



# EVALUATING THE INFLUENCE OF USING AUGMENTED REALITY AND VIRTUAL REALITY DURING THE DESIGN AND CONSTRUCTION OF PROJECTS: A REVIEW

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**ABSTRACT:** The construction industry is responsible for creating the surrounding built environment. However, that industry is one of the most complex and challenging industries that involves a broad range of stakeholders and complex processes. Recently, the construction sector shifted its interest toward the adaptation of Construction 4.0 concept that incorporates Augmented Reality (AR) and Virtual Reality (VR), which can help improve productivity. Adopting these technologies leads to saving costs, reducing safety problems, increasing the effectiveness of collaboration, and generating efficient scheduling, and monitoring the progress of construction. The aim of this study is to evaluate the influence of using AR/VR technologies during the design and construction of projects and to identify the major advantages and challenges of using them by the construction industry. AR/VR technologies can be applied during the whole lifecycle of a building project; however, the scope of this study is focused on the design and construction stages. Moreover, this study discusses the emerging trends of using AR/VR in construction projects, like the integration of AR/VR with emerging concepts such as the application of web technologies and Building Information Modeling (BIM). To maximize the benefits of AR/VR for architects, engineers, project managers, workers, and clients, this study proposes a BIM-based conceptual framework to integrate AR/VR into project workflows to enhance stakeholder engagement, to emphasize standardization, to secure data management, and to a future integration with other technologies. The successful development of the proposed framework would help parties involved in construction projects over their life cycle by increasing productivity while minimizing costs and delays.

## 1. INTRODUCTION AND BACKGROUND

The construction sector is facing shifts in its procedures and strategies, while the use of new approaches has brought a new insight known as Construction 4.0 (Forcael et al., 2020), which is related to Industry 4.0. Its essence is the digitalization and automation of the construction industry. The broad themes of Construction 4.0 are Digital technologies, Cyber-physical systems, and Industrial production. AR/VR technologies, which simplify and streamline the construction process of assets from start to finish through an operation that improves the efficient collaboration between all parties involved in a project, are very effective in that perspective. This new approach empowers the decision-making process and offers designers and engineers detailed information needed to visualize the construction progress of projects and to improve their productivity. Ongoing studies are necessary in order to determine the advantages of using such new technologies and aspects that are needed to evaluate and use them (Schneider, 2018). Considerable changes in project management have been brought about the use of AR/VR, which include visual technologies (Davila Delgado et al., 2020). These cutting-edge tools have made it possible for project participants to easily create, visualize, and modify complex project schedules in real-time. As a result, the efficiency of construction projects has increased. The successful use of AR/VR technologies in construction projects needs active involvement of several stakeholders, including owners, designers, and end users.

There is a growing trend in the studies related to the use of AR and VR in the construction industry. Many studies focused on improving the safety in construction projects. Li et al., (2018) conducted a critical review about applying Virtual Reality and Augmented Reality in construction safety to identify hazard recognition, safety instruction and inspection, and safety training. Babalola et al., (2023) highlighted the importance of occupational safety and health (OSH) performance improvement by using immersive technologies in the construction sector. Furthermore, many other studies were conducted focusing on training and educating trades in the construction industry. On another side, Tan et al., (2022) performed a systematic review about using AR/VR for education and training purposes in order to find and determine current technologies and future trends. Whereas Li et al., (2018) provided a comprehensive review about the use of VR in construction engineering education and training. Those studies presented a new education guideline by considering the visualization techniques for equipment and operational tasks training. Moreover, Adebowale and Agumba, (2022) presented a systematic review of the application of AR for improving the construction productivity based on monitoring and controlling, health and safety, and assembly in order to improve the overall construction organizations' productivity.

However, the need for additional studies to provide detailed reviews about the integration of AR/VR technologies with BIM concept during the design and construction stages of projects to improve the data accuracy and efficiency in data transmission do exist. Nowadays, engineers and designers want to move toward sustainability and decarbonization, thus using AR/VR can significantly influence their design and collaboration to achieve those objectives. This study aims to identify the benefits and challenges of using AR/VR in construction projects, therefore, it discusses the research gaps in this field and expresses the need for more studies and models' development to enhance the usefulness and efficiency of adopting AR/VR technologies in construction projects. Previous studies are lacking the adaptation of a comprehensive framework to integrate AR/VR into construction project plans. Hence, the main objective of this study is to propose a BIM-based conceptual framework for using AR/VR in construction projects to improve the workflow of information and increase stakeholders' engagement and collaboration.

## **2. PROPOSED METHOD**

AR/VR technologies have been used in recent years for research purposes in the construction sector for various sections. This study, however, considers only the application of AR/VR during the design and construction stages. The proposed methodology to attain the set objectives is structured into two main stages to ensure a comprehensive evaluation of the integration of AR/VR in construction projects. In the first stage, an intense review of the existing literature was conducted to provide insight into the applications of AR/VR in the construction sector, with the focus on determining the research gaps related to the designing, tracking, and collaborating. In the second stage, based on the findings of the first stage, a BIM-based conceptual framework is proposed to integrate AR/VR technologies into construction projects.

To better identify the benefits and challenges of these technologies, the focus of this study was on papers that have been published within the last eight years (2017 – 2024). Evaluating the recent papers can help in identifying the knowledge gaps and accordingly future studies are needed. Publications out of peered journal papers and conference proceedings are considered in this study. The two famous databases, Scopus and Web of Science, were selected as search engines to find the relevant articles. To narrow down the number of papers, a set of keywords was considered with the focus on the application of AR/VR in the design and construction stages of projects. The keywords used in the search included: augmented reality; virtual reality; mixed reality; virtual and augmented reality; immersive virtual environments; and extended reality. Once the papers were completely compiled, a filtering process started by looking at their titles, abstracts, and conclusions to select the most relevant papers in each area. In total, 24 studies that were published within the period between 2017 and 2024, were assessed and reviewed. The characteristics of the evaluated papers are presented in this section. Some journals are providing more attention to AR/VR in the construction sector than others, for example, the Automation in Construction Journal has 7 publications in this review. Figure 1 illustrates sample of the publications that are based on the applied research methods. It shows that modeling and case studies are prevalent approaches.

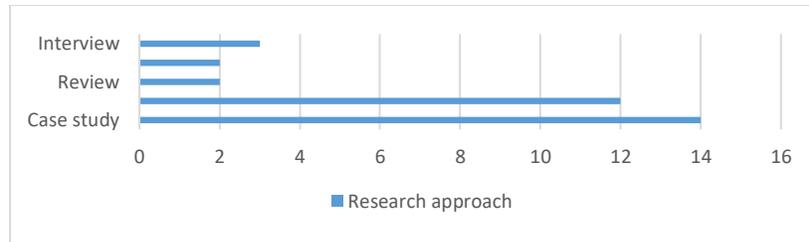


Figure 1: The distribution of research approaches of the evaluated papers

Based on the papers' evaluation in each area, the challenges of using AR/VR in construction projects would be determined. To be more specific, this research concentrates on the following areas: AR/VR in the design process, quality and defect management, scheduling and progress tracking, and communication therefore, a BIM-based conceptual framework to integrate using AR/VR technologies into construction projects by considering all sectors together is proposed.

### 3. LITERATURE REVIEW ANALYSIS

The aim of this study is to give sights into the potential of using AR/VR in the construction industry by investigating the above listed topics and identifying the areas that require additional studies.

#### 3.1. Using AR/VR during the design process

Designing projects, in the construction industry, involves several stages of planning and development that occur before the construction starts. However, the design process may be extended to include bidding and negotiation, construction administration, and post-construction. AR/VR technologies can be adapted to provide highly detailed and accurate designs that can be shared in real-time. This enables various project stakeholders to work together more effectively, resulting in better designs and more efficient construction processes. Panya et al., (2023) presented a platform to mitigate the effect of rework in changing the design by expanding the application of BIM and integrating it with AR/VR technologies. The developed framework integrates BIM with AR/VR functions, game engines, and computer programming. Their proposed methodology addressed the following four main aspects: 1) change factors (e.g., client-related and external factors-related changes); 2) Change identification (through inspection and visualization); 3) Design change (based on options and criteria, and then by AR and VR, all members will be notified of the recent design's change to communicate and take additional investigation effectively); and 4) Implement change (evaluate the change, take a decision, and finally update the change order). The limitation of their research is that it needed a real case project, including the whole building, not just the wall elements, to assess the validity and scalability of the introduced framework. Moreover, using programming tools, such as Python, for semi-automated approaches, like mapping the VR model, can enable the framework to be applicable to any project rather than a specific project. Balali et al., (2018) intended to integrate cost estimation and VR technology to allow various stakeholders to visualize different options, change orders, and the corresponding cost for each of those, to help them make the best decisions at a vital time during the preconstruction phase. As a result, a cost estimating model-based in a VR environment was developed, and a case study was conducted. The proposed model required the following: Cost estimating database (e.g., RS Means), exported as a CSV, a 3D modeling application (e.g., 3D Sketch Up or Revit), and a VR head-mounted display (e.g., Samsung Gear or Oculus Rift). The elements and materials in BIM model and the related cost information were imported to Unity 3D, a VR game engine used to enable the integration between a BIM model and a VR head-mounted display. The user will be able to visualize various options with an increase or decrease in each alternative design's cost, allowing for simple and quick comparisons. They mentioned that VR would save budget because of its low cost.

The end-users, who will occupy the buildings after construction, must be involved early during the design stage. Therefore, Petrova et al., (2017) evaluated the opportunities that the integration of BIM and VR can provide to improve the users' visualization process. More specifically, it investigated the effects of VR implementation in the design process. A case study has been applied on furnishing Aalborg University's Department of Civil Engineering in Denmark, which accommodates 150 employees and 450 students, with

a total area of 9000 m<sup>2</sup>. A total of 20 end-users participated in the visualization, including students, employees, management, maintenance staff, furniture providers, and VR system developers. From a technological perspective, the system required extra technical calibration, development, and functionality expansion. The workflow of Autodesk Revit, as BIM tool, to Unity 3D consumed time and effort, and some gamification principles were not implemented, such as resources used and direct communication within the VR environment. Moreover, some tasks were close to the traditional practices. For example, there was a need for a person to handle the budget manually, also the system was not able to save scenes, leading to making decisions by relying on printed materials. Davidson et al., (2020) proposed a prototype to improve and automate the bill of quantities, allowing users to understand project costs better through the Revit-VR plugin. The windows and furniture of a fully detached private house were used for this process. The result indicated significant potential time and cost savings and highlighted the modern importance of the bill of quantity in the construction processes. Table 1 lists the benefits and challenges of using AR/VR during the design process.

Table 1: Benefits and challenges of using AR/VR during the design process

Benefits	Challenges
Easily identify errors and quickly ask for revision	Level of awareness
Architects and contractors can make changes without the need to travelling to the real site	Lack of AR/VR experts
Design visualization	High cost
Improved budget and schedule	Upper management's insufficient understanding of these technologies
The level of collaboration and understanding between various participants is very high	Design team's inadequate knowledge

### 3.2. Quality/Defect management, scheduling, and progress tracking

In the construction industry, quality issues and defects often occur, which pose serious challenges that can cause project delays, budget overruns, and safety concerns. However, advancements in the AR/VR technologies have emerged as a potential game-changer for quality and defect management. In this regard, various parts of the construction industry should consider using these technologies to find conflicts and flaws and visualize and evaluate different elements' quality. Using AR and creating 3D models can help decision makers identify problems early during the design stage. For instance, engineers can evaluate the concrete's quality and detect tiny cracks with this technology, leading to proper and necessary measures (Rankohi and Waugh, 2013).

The successful execution of construction projects is contingent to effective time and cost management; therefore, it comes the importance of utilizing AR/VR technology. Integrating AR/VR into the construction workflow would significantly increase the efficacy and precision of these crucial processes. One of the proper ways in which AR/VR can be used to achieve this goal is by creating highly intricate 3D models of construction projects. These models can help identify potential conflicts and problems that might arise during the project's lifecycle. Consequently, AR/VR can help in reducing the time and cost and rectifying such flaws at a later stage. Furthermore, AR/VR technology can be employed to construct immersive virtual simulations of construction sites. These simulations assist project managers in keeping track of the construction site in real-time and quickly solving any problem that might occur, leading to more efficient workflows. In addition, AR/VR technology assists the project teams to collaborate more effectively, regardless of their physical location to have a productive collaboration and knowledge sharing. Utilizing AR/VR visualization tools, virtual simulations, and training programs would decrease delays, reduce inefficiencies, and ultimately deliver high quality construction projects (Davila Delgado et al., 2020). Moreover, applying AR/VR technology has completely changed how users can schedule and manage the project's construction progress. The progress of the project can be properly visualized by creating an as-planned model and comparing it with the as-built model, this would help inspectors and supervisors to keep track of any delays in completing the activities. Al-Adhmi et al., (2018) explored VR technology and its applications in diverse fields of building performance analysis, visualization, and construction. The authors mentioned numerous advantages of applying VR technology in various fields, including safety hazards prevention, minimization of costs, and enhancement of collaborations. The authors then provided different aspects of VR applications in the construction, including virtual mock-ups and simulations for safety training.

Subsequently, their study examined the use of VR in building performance analysis, with a particular focus on assessing buildings' energy efficiency and environmental impacts. Moreover, the authors used VR to visualize and analyze building data in real-time, enabling more informed decision-making.

Lin et al., (2020) presented a new approach to employ a cutting-edge strategy by using a real-time AR system based on 4D-BIM model for tower crane operations. The introduced system uses complex BIM data to create a 4D architectural framework of the construction, which is then integrated with AR technology to give the crane operator real-time navigational guidance. By utilizing AR's potential, the system enables the crane operator to move across the construction site with ease and provides an additional layer of security by including a collision detection module. The operator's physical, real-world view is coupled with the 4D BIM model using a head-mounted display (HMD), which also has a precise sensing system to track the operator's positioning and alignment and to prevent potential accidents with other construction site objects. Zhang and Pan, (2021) introduced a new approach for tower crane's layout planning that permits the use of the immersive capabilities of VR technology for high-rise modular integrated construction. The traditional method of crane's layout planning is based on two-dimensional (2D) drawings. Sometimes results are in mismatch between the plan and the real site, which causes serious errors in the final layout. Nevertheless, by enabling users to generate and operate a 3D model of the construction site, which includes modular units, cranes, and other equipment, VR technology overcomes this challenge. Therefore, users can quickly visualize the site and decide on the layout with more accuracy. Comparing the VR-supported technique to the conventional 2D approach, there were several advantages. First, it provided the crew with a 3D visualization of the construction site, allowing them to identify potential conflicts and make the required modifications. Second, it increased safety by reducing errors and giving a more accurate representation of the site. Third, because multiple users could engage with the model simultaneously, it allowed efficient teamwork. Um et al., (2023) presented a mobile augmented reality service for BIM that is incredibly cutting-edge and reasonably priced. The system synchronically combines the benefits of BIM, AR technology, and mobile devices to provide a new approach that enables users to visualize 3D BIM models in the real world. By using the developed mobile AR service, architects, engineers, and contractors can improve their collaboration and communication at the different stages of construction. This low-cost mobile AR service for BIM uses a marker-based AR approach that cleverly implements the actual environment's features, like walls and floors, as surfaces for 3D BIM models. The mobile's camera detects the markers in the real world and then flawlessly superimposes the matching 3D model onto the screen to create an extremely interactive experience.

While BIM and AR have traditionally been used independently in building projects, they may be integrated to provide a more efficient risk management strategy framework for cost and schedule risks. In that perspective, Alirezaei et al., (2022) provided a framework with the aim to use the advantages of integrating BIM and AR in risk management. Dynamic and real-time visualization of construction project's activities is made feasible by combining BIM with AR. Consequently, stakeholders can easily identify potential risks and hazards before they occur, reducing accidents and increasing safety in projects. Stakeholders can visualize the structure's design and identify any possible problems that might occur during the construction stage by using BIM and AR. Such information helps in making well-informed decisions. Furthermore, the integration of BIM and AR helps promote teamwork and communication among different groups engaged in a construction project, reducing the likelihood of misunderstandings and mistakes. Based on the reviewed literature, Table 2 provides key benefits and challenges that are related to the use of AR/VR for quality/defect management, scheduling and progress tracking.

Table 2: Benefits and challenges of using AR/VR for safety and worker training

Quality/Defect management, scheduling, and progress tracking	
Benefits	Challenges
Material handling	Proper investment
Site inspection	Expense of hardware and software
Precise decision making	Resistance to change
Precise measurement	
Site progress	
4D simulation	

### 3.3. Communication and collaboration

In contrast with other industries, the construction sector is divisive and fragmented because of its unique business activities. This fragmentation creates a challenging atmosphere for construction projects and causes a culture of blame where members of the project team try to avoid taking responsibility for inefficient performance instead of collaborating. Efficient collaboration is fundamental for successful decision-making, since communication is a key factor in building synergy and cooperation between stakeholders. To enhance project communication, the construction industry needs better methods and systems to promote progress through concerted decisions and actions (Xu and Moreu, 2021). One promising solution is the application of AR/VR technologies driven by BIM concept. This immersive multimedia technology enables users to interact with digital objects and simulate a user's physical presence in a virtual environment, offering a promising way to enhance project communication in the design and construction activities.

Harikrishnan et al., (2021) examined various communication scenarios in the construction industry where AR technology may substitute for face-to-face meetings. The research is based on data collected from current practitioners, which provides insights into the situations where AR may be an effective solution for addressing communication needs that are related to construction projects. Additionally, contextual factors have been determined through feedback from practitioners that would affect readiness to use AR for collaboration in construction projects. The aim of El Kassis et al., (2022) study was to determine and validate parameters that influence the use of AR technology on actual building sites. The study specifically looked at environmental and technical aspects that influence the propensity to utilize AR on construction sites. Researchers set up AR devices on a building site to collect data and facilitate communication between workers on-site and off-site to handle urgent problems. They recorded the calls without becoming involved, then transcribed and used thematic analysis to derive codes, themes, and aspects associated with AR utilization from the recorded data.

The CoVR framework is a Cloud-Based VR headset solution for AEC use cases, enabling multiple users to communicate (Du et al., 2018). Collected BIM data is used to construct a virtual environment that enables project participants to communicate more effectively from remote locations. CoVR users can participate in a shared, interactive virtual environment simultaneously. The system's game engine leverages BIM metadata to achieve a realistic environment and enable human-computer interaction. Furthermore, technology facilitates interpersonal communication by coordinating users' movements and actions. The architecture of CoVR comprises five layers: 1) BIM model; 2) middleware; 3) game engine; 4) users; and 5) cloud networking. The system uses a game engine to integrate physics engines, avatar animations, and multi-user audio communication. The system is compatible with various operating systems, including iOS, Windows, and Android. This compatibility allows users to access CoVR from various devices, such as laptops, desktops, tablets, game consoles, smartphones, and VR headsets.

Dinis et al., (2020) suggested an approach that focuses on enhancing the communication into construction projects, particularly among professionals who lack adequate skills. Five computer tools were applied, which were divided into three categories: a) Point Cloud; b) VR; and c) BIM Modelling tool. The initial set of tools was employed by using a laser scanner. The second set of tools included the cross-platform game engine Unity, which deemed being the ideal platform for constructing the virtual environment. Finally, Autodesk Revit and Dynamo were employed as BIM modeling tools. The suggested methodology employed a laser scanner point cloud to create a 3D point cloud in a virtual environment, facilitating the attachment of data (such as spoken strings of text) to the design team via users' engagement within that environment. Table 4 lists the key benefits and challenges of using AR/VR for communication and collaboration purposes.

In relation to the integration of AR/VR with BIM concept, it worth mentioning that AR/VR provide immersive environments that can improve data accuracy for error detection and design verification and also enhancing communication efficiency and reduce data silos by offering a centralized system with BIM can streamline the communication between stakeholders and improve the access and interpret of BIM data during design and construction stages. However, there is a need for additional studies to identify how AR/VR can utilize BIM data for real-time visualization, enhanced data sharing, and clash detection in construction projects.

Table 3: Benefits and challenges of using AR/VR for communication

Communication and Collaboration	
Benefits	Challenges
Improving cooperation	specialized hardware and software requirements
Saving time and cost	Technically skilled employees
Working remotely	Time and effort for developing
Attaching location-based data	security
	Avoiding from adoption

#### 4. PROPOSED FRAMEWORK

After reviewing published studies that focused on different areas and identifying the benefits and challenges of using AR/VR, it was found that there is a lack in adopting a comprehensive framework to integrate AR/VR in construction projects by considering different aspects. Therefore, there is a need to develop a BIM-based conceptual framework to integrate AR/VR in construction projects and to consider the design process, communication, and monitoring the construction progress of projects. As discussed before, stakeholders can use AR/VR at different parts of the project, which may lead to fragmented workflow in the project. Therefore, this study proposes a conceptual framework to integrate AR/VR into construction projects to address most of the above listed challenges, as illustrated in Figure 2. The proposed framework aims to integrate these technologies to enhance the efficiency and collaboration throughout the project lifecycle. The following section explains each component of this framework in more detail.

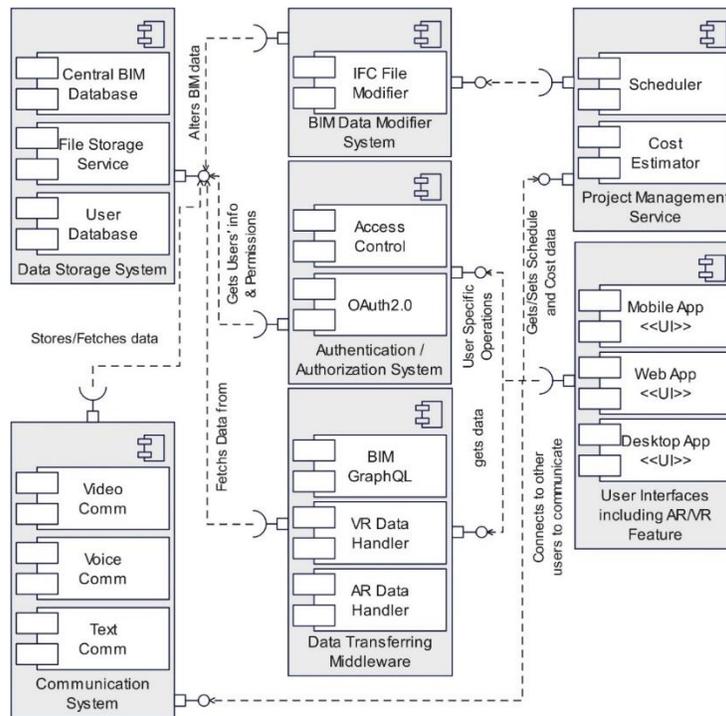


Figure 2: Proposed Framework

**Data Storage System:** The foundation of the framework is the Data Storage System, which provides a centralized repository for all the project-related data. It comprises three key subsystems: a) central BIM database that stores BIM model's data, necessary for providing a structured and detailed digital representation (i.e., AR/VR) of the construction project; b) file storage service that handles various project models (i.e., IFC) and specifications, such as drawings, documents, and reports, to ensure easy access and efficient storage management; and c) user database that manages user-specific information, including roles, permissions, and activity logs, which is crucial for controlling the access and maintaining the security.

The system fetches and stores data, which is required by other components to ensure seamless integration and communication across the framework.

**Communication System:** To foster collaboration in an AR/VR environment among project stakeholders including owners, engineers, architects, and contractors, the Communication System supports multiple modes of communication: a) Video Communication for virtual meetings and walkthroughs, which enhances remote collaboration; b) Voice Communication for discussions and real-time decision-making; and c) Text Communication to ensure traceability and documentation. This system makes sure that all users remain connected, facilitating efficient coordination in both AR/VR environments and traditional project settings.

**Authentication/Authorization System:** Since a huge amount of data must be dealt with while using AR/VR in projects, data security, privacy and sharing mechanisms should be considered. Implementing procedures to protect the data and to ensure seamless data and information exchange between AR/VR tools, BIM tools, and web technologies are required. The framework emphasizes security and role-based access through its Authentication/Authorization System, which includes a) OAuth 2.0, which is a secure protocol for user authentication, enabling third-party integrations without compromising credentials; b) Access Control, which manages permissions based on user roles to ensure that sensitive data is accessible only by authorized individuals. This system fetches user permissions and roles from the User Database, allowing secure and personalized operations.

**BIM Data Modifier System:** This core component enables dynamic modification to BIM data to reflect real-time changes in the project and AR/VR environment. It enables users to modify the BIM data except the geometry related data (which should be done in BIM tool, e.g. Autodesk Revit). There are two modifiers in that system, which include a) IFC File Modifier that Supports IFC standards for BIM data exchange, allows seamless interoperability across platforms, and b) BIM Data Modifier System that facilitates data updates, ensuring that all stakeholders work with the latest project information. This guarantees that the project remains aligned with all the schedule and cost adjustments.

**Data Transferring Middleware:** To bridge the data flow between AR/VR and BIM systems, the Data Transferring Middleware plays a critical role. This middleware has different parts including a) BIM GraphQL, which is a flexible query language for extracting, collecting, and integrating specific BIM data that enables the integration with other systems; b) VR Data Handler, which prepares BIM data for VR applications that enhances immersive visualization for reviewing the design and monitoring the progress; and c) AR Data Handler, which adapts BIM data for AR devices that enables an on-site visualization of construction elements in real-world settings. This middleware ensures efficient data transfer, allowing real-time updates.

**Project Management Service:** The project management service supports essential project planning and execution tasks, including a) Scheduler, which tracks the project timelines, milestones, and deadlines to ensure that activities align with the project plan; b) Cost Estimator, which provides detailed cost analysis and projections, to help stakeholders make informed decisions. This service also provides information to be shown in an AR/VR environment. For instance, users can see the current project situation in terms of progress as a 3D model and metadata. Thus, this service is directly integrated with BIM data and user inputs to enhance project planning accuracy.

**User Interfaces with AR/VR Features:** This framework offers versatile User Interfaces (UIs) tailored to meet the diverse needs of project stakeholders; a) Mobile (Tablet) App, which is designed for on-the-go access to project information and AR-based site visualization; b) Web App, which provides a more comprehensive interface for project management, such as schedule and cost tracking, file and specification management and so on, to increase the usability, accessibility, and scalability of AR/VR; and c) Desktop App, which is more robust and performant than the other devices especially for heavy projects. Each User Interface has AR/VR features that enhance collaboration and decision-making by enabling immersive experiences, such as virtual walkthroughs and real-world overlays. These interfaces connect directly to the BIM data, project management tools, and communication systems to deliver a seamless user experience.

#### **4.1. Benefits of the proposed framework**

Applying this framework, has the following benefits: Enhanced Collaboration: By integrating communication tools, AR/VR features, and centralized data storage, the framework fosters better teamwork among stakeholders. Real-Time Updates: Dynamic BIM data modification to ensure that all stakeholders have access to the most up-to-date data. Efficient Schedule and Cost Management: Integrated project management services streamline the planning process, reducing delays and cost overruns. Enhanced training sessions: Training improves team members' skills to utilize AR/VR technologies effectively by providing training sessions for workers and managers. An ongoing training program is necessary to update workers on task execution, equipment handling, and safety. Standardized data workflow: Developing a comprehensive guideline for AR/VR implementation in any construction project is crucial to have protocols for AR/VR utilization during the design and construction of projects.

#### **5. CONCLUSION**

AR and VR have a lot of potential in the construction industry. They can help architects, engineers, and construction professionals visualize designs and identify potential issues before construction starts. They can simulate dangerous and complex scenarios in a safe, and controlled environment. Also, they can help construction project managers to track progress, identify issues, and collaborate with stakeholders. In order to allow these technologies to continue improving and becoming more accessible, and having more widespread adoption in construction projects, this study aimed to investigate how AR/VR technologies are used in various areas in the construction sector, such as the design process, quality and defect management, schedule progress tracking and communication, and identify the challenges and benefits of their implementation in the construction industry.

This study reviewed recent papers related to the application of AR/VR in construction projects, providing insights into the main benefits and challenges of using these technologies. Literature analysis has identified research gaps, which can serve as a basis for future studies in this field. Moreover, this study has discussed emerging trends and future directions in the application of AR/VR in construction, such as the integration of AR/VR with other emerging technologies like the application of web technologies and BIM models. Each area has its benefits and challenges presented clearly in the discussion. However, there is an agreement on some benefits and challenges in all areas, such as the benefits of simulation/visualization and improved collaboration, and the challenges include high costs and uncertainties of the implementation costs and professionals' lack of awareness of these technologies. The proposed BIM-based framework demonstrates how these emerging technologies can revolutionize construction project management by enhancing efficiency, accuracy, and collaboration. Combining BIM, VR/AR, and robust schedule and cost management tools, this system paves the way for smarter and more connected construction practices.

The findings of this study can be of significant value to stakeholders, such as architects, engineers, contractors, and project managers. This study has some limitations and future directions. First, to ensure the practical application of the proposed framework, there is a need to conduct interviews with experts in this field, including engineers, architects, and project managers to determine the feasibility of the framework in real-world construction projects. Second, several areas also can be covered such as data acquisition and project documentation. Third, the study only focused on the design and construction phases. Therefore, covering the other stages, such as maintenance and operation, and end of life/demolition is influential. Finally, future studies need to take into account challenges related to data privacy issues that may arise because of using web-based applications, the high costs and complexity of using these approaches, and stakeholders' resistance to implementing this framework in real case studies.

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