Remote Project Management in the Metaverse Using BIM and Extended Reality (XR)

Vishak Dudhee[1,2][0000-0002-8155-9513], Prasanna Bandara[3][0009-0004-8978-3888], Charalampos Psarros[4][0009-0004-9564-2643], Azhar Nalakath[1][0009-0001-4895-3746], and Vladimir Vukovic[1,5][0000-0003-0702-2475]

[1] V-LAB LTD, The Beacon, Esplanade Avenue, Redcar, TS10 3AA, UK
[2] University of Exeter, Rennes Drive, Exeter, EX4 4PU, UK
[3] Tricore Technical Services, Villa Jubilant, 34 Falcon Ct, Stockton-on-Tees, TS18 3TX, UK
[4] Teesside University, Borough Road, Middlesbrough, TS1 3BX, UK
[5] Belgrade Metropolitan University, Tadeuša Košćuška 63, Beograd, 11158, Serbia
vishak@v-lab.uk, p.dinesh@tricore-ts.com, c.psarros@tees.ac.uk, azhar@v-lab.uk, vlad@v-lab.uk

Abstract. The integration of Building Information Modelling (BIM) with Extended Reality (XR) technologies has shown strong potential to advance project planning and visualisation in the construction sector. In the aftermath of COVID-19, the shift to remote and hybrid work has accelerated the need for collaborative tools that extend beyond traditional communication platforms. While digital practices are emerging, the potential role of the Metaverse in supporting remote construction project management remains underexplored. This paper looks at the feasibility of managing construction projects and facilitating stakeholder collaboration within a Metaverse environment through the integration of BIM and XR. A case study using a university building demonstrates how immersive environments can enhance spatial understanding, communication, and cross-disciplinary coordination. The findings highlight improved stakeholder engagement, reduced reliance on physical travel, and alignment with sustainability objectives such as net-zero emissions. Challenges were also identified which includes device performance, user comfort, and varying levels of VR proficiency. The study provides evidence that BIM-XR integration in the Metaverse offers a promising pathway for digital transformation in construction project management, while pointing to areas for further refinement and research.

Keywords: Building Information Modelling (BIM); Extended Reality (XR); Metaverse; Virtual Reality (VR); Construction Project Management; Remote Collaboration

1 Introduction

Globally, the construction industry employs approximately 7% of the working-age population, making it one of the largest sectors of the world economy [1]. Despite its scale, the industry has traditionally relied on incremental innovation, with approaches such as off-site construction and 3D printing still at an exploratory stage. At present, off-site

Research Paper
DOI: https://doi.org/10.46793/eLearning2025.308D
Part of ISBN: 978-86-89755-37-4

construction represents only around 2% of the global market [2]. Conventional on-site construction, whereby structures are assembled sequentially at their permanent location, continues to dominate industry practice. Furthermore, compared with other major sectors, construction remains among the least digitised [3].

The COVID-19 pandemic was an accelerator for the adoption of digital technologies and remote work practices, which led to the successful transition of many office-based roles within the construction industry to remote and hybrid arrangements. The post-pandemic period has also normalised flexible working practices, enabling employees to organise their schedules around non-traditional hours and alternative locations. This shift has fostered greater managerial trust in employees' ability to deliver tasks without direct physical supervision [4]. However, research indicates that remote work can undermine collaboration, with reliance on emails and videoconferencing often replacing real-time, in-person interactions. This substitution has been shown to hamper communication and, in turn, project coordination. Consequently, there is a growing demand for more effective modes of remote collaboration.

At this critical juncture in the sector's digital transformation, immersive technologies present a significant opportunity to enhance collaboration and efficiency. The Metaverse, when combined with BIM and XR, provides a platform where geographically dispersed teams can interact with models, simulate construction environments, and engage in real-time coordination. Against this backdrop, this paper investigates the integration of BIM and XR within a Metaverse environment to support remote project management and stakeholder collaboration. The study proposes a Remote Collaboration Framework and evaluates its application through a case study of the Teesside University's Student Life Building, assessing both the benefits and limitations of immersive collaboration for the construction industry.

2 Background

2.1 Remote Project Communication and Management

Effective communication is widely recognised as one of the most critical competencies required by project managers [5]. In the context of remote project delivery, this requirement becomes even more pronounced, as project managers must demonstrate not only advanced interpersonal skills but also the ability to adaptively and competently use a variety of digital communication platforms [6]. Furthermore, managing remote or "virtual" teams requires sensitivity to the communication preferences and working styles of dispersed team members. When managing multinational teams, project managers must also remain highly perceptive of cultural differences and familiar with the preferred communication channels across different contexts [7].

The implementation of video conferencing and other synchronous communication methods requires project managers to handle time zone variations and scheduling requirements [8]. The most commonly used email method for communication proves to be less effective at building trust and clarity between team members [9]. Project managers need to create well-organised written communication that delivers precise information to overcome these communication barriers. Active listening serves as a critical factor for achieving correct information exchange and team member relationship development [10]. Team members should use one-to-one communication to resolve personal issues and create trust while enhancing team unity. Research demonstrates that proper communication methods create high-performing project teams.

In international projects, the complexity of stakeholder management is increased by the differences in nationality, culture, and professional norms. Project managers must first develop cultural awareness and demonstrate empathy, cultural competence, and expertise to lead diverse teams effectively [11,12]. Failing to develop these skills will lead to cultural gaps, resulting in conflicts and misunderstandings, ultimately reducing project performance. Gap analysis has been suggested as a practical tool for evaluating the difference in culture and to identify the possible sources of tension that may arise among stakeholders [13]. Establishment of shared team culture is an essential factor as it provides a framework for acknowledging and respecting the diverse perspectives in the workplace. Engaging with the local and regional partners is also another strategy that can be used for understating the cultural gap and addressing the risks in collaboration [14].

Negotiation skills have an essential role in closing the cultural divides, resolving conflicts and promoting trust within multicultural project environments [15]. Effective project managers must integrate insights from economic and sociological factors of culture, as business and project management practices vary from place to place. This will help to develop more adaptive and inclusive approaches to communication and stakeholder management, leading to enhanced project outcomes in international and remote contexts.

2.2 Building Information Modelling (BIM)

Building Information Modelling (BIM) is a collaborative digital process for generating, storing, and managing multidisciplinary information across the entire life cycle of a construction project [16]. It involves developing a coordinated digital representation of the built asset, typically comprising information-rich 3D models linked with structured data such as product specifications, execution details, and handover information. BIM maturity is defined through a series of levels, from Level 0 to Level 3 and beyond [17].

Level 0 represents no collaboration and relies solely on 2D CAD drafting for production information, distributed via paper or electronic prints [18]. Level 1 introduces limited 3D CAD for concept work alongside 2D drafting for statutory and production purposes. Standards are governed by BS 1192:2007, and information is shared electronically through a common data environment (CDE), often managed by the contractor. Level 2 requires collaborative working with project-specific information exchange, coordinated across systems and participants. Interoperability is ensured through open formats such as IFC (Industry Foundation Class) and COBie (Construction Operations Building Information Exchange). This approach has been mandated by the UK government as the minimum requirement for public-sector projects [19]. Level 3 is characterised as a fully integrated approach in which all project data are embedded within common information models. Unlike the federated approach of Level 2, Level 3 emphasises the use of internationally recognised data standards to structure information consistently across disciplines. Crucially, this integration is conceived from a lifecycle perspective, ensuring that information flows seamlessly from design and construction through to operation and maintenance. Such an approach reflects the ambition to deliver a unified and standardised digital environment for the construction sector [20].

BIM Level 3 centres on cloud-based, extended collaboration [21]. Even prior to the COVID-19 pandemic, project teams were typically distributed across multiple organisations, including architects, engineers, contractors, and specialist subcontractors [22]. Cloud-based BIM offers significant benefits in such contexts by enabling access to complex models via a web browser without requiring high-specification hardware. Models are processed into standardised formats that can be merged from various file types (e.g., Revit RVT, IFC, Bentley DGN, BCF) using platforms such as 3D Repo, creating a single source of truth for all stakeholders [23]. This approach reduces reliance on locally installed software, simplifies IT requirements, and ensures that all users access the most up-to-date model version with revision histories preserved.

Cloud-based BIM has demonstrated significant improvements in collaboration and project management. It provides the ability for stakeholders to access models at any time and work collaboratively in real time by annotating concerns directly within and addressing them either in real time or asynchronously. This will help minimise delays that are often found during email correspondence and promote greater transparency among stakeholders [24]. Project coordinators can continuously monitor design progress, rapidly identify errors such as misaligned elements, and ensure corrections are made before construction commences. Cloud-based BIM provides a scalable and efficient digital framework that enhances collaboration across the Architecture, Engineering, and Construction (AEC) industry by improving accessibility, interoperability, and real-time communication.

2.3 Extended Reality (XR)

Extended Reality (XR) refers to a broad spectrum of immersive technologies which bring together the physical and digital environments. This includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). XR has become a transformative tool for visualising designs by offering an immersive and interactive experience that enhances the design, planning and stakeholder communication process [25]. XR supports the design review, assessment of alternatives, early identification of potential issues and informed decision-making for stakeholders in the AEC sector by allowing them to explore the digital models before construction [26].

XR enables the simulation of buildings and designs at scale and within their context. The immersive walkthrough feature allows everyone involved to visualise the spatial relationships and better understand the proportions and aesthetics in a realistic manner, giving them a better understanding of the design intent. The immersive visualisation experience provides more accurate feedback with a collaborative approach and helps reduce the risk of costly design revision later. XR also allows multiple users to be in the same virtual model in real time, wherever they are physically. Such shared environments encourage clearer communication, collective problem-solving, and joint decision-making [27]. For clients and end-users, XR provides a tangible way of engaging with proposed designs, which has been shown to improve satisfaction and alignment with project outcomes.

XR also has significant potential within Metaverse (an interconnected virtual environments that combine different digital worlds and augmented experiences) beyond the individual building projects. Urban-scale planning is supported within this XR framework by featuring modelling and exploration of entire cities. It also allows users to interact with architecture/buildings in innovative ways, with the integration of virtual buildings and infrastructure into a shared digital environment.

XR represents a paradigm shift in building model visualisation by providing immersive, interactive, and collaborative experiences. Its ability to improve design comprehension, support effective communication, and enhance decision-making establishes XR as a critical enabler of digital transformation in the AEC sector. As XR technologies continue to mature and become more widely accessible, their integration with the Metaverse is expected to influence the future of architectural practice, urban planning, and stakeholder engagement [28].

3 Remote Collaboration Framework

3.1 Framework Architecture

The Remote Collaboration Framework paves the path for stakeholders like project managers, architects, engineers, and contractors to collaborate in real time virtually, regardless of wherever they are physically in the world by connecting them to a shared digital workspace through Extend Reality (XR) technologies including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR).

The digital workspaces are accessed using XR devices like a VR headset. This allows stakeholders to participate in design reviews and manage projects without being physically present on site. This reduces non-essential travel, supports flexible collaboration, and increases efficiency. At the core of the framework is a Federated BIM Model that integrates architectural, structural, and mechanical, electrical, and plumbing (MEP) components. The model minimises miscommunication and errors by ensuring that all participants work with the same source of information.

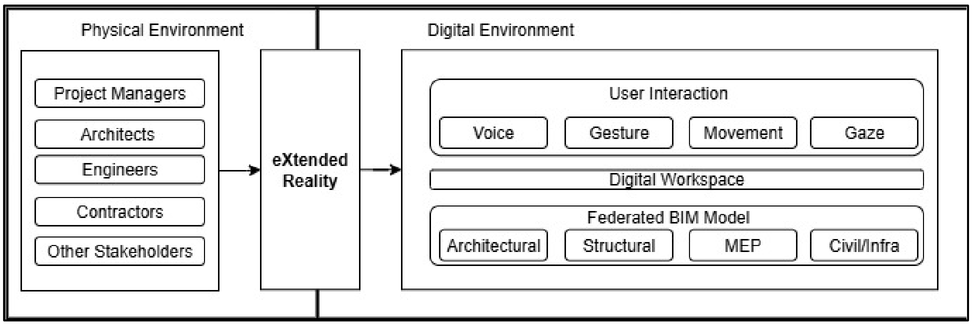

Fig. 1. Collaboration Framework Architecture

The framework (Figure 1) supports multiple user interaction methods, including voice, gesture, movement, and gaze tracking. These provide a collaborative experience which feels more natural compared to other techniques like emails and online meetings. Stakeholders can also conduct a walkthrough of the BIM models and suggest any design changes with annotations. The virtual site inspections also replicate the dynamics of an in-person meeting.

The digital workspace is not just a visualisation tool but a fully interactive environment where users can manipulate models, identify and resolve design conflicts, and maintain coordination across disciplines. Project managers can monitor progress while architects and engineers refine designs collaboratively, and contractors can avoid delays associated with outdated information with the real-time engagement supported by shared access to up-to-date data. Communication clarity and efficient workflow can be achieved with the integration of BIM with Metaverse, offering a practical means of managing construction projects remotely.

3.2 Metaverse Collaborative Platform

The case study was done using Horizon Workroom, which is a VR collaboration platform developed by Meta that provides an immersive workspace environment. The platform can be accessed through VR headsets such as the Oculus Quest 2. The platform also has customised avatars for users to represent themselves in the VR world. Users can then use the avatars to interact with virtual environments and collaborate with others in real-time.

The platform comes packed with a wide range of communication and collaboration tools. The spatial audio feature gives realism to the voice conversation between users. There is also a screen-sharing feature that allows users to showcase their work for discussion and feedback. The virtual whiteboard supports brainstorming and visual collaboration. Files can also be imported directly into the workspace. Options are available to integrate other productivity tools like the Oculus Browser and Zoom to streamline collaboration between users further. Hence, the platform provides web access for the users without having to leave the virtual world. Non-verbal communication is supported by using hand signs, body language and expressive gestures which provides a stronger sense of presence and interaction among the team members.

3.3 Compatible Devices

For visualising BIM models, the case study utilised desktop and laptop computers with sufficient processing power, alongside VR headsets such as the Oculus Quest 2. AR devices, including Microsoft HoloLens, were used to overlay BIM models within real-world settings, enabling users to experience designs in context. Mobile devices with VR headsets were also employed to access the Metaverse model from multiple locations. However, the quality of visualisation depends on factors such as model size, complexity, internet speed, and system hardware capacity.

4 Case Study

4.1 Project BIM Model

The Student Life Building at Teesside University's Middlesbrough Campus (opened in 2020) was designed to support a wide range of learning styles and attendance patterns. This was achieved through a technologically enabled environment. The building offers flexible spaces for collaborative learning alongside an information zone, consulting rooms, and a café. This study used a replicated BIM model of this building. The building has a complex spatial organisation and integration of multipurpose spaces which made it a suitable candidate for this study for evaluating the use of BIM in XR environments.

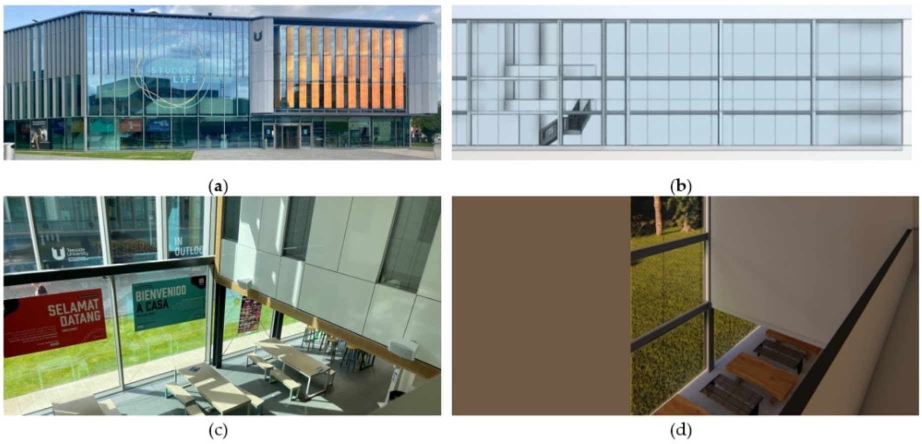

Fig. 2. (a) A photo of the Student Life Building; (b) The developed BIM model (Exterior); (c) Interior photo of the Student Life Building Atrium; (d) The developed BIM Model (Interior)

Architecturally, the building features a glass façade with dichroic glass fins (Figure 2a and 2c) and interconnected interior volumes shaped by timber-clad pods containing 26 consultation and study rooms. These pods are arranged between double-height volumes, with waiting areas doubling as quiet study spaces. The spatial configuration balances openness and connectivity with enclosed areas for individual or group study.

As the original BIM model of the building was not available, a replica was developed in Autodesk Revit using available architectural references, dimensional data, and photographic material (Figure 2b and 2d). The model was then imported into Unreal Engine and processed to generate realistic rendering and textures. Structural elements and materiel properties like the reflective characteristics of the dichroic glass fins and the natural finish of the timber-clad pods were incorporated to mirror the real-world building closely. The spatial layout, including circulation routes and study areas, was modelled to ensure fidelity to the original design. Even though the replica does not fully substitute the original BIM model, its accuracy was validated against available architectural documentation to provide a reliable digital representation. For exploring the flexibility another 3D model of a cricket stadium for the case study. In addition to the Student Life Building, a 3D model of a cricket stadium was also used to further test the applicability of BIM in XR environments.

The BIM model had to be optimised with reduced triangle sizes in tools such as Blender for integration with XR platforms to be accessed through standalone VR and AR devices. In 3D graphics, triangulation is used to construct all digital models, and reducing their number makes the BIM model lighter and more efficient for real-time rendering on standalone VR and AR devices. This allowed stakeholders to conduct immersive walkthroughs, assess spatial relationships, and test alternative design configurations remotely. The model provided valuable insights into spatial dynamics and stakeholder engagement by enabling exploration of the building at scale within the collaborative virtual workspace. Importantly, it demonstrated the potential of combining BIM with XR technologies in the Metaverse to support remote project collaboration, enhance communication, and inform decision-making in construction and architectural practice.

.

4.2 Metaverse Collaboration

Meta Horizon Workrooms is a VR platform designed to support immersive teamwork, which was used to implement the collaborative environment for this case study. Different devices like VR headsets, laptops and tablet computers were used by stakeholders such as Project Manager, BIM Coordinator, Architect and Engineer to connect to the shared virtual workspace. This framework, where users can get connected using different kinds of devices, provides accessibility and flexibility for users to engage with the model according to their role and available technology.

Figure 3 shows the overview of stakeholder interaction within the Metaverse workspace used for this case study. The BIM Coordinator and Project Manager accessed the federated BIM model in immersive 3D via VR headsets, providing them with spatial analysis and in-context discussion. The Architect, working on a laptop, contributed design insights and integrated updates through the desktop interface. The Engineer, accessing the environment via a tablet, was able to participate in mobile reviews and provide feedback during live sessions.

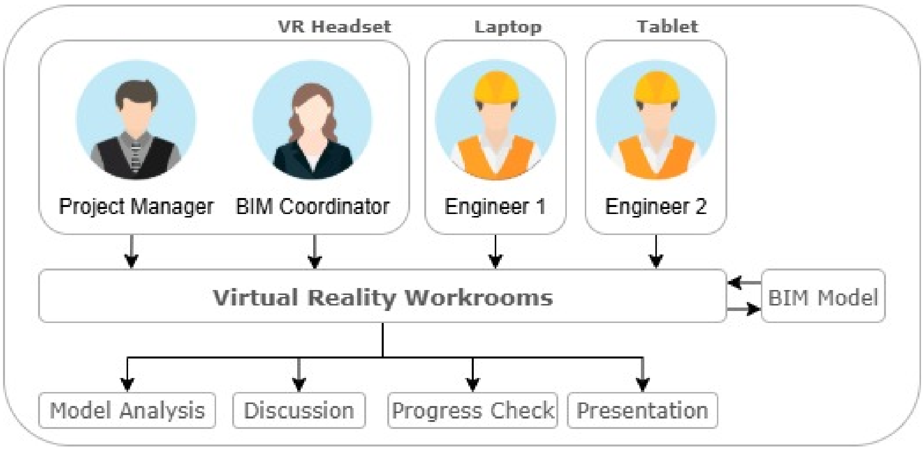

Fig. 3. Case study collaboration approach

Different collaborative activities, such as model analysis, progress reviews, design coordination, and presentations in the immersive world, were done using Horizon Workrooms. These were supported by the platform's core features like spatial audio, avatar, screen sharing and the virtual whiteboard. The combination of all these features resulted in a realistic, immersive and interactive experience that closely replicated the dynamics of an in-person meeting without the physical or geographical constraints.

Participants can annotate models to provide reviews in the virtual workspace. They can also use intuitive gestural input along with verbal feedback and engage in detailed coordination sessions. Being able to communicate with each other in the virtual world using intuitive inputs has improved communication efficiency and helped in reducing delays associated with asynchronous exchanges. This also limited the need for physical travel to an extent, demonstrating clear benefits of the framework for both sustainability and productivity. The results highlight the potential of Metaverse-based collaboration to support digital transformation in the construction industry.

4.3 Results

The case study demonstrated the practical benefits and limitations of integrating BIM models with XR technologies in a Metaverse-based collaborative platform. A federated BIM model of the Student Life Building was successfully uploaded into Meta Horizon Workrooms, enabling participants to interact with the design in real time. Stakeholders joined the environment through different devices, including Meta Quest 2 headsets, desktop computers, and tablets. This setup created a mixed participation scenario where some users experienced full immersion through VR headsets, while others engaged through standard screen-based interfaces.

Participants reported enhanced spatial awareness and design comprehension when reviewing the BIM model in virtual reality compared with traditional 2D plans or desktop-based 3D models. Being able to visualise the model at true scale in the immersive environment during the walkthrough helps improve clarity and detect misaligned elements intuitively. The ability to combine real-time voice and gesture input, along with the avatar-based presence of the user, provided a sense of natural communication. This helped to improve the effectiveness of coordination meetings.

Figures 4(a) and 4(b) show the initial interaction with the uploaded BIM model. Participants accessed the virtual workspace, viewed the building design in 3D, and began collaborative discussions. The shared environment replicated the dynamics of a physical meeting room, while overcoming geographical constraints by connecting participants across different locations.

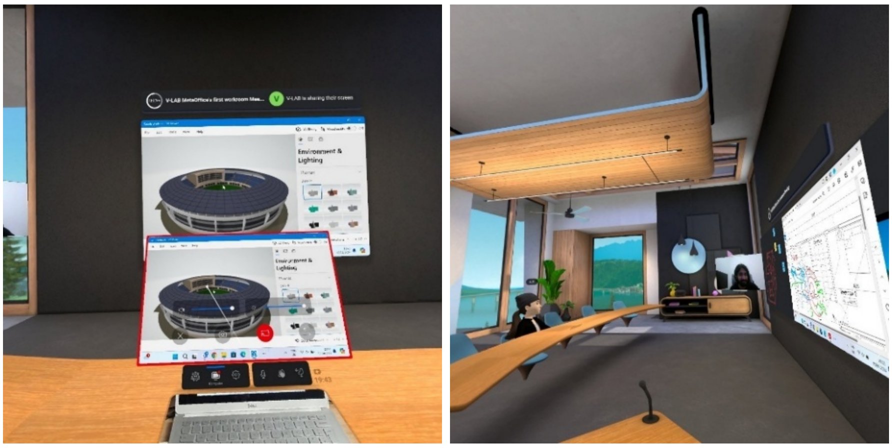

Fig. 4. Stakeholders accessing the uploaded BIM model within Horizon Workrooms. (a) Initial view of the default building model in the shared virtual workspace. (b) Multi-device participation, showing interaction between VR headset users and desktop participants.

Figures 5(a) and 5(b) highlight the use of the platform for design coordination. In Figure 5(a), a building design is displayed on the shared screen, while participants discuss its features and raise coordination issues. In Figure 5(b), an avatar representing one of the team members explains the design directly within the environment, suggesting modifications and highlighting areas of concern. This interaction demonstrated how avatar presence, combined with spatial audio, can make virtual design reviews more engaging and productive.

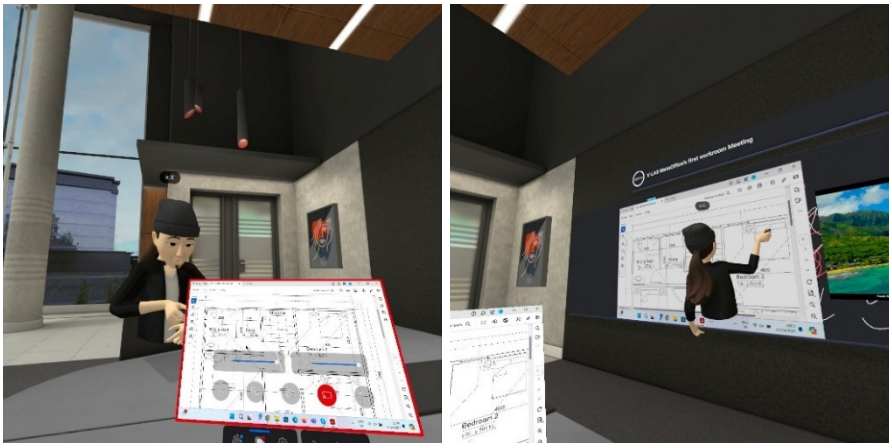

Fig. 5. Collaborative design coordination in the Metaverse environment. (a) Shared screen display of the BIM model during discussion. (b) Avatar-based explanation of design features with real-time feedback and modification proposals.

Figures 6(a) and 6(b) illustrate deeper collaboration and issue management. Figure 6(a) shows suggestions for plan modifications overlaid directly on the model, providing clarity on how changes would be implemented and which sections were affected. Figure 6(b) captures a broader group discussion in which participants debated multiple design items, combining both VR-immersed users and screen-based participants. These sessions confirmed that hybrid participation is feasible, although headset users reported greater immersion and focus compared with those joining via desktop.

Fig. 6. Model modification and interdisciplinary discussion. (a) Overlay of suggested design changes within the shared BIM model. (b) Group interaction and debate on multiple design items across VR and desktop interfaces.

Participants highlighted increased engagement and inclusivity during collaborative sessions. The avatar-based presence helped maintain meeting etiquette, while shared model viewing supported more focused discussions. However, several challenges were noted. Performance varied across devices, with some latency occurring during the rendering of complex geometries and lower-bandwidth connections. Extended VR sessions also caused discomfort for some users, including dizziness and loss of balance. Additionally, varying levels of familiarity with VR controls created a learning curve, indicating the need for onboarding and training.

Even though several limitations were found, the integration of BIM and XR within Horizon Workrooms was positively received. Early stage planning, stakeholder engagement and interdisciplinary coordination were improved with XR as demonstrated by the hands-on sessions. The framework shows strong potential for improving productivity and sustainability in construction project delivery, as evidenced by the reduced reliance on physical travel and real-time design evaluation with virtual collaboration.

5 Discussions

This study investigated the integration of Building Information Modelling (BIM) and Extended Reality (XR) within a Metaverse environment, with a focus on remote project management, stakeholder collaboration, and immersive visualisation. The study's findings highlight the potential and limitations of adopting XR technology in construction project workflows. There was an accelerated shift towards the digital distributed working models that stressed the need for collaborative tools which go beyond the traditional tools like email, online meeting and file sharing when COVID-19 hit the world. The results from this case study put forward the Metaverse-based collaboration platform as a viable solution for addressing such needs. By enabling stakeholders to interact with federated BIM models at scale, supported by real-time communication features such as spatial audio, avatars, and virtual whiteboards, the framework enhanced spatial awareness, strengthened engagement, and improved the efficiency of design coordination.

The use of avatars contributed positively to participant presence and meeting etiquette. While avatar realism in terms of facial expression remains limited, gestures and spatial positioning offered sufficient cues to replicate aspects of non-verbal communication. This indicates that even with current technological constraints, avatar-based collaboration can approximate the dynamics of physical meetings. Future advances in photorealistic avatars and facial tracking could further improve inclusivity and authenticity in virtual collaboration. Communication quality was generally strong, particularly due to the use of spatial audio, which made conversations more natural and intuitive. However, participants noted that multilingual collaboration remains a challenge. The potential integration of real-time translation or subtitles represents an important area for further research, as it could increase accessibility for multinational teams and reduce language barriers in global projects.

With respect to model interaction, the integration of BIM into the XR environment enhanced design comprehension and facilitated intuitive problem-solving. Participants reported a higher ability to detect conflicts such as clearance issues and misalignments, compared with reviewing 2D drawings or desktop-based 3D models. This validates the growing body of research that positions XR-enhanced BIM as a powerful tool for collaborative design review. Nevertheless, limitations in visual fidelity were observed. Certain material textures and reflective surfaces were not rendered with full accuracy (e.g. transparency), which reduced realism and could impact decision-making in design contexts where material finish is critical. Improvements in rendering algorithms and device performance are therefore necessary to achieve fully immersive visual quality. Device performance varied, with latency observed in complex models or under lower bandwidth conditions. Technical and ergonomic challenges were also noted. Some users experienced discomfort during prolonged VR sessions, highlighting the importance of ergonomic headset design and user adaptation periods. Additionally, differences in VR proficiency across participants affected collaborative efficiency, reinforcing the need for onboarding and training sessions.

The findings from the study confirm that XR-enabled collaboration has transformative potential for construction project management. It is also observed that there is a greater impact in early-stage planning and multi-stakeholder engagement. While technical limitations remain, the study provides evidence that immersive environments can improve communication, reduce travel, and contribute to broader sustainability objectives by supporting remote collaboration.

6 Conclusion

This paper presented a Remote Collaboration Framework that integrates Building Information Modelling (BIM) and Extended Reality (XR) technologies within a Metaverse environment. Through a case study using the Student Life Building and the Meta Horizon Workrooms platform, the study demonstrated how immersive environments can enhance spatial awareness, strengthen communication, and support cross-disciplinary collaboration in construction projects. The research results showed that XR-based Metaverse systems replicate the dynamics of face-to-face meetings while limiting physical travel needs, which supports environmental sustainability and digital transformation initiatives. The study revealed multiple challenges such as device performance issues, rendering quality problems, user comfort during long VR sessions and differences in user technical abilities. These challenges highlight the importance of onboarding, training, and continued refinement of XR platforms to ensure effective adoption.

The case study demonstrated BIM-XR integration through Metaverse technology which shows great potential for future remote project management systems. The framework serves as an essential tool to increase productivity while helping construction projects meet sustainability goals through better team communication and coordination.

Future research needs to focus on developing virtual environment realism and making XR technology accessible to all users. The complete realisation of virtual environments for efficient project delivery requires additional research into intelligent collaboration tools.

Acknowledgments. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure of Interests. The authors declare no competing interests. The use of Meta Horizon Workrooms, Oculus Quest 2, Microsoft HoloLens, and other software or hardware in this study was solely for research and demonstration purposes. The authors did not receive financial support, sponsorship, or promotional incentives from the respective companies.

References

1. Coskun, S., Washington, C. and Erdogmus, E. (2024) "A Study on Causes of Gender Gap in Construction Management: High School Students' Knowledge and Perceptions across Genders," Buildings, 14(7), p. 2164. Available at: https://doi.org/10.3390/buildings14072164.
2. National Association of Home Builders (2025) The Offsite Construction Market Share Flattens Nationally in 2024, 28 August. Available at: https://www.nahb.org/blog/2025/08/the-offsite-construction-market-share-flattens-nationally-in-2024
3. Abioye, S.O. et al. (2021) "Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges," Journal of Building Engineering, 44, p. 103299. Available at: https://doi.org/10.1016/j.jobe.2021.103299.
4. McPhail, R. et al. (2023) "Post-COVID remote working and its impact on people, productivity, and the planet: an exploratory scoping review," The International Journal of Human Resource Management, 35(1), pp. 154–182. Available at: https://doi.org/10.1080/09585192.2023.2221385.
5. Henderson, L.S. (2008) "The Impact of Project Managers' Communication Competencies: Validation and Extension of a Research Model for Virtuality, Satisfaction, and Productivity on Project Teams," Project Management Journal, 39(2), pp. 48–59. Available at: https://doi.org/10.1002/pmj.20044.
6. Akhorshaideh, A.H.O. et al. (2024) "The impact of IT tools on project management efficiency in the public sector: The mediating role of team communication," Journal of Project Management, 9(4), pp. 345–352. Available at: https://doi.org/10.5267/j.jpm.2024.8.002.
7. Pullan, P. and Prokopi, E. (2016) Leading virtual project teams: dos and don'ts. Newtown Square, PA: Project Management Institute.
8. Morley, S., Cormican, K. and Folan, P. (2015) "An Analysis of Virtual Team Characteristics: A Model for Virtual Project Managers," Journal of technology management & innovation, 10(1), pp. 188–203. Available at: https://doi.org/10.4067/s0718-27242015000100014.
9. Morgan, L., Paucar-Caceres, A. and Wright, G. (2014) "Leading Effective Global Virtual Teams: The Consequences of Methods of Communication," Systemic Practice and Action Research, 27(6), pp. 607–624. Available at: https://doi.org/10.1007/s11213-014-9315-2.
10. Goldstein, S. and Naglieri, J.A. (eds.) (2014) Handbook of Executive Functioning. Springer New York. Available at: https://doi.org/10.1007/978-1-4614-8106-5.

11. Obikunle, O. (2002). Dealing with cultural diversity in project management: a dilemma in communication. Paper presented at Project Management Institute Annual Seminars & Symposium, San Antonio, TX. Newtown Square, PA: Project Management Institute.
12. Huang, J. (2016) “The Challenge of Multicultural Management in Global Projects,” Procedia - Social and Behavioral Sciences, 226, pp. 75–81. Available at: https://doi.org/10.1016/j.sbspro.2016.06.164.
13. Ranf, D.E. (2010) “Cultural Differences In Project Management,” Annales Universitatis Apulensis Series Oeconomica, 2(12), pp. 657–662. Available at: https://doi.org/10.29302/oeconomica.2010.12.2.18.
14. Isern, G. (2015) “Intercultural Project Management for IT: Issues and Challenges,” Journal of Intercultural Management, 7(3), pp. 53–67. Available at: https://doi.org/10.1515/joim-2015-0021.
15. Lückmann, P. (2015) “Towards Identifying Success Factors for Cross-cultural Project Customer Engagement: A Literature Review,” Procedia Computer Science, 64, pp. 324–333. Available at: https://doi.org/10.1016/j.procs.2015.08.496.
16. Wang, T. and Chen, H.-M. (2023) “Integration of building information modelling and project management in construction project life cycle,” Automation in Construction, 150, p. 104832. Available at: https://doi.org/10.1016/j.autcon.2023.104832.
17. Brewer, R. (1988) “Building information,” Batiment International, Building Research and Practice, 16(6), pp. 346–351. Available at: https://doi.org/10.1080/01823328808726925.
18. Succar, B. (2009) “Building information modelling framework: A research and delivery foundation for industry stakeholders,” Automation in Construction, 18(3), pp. 357–375. Available at: https://doi.org/10.1016/j.autcon.2008.10.003.
19. Eadie, R. et al. (2013) “BIM implementation throughout the UK construction project lifecycle: An analysis,” Automation in Construction, 36, pp. 145–151. Available at: https://doi.org/10.1016/j.autcon.2013.09.001.
20. Lidelöw, S., Engström, S. and Samuelson, O. (2023) “The promise of BIM? Searching for realized benefits in the Nordic architecture, engineering, construction, and operation industries,” Journal of Building Engineering, 76, p. 107067. Available at: https://doi.org/10.1016/j.jobe.2023.107067.
21. Goulding, J. S., Rahimian, F. P., & Wang, X. (2014). Virtual reality-based cloud BIM platform for integrated AEC projects. Journal of Information Technology in Construction, 19, 308-325.
22. Fellows, R. and Liu, A.M.M. (2012) “Managing organizational interfaces in engineering construction projects: addressing fragmentation and boundary issues across multiple interfaces,” Construction Management and Economics, 30(8), pp. 653–671. Available at: https://doi.org/10.1080/01446193.2012.668199.
23. Goulding JS, Rahimian FP, Wang X (2014). Virtual reality-based cloud BIM platform for integrated AEC projects, ITcon Vol. 19, Special issue BIM Cloud-Based Technology in the AEC Sector: Present Status and Future Trends, pg. 308-325, https://www.itcon.org/2014/18
24. Nguyen, Tuan Anh, Nguyen, Tu Anh and Tran, T.V. (2024) “Building Information Modelling (BIM) for Construction Project Schedule Management: A Review,” Engineering, Technology & Applied Science Research, 14(2), pp. 13133–13142. Available at: https://doi.org/10.48084/etasr.6834.
25. Dudhee, V., Bandara, P.D., Vukovic, V., Nalakath, A., Bass, P., Bass, E.: Artificial Intelligence-Enhanced Virtual Reality for Health and Safety Training in Construction (2024)
26. Dudhee, V. and Vukovic, V. (2021) “Integration of Building Information Modelling and Augmented Reality for Building Energy Systems Visualisation,” Springer Proceedings in

Energy. Springer International Publishing. Available at: https://doi.org/10.1007/978-3-030-63916-7_11.
27. Dudhee, V. and Vukovic, V. (2021) “Building information model visualisation in augmented reality,” Smart and Sustainable Built Environment, 12(4), pp. 919–934. Available at: https://doi.org/10.1108/sasbe-02-2021-0021.
28. Dudhee, V, Vukovic, V & Rahimian, F 2022, Building Sensory Information in Augmented Reality: A Conceptual Framework. in A Roxin (ed.), Nouvelles perspectives du BIM: Le jumeau numérique de la construction intelligente (smart building) . 1 edn, Eyrolles, pp. 109-122. <https://izibook.eyrolles.com/produit/9610979/9782212356199/nouvelles-perspectives-du-bim>