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"INTEGRATION OF AUGMENTED REALITY (AR) FOR CONSTRUCTION SITE VISUALIZATION AND MANAGEMENT"

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Abstract: This study explores the utilization of virtual reality (VR) and augmented reality (AR) in project management, focusing particularly on planning and reporting within the context of a residential bungalow construction project based in Pune. The primary concept revolves around visualizing changes to the project execution plan through a VR model, rather than automatically linking them to the schedule. Additionally, the study aims to integrate Building Information Modelling (BIM) techniques into the project development process. The use of AR in construction sites is expected to enhance efficiency, productivity, quality, and health and safety standards, thereby potentially reducing project costs and completion time. The main objective of this study is to develop an innovative method that employs AR technology, particularly smart glasses, to provide construction workers, foremen, equipment operators, and site engineers with comprehensive and informative animations. These animations will facilitate better understanding and supervision of various phases of construction activities, such as masonry, formwork, and rebar work, leading to more efficient, productive, and safer practices. The research also emphasizes the potential of AR and VR technologies in addressing various construction management challenges. AR proves successful in project planning, progress monitoring, employee training, safety management, and time and cost management, while VR serves as an effective visualization tool and aids in employee training, safety management, and quality and defect management. Furthermore, both AR and VR facilitate communication and collaboration among geographically distant stakeholders and construction sites. In conclusion, this study provides a comprehensive overview of the application of AR and VR technologies in the construction industry, particularly in the context of a residential bungalow project in Pune. By leveraging BIM techniques and innovative AR and VR solutions, significant improvements in project efficiency, savings, and quality can be achieved.

Keywords: Augmented Reality (AR), Virtual Reality (VR), Building Information Modelling (BIM), Construction Management.

INTRODUCTION

In recent years, the construction industry has undergone a significant transformation fueled by advancements in technology. One such innovation that has gained substantial traction is Augmented Reality (AR). AR technology superimposes virtual elements onto the real world, creating a blended environment that enhances the user's perception of reality. This technology has found numerous applications across various industries, and its integration into construction site visualization and management has emerged as a promising frontier for improving project efficiency, safety, and communication.

Augmented Reality:

Augmented reality (AR) represents a groundbreaking technology that seamlessly merges digital information or computer-generated content with the physical world, thus creating a harmonious blend of virtual and real environments. Distinguished from virtual reality (VR), where users are entirely immersed in a simulated environment, AR enriches the existing environment by overlaying contextual digital elements. This dynamic fusion of virtual and real elements introduces unprecedented opportunities for enhancing visualization, communication, and decision-making processes.

Figure 1: Implementation of Augmented Reality in Construction

OBJECTIVES

1. To Implement AR technology in construction site management to enhance design visualization through real-time 3D models.
2. To Enable stakeholders to participate in collaborative decision-making by interacting simultaneously with augmented models.
3. To Utilize AR overlays to provide on-site assistance and training, thereby improving safety protocols and work efficiency.
4. To Employ AR for early detection of issues and discrepancies to minimize delays and reduce rework, ultimately leading to superior project outcomes.

LITERATURE REVIEW

Mahmoud Albahbah et.al (2021), Augmented reality (AR) and virtual reality (VR) are advanced technologies that can provide significant advantages to the construction industry. In recent years, many researchers have focused on implementing AR and VR technologies in the construction project management domain, where these technologies have shown a significant contribution to the advancement of the construction project management aspects in many areas. However, there is a lack of a structured review that synthesizes the existing body of knowledge about the implementation of AR and VR technologies in the various aspects of construction project management. Therefore, this study aims to fill this gap via conducting a scoping review on the application areas of AR and VR technologies in construction project management. Ninety-four studies retrieved from peer-review journals and conference proceedings were included, reviewed, and analyzed. The studies were classified according to publication date, publication venue, study design, and geographical location. The main features of AR and VR systems, including the display method, interaction device, spatial registration method, and level of immersion, were identified and discussed. The application areas of each technology were thematically analyzed and classified under main topics, where the results revealed seven application areas for AR technology and five application areas for VR in the construction project management aspects.

Ayodeji Emmanuel Oke et.al (2021), Augmented reality (AR) evolved from virtual reality (VR), which originates from simulators in the 1920s. In 1968, the Head Mounted Display (HMD) was first introduced and from there Augmented Reality Technology (ART) started (Sutherland, 1968). This machine with AR elements utilizes 3D images, vibrations, sound, aroma and provides sensing-related functions. This machine was not sold in a large commercial way due to its high complexity, cost, and scalability limitations. Since then, ART development became easier. Later in 1999, Hirokazu Kato introduced AR Toolkit from Hit LAB. This amongst other technological developments in early 2000 attracted more developers to ART.

Akgun et.al (2020), Insufficiency of existing infrastructure for the increasing population & urbanization and substantial rise in the necessity of power and energy worldwide can be regarded as an indication of investments to be made in those fields for the upcoming decades. In the future 40 years, it is estimated that the approximate total cost of infrastructures will sum up to 70 trillion US Dollars (Armstrong, 2012). Successful completion of infrastructure & energy and power plant projects requires a highly efficient and well-rounded organization with specialized technical staff. Information technology (IT) has become a key element of any organizational infrastructure. There is a perception that the level of an organization's dependence on IT in the twenty-first century is like the reliance on electricity in the previous century (Alshawi, 2007).

Ozcan-Deniz et.al (2019), Recent developments in Virtual Reality (VR) have positively affected the way design and construction parties understand, revise, and complete building projects. VR offers unique capabilities such as stepping into a 3D model of the building during early design stages and maneuvering with interactive features in the virtual environment. With these opportunities, designers, contractors, and owners can now share data and make crucial decisions even before the model is implemented at the construction site. A variety of applications and uses of VR are possible for contractors, yet the detailed analysis of key enablers and challengers from general contractors' (GC) perspective is missing. This study aims to perform a detailed review of VR applications in the construction industry by conducting a multiple case study approach. Data collection was performed on twenty-seven (27) case studies from eighteen (18) construction companies in the U.S. to report the uses and benefits of VR in the construction industry from GCs' perspective. Findings revealed the main uses of VR such as design reviews for clients and occupants, project coordination, monitoring the construction process, and training.

Kyle E. Haggard et.al (2018), Case Study on Virtual Reality in Construction Virtual reality has evolved into a practical technology that has recently been introduced across many

different industries. In the construction industry alone, the innovative tool has started to show its worth by limiting rework, time savings, and identifying design flaws. This case-study outlines the goals, benefits, and challenges for virtual reality in construction as it relates to Builder's Spectrum/Vertex project. Due to the infancy of technology, suggestions were collected from the interviewees and discussed in the subsequent paragraphs. The information for this case study was collected from: phone call interviews from Builders' field and office employees, the vice president of Vertex Pharmaceuticals (who will occupy the building), and the architect on the project. The findings of this case study were that Builders were able to identify design flaws, save money, and save time.

METHODOLOGY

The incorporation of Augmented Reality (AR) into construction site management represents a comprehensive and strategic initiative aimed at modernizing traditional practices and enhancing the overall efficiency of construction projects. It begins by precisely defining objectives, clearly articulating the general goals and aspirations of the AR implementation. Subsequently, a thorough needs assessment is conducted to pinpoint the unique challenges and opportunities specific to the construction project, laying the groundwork for a targeted and well-informed integration strategy. Selecting appropriate AR tools and platforms becomes a crucial step, necessitating thorough research and evaluation to ensure alignment with the project's needs and requirements. Representative construction projects are then meticulously chosen as case studies to provide a nuanced understanding of how AR can be effectively applied across various scales, complexities, and developmental stages. Finally, the design of the AR Integration Framework entails establishing protocols and processes to seamlessly incorporate AR into different facets of construction site management. Training programs for stakeholders play a crucial role in this methodology, aiming to provide construction personnel, managers, and other relevant parties with the necessary skills to effectively utilize AR tools tailored to their specific roles.

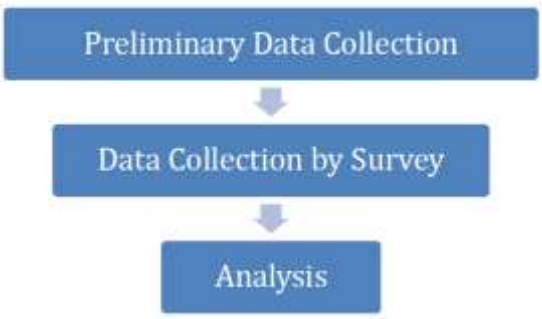


Figure 2: Methodology Flowchart

Figure 3: Site view (Navisworks model)

CASE STUDY

This case study chapter focuses on the integration of Augmented Reality (AR) and Building Information Modelling (BIM) technology in the construction of a single-storey bungalow located in Pune. Four different bungalows are considered for this study. The ongoing nature of the project provides an ideal scenario for this study, allowing for a comparison between pre and post construction tasks. The utilization of AR-based BIM models enables visualization of both the planned and executed stages of the project, offering potential benefits for building inspection, monitoring, and enhancing data management throughout the building's lifecycle.

The selected bungalow project features a single-storey design and is situated in Pune. It is planned to serve as a residential dwelling. The structure comprises fully reinforced concrete and has completed the structural construction stage by mid-April. Currently, the project is progressing into the architectural phase.

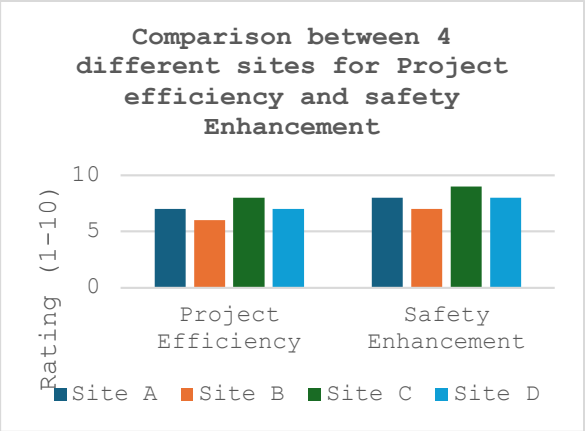
RESULT AND DISCUSSION

In this study I compared four different construction sites, highlighting their utilization of AR and VR technologies in project management.

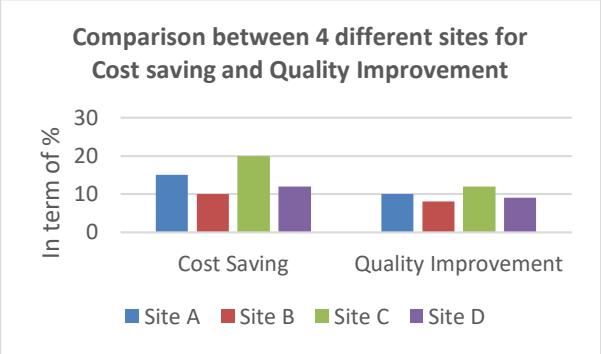
Table 1: Comparison between 4 different sites

Site	AR Implementation	VR Implementation	Project Efficiency (1-10)	Cost Savings (%)	Quality Improvement (%)	Safety Enhancement (1-10)
Site A	Limited	Extensive	7	15	10	8
Site B	None	Moderate	6	10	8	7
Site C	Extensive	Limited	8	20	12	9
Site D	Moderate	Moderate	7	12	9	8

Graph 4: Comparison between 4 different sites for Project efficiency and safety Enhancement



Graph 5: Comparison between 4 different sites for Cost saving and Quality Improvement



This comparison gives insights into the effectiveness of AR and VR technologies in enhancing project management processes, cost savings, quality improvement, and safety enhancement specifically in residential construction sites within Pune.

CONCLUSION

- This study makes a valuable contribution to the existing knowledge by investigating the integration of Augmented Reality (AR) and Building Information Modeling (BIM) within the construction industry. It addresses a gap in the literature by examining the potential and limitations of AR technology, particularly in inspection, control, and monitoring tasks. By developing a prototype AR application tailored to mobile devices, this research advances the theory of AR and BIM integration, marking a significant step forward in digitalizing the construction sector.
- The novelty of this study lies in its methodology, which involves using a commercial AR application to understand the potential of AR technology in construction, and then leveraging this understanding to develop a custom AR application prototype. Through case studies, it was found that the prototype could successfully overlay virtual and actual objects in 90% of cases. This capability has the potential to transform how construction professionals visualize BIM within physical environments, effectively overlaying future plans onto current conditions.
- Regarding the accuracy of virtual object placement within AR environments, the prototype demonstrated an average accuracy of 100%. This level of precision is crucial for cost reduction and timesaving in construction projects, indicating promising prospects for future AR applications. Additionally, the prototype exhibited a compatibility rate of 100% between complex data from multidimensional BIM and AR-compatible devices, suggesting significant potential for revolutionizing construction management practices.
- The AR app prototype, developed using Unity 3D, offers high integrity, interoperability, and portability. Its adaptability to various devices and design requirements facilitates a more inclusive and user-focused AR environment within the construction industry. User satisfaction with navigation and interaction within the AR environment averaged at 95%, suggesting a need for further innovations to simplify interactions with AR models.
- A key finding from the research was the impact of connectivity on AR-BIM integrations. Unlike traditional approaches relying on stable internet connections, the AR-BIM app prototype operated independently of internet access in 90% of trials, enhancing its versatility and suitability for remote construction sites with limited connectivity.
- Overall, the proposed AR app prototype demonstrates significant potential for shifting towards more integrated, visual, and intuitive project management and execution. It achieved a success rate of 95% in integrating 3D BIM into the physical world, with a primary focus on user safety during AR interactions, maintaining a safety evaluation rate of 100%. This underscores the importance of balancing technological advancements with user safety considerations.

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