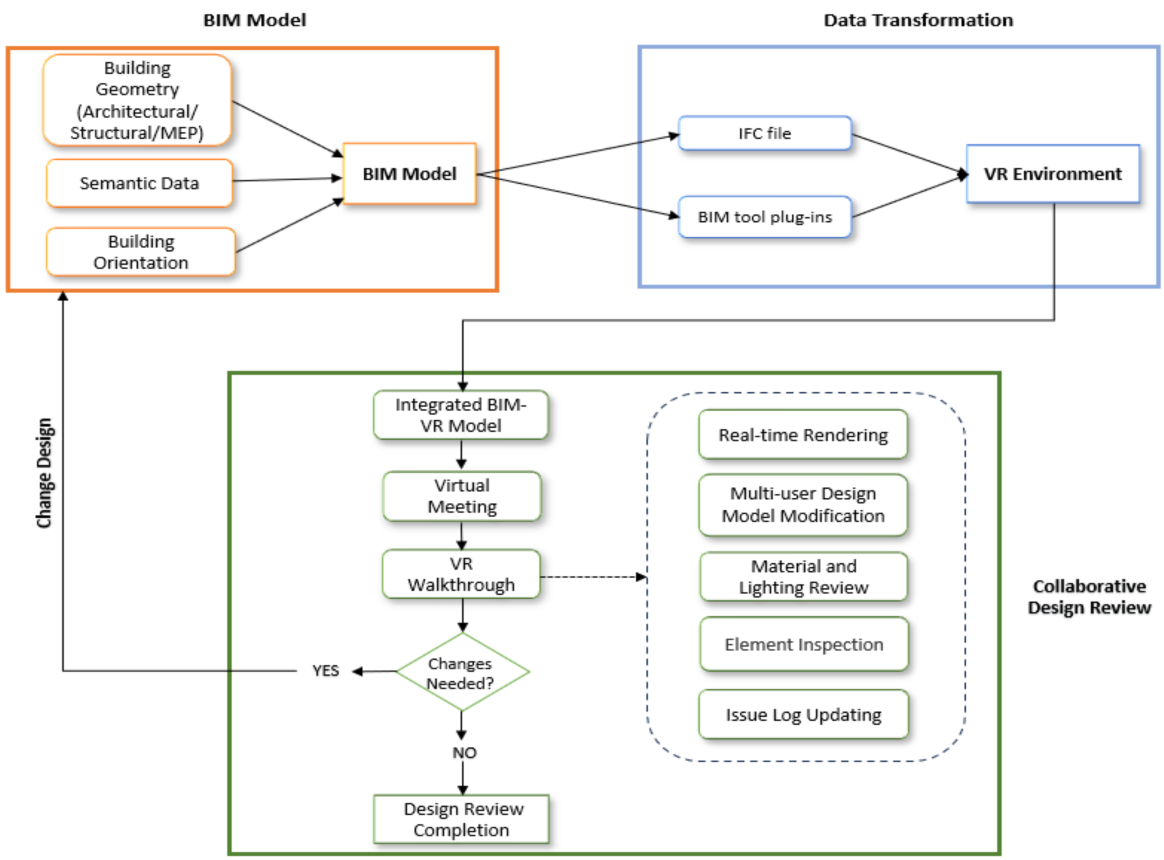

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Figure 1: Conceptual framework for BIM-VR design review.

BIM Model, which provides the main design input, can include i) the geometry of the building elements such as architectural, structural, and MEP elements, ii) their semantic data such as material specifications, and iii) building orientation, which is necessary for lighting and sun studies. By creating BIM models, data can be stored and managed more efficiently, and information can be shared in various dimensions, enabling real-time information transmission (Kim et al., 2021). In the next stage, once the BIM Model is ready, it will be transformed and imported into a VR platform. This process entails geometry and semantic data transformation from BIM to the VR environment. Most of the existing VR platforms have facilitated this process by developing plug-ins that can be used in the commonly used BIM tools such as Revit and Navisworks, or by importing Industry Foundation Classes (IFC) files, which provide more flexibility with using any BIM tool. This transformation could be executed on the cloud storage or the local disk storage. The imported BIM model to VR can be visualised in immersive VR using Head-mounted VR headset or non-immersive VR using desktop computers, tablets or mobile phones. Multi-user VR platforms enable participants to work together in the same virtual space, which is necessary for collaborative design review sessions (Podkosova et al., 2022). Finally, an integrated BIM-VR model is produced to support collaborative design reviews. In the collaborative design review, the users can walk through the model, which allows them to explore and interact with objects in real time (Sampaio, 2018). The design reviewers can communicate and document the design issue in real-time in a collaborative virtual meeting. Following the design review, any required changes are documented and can be applied to the BIM model. The next revision of the design can be reviewed until the design review process is complete. In the next section, the implementation of the proposed framework in a case study is presented.

4 CASE STUDY

The proposed framework was applied to a university building in the UK to examine its efficiency and practicality. The complex design of the building made the design review process time-consuming and tedious necessitating a collaborative design review. The BIM model of the building was developed in Revit, and two VR platforms, i.e., Arkio and Vrex, are used to conduct the design review. The aim is of the case study is to demonstrate validity and practicality of the proposed framework. The functionalities of these platforms for design review are also evaluated from different aspects such as the efficiency of the data transformation process, the interoperability of the VR platforms, and the available tools in the platforms for collaborative design review.

4.1 Design Review in Arkio Platform

Using the Arkio plug-in for Revit, the Revit model of the buildings can seamlessly be imported into the VR environment, which facilitates the data transformation process from BIM to VR. Following the steps identified in the proposed framework, the design review process was done as demonstrated in Figure 2. The walkthrough feature in Arkio allows exploring the VR using the view tool to access different elevations, the orbit tool to freely tilt the model, and the teleport tool to quickly jump to points in the model.

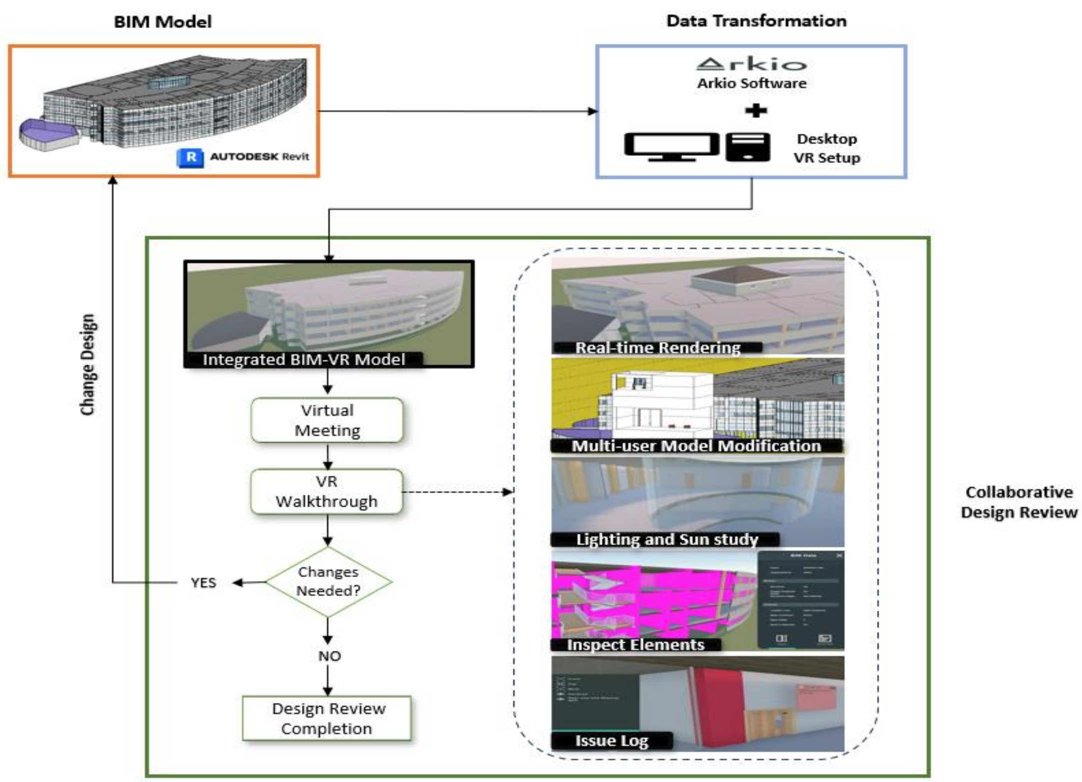

Figure 2. Implementation of the conceptual framework using Arkio.

Furthermore, the Arkio platform facilitates collaborative design through real-time rendering, multi-user model modification, element inspection, lighting and sun study tools, and issue log generation. Real-time rendering functionality allows quick visualization of 3D model changes in VR, aiding in quick decision-making during design review. In this case study, two model modifications were applied. Multi-user VR interaction allows real-time model modifications of the model during design review, which can then be exported back as native Revit geometry. The location and orientation of the site could be determined using Arkio's 3D map feature to get the desired lighting and sun effect on the building, which saved significant time and effort in bringing the design to the appropriate scale and context. Additionally, Arkio platform allows the inspection of the model elements inside the VR environment by creating a section, which assists in concealing unwanted elements, and by highlighting the components of the same type (e.g., walls). The semantic data of the BIM model can also be retrieved and displayed for inspection in the VR environment.

Issue logs for any clashes or other issues noted can be generated using sticky notes and note views, and alternative design suggestions can then be added through the model modification feature. Finally, by exporting the VR model to Revit using the Arkio-Revit plug-in, the identified design issues can be rectified in Revit, and the review cycle is repeated.

4.2 Design Review in Vrex Platform

In the second experiment, Vrex platform served as a VR environment for the design review. Given the limitation of no direct data transformation from Revit to Vrex, the Revit 3D model was converted to Navisworks file format, enabling a smooth data transformation of the model into the VR environment using the Vrex plug-in for Navisworks. The design review process was carried out following the processes outlined in the proposed framework, as shown in Figure 3.

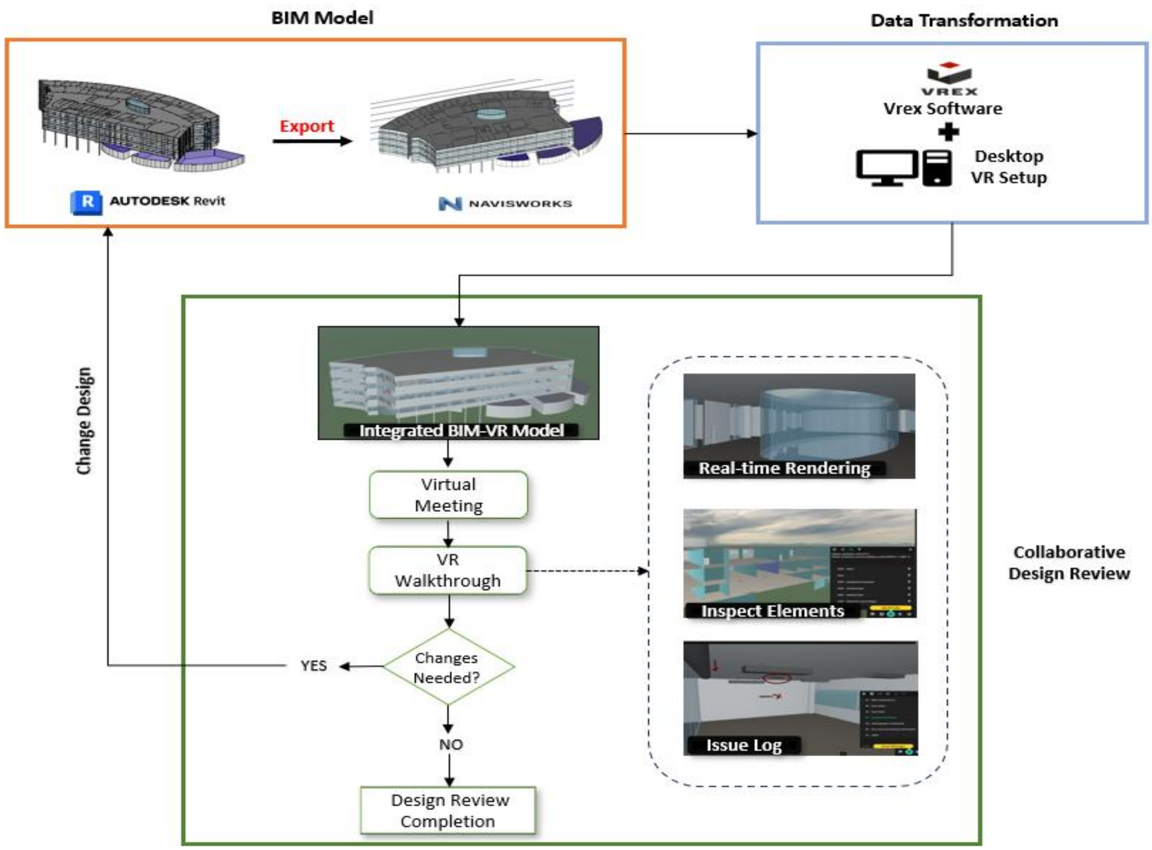

Figure 3. Implementation of the conceptual framework using Vrex.

Vrex supports the VR walkthrough feature using the point-and-click tool for teleporting to any point, the fly option to freely navigate the floors, and the orbit option to freely tilt the model. Vrex also offers collaborative design review through real-time rendering, material inspection and issue log updating. Vrex can be integrated with some Common Data Environment (CDE) platforms such as BIM 360, Aconex and BIMcollab for sharing the design review information and the identified issues between different stakeholders. In this study, BIMcollab was used for issue log updating, which supports the creation of issue viewpoints. Furthermore, the issue manager allows users to teleport to the established viewpoints for addressing the BIM Collaboration Format (BCF) issues, which will be uploaded to the BIMcollab cloud, facilitating seamless issue log management through its interaction with other BIM tools. The model information tool in Vrex enables the inspection of model elements by reviewing the attributes of BIM objects in the building and hiding unwanted sections.

Real-time rendering in a VR environment with the Vrex plugin aids in identifying and reviewing issues. The Navisworks software can be used for detecting clashes, which can be added as BCF issues through the BIMcollab plugin, and then transferred into the VR environment for design review using the Vrex plug-in. Once the design is reviewed, and the comments and suggestions for rectifications are documented, the 3D model can be modified in Revit software, and the review cycle continues until the final project design is achieved.

5 Discussion

The conducted case study demonstrated the practicality and applicability of the proposed framework for collaborative design review. Using two VR platforms for the case study project implied that the framework is flexibly adoptable across different multi-user VR platform. The choice of the platforms is influenced by the project needs as well as the existing workflow of the design review processes. Analysing the case study revealed that VR can provide an effective collaborative space for the design review. Both Arkio and Vrex proved the capabilities expected from BIM-VR integration specified in the literature, such as real-time rendering enabling quick visualisation of design changes to assist in quick decision-making, immersive data visualization enhancing the overall design workflow, ease of communication during review, and reduction of review time and cost (Schiavi et al., 2022). Arkio supported seamless data transformation of the Revit data into VR while Vrex required an intermediate step of file conversion (i.e., use of Navisworks). Arkio excelled at multi-user model modification by allowing the users to manipulate objects at any scale in the VR environment. Furthermore, Arkio supported sun studies which could save significant time and effort in achieving the desired lighting inside the building. On the other hand, Vrex has more interoperability capabilities by offering integration with CDE platforms such as BIMcollab, which facilitates documentation of design issues and revisions by collecting the location, snapshots, and user input data of the issue.

The case study highlights that integrating the proposed BIM-VR framework into design review processes addresses common challenges such as poor stakeholder collaboration, ineffective communication with non-experts, and inefficient management of design information. VR's interoperability, ability to connect with CDE platforms, and immersive visualization capabilities enhance stakeholder engagement, streamline communication, and reduce review time and costs. However, the adoption of this framework faces limitations including the need for costly high-end VR equipment, complex model conversions, restricted model interaction on some VR platforms, and the requirement for specialized expertise and organizational digital maturity, which can be barriers especially for smaller firms.

6 Conclusion

The integration of BIM and VR has been considered a novel and practical approach in the AEC industry for promoting collaboration among the stakeholders for design reviews given the growing complexity of modern construction projects. This research proposed a framework to assist the practitioners in incorporating BIM and VR into the design workflow to facilitate collaborative design reviews. The proposed framework utilised BIM to create the BIM model containing 3D visualization of the project and other attributes of the building. Transforming the BIM model to VR, an integrated BIM-VR model with various functionalities can be used for design reviews. The research used two VR platforms in a case study to illustrate the framework's validity and practicality in a complex project. Despite limitations like high-end device requirements, interoperability issues, and lack of knowledge, the findings showed the potential of immersive BIM-VR environments for cross-disciplinary collaboration and quick decision-making. The main contribution of this research is to conduct a comparative study that assists the AEC industry practitioners in understanding the capabilities of two VR platforms and incorporating BIM and VR in their design review workflow, which will reduce the design time cost, and errors. Future research can be done by evaluating and comparing effectiveness of different VR approaches including immersive, semi-immersive and non-immersive VR in the design review process.

7 References

Adriana Cárdenas-Robledo, L., Hernández-Uribe, Ó., Reta, C. and Antonio Cantoral-Ceballos, J. (2022) 'Extended reality applications in industry 4.0. – A systematic literature review', Telematics and Informatics, 73, p. 101863. Available at: https://doi.org/10.1016/j.tele.2022.101863.

Aref Maksoud, Hussien, A., Emad Mushtaha and Isam, S. (2023) 'Computational Design and Virtual Reality Tools as an Effective Approach for Designing Optimization, Enhancement, and Validation of Islamic Parametric Elevation', Buildings, 13(5), pp. 1204–1204. Available at: https://doi.org/10.3390/buildings13051204.

Arkio (2022) Arkio Software. Available at: https://www.arkio.is/ (Accessed: 20 Jan 2026).

Berg, L.P. and Vance, J.M. (2016) 'An Industry Case Study: Investigating Early Design Decision Making in Virtual Reality', Journal of Computing and Information Science in Engineering, 17(1). Available at: https://doi.org/10.1115/1.4034267.

Boton, C. (2018) 'Supporting constructability analysis meetings with Immersive Virtual Reality-based collaborative BIM 4D simulation', Automation in Construction, 96, pp. 1–15. Available at: https://doi.org/10.1016/j.autcon.2018.08.020.

Cheng, J.C.P., Chen, K. and Chen, W. (2020) 'State-of-the-Art Review on Mixed Reality Applications in the AECO Industry', Journal of Construction Engineering and Management, 146(2), p. 03119009. Available at: https://doi.org/10.1061/(asce)co.1943-7862.0001749.

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M. and Rahimian, F.P. (2019) 'Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: a proof of concept study', Frontiers of Engineering Management [Preprint]. Available at: https://doi.org/10.1007/s42524-019-0039-y.

Du, J., Shi, Y., Zou, Z. and Zhao, D. (2018) 'CoVR: Cloud-Based Multiuser Virtual Reality Headset System for Project Communication of Remote Users', Journal of Construction Engineering and Management, 144(2), p. 04017109. Available at: https://doi.org/10.1061/(asce)co.1943-7862.0001426.

Ehab, A., Burnett, G. and Heath, T. (2023) 'Enhancing Public Engagement in Architectural Design: A Comparative Analysis of Advanced Virtual Reality Approaches in Building Information Modeling and Gamification Techniques', Buildings, 13(5), p. 1262. Available at: https://doi.org/10.3390/buildings13051262.

Ehab, A. and Heath, T. (2023) 'Exploring Immersive Co-Design: Comparing Human Interaction in Real and Virtual Elevated Urban Spaces in London', Sustainability, 15(12), pp. 9184–9184. Available at: https://doi.org/10.3390/su15129184.

Enscape (2019) EnscapeTM - Architectural Virtual Reality - Virtual Reality Walkthrough, EnscapeTM. Available at: https://enscape3d.com/features/architectural-virtual-reality/ (Accessed: 20 Jan 2026).

Fuzor (2020) Fuzor, www.kalloctech.com. Available at: https://www.kalloctech.com/ (Accessed: 20 Jan 2026).

Getuli, V., Capone, P., Bruttini, A. and Isaac, S. (2020) 'BIM-based immersive Virtual Reality for construction workspace planning: A safety-oriented approach', Automation in Construction, 114, p. 103160. Available at: https://doi.org/10.1016/j.autcon.2020.103160.

Heydarian, A., Carneiro, J.P., Gerber, D., Becerik-Gerber, B., Hayes, T. and Wood, W. (2015) 'Immersive virtual environments versus physical built environments: A benchmarking study for building design and user-built environment explorations', Automation in Construction, 54, pp. 116–126. Available at: https://doi.org/10.1016/j.autcon.2015.03.020.

Horvat, N., Kunnen, S., Štorga, M., Nagarajah, A. and Škec, S. (2022) 'Immersive virtual reality applications for design reviews: Systematic literature review and classification scheme for functionalities', Advanced Engineering Informatics, 54, p. 101760. Available at: https://doi.org/10.1016/j.aei.2022.101760.

Howie, S.R., Liang, S., Grech, A., Syed Awais Munawar and Gilardi, M. (2023) 'Industry 4.0 Design Reviews: A Conceptual Virtual Reality Interface', In Proceedings of the 2023 10th International

Conference on Industrial Engineering and Applications (pp. 273-282) [Preprint]. Available at: https://doi.org/10.1145/3587889.3588211.
IrisVR (2020) VR for Architecture, Engineering, and Construction, @IrisVR_Inc. Available at: https://irisvr.com/ (Accessed: 20 Jan 2026).
Kim, J.I., Li, S., Chen, X., Keung, C., Suh, M. and Kim, T.W. (2021) ‘Evaluation framework for BIM-based VR applications in design phase’, Journal of Computational Design and Engineering, 8(3). Available at: https://doi.org/10.1093/jcde/qwab022.
Lin, Y.-C., Chen, Y.-P., Yien, H.-W., Huang, C.-Y. and Su, Y.-C. (2018) ‘Integrated BIM, game engine and VR technologies for healthcare design: A case study in cancer hospital’, Advanced Engineering Informatics, 36, pp. 130–145. Available at: https://doi.org/10.1016/j.aei.2018.03.005.
Mayer, P., Funtík, T. and Honti, R. (2022) ‘MEP Coordination and Clash Management In Bim And Common Data Environment’, Czech Journal of Civil Engineering, 8(2), pp. 54–63. Available at: https://doi.org/10.51704/cjce.2022.vol8.iss2.pp54-63.
Menegon, J. and da Silva Filho, L.C.P. (2022) ‘The Impact of Industry 4.0 Concepts and Technologies on Different Phases of Construction Project Lifecycle: A Literature Review’, Iranian Journal of Science and Technology, Transactions of Civil Engineering [Preprint]. Available at: https://doi.org/10.1007/s40996-022-00989-5.
Mindesk (2020) Mindesk – Your real-time BIM and CAD platform, Mindesk. Available at: https://mindeskvr.com/ (Accessed: 20 Jan 2026).
Omrany, H., Ghaffarianhoseini, A., Chang, R., Ghaffarianhoseini, A. and Pour Rahimian, F. (2023) ‘Applications of Building information modelling in the early design stage of high-rise buildings’, Automation in Construction, 152, p. 104934. Available at: https://doi.org/10.1016/j.autcon.2023.104934.
Osorto Carrasco, M.D. and Chen, P.-H. (2021) ‘Application of mixed reality for improving architectural design comprehension effectiveness’, Automation in Construction, 126, p. 103677. Available at: https://doi.org/10.1016/j.autcon.2021.103677.
Panya, D.S., Kim, T. and Choo, S. (2023) ‘An interactive design change methodology using a BIM-based Virtual Reality and Augmented Reality’, Journal of Building Engineering, p. 106030. Available at: https://doi.org/10.1016/j.jobe.2023.106030.
Podkosova, I., Reisinger, J., Kaufmann, H. and Kovacic, I. (2022) ‘BIMFlexi-VR: A Virtual Reality Framework for Early-Stage Collaboration in Flexible Industrial Building Design’, Frontiers in Virtual Reality, 3. Available at: https://doi.org/10.3389/frvir.2022.782169.
Potseluyko, L., Pour Rahimian, F., Dawood, N., Elghaish, F. and Hajirasouli, A. (2022) ‘Game-like interactive environment using BIM-based virtual reality for the timber frame self-build housing sector’, Automation in Construction, 142, p. 104496. Available at: https://doi.org/10.1016/j.autcon.2022.104496.
Prabhakaran, A., Mahamadu, A.-M., Mahdjoubi, L., Manu, P., Che Ibrahim, C.K.I. and Aigbavboa, C.O. (2021) ‘The effectiveness of interactive virtual reality for furniture, fixture and equipment design communication: an empirical study’, Engineering, Construction and Architectural Management, ahead-of-print(ahead-of-print). Available at: https://doi.org/10.1108/ecam-04-2020-0235.
Prabhakaran, A., Mahamadu, A.M., Mahdjoubi, L. and Manu, P. (2020) ‘An Approach for Integrating Mixed Reality into BIM for Early Stage Design Coordination’, MATEC Web of Conferences. Edited by L. Nazarko, J.P. Pantouvakis, B.T. Kalsaas, and C.H. Ko, 312, p. 04001. Available at: https://doi.org/10.1051/matecconf/202031204001.
Reaver, K. (2022) ‘Mixed Reality in Multiuser Participatory Design: Case Study of the Design of the 2022 Nordic Pavilion Exhibition at the Venice Biennale’, Buildings, 12(11), p. 1920. Available at: https://doi.org/10.3390/buildings12111920.
Roupé, M., Johansson, M., Maftei, L., Lundstedt, R. and Viklund-Tallgren, M. (2020) ‘Virtual Collaborative Design Environment: Supporting Seamless Integration of Multitouch Table and Immersive VR’, Journal of Construction Engineering and Management, 146(12), p. 04020132. Available at: https://doi.org/10.1061/(asce)co.1943-7862.0001935.
Safikhani, S., Keller, S., Schweiger, G. and Pirker, J. (2022) ‘Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: systematic review’, International Journal of Digital Earth, 15(1), pp. 503–526. Available at: https://doi.org/10.1080/17538947.2022.2038291.
Sampaio, A.Z. (2018) ‘Enhancing BIM Methodology with VR Technology’, State of the Art Virtual Reality and Augmented Reality Knowhow [Preprint]. Available at: https://doi.org/10.5772/intechopen.74070.

Schiavi, B., Havard, V., Beddiar, K. and Baudry, D. (2022) ‘BIM data flow architecture with AR/VR technologies: Use cases in architecture, engineering and construction’, Automation in Construction, 134, p. 104054. Available at: https://doi.org/10.1016/j.autcon.2021.104054.
Tea, S., Panuwatwanich, K., Ruthankoon, R. and Kaewmoracharoen, M. (2021) ‘Multiuser immersive virtual reality application for real-time remote collaboration to enhance design review process in the social distancing era’, Journal of Engineering, Design and Technology, 20(1), pp. 281–298. Available at: https://doi.org/10.1108/jedt-12-2020-0500.
Truong, P., Hölttä-Otto, K., Becerril, P., Turtiainen, R. and Siltanen, S. (2021) ‘Multi-User Virtual Reality for Remote Collaboration in Construction Projects: A Case Study with High-Rise Elevator Machine Room Planning’, Electronics, 10(22), p. 2806. Available at: https://doi.org/10.3390/electronics10222806.
Ververidis, D., Nikolopoulos, S. and Kompatsiaris, I. (2022) ‘A Review of Collaborative Virtual Reality Systems for the Architecture, Engineering, and Construction Industry’, Architecture, 2(3), pp. 476–496. Available at: https://doi.org/10.3390/architecture2030027.
Vrex (2022) VREX - BIM and CAD collaboration in VR (Virtual Reality), Vrex. Available at: https://www.vrex.no/ (Accessed: 20 Jan 2026).
Wang, J., Zhang, S., Fenn, P., Luo, X., Liu, Y. and Zhao, L. (2023) ‘Adopting BIM to Facilitate Dispute Management in the Construction Industry: A Conceptual Framework Development’, Journal of Construction Engineering and Management, 149(1). Available at: https://doi.org/10.1061/(asce)co.1943-7862.0002419.
Wang, K., Zhang, C., Guo, F. and Guo, S. (2022) ‘Toward an Efficient Construction Process: What Drives BIM Professionals to Collaborate in BIM-Enabled Projects’, Journal of Management in Engineering, 38(4). Available at: https://doi.org/10.1061/(asce)me.1943-5479.0001056.
Wen, J. and Gheisari, M. (2020) ‘Using virtual reality to facilitate communication in the AEC domain: a systematic review’, Construction Innovation, 20(3), pp. 509–542. Available at: https://doi.org/10.1108/ci-11-2019-0122.
Wolfartsberger, J. (2019) ‘Analyzing the potential of Virtual Reality for engineering design review’, Automation in Construction, 104, pp. 27–37. Available at: https://doi.org/10.1016/j.autcon.2019.03.018.
Yu, R., Gu, N., Lee, G. and Khan, A. (2022) ‘A Systematic Review of Architectural Design Collaboration in Immersive Virtual Environments’, Designs, 6(5), p. 93. Available at: https://doi.org/10.3390/designs6050093.
Zhang, Y., Liu, H., Kang, S.-C. and Al-Hussein, M. (2020) ‘Virtual reality applications for the built environment: Research trends and opportunities’, Automation in Construction, 118, p. 103311. Available at: https://doi.org/10.1016/j.autcon.2020.103311.
Zhang, Z., Wong, M.O. and Pan, W. (2023) ‘Virtual reality enhanced multi-role collaboration in crane-lift training for modular construction’, Automation in Construction, 150, p. 104848. Available at: https://doi.org/10.1016/j.autcon.2023.104848.