BIM-Enabled Virtual Reality Technology in Construction Industry.

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Abstract: *Construction 4.0 (a concept of Industry 4.0) is an ongoing transformation that aims at digitalization and automation of traditional construction and industrial practices using modern smart technology. The technological development especially of the construction sector is of utmost importance to meet the requirements of rapid construction projects aiming at quality work, increased productivity, and cost savings. One such technology that has come to the limelight is Virtual Reality (VR), which is a computer-generated smart environment that is artificially created using various types of hardware and software. This smart environment is created to resemble a real-life structure that can be explored, visualized, and interacted with by users using electronic devices for better decision-making before actual construction. The purpose of this paper is to design a Virtual Reality model using Building Information Modelling (BIM) and to examine the impact and influence of Virtual Reality Technology in the Indian construction industry with the help of a questionnaire survey. This study provides necessary information for implementing Virtual Reality technology in the construction industry. The results of this study provide a research road map to researchers for their future efforts.*

Keywords: Virtual Reality, BIM, Construction Industry, Construction 4.0, Smart Technology, Covid- 19, etc.

1. INTRODUCTION

Virtual Reality (VR) is a computer-generated simulation of a lifelike three-dimensional (3D) smart environment that can be interacted in a seemingly real or physical way by an individual. This is done by a combination of hardware, software, and interaction devices (VR-consoles) that replace the real world with a virtual world through computer-based simulations. These simulations help in generating a human-pivoted point of view rather than a software-generated one, thereby creating the feeling of being present in the simulation, in other words being mentally immersed. Therefore VR generates a believable reality, and yet does not physically exist.

One of the major uses of VR technology is the user's ability to experience the entire design of a structure in a virtual environment before it is built in the real world. The technology is supported through auditory and other sensual inputs that help the user to feel as if they were experiencing the design in real. They can visualize the entire structure's design parameters and can easily navigate within the design. Navigation includes the ability to move around and explore features of the 3D smart environment with the ability to select and manipulate objects in the scene. Therefore, team members from any part of the world can simultaneously walk through the site virtually and examine the design details in real-time together. Unlimited digital walkthroughs of the virtual structure can be done that allows for experiencing an actual feel of what to expect when the structure is complete.
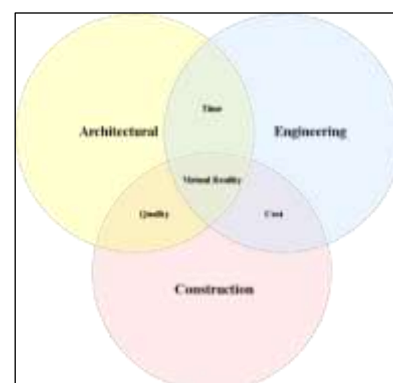
Figure 1. Virtual Technology in Architectural, Engineering, and Construction (AEC) industries.

Hence, the capability to visualize the layout and practice the development of the project plan in a 3-D interactive and immersive smart environment will lead to a deeper understanding during the planning phase, improve the constructability of the venture, and reduce changes and rework, which will be detected before the beginning of construction. This will fundamentally enhance the quality of project preparation, minimize costs and risks, accelerate the project completion process and improve the understanding between the managing departments, because of the quality of VR innovation and its execution in the construction and development business.

Types of Reality - Based on user engagement and the level of immersion, VR can be classified into the following types:

1. **Computer-Based VR -** This uses a PC and a screen to establish a virtual environment. Clients utilize input tools like a mouse pointer, a trackball for interfacing with the environment, and its elements.

2. **Immersive VR** - This sort of VR utilizes a Helmet-Mounted display to give a more vivid visual experience by re-enacting the feeling of sight and hearing.

3. **Augmented Reality** – This reality permits the user to see the real world with overlaying virtual components. It consolidates genuine and computer-based scenes and pictures to convey a unified yet enhanced perspective on the world.

4. **Mixed Reality** – This type of reality is the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real-time.

5. **Networked VR** - Networked VR platform connects multiple users over a network. This is utilized for working and collaborating on research amongst peers. A similar virtual environment is created

and run simultaneously for more than one user. This uses the capability of the web to associate and connect individuals. The users can interact with the environment simultaneously, including observing the same room in the house.
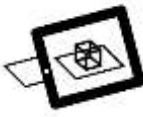
VIRTUAL REALITY (VR)	AUGMENTED REALITY (AR)	MIXED REALITY (MR)
Fully artificial environment.	Virtual objects are overlaid in a real-world environment.	Virtual environment combined with the real world.
Full immersion in a virtual environment.	The real world is enhanced with digital objects.	Interact with both the real world and the virtual environment.

Figure 2. Types of reality.

2. NEED OF THE STUDY

VR technology has been available for use for decades but only recently has this technology captivated a significant and sustained interest in several domains. Figures 3 and 4 represent the data collected from Google Trends explaining the varying interest in VR technology in a global market and India. As both figures 3 and 4 illustrate, there has been a fluctuating interest in VR technology. In some years, it is seen that the interest in these technologies has increased steeply. But this upward trend is inconstant and keeps oscillating. It can also be observed in figure 5 that India currently stands at the 45th position in terms of 'Interest by Region' for VR. This, when compared to technology-driven economies suggest that within their country, VR is widely used in many sectors including the Architectural, Engineering, and Construction (AEC) industry as well. Hence identifying the impact, influence, and barriers for adopting VR technology especially in the Indian construction industry is needed. This study will help us understand VR's capabilities, its benefits, and its prospects in the construction sector.
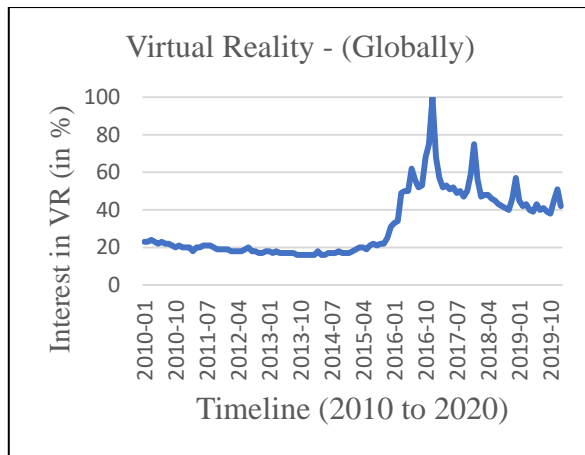
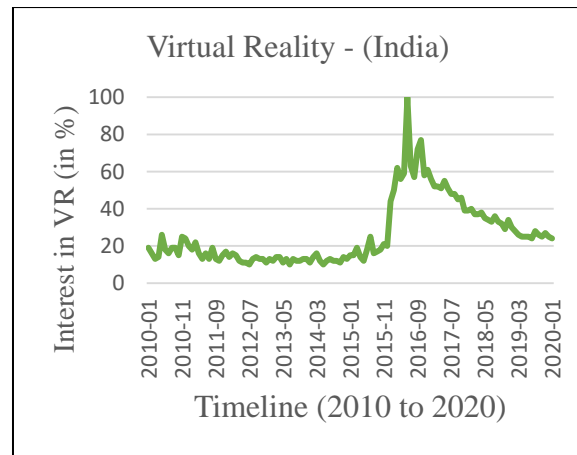*Figure 3. VR interest trend globally from 2010 to 2020*

Figure 4. VR interest trend in India from 2010 to 2020.

Figure 5. India stands at 45th position in terms of interest in VR.

3. LITERATURE REVIEW

The latest technological advances provide researchers with the opportunity to substantially improve the efficiency and quality of project design and construction to achieve success. As one of the featured technologies, virtual reality has been utilized to solve various design and construction problems. These issues incorporate choices made in the early conceptual design and planning phases, in the detection of clashes, design coordination, project planning, urban design, architectural education, safety training, facility management, etc.

Presently, BIM is becoming the new development standard in the construction industry. The advantages acquired from BIM relate to the quality and profundity of data in the model. Although BIM addresses a new method that is replacing the conventional techniques of management and development projects, due to its complexity, it presents obstacles and limits to boundless use. Combing Virtual Reality with BIM can assist users to visualize the rich data contained in the BIM framework and create interactive visualizations of the project in real-time, thereby helping to build consensus among the main stakeholders of the project. Furthermore, the combination of VR-BIM has shown great potential, allowing the team members to envision and understand the intricacy of a project. The outcome of this is improved coordination and communication concerning design, construction, operation, and maintenance processes.

Table 1 summarizes the design and construction studies using virtual reality with or without BIM.

S.No	Author	Year	Explanation	Used alongside BIM
1	K. Adhikari et al	2021	Discusses key strategies for managing projects and construction risks during and post COVID-19 pandemic.	No
2	M. Ghobhadi et al	2020	Conducted semi-structured interviews to understand the adaptability and acceptance of VR in the Construction Industry.	No
3	F. Arif et al	2020	Presented a review of Immersive Visualization and summarized the factors that are controllable in construction projects.	No
4	A. Sidani	2019	Review of previous works in the field of BIM-based Virtual Reality (VR)	Yes
5	S. Alizadehsalehi et al	2019	Provided review and information of the latest VR systems in construction industry and education environment.	No
6	Du et al.	2018	Focused on collective decision making	Yes
7	E. Petrova et al	2017	Presented findings from a case study by integrating BIM and VR.	Yes
8	A. Behzadi	2016	Explored and reviewed the changes in the AEC industry resulting from VR and AR.	No
9	Fang et al.	2014	Implemented a VR training module for crane operators by simulation of the as-built work scenarios.	Yes
10	Woksepp and Olofsson	2008	Reviewed the ways through which VR models are recognized and are used by AEC professionals in their everyday work.	No

Table 1. VR in different areas of Design and Construction

4. RESEARCH OBJECTIVES

The main objective of this study is to design a detailed and realistic model for experiencing VR technology using BIM. Additionally, factors are to be identified based on the impact, influence, and barriers to adopting VR technology, especially in the Indian construction industry.
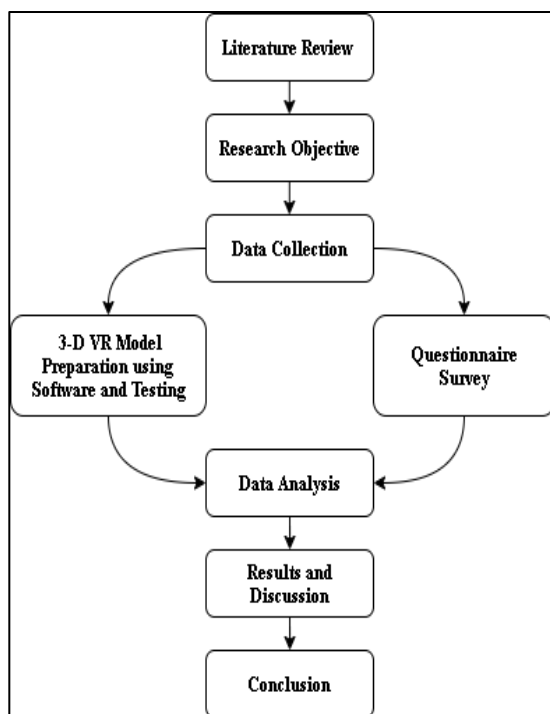
5. RESEARCH METHODOLOGY

Figure 6. Research Methodology Flowchart

To achieve the research objectives, firstly all the latest technological developments related to VR have been researched. This research was done through scholarly journals, websites, videos, and case studies. After completion of literature reviews, the identification, installation, and registration of software such as - AutoCAD, Autodesk Revit, Enscape, Modelo, etc. were done that were required for preparing a sample 3-D VR BIM model. The software were used to draw and design a two-dimensional (2-D) model of a bungalow that was converted to a three-dimensional (3-D) model using Autodesk Revit software. Further high-quality detailing and rendering were done to make the 3D model look as realistic as possible. The model rendered was ready to be tested for experiencing Virtual Reality with the help of hardware devices.

Additionally, a quantitative approach was used to get information about the awareness, influence, and impact of VR technology in the Indian construction industry. The data is collected from a structured questionnaire survey that was circulated amongst civil engineers, architects, engineering students, and faculty. Since these individuals belong to the AEC industry, their opinion on the application of Virtual Reality was paramount for this research. The data collected from the survey were further analysed to generate results.
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6. RESULTS AND DISCUSSION

A sample 3-D VR Model was created and tested for its VR capability. The model was developed using BIM technology that was combined with other software to generate a VR model.

Figure 7 shows the various stages of development of the model. The sample bungalow offers a living room, bedroom, kitchen, washroom, terrace, etc. The plan was initially developed in a 2-D format as seen in figure 7 image **'A'** and then converted to 3-D as seen in image **'B'**. After the 3-D plan was ready, upon extensive rendering through different software's the VR model was created as seen in series of images **'C'**, **'D'**, and **'E'.**

The VR model as seen in figure 7 provides a holistic 360° view of the bungalow offering an individual to get a real-life-like experience of the design before it is built. The model offers a walkthrough mode, wherein the individual can easily navigate around the given project plan for in-depth analysis of the design and structure. A thorough visual examination of the design and structure will help the users identify errors and clashes within the project plan. This will help them make better decisions while making any changes to the design before the actual construction. This will offer the stakeholders of any project an opportunity to prevent any rework, and hence reducing project costs and minimizing the time required for successful completion of the project. This will also have a positive impact on the quality of the construction project. Another advantage of this VR model is that

multiple users can examine it in real-time simultaneously. This VR model file can be shared and viewed online such that users can experience it from any part of the world.

Indian Construction Industry. The questionnaire survey results indicated that most of the participants were aware of Virtual Reality technology but have never experienced using it.

It was found that the participants were inclined towards using VR in the future to understand
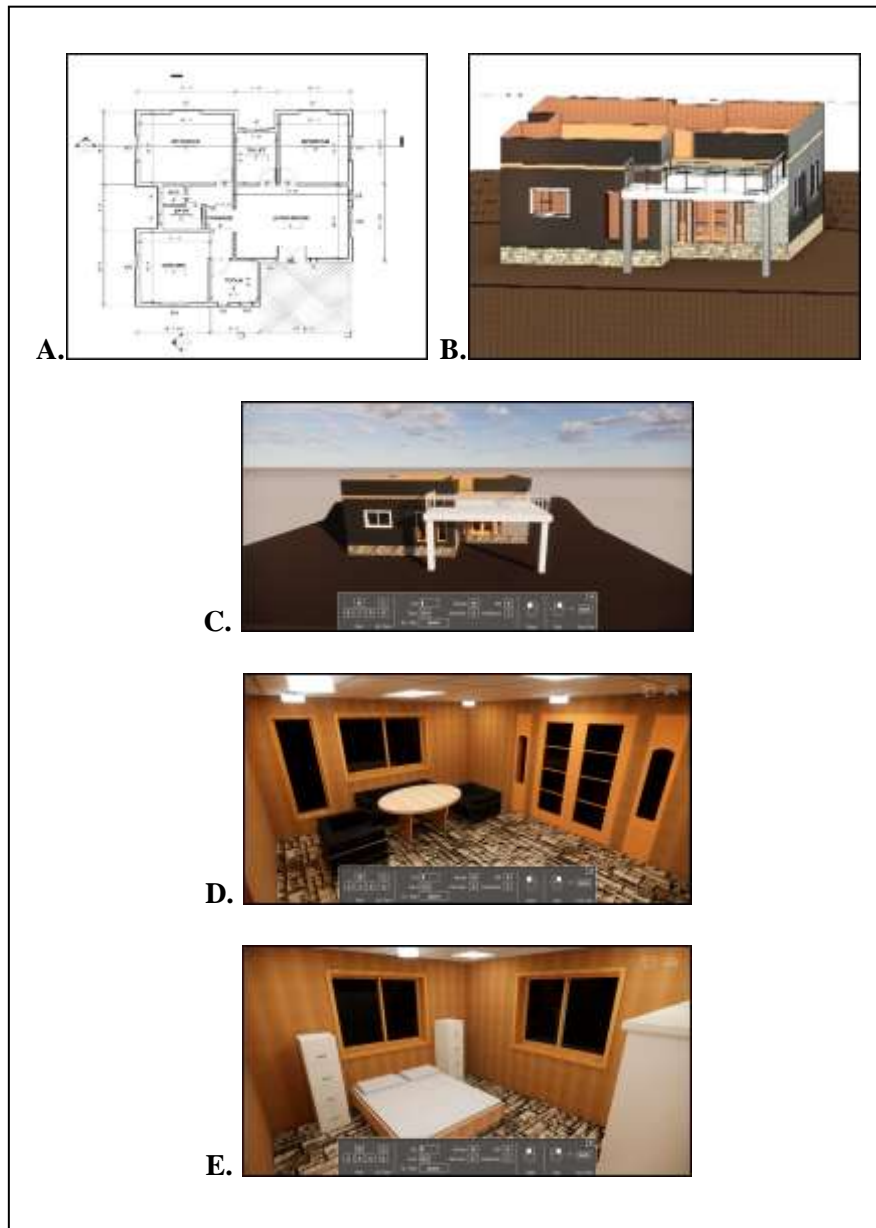

Figure 7. Development of sample VR Model using BIM.

Moreover, it will allow non-physical and contactless experience for designing and visualizing a project during this Covid-19 pandemic. Furthermore, data collected from the questionnaire survey as shown in figure 8 were analysed to understand the impact and influence of Virtual Reality Technology in the

and visualize the design and details of a given project for better decision making, before its actual construction. Responses also indicated that the AEC industries need to be equipped with VR technology since it is a need, especially amidst the Covid-19 pandemic situation so that users can access and visualize the design from any part of the world. Additionally, the survey questions related to acceptance of VR included responses such as comfort in using VR, broader understanding of design, easy 3-D visualization of VR model, real-life experience, smart technology, etc.

Barriers to the adoption of VR included responses such as lack of access to the technology, cost of hardware and software support, graphic quality of VR models, unavailability of skilled professionals for preparing VR models, etc. These survey results state that despite few barriers there is a wide range of applications of VR in the construction industry. The response from participants indicated that VR technology could be beneficial across AEC industries and that they look forward to experiencing this technology. Thus, Virtual Reality can be used as a powerful design and decision-making tool in the construction industry.

CONCLUSION

Lack of visualization of construction projects leads to constant changes throughout the project lifecycle, errors in design causing rework and reduction in the quality of the project, disturbance in the planning of construction, and impact on the cost of the project. Building Information Modelling (BIM) and Virtual Reality (VR) can greatly benefit the industry by reducing rework and enabling the users to visualize a detailed layout of a project through a 3-D immersive smart environment. A thorough analysis of the design layout will help achieve quality work, increase productivity, and cost savings. For this purpose, the present study does two

things: first, prepare a sample building model using BIM and test its applicability as a VR model. Second, identify the impact, influence, and barriers of using VR technology in the Indian Construction industry obtained from the questionnaire survey results. Based on these results, it was found that there is a lack in the use of Virtual Reality technology due to
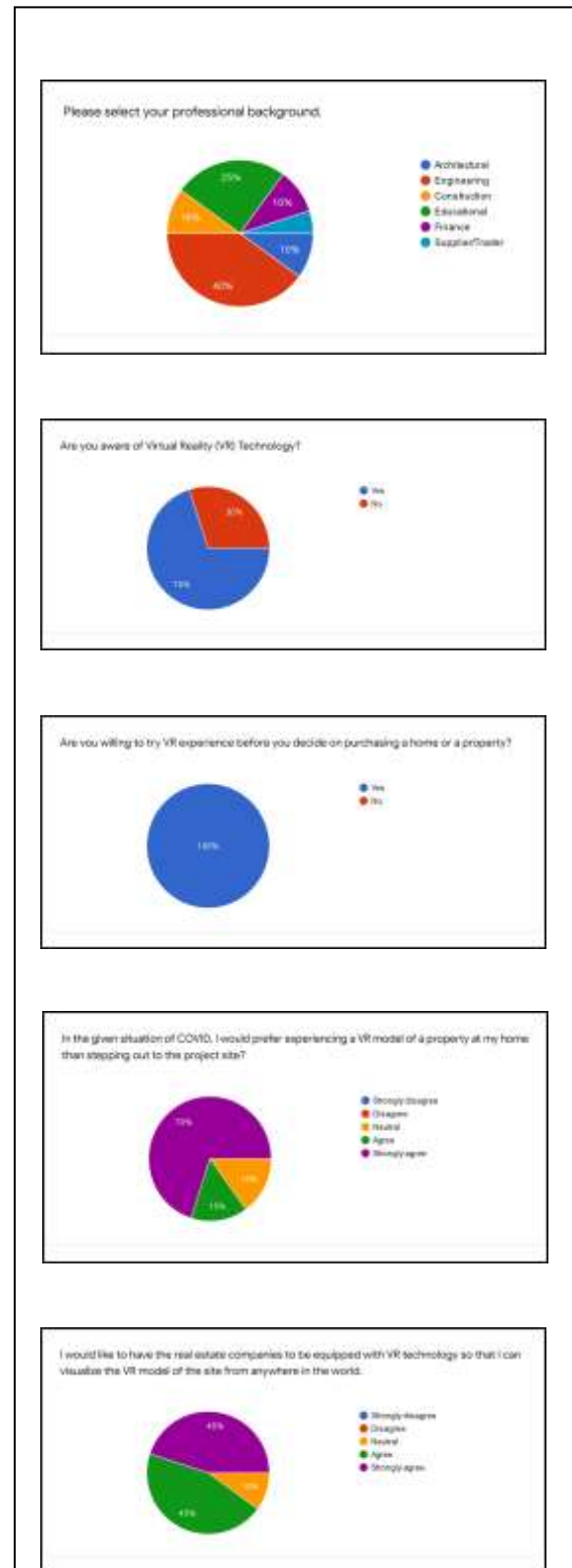

Figure 8.Sample data collected from Questionnaire Survey.

insufficiency in knowledge about the technology, high cost, etc. But continuously improving and reducing costs of hardware and software required to use VR technology can greatly benefit the industry, by boosting team collaboration, data visualization, decision making, and design review. Assuming that Virtual Reality will only improve with time, it

is almost certain that such technology will play a crucial role in the AEC industry for years to come.

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