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Systematic Literature Review of Korean Research for the Integration of VR, AR, and MR Technologies in Construction BIM: An Exploration Across the Construction Lifecycle

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Abstract: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) epitomize the technological frontier of the Fourth Industrial Revolution, bearing significant relevance to the construction sector. These immersive technologies, closely aligned with the burgeoning metaverse paradigm, have spawned a variety of applications within the construction industry, notably in the whole construction stage. However, their transition to on-field applications remains limited, especially in South Korea. This study aims to meticulously scrutinize the current landscape of VR, AR, and MR research in construction by delving into various overseas studies that employ these technologies across the construction lifecycle. Utilizing the RISS, Dbpia, KCI database, a systematic accumulation of bibliographic data from pertinent research papers will be conducted to discern the prevailing research trends and the practical implications of VR, AR, and MR in Korean AEC field. The analysis will encompass a review of the goals, methodologies, and outcomes of these studies, providing a scaffold for future research in this domain. The investigation will also shed light on the potential synergy between these immersive technologies and Building Information Modeling (BIM), which encapsulates the whole construction lifecycle, thereby illuminating pathways for enhanced digital model utilization in pre-construction processes. This endeavor not only seeks to bridge the existing research gap but strives to propel the Korean AEC field towards a digitally-augmented horizon by leveraging the capabilities of VR, AR, and MR.

Key words: Construction Lifecycle, Building Information Modeling (BIM), Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR)

1. INTRODUCTION

Recently, virtual reality (VR) technology has become increasingly important in the field of architecture, and research has been conducted on how to incorporate VR's basic technology into 3D design and architectural design [1]. In addition, VR technologies that were once visually proposed at the final stage of the design process are now being utilized in all stages of the design process [2]. Augmented reality (AR) and mixed reality (MR) technologies have also been proposed for use in various ways in architecture, construction, and engineering (AEC) field [3], [4].

However, *in South Korea, the use of VR/AR technology is not universalized* [5], and the use of VR/AR among construction companies' smart construction technologies is the lowest among other smart construction technologies, at 7.4% of all companies and 25% of large offices [6].

For immersive technologies such as VR, AR, and MR, despite the growth of their use in BIM [7], a lack of understanding of their integration in the architectural process has been noted [8]. Especially in South Korea, BIM technology is being mandated by the government, but it has been pointed out for many years that the visualization methods to utilize it are limited to 2D images [9], [10]. Furthermore, while there are studies on the research trends of immersive technology utilization from the perspective

of BIM in the AEC field overseas [11], in South Korea, there are no studies on the status or trend of immersive technology for BIM through the whole construction lifecycle stages.

Given the current status of immersive technology utilization in the domestic AEC field, it is necessary to take a closer look at the current status and trends of the goals, methodologies, and application results of immersive technology utilization. In particular, in the domestic AEC field, technology development and legislation are being carried out centered on BIM led by the government, so it is necessary to pay attention to immersive technology research from the BIM perspective. In particular, as the government has announced plans to expand BIM beyond design and construction to whole stages of the construction lifecycle [12], it is worth paying attention to the stages covered by previous studies. Therefore, this study focuses on previous studies on the utilization of immersive technologies (VR, AR, MR) for BIM in all stages of the construction lifecycle in the AEC field.

In this study, a systematic literature review analysis was conducted on previous studies on the utilization of BIM-related immersive technologies in the AEC field of South Korea to identify the directions and limitations of BIM-based immersive technology utilization research in the AEC field. Specifically, the aim was to identify the trends in the use of immersive technologies for BIM in Korean AEC research and, in the case of Korean research, which stages of the construction lifecycle are active in the use of immersive technologies for BIM.

2. Materials and Methods

In this study, we conducted systematic literature review analysis to identify research trends in the utilization of immersive technologies for BIM in the Korean AEC field. Systematic literature review is a means of evaluating and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest. Figure 1 shows the process of this study.

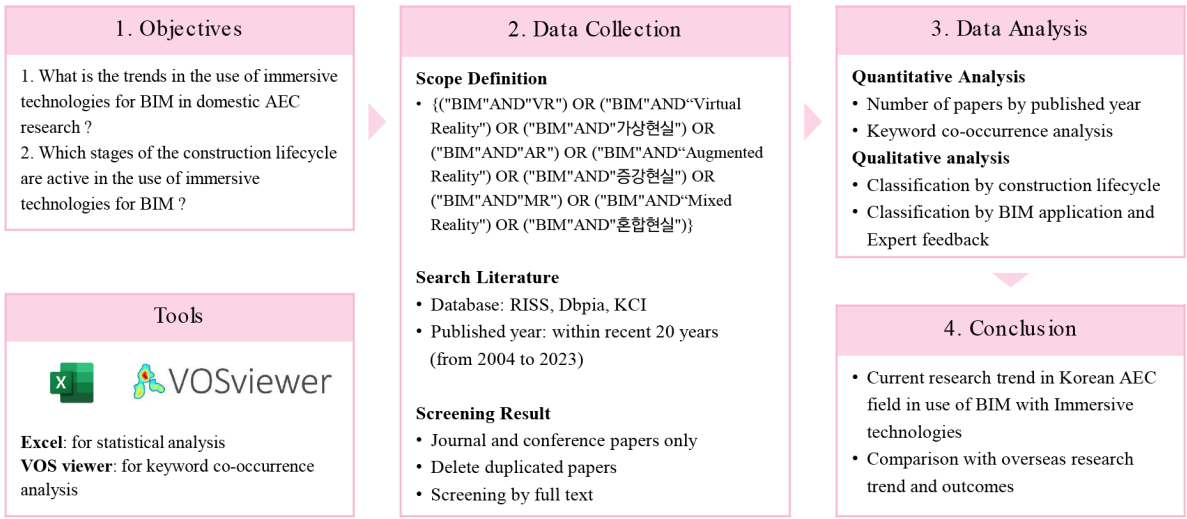

Figure 1. Research Process Diagram

The data for the analysis was collected from domestic academic databases RISS, Dbpia, and KCI, and utilized journal articles and conference papers. For immersive technologies (VR, AR, MR), the search terms were set to include both Korean and English words to avoid missing research papers due to differences in Korean and English words in Korean papers. The final search terms used were ("BIM"AND"VR") OR ("BIM"AND"가상현실") OR ("BIM"AND"Virtual Reality") OR ("BIM"AND"AR") OR ("BIM"AND"증강현실") OR ("BIM"AND"Augmented Reality") OR ("BIM"AND"MR") OR ("BIM"AND"Mixed Reality") OR ("BIM"AND"혼합현실"). The bibliographic information of the papers was collected from each database, and the bibliographic information required for the analysis was obtained by excluding duplicate papers and selecting literature in the AEC field. Utilizing the bibliographic information, articles were selected that were closely related to the topic of this study through their titles and abstracts. Through the above process, a total of 130 papers published in the last 20 years were collected for quantitative analysis.

3. SYSTEMATIC LITERATURE REVIEW RESULTS

3.1. By Publication Year

A total of 130 papers published over a 20-year period from 2004 to 2023 were analyzed for annual publication counts to understand the yearly flow of research on the use of immersive technologies in Korean AEC field. The articles were divided into five time periods with publication years separated by four-year intervals, and the results can be seen in Figure 2 and Table 1.

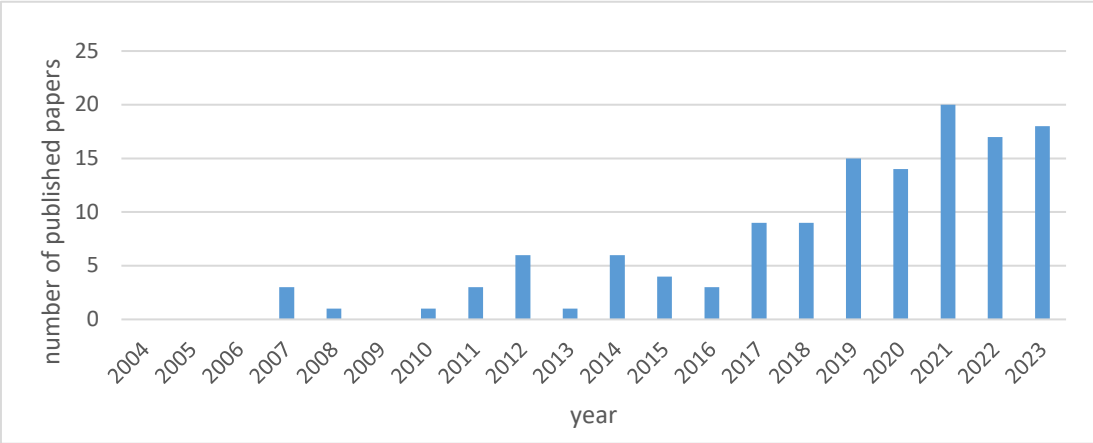

Figure 2. Number of Paper by Publication Year

First, the graph in Figure 2 shows the specific years when the number of publications increased. For the first eight years after 2004, there were relatively few papers meeting the keyword search criteria (around one per year on average for each). However, in the 2010s, the number of publications gradually increased as interest in BIM, VR, and AR increased. Specifically, in 2012, the number of papers increased due to the development of smartphone-based AR technology due to the proliferation of smartphones in the 2010s, and in 2014, the number of related papers increased due to the announcement of Google Glass (AR) in 2013 and Google Cardboard (VR) in 2014. The increase in the number of papers from 2017 can be related to the release of commercialized stand-alone VR HMDs in 2016. The sharp increase after 2019 can be linked to the announcement of government mandates for BIM and the release of wireless VR HMDs, and since 2019, more than 10 papers have been published annually, indicating that more researchers are now interested in the application of immersive technologies in BIM.

The following Table 1 shows that the number of papers has increased somewhat since the release of simple devices such as cardboard, and that the number of papers from 2016 is more than 80% of the total number of papers, indicating the increased interest in the use of immersive technologies in AEC in relation to BIM since 2016.

Table 1. Number of Publication by year (4-year basis)

Period	Years	Published Papers (Percentage)	Average Papers per Year
1	2004~2007	3 (2.31%)	0.75
2	2008~2011	5 (3.85%)	1.25
3	2012~2015	17 (13.08%)	4.25
4	2016~2019	36 (27.69%)	9
5	2020~2023	69 (53.08%)	17.25
Total	20 years	130 (100%)	6.5

Many researchers have been studying the application of immersive technology for BIM in the AEC field, but as mentioned in the introduction, the application of immersive technology in the Korean construction industry is insufficient. In order to understand the reasons for this lack of research, this study identified the overall research trends of previous studies and the research status of each stage of the construction lifecycle.

3.2. Keyword Co-Occuraence Analysis

The 130 articles described in Table 1 were imported into VOS viewer software (version 1.6.20) to perform keyword co-occurrence analysis. Prior to the analysis, keywords written in Korean and synonymous keywords were merged. To increase the representativeness of the keyword clustering results to some extent among the 359 keywords, the minimum threshold of keyword co-occurrence was set to '2', resulting in 58 co-occurring keywords classified into 5 color clusters as shown in Figure 3.

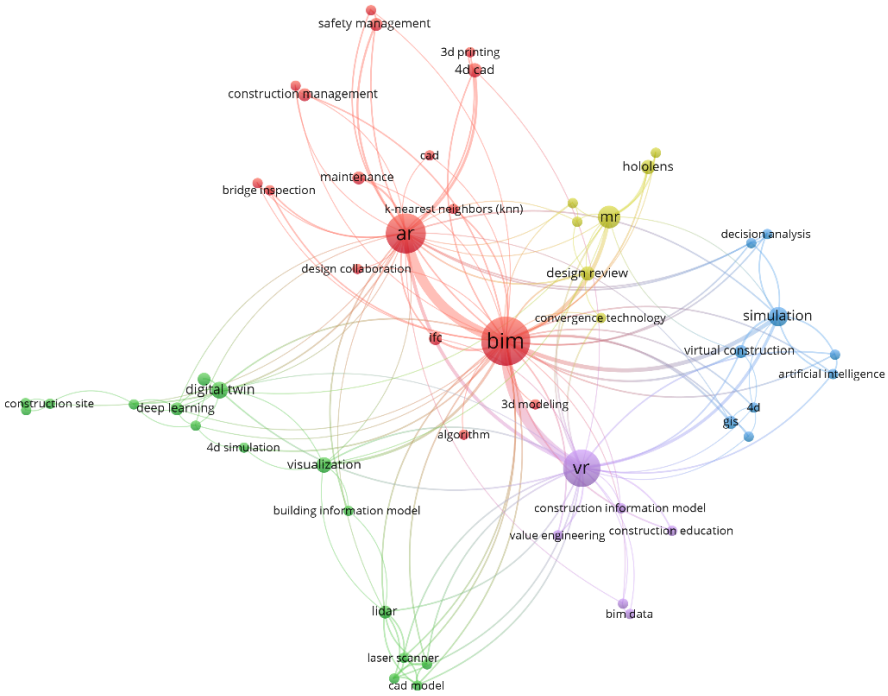

Figure 2. Data Keyword Network (minimum occurrence: 2)

The size of the node circles in the network visualization generated by VOS Viewer indicates the frequency of occurrence of keywords. The larger the size of the node, the more often the same keyword is found in different papers, and the width of the line indicates the strength of the connection between two keywords. Therefore, the keyword co-occurrence analysis network visualization in Figure 3 shows the knowledge structure and research trends in immersive technologies for BIM in Korean AEC field.

In Figure 3, the largest node in the center is BIM and AR, with other nodes clustered around VR, Simulation, MR, Digital Twin. *Cluster 1* (red) is centered on BIM and AR, with keywords such as 4d cad, construction management, ifc, safety management, and maintenance, and includes contents such as construction management [13], [14] and maintenance utilizing AR [15]. *Cluster 2* (purple) is centered on VR and consists of keywords such as smart construction, bim data, construction education, construction information model, value engineering, and includes contents such as smart construction using VR and BIM data. *Cluster 3* (blue) is centered on simulation, with keywords such as virtual construction, GIS, 4D, artificial intelligence, decision analysis, drones, free-form buildings, and user behavior evaluation, and includes contents such as virtual construction for 4D simulation in the construction stage [9], [10]. *Cluster 4* (green) is centered on Digital Twin and consists of keywords such as visualization, deep learning, smart city, LiDAR, and includes contents such as visualization for smart cities and digital twins [4]. *Cluster 5* (yellow) is centered on MR, with keywords such as design review, hololens, decision making, and contents such as design review and decision making using MR.

3.3. Classification analysis by construction lifecycle stage

In order to identify the specific role of immersive technology in BIM research in the Korean AEC field, this study selected 27 articles that were listed in the KCI and were closely related to the topic and conducted a qualitative analysis. The criteria for relevance were 1) whether the keywords included BIM and immersive technologies, 2) whether the content of the paper could be analyzed by mapping it to the stages of the construction lifecycle, and 3) whether the affliation of first author is Korean institution.

In this study, the papers were mapped to various construction lifecycle stages based on previous research on research trend of immersive technologies for BIM [11], the results are shown in Table 2.

Table 2. Classification by construction lifecycle stage

Stage	Research Category	References
Design	Using immersive technology in design process	Heo *et al*. (2012), Ryu *et al*. (2014), Yu & Lee (2018), Kim *et al*. (2019), Ikhbayar *et al*. (2022), Lee & Lee (2023)
Construction	Using immersive technology for pre-comstruction	Jang *et al*. (2008), Seo *et al*. (2023)
	Using immersive technology for construction management	Kim *et al*. (2018), Kwon *et al*. (2022), Lee *et al*. (2022), Suk *et al*. (2023)
	Using immersive technology for virtual construction simulation	Seo & Park (2017), Baek (2018), Seo (2020), Park *et al*. (2020)
	Using immersive technology for safety issue	Jeon *et al*. (2021), Jeon *et al*. (2022)
	Using immersive technology for cooperation in construction	Park *et al*. (2020)
Operation and Maintenance	Using AR for management system	Moon *et al*. (2015), Shin *et al*. (2022)
Whole Lifecycle	Using immersive technology for supporting decision making	An *et al*. (2010), Lim & Ock (2012), Shin *et al*. (2014), Choi & Shin (2014)
	Technical implement for immersive technology	Ahn *et al*. (2018)
	Case study of VR/AR application by lifecycle	Lee *et al*. (2019)

As shown in Table 2, 6 papers were selected for the design stage, 13 for the construction stage, 2 for the operation and maintenance stage, *none for the renovation and demolition stage*, and 6 for the whole lifecycle stage. The stage with the highest percentage was found to be the construction stage.

The applications of immersive technologies using BIM in the *design stage* categorized as utilization in the design process. In the design process, AR technology can be utilized to update BIM models without the need to create mockups [16], VR could be utilized for simulation of IoT devices [17]. Work processes and possibilities for linking BIM and AR were reviewed [18], and a design process for utilizing BIM and VR was also proposed [19]. MR could be utilized to pre-assess BF certification levels in the design stage [20], and in the value engineering (VE) process to examine the feasibility of applying or adopting alternatives to reduce costs and improve performance of a project, VR can be utilized for effective decision-making due to its realism and immersion [21].

The applications of immersive technology with BIM in the *construction stage* were categorized into pre-construction, construction management, virtual construction, safety, and collaboration. Before construction, VR can be used for equipment planning for tower cranes [22], and BIM data can be used to visualize the impact of blasting in underground spaces [23]. During construction, 4D objects and AR objects can be linked to implement schedule information to utilize changing information [13], BIM models can be visualized in an MR environment to perform process management and progress management [4], BIM and AR can be used for fast-track construction of fabrication facilities to efficiently execute site management [14], AR can be used for quality control of rebar placement in railway facilities to increase convenience and efficiency compared to the existing inspection method [24]. In addition, for virtual construction simulation, a multi-screen based system could be utilized to review drawings [10], virtual construction sites containing process information could be utilized to effectively communicate safety information using VR [25]. BIM material automation technology [26] and BIM-MR data linkage and marker generation methodology and operation for virtual construction were reviewed [27] to enable such virtual construction. BIM-based AR technology and information content for a safety management system for railroad infrastructure construction were identified and evaluated [3], and a framework and system for AR-based safety inspection were developed [28]. Finally, a scenario of an immersive technology-enabled collaboration system using BIM data was also proposed to solve communication problems between workers during the construction stage [29].

The application of immersive technology using BIM in the *maintenance and operation stage* was categorized as facility and structure maintenance. Non-marker-based AR technology could be utilized in the maintenance stage of BIM data created in the design stage [30], and if the geometry and attribute information of the BIM model is converted to IFC format and implemented into augmented reality, it can be effectively utilized in the maintenance of underground facilities [15].

The applications of immersive technology with BIM *across all stages of the construction lifecycle* were categorized into decision support, technical implementation, and case studies. AR-based simulation systems could be utilized to support participants' decision-making in the design, construction, and maintenance stages [31], and complex, diverse decision-making processes, such as in the case of

free-form buildings, could be improved [32]. IFC Viewer's solution [33] and VR services using it were also developed [9] for decision support in all stages of the construction lifecycle. A case study of BIM data-based VR visualization for construction and maintenance stages in China was also conducted [34].

3.4. Classification analysis by BIM application type and Export review

A previous study analyzing the current state of research on VR, AR, and MR in the field of architecture checked whether experts made feedback in the analysis, and pointed out the reality of technology development that is not related to the requirements of the practice field [35]. Therefore, this study also checked the classification of BIM use for the previously adopted papers and checked whether expert interviews or reviews were conducted in the development of frameworks or methodologies.

As shown in below Table 3, in the case of BIM utilization, 20 of the 27 selected papers, about 74%, did not simply mention BIM, but conducted research using or integrated with BIM software. In terms of expert feedback, about one fourth of the 27 selected papers in this study conducted interviews or gathered expert opinions to suggest or validate the content of the study.

Table 3. Classification by BIM application type and Expert feedback

Bim Application	Expert feedback	References	Ratio
Mentioning BIM	Conducted	Jeon et al. (2022)	3.7%
	Not conducted	Shin *et al*. (2014), Moon *et al*. (2015), Kim *et al*. (2018), Ahn *et al*. (2018), Lee *et al*. (2019), Lee & Lee (2023)	22.2%
Using/Integrated with BIM tool	Conducted	An *et al*. (2010), Lim & Ock (2012), Seo & Park (2017), Lee *et al*. (2022), Ikhbayar *et al*. (2022), Suk *et al*. (2023)	22.2%
	Not conducted	Jang *et al.* (2008), Heo *et al.* (2012), Ryu *et al.* (2014), Choi & Shin (2014), Baek (2018), Yu & Lee (2018), Kim *et al.* (2019), Park *et al*. (2020), Park *et al*. (2020), Seo (2020), Jeon *et al*. (2021), Kwon *et al.* (2022), Shin *et al*. (2022), Seo *et al.* (2023)	51.9%

4. DISCUSSION

This paper is a systematic literature review of research papers on immersive technologies for BIM published in South Korea over the past 20 years. A systematic literature reviews was conducted focusing on keywords, construction lifecycle stages, BIM utilization, and expert feedback. Keyword network analysis was conducted to identify the *research trends of immersive technologies for BIM in the Korean AEC field*. As a result, the clusters centered on BIM, AR, VR, simulation, digital twin, and MR identified research trends such as construction management and maintenance, smart construction using VR, virtual construction for 4D simulation, visualization for Digital Twin, and design review using MR.

To identify the specific role of *immersive technologies for BIM by the construction lifecycle* in the Korean AEC field, 29 peer-reviewed KCI-listed journal papers were analyzed. The results showed that in the design stage, studies were mainly conducted to utilize BIM-based immersive technologies for the design process, while in the construction stage, studies were conducted for pre-construction verification, process management during construction, virtual construction simulation, safety, and collaboration. For the maintenance and operation stage, studies of facilities and maintenance were found to have been conducted utilizing BIM-based immersive technologies, and no studies were conducted for the renovation and demolition stages, but various studies were conducted for decision support, technical implementation, and case studies across all stages of the construction lifecycle. However, while the government plans to expand the use of BIM across all stages of the lifecycle, there is a lack of research on the use of immersive technologies for BIM in the maintenance, renovation, and demolition stages.

An examination of the *use of BIM for research and expert feedback* revealed that approximately 74% of the 27 selected papers utilized BIM software or integrated it into other software. However, *only 7 out of the 27 papers* conducted expert opinion gathering or interviews, so in the case of Korean studies, research results often did not reflect practical requirements or were not evaluated in practical aspects.

Compared to the overseas research trends on the use of immersive technologies for BIM [11], in terms of research hotspots and trends, the clusters were similar in that they were formed around AR, VR, and Digital Twin, but in overseas cases, the clusters were formed around 3D modeling techniques for BIM and design optimization. In terms of the use of BIM-based immersive technologies according to the construction lifecycle stages, there are fewer studies conducted in the renovation and demolition stages, and the fact that construction stage has a higher proportion of studies was same as overseas.

5. CONCLUSION AND FURTHER STUDY

This paper explored the research trends and challenges of immersive technology research for BIM in the Korean AEC field, both quantitatively and qualitatively. This is the first attempt to conduct a systematic literature review on immersive technology in South Korea, and it could be a useful basis for researchers in the AEC field as it has been 10 years since immersive technology has been commercialized and expectations are increasing due to new devices. However, since this study extracted and analyzed bibliographic information from the Korean literature databases, it has the limitation of not including the research trends of Korean researchers who published their research in overseas specialized journals. Therefore, future studies can provide a more accurate and comprehensive understanding of the research trends and achievements of immersive technology for BIM in Korean AEC field by including the contents of other databases such as WoS and Scopus.

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REFERENCES

[1] U. Jung, J.H. Lee, J. Park and D.W. Sohn, "An Analysis of Architectural Literature Review using VR", *Proceedings of Spring Annual Conference of the Architectural Institute of Korea*, vol. 41, no. 1, pp. 206-207, 2021.

[2] J.H. Lee, "A Study on Space Design Cases Using VR Technology", *Journal of the Korean Society Design Culture*, vol. 26, no. 3, pp. 355-368, 2020.

[3] H. Jeon, Y. Yu, B. Ko, S. Kim, and B. Koo, "Augmented Reality-Based Safety Inspection Framework for Safety Management in Railway Bridge and Tunnel", *JOURNAL OF THE KOREAN SOCIETY FOR RAILWAY*, vol. 24, no. 7, pp. 590-607, 2021.

[4] D.Y. Kwon, G.H. Jang, and S. Kim, "Progress Management Visualization Process Using BIM-based MR Technology", *Journal of the Regional Association of Architectural Institute of Korea*, vol. 24, no. 2, pp.79-86, 2022.

[5] B. Jo, H.H. Cho, and C.B. Son, "An Analysis on the Utilization Status of VR and AR in the Construction Industry and Its Improvement Measures", *Journal of the Architectural Institute of Korea*, vol. 37, no. 1, pp. 229-236, 2021.

[6] G.P. Lee, S.Y. Choe, T.H. Sohn, and S.I. Choi, "Survey on Smart Technology Applications of Korean Construction Companies and Strategies for Activation", *CERIK*, Seoul, Korea, 2019.

[7] Y. Zhang, H. Liu, S.C. Kang, and M. Al Hussein, "Virtual reality applications for the built environment: Research trends and opportunities", *Automation in Construction*, vol. 118, 103311, 2020.

[8] M. Casini, "Extended Reality for Smart Building Operation and Maintenance: A Review", Energies, vol. 15, no. 10, 3785, 2022.

[9] D.C. Choi and H.M. Shin, "A study on BIM-based immersive Virtual Reality services for decision support", *The Korean Society of Science & Art*, vol. 17, pp. 435-442, 2014.

[10] M.B. Seo, and H.J. Park, "Development of Virtual Reality Multi Screen Simulation System based on BIM", *Journal of the Computational Structural Engineering Institution of Korea*, vol. 30, no. 3, pp. 231-238, 2017.

[11] Z. Liu, S. Gong, Z. Tna, and P. Demian, "Immersive Technologies-Driven Building Information Modeling (BIM) in the Context of Metaverse", *Buildings*, vol. 13, no. 6, 1559, 2023.

[12] Ministry of Land, Infrastructure and Transport, "Construction BIM Basic Guidelines", 2020.

[13] H.S. Kim, S.K. Kim, A. Borrmann, and L.S. Kang, "Improvement of Realism of 4D Objects Using Augmented Reality Objects and Actual Images of a Construction Site", *KSCE Journal of Civil Engineering*, vol. 22, no. 8, pp. 2735-2746, 2018.

[14] S.W. Lee, K.S. Lee, S.I. Choi, S.C. Ryu, and J.S. Park, "AR system for FAB construction management using BIM data under fast track condition", *KIBIM Magazine*, vol. 12, no. 4, pp.1-18, 2022.

[15] J. Shin, S. An, and J. Song, "Development of an augmented reality based underground facility management system using BIM information", *Journal of Korean Tunnelling and Underground Space Association*, vol. 24, no. 6, pp. 525-538, 2022.

[16] K.J. Heo, S. Lee, and S.K. Jung, "A Study of Augmented Reality based Visualization using Shape Information of Building Information Modeling", *Spatial Information Research*, vol. 20, no. 2, pp. 1-11. 2012.

[17] J.H. Yu and Y.G. Lee, "A Basic Study on Utilization of Building Information for n Internet of Things (IoT) Simulation System Development", *Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology*, vol. 8, no. 1, pp. 867-874, 2018.

[18] J.H. Ryu, D.S. Baek, and E.H. Lee, "A Study on Application of Augmented Reality Technology in Presentation of Architectural Digital Model - Focused on the Suggestion of Desk-top and Mobile Architectural AR Application and work-flow -", *Design Convergence Study*, vol. 13, no. 1, pp. 83-97, 2014.

[19] J.S. Lee and S.Y. Lee, "A Study of the Integrated Design Process with the Use of VR Technology - Focused on Differences between Architectural Design Process and the Integrated Design Process with the Use of BIM -", Journal of the Architectural Institute of Korea, vol. 39, no. 7, pp. 87-97, 2023.

[20] Y.D. Kim, S.Y. Choo, J.H. Seo, and T.H. Kim, "An Application of BIM-based Mixed Reality to Improve BF Certification", *Korean Journal of Computational Design and Engineering*, vol. 24, no. 2, pp. 211-222, 2019.

[21] K. Ikhbayar, C. Jin, C. Hyun, and S. Lee, "A Review Method of the Applicability for VE Alternatives using Building Information Modeling based Virtual Reality" , *Korean Journal of Computational Design and Engineering*, vol. 27, no. 2, pp. 189-203, 2022.

[22] S.J. Jang, H.J. Jeon, T.B. Shim, S.J. Eom, S.H. Yun, and J.H. Paek, "A Study on the Tower-crane Equipment Planning Support System in the BIM Environment", *Journal of the Architectural Institute of Korea Structure & Construction*, vol. 24, no. 7, pp.109-116, 2008.

[23] M.B. Seo, S.M. Choi, S.J. Oh, S.U. Kim, and J.H. Shin, "BIM-based visualization technology for blasting in Underground Space", *Smart Media Journal*, vol. 12, no. 11, pp. 67-76, 2023.

[24] C. Suk, Y. Jeong, H. Jeon, Y. Yu, and B. Koo, "Development of BIM and Augmented Reality-Based Reinforcement Inspection System for Improving Quality Management Efficiency in Railway Infrastructure", *Korean Journal of Construction Engineering and Management*, vol. 24, no. 6, pp. 53-65, 2023.

[25] J. Park, S.H. Lee, S.H. Kim, J.H. Won, and Y.C. Yoon, "A Study on Safety Information Provision for Workers using Virtual Reality-based Construction Site", *Journal of the Korean Society of Safety*, vol. 35, no. 1, pp. 45-52, 2020.

[26] M.B. Seo, "Automation of BIM Material Mapping to Activate Virtual Construction",*Smart Media Journal*, vol. 9, no. 3, pp. 107-115, 2020.

[27] J.W. Baek, "A Study on the Marker Tracking for Virtual Construction Simulation based Mixed-Reality", *Journal of Korea Academia-Industrial cooperation Society*, vol. 19, no. 12, pp. 660-668, 2018.

[28] H.I. Jeon, Y.S. Yu, B.S. Koo, H.L. Seo, and J.H. Kim, "Deriving AR Technologies and Contents to Establish a Safety Management System in Railway Infrastructure", *KSCE Journal of Civil and Environmental Engineering Research*, vol. 42, no. 3, pp. 427-438, 2022.

[29] S.J. Park, I.G. Hwang, R. Ryu, and Y.S. Kim, "A Study on the Guidelines of XR Collaboration System at the Interior Work of Construction Sites through 3D Scanning", *Korean Journal of Computational Design and Engineering*, vol. 25, no. 3, pp. 329-341, 2020.

[30] S.Y. Moon, S.Y. Yoon, H.S. Kim, and L.S. Kang, "Improved Method for Increasing Maintenance Efficiency of Construction Structure Using Augmented Reality by Marker-Less Method", *Journal of the Korean Society of Civil Engineers*, vol. 35, no. 4, pp. 961-968, 2015.

[31] J.Y. An, J.M. Choi, S.H. Kwon, D.H. Song, and J.H. OK, "A Study on the Development of the Project Management System based on Augmented Reality", *Journal of Korea Academia-Industrial cooperation Society*, vol. 11, no. 8, pp. 3083-3093, 2010.

[32] J.S. Lim and J.H. Ok, "A Pilot Study on the Development of an Augmented Reality-based Decision Support System for Free-Form Buildings Construction Management", *Korean Journal of Computational Design and Engineering*, vol. 17, no. 3, pp. 175-187, 2012.

[33] H.M. Shin, K.J. Park, and D.C. Choi, "A study on BIM-based immersive virtual reality techniques applied to basic research for content development IFC Viewer", *The Korean Society of Science & Art*, vol. 14, pp. 297-305, 2014

[34] J.N. Lee, I.H. Kim, J.S. Choi, and J. JIN, "Case Study of Visualization based on BIM in China Construction", Korean Journal of Computational Design and Engineering, vol. 24, no. 4, pp. 402-410, 2019.

[35] A. Stals, and L. Caldas, "State of XR research in architecture with focus on professional practice – a systematic literature review", *Architectural Science Review*, vol. 65, no. 2, pp. 128-146, 2020