Integrating Augmented Reality with BIM Tools for Modular Construction

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**Abstract.** In the last decade Building Information Modeling had gained a significant popularity considering its efficiency in integrating multiple tasks during construction. The present study provides a methodology of integrating Augmented Reality with Building Information Modeling (BIM) to provide specific information on modular construction. The primary goal is to provide collaborative efforts to optimize operational efficiency and encounter any challenges faced in the construction process, Enhancing design construction. This study deals with the technical implementation of 2D CAD Drawings into 3D BIM models with efficient structural elements & properties, implementation of 3D BIM models into AR (Augmented Reality), and testing in real-world construction sites. This provides significant contributions to the improvement of construction techniques by providing a realistic framework for the seamless integration of AR with BIM tools in the setting of modular construction projects. Combining AR with BIM in modular is a revolutionary step in technology for the construction industry. With improved 3D Modeling, this new way of working sets a high standard for quality and eco-friendliness in modern construction. This capability not only improves design validation but also reduces costly rework by addressing issues and optimizing the construction life cycle. This technical process increases the advantage of modular construction’s specific requirements.AR guides the assembly team by overlaying step-by-step assembly guidelines into the real world

**Keywords:** Building Information Modeling (BIM), Augmented Reality (AR), Modular Construction, 2D CAD Drawings, 3D BIM Models

# Introduction

Building Information Modeling (BIM) represents a standard transformation in the architecture and construction industry it provides a detailed understanding of the digital model of a building that contains both physical and functional properties [2]. This 3D digital Model can be accessed by anyone associated with this project using information and building information modeling enhances the worker's productivity by helping them to make decisions based on the 3D BIM Data especially in complex projects [9]. Building information modeling and Augmented reality have powerful tools that when integrated provide an improvised understanding of Building. This detailed 3D model provides stakeholders with a clear understanding of the complex design of Elements and the arrangement of the elements before the actual construction is scheduled BIM helps stakeholders see the full life of the building with clear visuals, making it easier to maximize value for the building owner [6], Augmented Reality also provides an overlay of a digital 3D model on the existing construction model in the physical world offers stakeholders to experience BIM 3D model in the real world in real-time within the construction area. BIM improves design and asset management by facilitating real-time updates and digital models helping asset owners make better decisions [5] BIM and AR establish vital communication and collaboration through the information provided by the digital 3D model [3].AR provides interactive visualizations that any nontechnical stakeholders can easily understand & provides efficient decision-making BIM reduces complexity by providing instructions for assembly of prefabricated, which includes work efficiency [4]. According to construction processes, BIM helps modular construction by giving precise instructions on the assembly of structural prefabricated components which ensures design fits the cloud-based system and allows real-time monitoring of the construction process making it easy to adjust the project needs and reduces work delays [7] AR offers real-time assistance and installation which reduces errors and rework, and the integration of technology improves quality control & resolves major errors at the minor stage BIM joins technology and enhances workers productivity by generating smooth workflows and reduces the chances of mistake’s in construction [8] and BIM enables clash detections which identify any potential error before they take place in a construction site while using BIM in construction brings challenges it also creates a friendly environment which develops the quality control. [10], BIM helps in the development of the project management and cost estimation and control, the data the BIM provides regarding the cost estimation and material take-off & scheduling is more accurate, which are accompanied by AR real-time assistance which ensures the construction process and reduces delays BIM provides help support to building projects for better understanding the 3D digital model and communication throughout the project life cycle [1].

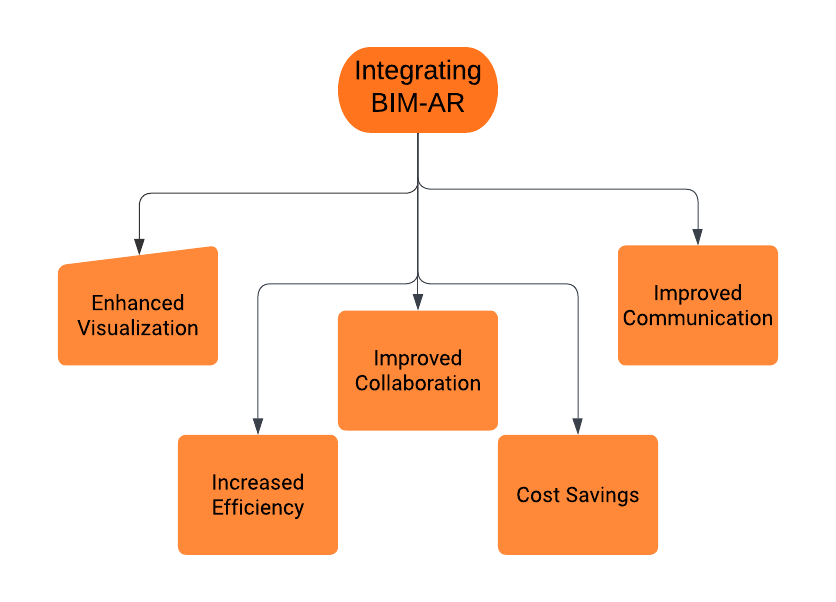
BIM helps in planning and scheduling the construction process and identifies any potential dangers AR provides sufficient training to Workers BIM makes it easy for teams to manage the project details and increases teamwork and access to share the digital 3D model details [2] when the construction Is completed the 3D BIM model serves as a significant resource that provides detailed information about the 3D BIM model [4], AR improves personal maintenance to interact with the 3D BIM model in real time which increases the efficiency of maintenance and repair task implementation of BIM with safety planning includes work steps and temporary structures which reduces risks and related to scaffolding during construction [3]

# 1.1 Background & context

Modular construction, Represented by prefabrication building components off-site and the assembly of prefabricated building components accordingly on-site has achieved a significant ability to reduce construction time & improve quality control. However, the present complications involved in the coordinating design and assembly processes impose serious challenges, traditional methods can not tackle these challenges which leads to errors that can minimize the project outcomes Building information modeling has transformed both the construction & architecture industry by providing a 3D digital representation of building models with their physical and functional properties BIM Enables strong collaboration among the stakeholders which facilitates them to visualize and analyze every aspect of the project before construction, while AR imposes the 3D digital model into the physical world the demonstration of augmented reality develops modular construction by providing access to real-time visualization of 3D Bim models and improves the assembly process and its accuracy mobile solutions like infospot connects the bridge gap between digital and real-world [12][18]. The experience provided by AR in real-time is significant in decision-making with the help of AR-BIM in the construction industry professionals can fill the gap between real and digital world environments.

# 1.2 Importance of AR-BIM in Modular Construction

The integration of AR with BIM tools in modular construction presents a technological advancement in the construction and architecture industry through the integration & collaboration of BIM and AR the 3D digital model has great changes in the visualization capabilities, and also changes the approach towards the construction project and execution BIM enables sufficient data and accurate representation of the 3D BIM model along with its components while AR presents the 3D digital model in the real world it overlays the building model into the real world and provides a clear understanding to stakeholders which reduces misunderstandings between the professionals which leads to decrease in errors in the construction site and construction takes place without any delays the implementation of AR and BIM significantly improves the capabilities allowing the stakeholders for better understanding of the project [11]. In addition to increasing efficiency and accuracy, AR-BIM integration offers extensive benefits in planning and scheduling, by enabling on-site assistance and real-time monitoring it provides accurate quality control this not only offers productive project execution and effective cost-saving & project timelines the implementation of AR and BIM significantly improve planning and scheduling through on-site resistance and real-time monitoring the combination of promotes innovation and sustainability in the industry [14][18]. the integration of BIM-AR in modular construction not only optimizes the construction process but also revolutionizes the industry toward innovation and sustainability.



**Fig**.1 Integration of BIM-AR

# Scope of the project

The research on integrating augmented reality with BIM tools for modular construction the study will begin by conducting an extensive review of existing AR and BIM technologies and understanding the potentiality & abilities of the applications in modular construction this includes the analysis and the technical parameters and capabilities of various tools. This project gives the scope to significant strategies for integrating AR with BIM to improve the workflow and streamline modular construction. The main part of this research is the case studies of real-world construction projects done by integrating AR and BIM. The main focus is on the analysis of the outcomes, benefits, and potential errors that are encountered. These insights will be essential in a set of guidance and best practices for the implementation of AR-BIM. integration in modular construction.

The final study for the above research evaluates the overall impact of AR-BIM integration on modular construction projects' efficiency and accuracy & success through the evaluation of its potential to revolutionize construction practices. By approaching these objectives the project's prime objective is the contribute a significant value of knowledge to the construction field and provide the integration of AR-BIM in modular construction which leads to effective and innovative building processes

## Literature Review

# 2.1 Overview of Augmented Reality AR in Construction

Augmented reality has become an innovative technology in the construction industry, addressing effective improvements to various processes by superimposing the digital data of building models into the real world. AR assists construction experts in visualizing complicated information directly on the site which develops communication, decision-making, and productivity. According to Irizarry et al.(2013), AR improves project understanding and Collaboration by facilitating real-time updates, and clear and natural representation of construction plans and workflow AR can manage tasks and provide a detailed understanding of the construction project. The implementation of AR in the construction industry majorly aims at accuracy and reducing errors and reworks Wang et al (2014) AR provides a better comprehension of spatial dynamics and building functionalities which effectively reduces differences between the digital representation and the actual construction building integration of the digital model into the physical environment reduces costly mistakes effectively and the construction process goes accordingly to the planned design.AR is also considered for safety management it allows one to view potential dangers and take immediate action and provide safety against the possible danger according to Park et al (2018) it mainly discusses and provides guidelines bring awareness among the construction workers and create safe working on construction sites.

## Building Information Modeling

Building information modeling is the digital representation of the physical functional characteristics of the building it operates as a shared information asset for the data of the building it establishes a strong foundation for decision-making during the project workflow according to (the National Institute of Building Science,2015) BIM tools such as AutoDesk Revit, ArchiCAD, provides a wide range of skill for designing and visualizing and managing the information of the building displaying the animated 3D BIM Model using AR enhances the visualization and efficiency and productivity in the construction process[12].

The application of BIM Tools in the construction industry is comprehensive these tools help to create accurate 3D models that integrate architectural, structural, and MEP systems this provides better collaboration and reduces the probability of disputes during construction BIM assists various phases of a construction project from initial design to building management. which generates communication among the stakeholders One of the primary advantages of BIM is it contains clash Detection and resolves a potential problem before the construction begins saving time and resources the constant location tracking provides relevant information right when it is required which helps the stakeholders to use BIM-on site smoothly[16] and it generates a systematic approach toward cost estimation, sustainability, and scheduling making it an effective tool for modern construction projects

## 2.3 Case studies of AR-BIM integration in modular construction

The integration of AR-BIM in modular construction has shown positive results especially in improving efficiency and reducing construction time modular construction also includes the assembly of prefabricated building elements in the construction site which improves the actual planning and visualization abilities offered for AR-BIM

A case study by Li et al. (2018) explores the use of AR-BIM integration in modular construction projects of a residential building. This study states That AR provides an accurate arrangement of prefabricated modules which reduces reworks and errors BIM Facilitates detailed models and provides information which are important for the assembly of the modules and ensures the proper arrangement of each element of the combined use of AR-BIM allows professionals to visualize the exact coordinates of the each element and enhances the assembly process overall speed and accuracy in construction projects

A case study by Kim et al (2020) this study states hospital construction projects. This project uses AR-BIM to visualize complicated building systems, the integration was specifically used for the assembly process of the elements such as complicated building systems like HVAC (Heating, ventilation, and Air conditioning) and electrical connections being installed. By the use of AR in the construction project the construction worker or experts will be able to access comprehensive data in these systems when this AR application is implemented in the construction site. This implementation enables the construction experts to resolve and identify potential errors before the installation of the elements, improving the project efficiency and reducing the construction time by 20% in these case study demonstrates the potential of AR-BIM implementation to develop modular construction workflow.

## Project Methodology

In this project, the methodology mainly aims to integrate augmented reality with BIM Tools for modular construction this design phase focuses on creating an efficient interaction between AR applications and 3D BIM models to enhance visualization and design validation, and construction management

the primary objective is to enhance real-time visualization for modular components AR allows users to project 3D digital BIM models into the real world in a construction site and provides an immediate dynamic view of how the design will be exhibited in the real world. This expertise allows Stakeholders visualize the final 3D model before the construction begins and provides a better understanding and adjustments during the planning phase (Fig.2). It facilitates quick alignment, reduces errors, and reworks this study examines how augmented reality can aid the assembly process in construction [12].

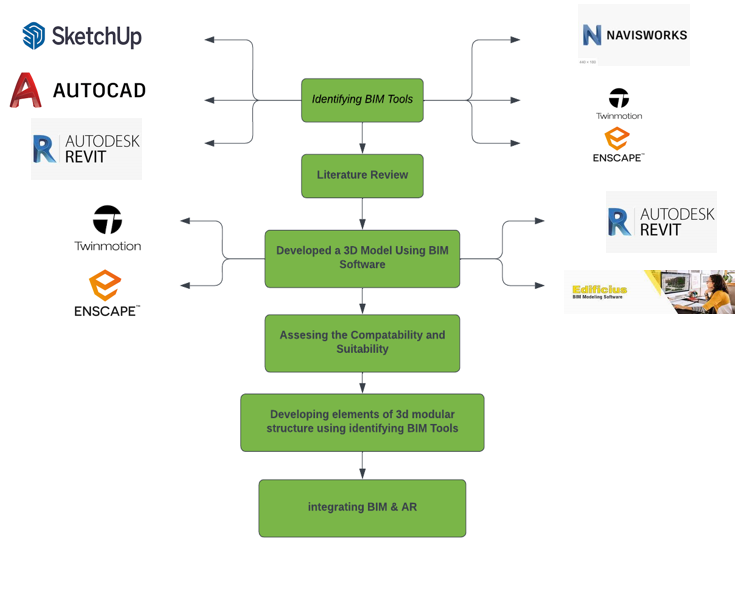
The other major objective is to improve on-site accuracy AR facilitates specific data and visual guidance, allowing to access to the workers to see blueprints and other information on to the physical site (Fig.5). and it also provides real-time feedback and ensures that the implementation takes place accurately to the design specifications by recognizing any errors between the 3D digital BIM model to the actual construction and AR Ensures immediate action against the errors, minimizing the errors and rework. This represents the vision for the digital future of the building environment it also discusses how tools can enhance collaboration and improve efficiency[17]

AutoDesk Revit is considered the most efficient tool for creating a digital 3D BIM Model for modular construction and their installation of assembly its robust modeling ability provides a detailed representation of various elements of the construction Project, which includes structural, Architectural and MEP elements (Fig.3.Fig.4) by Utilizing AutoDesk revit Advanced options the user can create an extensive 3D BIM Model that can acquire the complex details of modular elements, providing accuracy through the design and construction process(Fig.7,Fig.8) the overlapping of digital data into real-world this increases the visibility helps streamline operations develops overall productivity [18].

Revit's parametric modeling approach allows for the creation of modular components with accurate precision the user can define various parameters such as dimensions, material, and assembly sequences which will Ensure that each component matches to design specifications this level of detailing is important for modular construction where the prefabricated components are created off-site and installed on site it has the ability to analyze and visualize components in the digital world for the assembly in the physical environment. which helps in recognizing a potential error and optimize assembly process[17].

Developing Augmented reality AR applications using Unity 3D to impose 3D BIM models onto the physical world provides a powerful toolset for the architecture engineering and construction industries' unity 3D enables a versatile and flexible platform for generating interactive AR experiences making it perfect for visualizing 3D BIM Models on to the real world settings (Fig.6). This ability enables a more intuitive understanding in how the design will look and function once it is built

Unity 3D helps to develop an environment that supports a wide range of AR devices and platforms such as smartphones, tablets guarantees broad accessibility and versatility with the help of a powerful graphics engine unity can render detailed and complex 3D BIM Models in real-time, providing high precise visualizations and that provide decision making and collaboration among the experts the interactive nature of AR which is built in the unity3D allows user to manage 3D BIM Models and the perspective of viewing the model in different angles and explore design options in a immersive way[18]

Unity 3D moreover contains an immense library for plugins and integration of various facilities integration of real-world data into various AR applications Providing accuracy in the context of 3D BIM visualization by linking the 3D BIM model to the real-time live data feed, the user can view any changes which takes in the real-time and analysis the model after the changes and its impact on the construction project (Fig.9) this dynamic collaboration of the digital world to real world enhances communication and reduces errors and reworks and assists more efficient project planning and implementation[12].

**Fig.2** Methodology

## 3.1 Application Development

Creating an Augmented reality application that uses data from the Revit models presents significant development in the integration of the digital and physical construction workflow this application utilizes Revit’s extensive BIM data to provide real-time visualization and interaction through the AR interface, improving project management and stakeholders collaboration

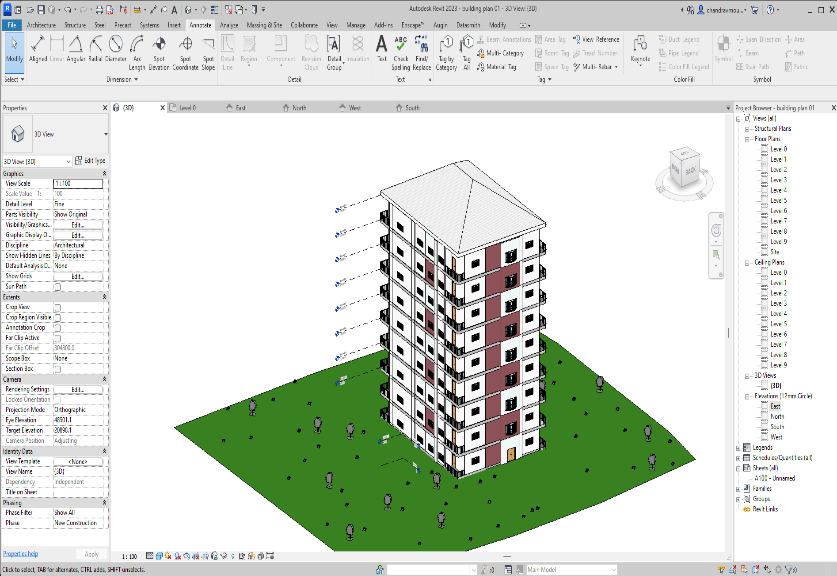
The enhancement of AR applications using Revit data involves several key components firstly the integration of the 3D Revit BIM Model into AR Application requires the connection of a robust data pipeline this includes drawing out relevant data from the 3D Revit model this data including geometric information, material properties and construction details and conversion or implementation of this relevant data into the AR platforms. Tools and API provided by Autodesk Revit and Unity 3D are instrumental in providing data transfer and synchronization. Augmented reality provides cognitive guidelines and reduces mistakes this advancement showcases the streamline and workflow [12][18]

This real-time synchronization is considered significant ensuring that the AR application reflects the most present state of the 3D Revit model this synchronization allows the users to view live feedback updates and modifications it enhances situational awareness and operational function this underscore the transformative potential of augmented reality and its execution [14][18] that occur in the 3D BIM environment this user is allowed to interact with the AR interface to explore and manage changes in 3D BIM Model, such as the adjustment of element positions and evaluating design alternatives, assessing construction workflow

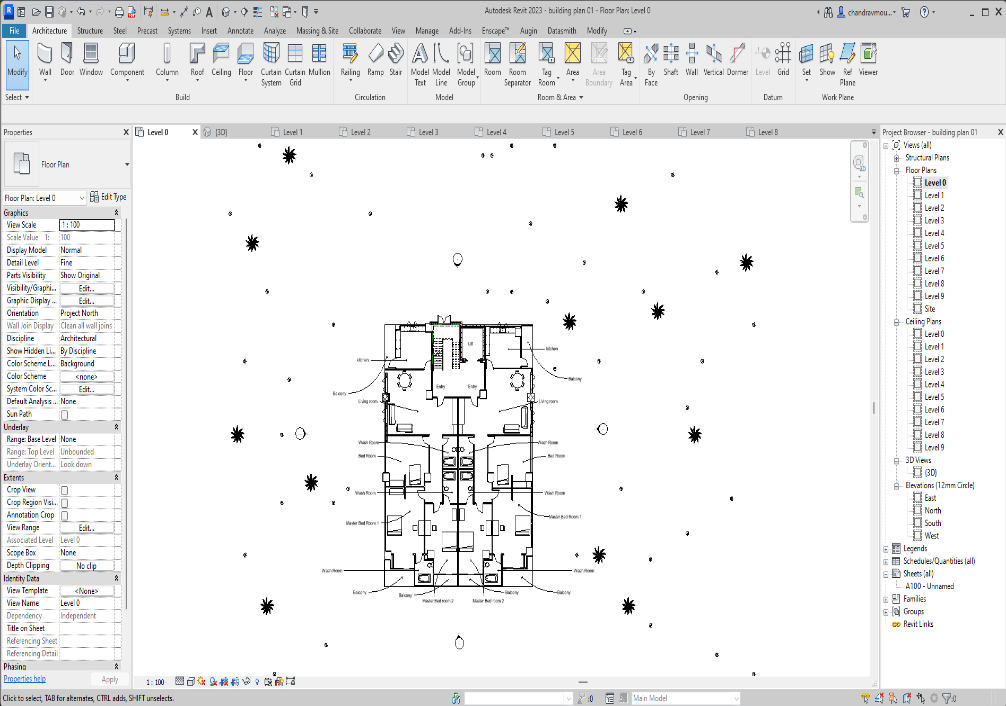
This interactive nature of AR Application improves the user experience by providing extensive and effective access to complex BIM data, stakeholder enables effective spatial awareness and decision making and regular updates provide effective responses to the issues and improve overall project efficiency.

## BIM Tools Used

* + 1. **Autodesk Revit 3D**

Used for creating detailed 3D BIM Models for modular construction and assemblies by providing advanced parametric design and abilities here the user can create a precise representation of modular components such as structural frames, architectural finishes, and MEP Connections[12][18], by specifying different parameters such as dimensions and materials used in the 3D BIM Revit Model. This Revit tool provides exact details on how the elements fit together which shows effective visualization and coordination it emphasizes the need for a location tracking system on the construction site [11][16]this detailed 3D BIM Model helps to identify errors or conflicts and guarantees that all the elements align with the design specifications.

**Fig.3** Residential Building Drawing (AutoDesk Revit 3D)



**Fig.4** Residential Building Typical Floor plan (AutoDesk Revit 3D)

* + 1. **Unity 3D**

Unity is considered the most powerful software platform that helps to develop augmented reality application that integrates building information modeling (BIM) Data from Autodesk Revit and visualize the model from Twinmotion by using Unity's advanced tools the user can provide significant experience of AR which imposes BIM Data into the physical world environment, provide effective and detailed visualizations this integration allows real-time interaction with BIM building model Unity will provide comprehensive environment support in the creation of dynamic, engaging AR application that provides the modular construction Workflow and collaboration. provide better visualization of the complex BIM Data for initiation. user-friendly format



**Fig.5** Importing the 3D BIM Model into Augmented Reality



**Fig.6** Importing the 3D BIM Model into Augmented Reality

**3.2.3 Twinmotion**

Twin motion enables advanced rendering and visualization capabilities for BIM models, it helps to generate high-quality realistic images and animation of modular construction building design by the use of Twin motions powerful tools the user can produce detailed BIM drawing and visualization that shows significant aesthetics and operational aspects of modular elements these rending can be assets can be imported into unity 3D where the 3D BIM model is integrated into AR application this process enhance AR experience with realistic visuals and providing user significant representation in modular construction design on the physical context ultimately improving stakeholders collaboration



**Fig.7** AutoDesk Revit 3D model in Twinmotion



**Fig.8** AutoDesk Revit 3D model in Twinmotion

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**Fig.9** AutoDesk Revit 3D model Interior in Twinmotion

# 4 Analysis and Techniques

The traditional method of modular construction is often based on 2D Blueprints and physical mockups which leads to inaccuracies inefficiencies and limited stakeholder engagement.AR provides methods to use augmented reality to impose 3D digital BIM Models into the physical site and offers real-time visualization and interaction the implementation of AR to support the assembly process in the construction of this comprehensive survey synthesis of existing research on AR application [12][14] This technology develops immediate and detailed adjustment and immediate error detection during the construction Workflow accuracy is improved as Augmented reality enhances dynamic interaction which represents modular construction and minimizes reworks. The stakeholders are satisfied with the immersive experience and clear communication.AR allows clients and team members to visualize and interact which leads to better project outcomes the BIM-based augmented reality system centered on component-based engineering to enhance the construction process. This also improves efficiency in construction site [18][13]

Error tracking in the construction process with AR includes documentation and analyzing the type of error which is caused during the construction workflow Here AR is used to compare the traditional methods. This implies the identification of common errors or inefficiencies in both scenarios and the identification of the pattern that shows underlying issues the BIM Adoption in construction projects identifies key barriers and solutions for effective implementation[11][18] by evaluating how AR assists the effects of the mistakes and their rate and identifying repeated problems, it becomes possible to achieve marked targets and improvements this analysis helps to improve AR application effectiveness, and more accurate and effective construction Workflow

Performance evaluation for implementation of AR includes many measuring key metrics to assess the impact of AR in the construction workflow this includes quantifying advantages such as it reduces design iteration times, this also indicates AR streamlines and design procedures for providing for fast adjustments and revisions, evaluation of the rate of errors in the construction site. By analyzing these performance metrics it is possible to measure the overall effectiveness of AR in developing accuracy and productivity in the construction it aims to deliver context information to improve decision-making and safety.[16][18], which enhances the clear advantage of it.

**5 Conclusion**

The implementation of AR with BIM for modular construction represents a revolutionary development in the construction industry real-time rendering visualization and interaction provide AR significant improvement in the understanding of complicated 3D models and their integration into the real world this implementation not only develops the accuracy of modular construction & Assembly but also provides efficient decision making and communication among the industry experts this integration also reduces errors and reworks and initiates faster construction timelines, however, this integration leads to challenges such as the need for the robust data synchronization of the 3D BIM Model and improvement for user-friendly AR application remains. Future research mainly aims to optimize these aspects and provide integration impacts this overall implementation of AR-BIM assures revolutionized construction procedures, and minimizes the gap between digital and real-world leading to more efficient error-free project execution this examines the challenges that widespread adoption of building information modeling in a construction project it also facilitates the management and provides benefits and outling strategies for successful integration. The integration of AR-BIM in modular construction has performed efficient development in efficiency and accuracy, and the construction experts' collaboration with this application of AR provides the Visualization of 3D BIM Models within the actual construction site which allows real-time interaction and immediate user feedback.

Case studies reveal that AR-BIM implementation effectively reduces any errors and reworks by imposing the digital 3D model into the real world this leads to more detailed assembly of the prefabricated elements and a reduction of construction procedure time by 20% is the highlight of the Kim et al (2020) the introduction of a mobile BIM augmented reality system based on component engineering to optimize the construction flow . The AR-BIM Approach also develops planning and scheduling and offers assistance for real-time and quality control by visualizing this detailed design and operation components, AR helps to identify any potential mistakes before manifesting them in the construction site it optimizes the construction process and provides overall project outcomes this significant improvement enhances situational awareness and safety & operational efficiency and generates more responsive and informed construction environment

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