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Original Research Article

AUGMENTED AND VIRTUAL REALITIES: THE FUTURE OF BUILDING DESIGN AND VISUALIZATION

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Abstract

The present study precisely conveys the methodology of developing a three-dimensional (3D) architectural model of a villa with its walk-through and displaying the model in virtual reality, which as a result, be used by the clients to spectate, customize and buy the real estate property. Additionally, the case study highlights the advancement in architecture, as certain specifications of each element of a 3D model can be viewed in a virtual environment. Virtual reality is a transpiring platform, and in addition to that, the real-estate sector shows its incorporation in designing, marketing, and selling projects. The teaching and learning process can be eased out by intervening it with technology that generates an enhanced visualization environment. These technologies, when used constructively, save time and energy and also hoard economic standards ensuing lucrative benefits.

Keywords: CE-Pedagogy (CE: Civil Engineering), modeling, Augmented Reality, virtual reality, real-estate, simulation

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1. INTRODUCTION

Developing technologies possess the power to fascinate as well as deliver potential growth today in this competitive era. Modern-day work class is inbounded to make it compatible with the new growing technologies, which would help them perform exceptionally well. The advancement in engineering has explored virtual reality into relevant social interaction concepts majorly linked with reality-based and immersive media frameworks. Properties that are generally explored in these frameworks are primarily educational uses and social learnings. Conceiving these parameters linked with the practical aspects of civil engineering and infrastructure management aligns with the theoretical principles. It is really fascinating that modern technologies have the caliber to change the lives of mankind on a day-to-day basis, without being resistant to the development going around. “Virtual reality (VR) takes hold of computer technology as the core to combine pertinent science and technology to generate a digital environment that is highly indistinguishable to a specific range of real environments in terms of sight, hearing, and touch”, [1]. The device was built by Morton Helich in 1957 and was composed of a complex structure including features like stereo sound, a vibrating seat, and a large display that predated personal computers. This device possessed qualities of producing wind-blowing effects and even smell sometimes because of its three-dimensional display function and stereo effect, but due to lack of tracking, it was not able to deliver a state-of-the-art immersive experience. While in 1968, Ivan Sutherland produced a device that could be head-mounted, which was put to hold as Altair 8000 - the first personal computer was launched seven years after it. The education system has recognized the essentiality of information and communication technology due to its inception and development. Considering the educational tasks, 3D geometrical representations can allow a passive learner to grasp and interpret things more effectively compared to traditional methods of teaching. The communication platform empowers the participants, inclusive of a student, teacher, or any industry professional, to exchange data concerning a specific domain and authorizes interaction and collaboration in the learning process. Peeking in today’s time, where VR technology and 3D models are profusely incorporated as an assisting method for lecturers and students [2]. The application of virtual instructional models to support civil engineering education includes classroom education and e-learning [3]. When it comes to construction planning, virtual models help students to understand the characteristics of the subject. The main aim is to deliver the idea of instructional construction techniques through virtual environments. Visual interactions can make a big difference in engineering education, especially in civil engineering discipline in learning new construction activities and materials [4]. Teaching the subjects of civil engineering domain mainly includes connotations and development history of the domain, the category, structural description, components or building blocks, planning and designing parameters of the project. As the core content of civil engineering discipline cannot be brought into classrooms, field trips or industrial visits could be an answer to this problem, but students who are finding all this difficult to digest can remain in a dilemma of how and what to process [5]. Hence VR technology is one of the best solutions to this problem, since it presents a more intuitive and well-defined model in front of students, which allows them to comprehensively observe and understand the concepts in depth [6].

Coming to the real-estate sector, which is heading towards new opportunities and technological advancements, the most obvious option which comes into the picture is the use of Augmented Reality and Virtual Reality [7]. The scope of the Construction Management industry inside the AEC, the acronym AEC stands for Architect, Engineering, and Construction industry, which has shown potential growth in every possible aspect [8]. Technology has the caliber to disrupt the traditional flow and bring in new vivid alternatives, which can be a boon and thus deliver new milestones. Technology offers new exciting, and meaningful opportunities, which in return, change the face of how users work and deliver evermore complex projects for the customers [9]. A digital shift is taking place, and the development of the digital platform is advancing so fast that the industry struggles to keep up with the pace of advancement [10]. The inculcation of students pursuing civil engineering becomes deficient if they are not able to grasp the practical aspects of civil engineering principles. To resolve this issue, making civil engineering students conceive those methodologies and principles in such a manner that aligns both practical aspects as well as theoretical principles can be helpful. Such an approach also strives to incorporate strong visualization skills among students in order to develop prominent conceptualizations. Augmented reality is one of the most practiced and implemented technologies used all over the globe. Not only the augmented reality, but also the virtual reality is a well-versed and most commonly used technology that comes hand in hand with augmented reality. Their implementations can be found in plots like education, health care, gaming, and engineering [11]. From a role point of view, both AR and VR respectively clarify that augmented reality encourages the user interaction between a model and reality, digital world and real world, while displaying the virtual images or models created while they remain with see-through capability, whereas virtual reality has a prominent role in embracing a totally immersive experience [12]. Thanks to the emerging AR/VR showcasing platforms like Microsoft Holo lens, Oculus rift, and many more, the so-called immersive, see-through, and convenient technologies are gaining a great deal of attention. Going back to the times when these technologies came into existence in the 20th century, no one would have imagined that this could be a boon for mankind.

Attracting tremendous human interest in not much of the time since launch, AR/VR has simulated reality which can be seen as early as the 1930s [13], rather than a dream [14] or robust computer-based simulation [15]. Moving from the late 1900s to the next few years until 2015-16 we can clearly observe that there has been a wide range of studies and experimentations conducted to facilitate the development of novel applications within AR/VR like more latency, higher frame rates which ultimately have raised hopes for simulation and enhanced augmenting/reality [16]. The gaming industry has shown crucial assimilation of augmented reality, and virtual reality into their new and enhanced gaming platforms like Pokémon Go [17], and films like Star Trek Bridge Crew n.d. [18]. The year 1990 was the frame wherein AR/VR experienced a boom but eventually subsided due to the unavailability of eligible digital content and hardware, but emerging technologies like holography and lithography have excellently restructured the AR/VR display systems [19]. Augmented reality holds the caliber to cater to an effective method of contextual communication between on-site and off-site personnel [20]. A countable number of AR-based applications have been implemented, used, and could be found in the real estate as well as construction sectors like subsurface visualization [21], maintenance and regulatory operations [22], reviewing the design and visualization parameters, etc. [22-25]. Modern-day AR and VR developments have made sure that nothing is unachievable when it comes to designing, developing, promoting, advertising, and ultimately selling a finished product in whichever field or firm you may implement it in. These recent upgrades can enable users to virtually annotate and customize their products according to their likeability, feasibility, and aesthetic point of view. Real-time annotation with remote collaborators is one of the best-served features at hand [26]. This not only limits customization but also helps the user to have a dialogue between personnel working on and off-site simultaneously, hence saving the majority of the time and energy, resulting in a green and clean means of work culture.

Virtual reality in parallel space with augmented reality has gained recognition in every suitable field. This is a visualization technique referred to as purely virtual presence and is getting overwhelming attention for improving professional working standards and shared spaces [27]. Benford et al. [28] introduced a categorization of shared spaces based on their criteria like transportation, artificiality, and spatiality. They can possibly be categorized as media spaces, spatial video-conferencing, collaborative

virtual environments, telepresence systems, and also collaborative augmented environments. Further researchers have contributed their very role in delivering the importance and beneficial highlights of virtual reality in the construction as well as real estate sector [29-31]. Virtual Reality, being a constructive tool, has proven to be efficacious in providing better visualization and understanding capabilities. For example, in the architectural domain and training, students can perceive distinctive architectural spaces through a 3D object, rather than viewing traditional drawings. In addition to that, architectural training using traditional 3D approaches relies on the use of a mouse or keyboard to interact with the computer-generated structural form. The characteristics of Virtual reality make it a prime option for technological interventions in schools of civil engineering and the real-estate sector as well. However, in the VR environment, the immediate results of interactive activities, such as pulling and grabbing, can be visualized in a contemporaneous demeanour [31]. Despite such technological research and advancements, VR remains limited to the systematic investigation of its nexus bond with construction engineering, design, management, and the most powerful platform is, real estate. A significantly large research gap we can say is observable in terms of systematic inspection of the growth of virtual reality and its effectual implementation [32]. Today when considering the dreadful pandemic, it is almost impossible to get in person with the site personnel and have a meeting or discussion, but thanks to such well-developed virtual meeting platforms, which have made it possible to connect to every single human being and convincingly complete the desired task. AR/VR add-ons make it lively and interactable on the person-to-person level and change the face of finalizing the deal [33].
To perceive a crystal-clear idea of how AR- and VR-based technologies can change the face of real-estate communications and, more importantly, inside the civil engineering schools for the purpose of tutoring. This paper clearly tends to justify the contexts in which the aforementioned technologies can enable, potentially hinder or revamp the idea of design and development, planning, marketing, and selling a finished product in addition to the user-friendly customization support at hand as well as deliver quality education to the aspiring civil engineers.

2. OBJECTIVE

The bestowed case study project is officially undertaken, while undergoing an internship program at Panchshil Realty at Wagholi - a Pune-based real-estate firm: as a part of research and analysis. The project is mainly focused on developing an alternative to the traditional method of buying-selling, or marketing products in the real estate industry. The construction industry today is moving towards a new market and would profusely incorporate new modern-day technology to deliver new incentives [34]. To save time and money at the same time is not everybody's cup of tea, but giving a try to an upcoming method of transitioning the whole idea of site-seeing, customizing, buying, or selling on the virtual reality platform by making use of AR & VR is like a dream come true. This technology tends to deliver results with new potential, eventually saving time for both parties involved in the business [35]. As a plunge into this case study, the initial decision-making and abstract model-designing process were taken up as a challenge. The initial week of work was to get all the pointers and brainstorm the ideas of how efficiently we as engineers can utilize the 3D modeling platform and virtual reality platforms to make something worthwhile and use it in the most productive way. To advocate this project, a keen observation of how the real-estate companies operate, market, and sell their finished products like villas, bungalows, nBHK's (where n = 1, 2, 3…) or even township, is the most prior part of setting out the format of the research. It is really fascinating that typically how; a sales and marketing firm gets into the depth of field and displays the mock villas to the clients.

3. METHODOLOGY AND FLOWCHART

The model development phase needs a two-dimensional (2D) plan which is readily available. The same 2D plan devised an imaginary plan that eventually took the shape of a 3D model later in the end. 3D modeling is actually a part of graphics that deals with creating 3D models. 3D modeling requires, like everything else, a certain amount of experience and gradual training. A 3D constraint modeler lies only in his skills and imagination. 3D modeling software allows you to easily create any view or section or later detail. It also allows you to use the "walk-through" tool to create an animated visualization of a project that has the task of simplifying communication with the customer or just for the sake of a better idea of the virtual buildings [36]. By now, the structural model for the villa was ready. Being an apprentice, it was never easy to develop the structural model, as shown in Figure 1. Now the model at its early stage looked monotonous and needed an interior upgrade, so the next task was to design and develop the interior for the same. In the present study, the BIMObjects.com particularly conferred several add-ons that helped in completing the leftover interior design [37]. The day count now was around 45 days, and the substantial hard work paid off as the Revit-based 3D model was finally ready, as shown in Figure 2.

Fig. 1. Structural model of the ground floor

The walk-through or rendering has conglomerate tools that help us complete our desired task. Different software platforms demand their own hardware as well as software requirements. When it comes to developing a walk-through of a three-dimensional model, Lumion [38] and Sketchup [39] are the software's which tend to deliver exceptional results. Due to hardware constraints, Revit is the only software that helped in the study to render and develop the walk-through of the 3D model. Getting hands-on experience with new developer tools is completely a new experience that is both informative and exciting at the same time. Once the walk-through got ready, the same now was to be exported onto a platform that can create an environment where design alternatives were populated in a generative fashion. Virtual Reality can assist the user in navigating and organizing the solution spaces in a three-dimensional environment. This is a form of data visualization tool which is immersive in addition to the fact that every solution can be considered and assessed independently. A major role can be played by generative design in mass-populating future virtual worlds in VR, where came in a tool called IrisVR [40]. The virtual surrounding hardly holds any physical constraints to our real world; generative design techniques can not only assist designers but also end-users to generate and customize their own surrounding virtual environments in a swift, creative, and emergent mode [41]. Being a prominent developer tool, it helped transition the 3D model onto a virtual reality platform, as depicted in Figure 3, which can be viewed using several VR gears. Oculus Pro VR headsets [42] are found to be the most compatible pair for getting the immersive VR experience, but because of their unavailability, the PlayStation 4 VR gear is used to achieve desired results. Interconnecting the 3D Revit model with augmented reality software (Kubity Go) and virtual reality software (Iris Vr) enabled us to achieve the desired result. The complete process of getting to know what it takes to develop a 3D model, link it to a VR platform, search for the most compatible developer tool and finally obtain a result out of all this is a complete learning package at the backend. While on the front-end, this method of simulation and immersive experience can make the workflow of client and firm unchallenging and quite effortless.

4. DEFINITIONS OF CONCEPTS

Augmented Reality: The term augmented reality (AR) is defined as a real-time direct or indirect field of vision of an environment similar to that of the real world, which is enhanced/augmented by computer-generated data in addition to the physical environment [43]. Many international research universities and enterprises have invested in the research of augmented reality in recent years, resulting in tons of papers and scientific research results. Such results demonstrate that augmented reality is a feasible, innovative, human-computer interaction technique [44]. In 1968, an application based on a Head Mounted Device (HMD) was proposed by Sutherland [45]. Applications and technologies for augmented reality are often used at work, in education, when playing, during leisure, and in many other situations. The use of AR technologies, which were originally designed for very special purposes, namely cockpits of military aircraft, is now available for commercial purposes as well [46]. Augmented Reality in Construction: AR is used in numerous phases and divisions of construction projects. In order for construction projects to become more automated, augmented reality is the most obvious thing to be implemented [47]. Using context-related objects, AR supplements the normal experience of the user, such as looking through walls to view columns or underground level to look at the subsurface utilities that were installed [48]. Over the past several years, architects and designers have gradually moved away from conventional designs and are now exploring new avenues. There are many examples of unconventional architecture across the globe, as well as extreme engineering used to construct these structures. Nowadays, designing a structure and analysing it using software is a norm. The analysis has become easier regardless of the size and shape. Additionally, when it comes to implementing those designs in the field, we still count on human experience and their intuitions. Regardless of the control measures which are taken in order to ensure the quality, it is often difficult to sustain the level of precision that a computer analysis can achieve but augmented reality aims to bridge this gap [49].

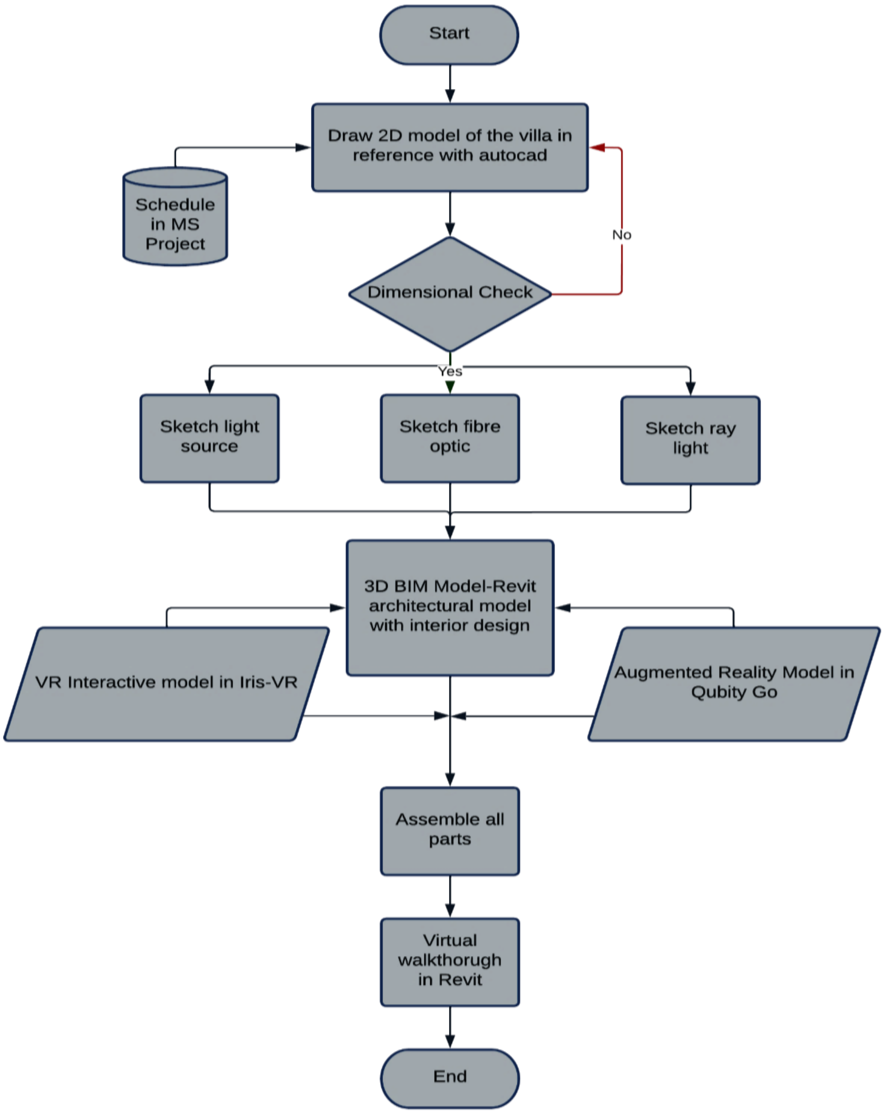


Fig. 2. Flowchart for developing a 3D model of the villa [63]

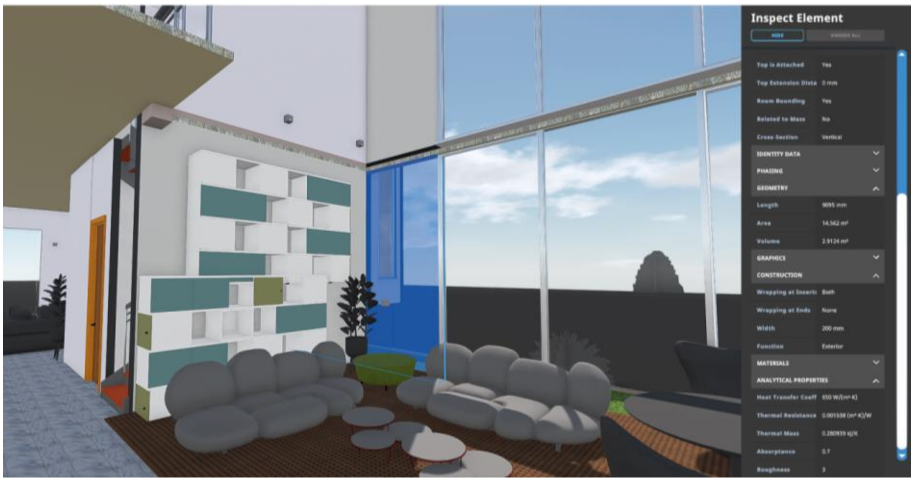


Fig. 3. View of the hall of the villa in virtual reality

Virtual reality: Since the year 1989, when Jaron Lamier came out with the term for the very first time, VR (Virtual Reality) has ordinarily been narrated as a computer-simulated environment that people can take into use in order to interact with and within. A virtual reality system is a combination of software as well as hardware that enables developers to create VR-based applications [50]. Virtual Reality has sought to get the general public's attention since the 1980s, but without any actual success. During the 80's, technologies related to virtual reality were unknown to the public, but then they aroused the interest of the media. Since 2014, virtual reality devoted to the general public has been boosted by the arrival of helmets that are both efficient as well as affordable. Developer version of the Oculus Rift headset was released in 2013, and the same stepped into the mainstream market in March 2016 [51].

Virtual Reality in Construction: The building industry or, say construction sector, in general, has witnessed rapid recognition and adoption of virtual reality (VR) in CEET, which is an acronym for construction engineering education and training, due to its benefits of providing an engaging and immersive learning environment [52]. As a result of the inability, unreachability, and inexperience of field personnel and consultants, construction projects fail at a high rate in the construction industry. In this case, VR technologies allow them to truly experience a project before it is built [53]. For the sake of cost estimation, researchers developed a framework for construction using VR technology. They developed a real-time VR model to allow stakeholders and users to choose the material for walls, floors, and other components, and have a real-time view of the price impact. Linking cost estimation to virtual reality can be beneficial to the Architectural Engineering and Construction industry, especially to the estimators [54]. In addition, researchers utilized virtual reality to improve safety in construction. Researchers have designed a safety training program that uses virtual reality that provides individualized feedback to improve the training outcomes of the participants [55]. The results indicate that VR technology used in safety training programs provides workers with high-fidelity simulations [56]. In the AEC domain, virtual reality can be used as a tool for collaboration, project management, and education to improve, facilitate, and close the gaps in the implementation of BIM in projects [57]. In addition, it also promotes iterative decision-making among project stakeholders, increasing awareness and communication [58]. Cho et al. in 2019 showed that there is a big gap in virtual reality interest between academia and industry in the AEC domain [59]. This suggests potential benefits and the necessity of using virtual reality in AEC education.

Virtual Reality in Civil Engineering education: The most prominent and basic requirement of civil engineering curriculum is to make aspiring civil engineering undergraduates, graduates, or postgraduates to get their concepts clear and have a transpicuous idea of the crux of civil engineering principles. Virtual reality is a helping hand that lays out numerous advantages for the students to ease their learning process. Several research and reviews by experts have been conducted in the past years regarding the context of implementing or incorporating VR platforms in civil engineering education curriculum [60]. Sampaio et al. [61] developed a virtual reality model which was interactive by nature. It was created to explain the process of bridge construction for civil engineering students, and as a result, the students were able to interact with the model in a particular sequence of construction and equipment used and also analyse numerous elements of the simulated bridge. This VR model delivered data in the form of visual animation recordings to the students. Fogarty et al. conducted a study in order to examine the usage of Virtual reality in assisting students. The model can help assist students in understanding complex structural engineering principles and concepts. The feedback and quantitative experimental observations demonstrated that after implementing the VR platform as a teaching method, students were able to grasp the concepts, interact with the model confidently and raise queries which helped them clear their doubts effectively [62]. On the other end, Sun et al. explored the potentiality of Virtual Reality and its application in civil engineering field practices and training [63]. Alizadehsalehi et al. [64] employed teaching methods which were assisted through Virtual Reality platforms on a graduate-level course for making VR interact with the construction process and design. The students undergoing this graduate-level course used Head-mounted systems, i.e. (HDMS) of various types throughout the course for learning. Tang et al. investigated the use of mixed reality, i.e., merging of both the real world and the real world to develop new environments and visualizations, to facilitate students' learning process [65].

Using CAVE-based Virtual Reality for delivering educational concepts: The term CAVE is an acronym for Cave Automatic Virtual Environment, upon which the researchers have argued that it is one of the most suitable and beneficial facilities for students to learn the concepts in Virtual Reality. The potential aim of CAVE is to develop an immersive virtual environment generated by positioning the locations. Typical CAVE systems comprise a projector system projecting an environment upon a wall that conjugately works with cameras and sensors embedded around the facility. The user/student is then provided with a head-mounting device along with some other gadget to establish position and location in the VR [66]. Similarly, the study presented in Wang et al. literature proficiently reviewed various other studies which proclaimed the Virtual Reality based method of training is efficient and effective enough in improving the concentration levels of students/trainees, etc. [67]. Back in time, Messner et al. developed a CAVE-like facility that received valuable responses from feedback surveys and students who actually used the facility. It was an immersive experience that used virtual environmental conditions to augment the concepts. While few feedbacks also depicted that some of the users found it difficult to get command over how the facility can be used, while some showed ergonomics issues. Later the team reported that these issues can be resolved and are cost-effective in the industry setting as well [68]. Pertaining to the issues discussed above, Fogarty et al. reported that these are some of the typical issues which are likely to occur in CAVE-like facilities, where the global environment controls or commands the instructor while being an attendant in the immersive habitat. On the parallel side, students offer a vivid point of view for contemplating the perspective of CAVE. Thus, these issues can be resolved effectively by implementing various guidelines and also conducting practice sessions before approaching the Virtual reality-based CAVE habitat [69].

Field Visits vs. Learning based on Virtual Reality platforms: Since the aforementioned research and experimental studies state that VR is helpful in civil engineering education, but an argument over field practices vs. VR-based teaching has always been in the grapevine. Talking about the same, researchers state that VR applications for explaining practical experiences in lab environments are really beneficial as compared to physical site visits. On the same point of interest Sun et al. proclaimed that because of constraints like site availability and permissible time periods, real-time field or site visits is a limitation when it comes to consuming experience. While there are certain concepts that are viable to learn only after the construction process gets completed. Another limitation that was a part of the argument stated that the group size can affect the field visit, as large groups can not only hinder the decorum of the place but also break the concentration level while learning. Hence as a solution to resolve these limitations and overcome these constraints, interactive technologies can play a crucial role in curbing the loss of concentration as well as engaging students while going through the field visits [70].

Drawings and Blueprints: A 2D AutoCAD plan of the villa was collected, which included the ground floor plan, first-floor plan, elevation plan, sectional plan. The file with AutoCAD file format that is ".dwg" was then exported to the Revit Architectural software in order to design a 3D model of a villa. This 2D exported drawing in Revit helped us to design the required model with precise dimensions and other details like placing the number of levels in Revit, interior components, etc. This also helped us in placing the different villa components on the scaled distances shown in accordance with the CAD file. The CAD file was fully scaled and drawn, taking the original villa drawing into consideration.

Model Development: Modeling is a virtual version of the building design. The model describes not only the geometry of the model elements, but also captures the design intent and logical relationships between the elements in the model. One can think of the 2D model views (plans, sections, elevations, and so on) as elements of the 3D model. Changes made to one view are instantly visible in all other views of the model, keeping the views in sync at all times. The 3D model is used to create the 2D views that make up the printed document set.

This section focuses on the software which was used, their advantages, and disadvantages while executing the project. The information about the software mentioned below also depicts the alternative software which can be used in the project.

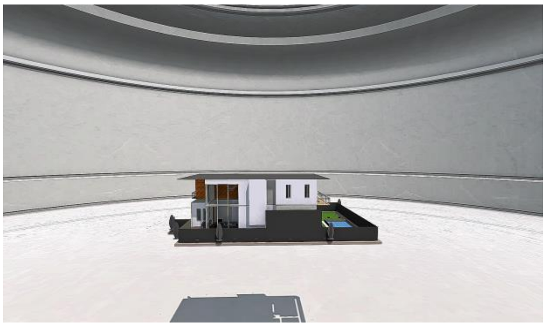
Software Platforms & Tools: It is very conspicuous that a variety of software and developer tools have made the life of designers and developers smooth enough. Codifying the ideas into a developing platform has been a boon for the developers. Procuring the same advantages of such dynamically designed software the aforementioned case study resulted in a fully-formed 3D model. For moulding ideas and to make the planning come true following software's were incorporated mainly to ease the model development process.

Revit: The significant reasons for opting for Autodesk Revit are as follows. Firstly, it is bi-directional associativity of all views of the model. Editing any part of a model leads to an immediate change in all its views. The complete information of the model is stored centrally in the project file. Because of this, editing becomes faster, and with fewer mistakes are made while editing. Designing in Revit uses real objects, like walls, foundations, columns, roofs, etc. that forms engineering intuition and thinking. It automatically generates plans, facades, sections and specifications as derivatives to represent a single model building, and automatically updates the three-dimensional model in order to prevent errors in design [71]. There are also some disadvantages of Revit, which we faced during our project, which was software's user interface. Other file formats which are imported into Revit may lose various types of information, including CAD, material, and other various statistical data, so we have to reconstruct the same, which leads to waste of time and thus in order to reconstruct the same could cost us plenty of time [72]. Though there are also some alternative software for 3D modeling which are readily available, including Sketchup, 3ds Max, etc. The next part which comes up is rendering, and the best-suited software for rendering are Lumion and Enscape. But, due to the non-compatibility of our device, we used Revit architecture for rendering too. When it comes to rendering in Revit, the result is very poor as compared to the rendered model in other aforementioned software, and hence these constraints affect the resulting model.

IRIS-VR: IrisVR software, allows 3D Revit models to be used in virtual walk-throughs. Additionally, IrisVR permits the features like model markups, drawing, and annotation, which can be screen captured for future use [73].

Kubity-Go: A cloud based three-dimensional communicating tool which works on numerous platforms, including desktop computers, web, smartphones, tablets, augmented reality gear, and virtual reality glasses. Kubity has practical applications for architecture, interior design, engineering, product design, film, and video games, among others. The majority of its users create 3D models using SketchUp or Autodesk Revit software.

Customer Experience: To get through the core of how well walk-through was designed and developed, we conducted a small walk-through simulation setup where we actually tested the fully developed VR walk-through by involving interested people to head-mount the VR glasses with controllers to move around and explore the whole project in order to get an immersive experience. These figures are depicted in figure 4 and help the researchers assimilate the idea from front elevation, and side elevation to the interiors of the villa in VR. Figure4 consists of a series of figures that shows how a 3D model of a villa looks when viewed on a virtual reality platform. Starting from the front elevation Figure4a, moving towards the next major section where Figure4c, Figure4d, Figure4e shows the side views and poolside view of the same villa model in virtual reality. Figure4f takes us to the entrance of the villa followed by Figure4g to Figure4t shows complete interior as well as elemental details which are a crucial part of interior design of the villa model. This definitely is a win-win situation wherein the design support and developers can put their efforts to develop a 3D model consisting of minute details for both external and interior design which helps the clients to get a perception of how well designed the property is. Using a virtual reality platform itself is not only a boon for saving time, money and energy but also it helps the clients to perceive the location, ambience & surroundings, space management and structural design all at one place and that too in an immersive medium. Cost Comparison Analysis: While studying the economic plot of the sample villa we came across the cost factor of a traditional approach which generally involves clients arriving on site to see the sample apartments, flats or villas before purchasing the particular property. It surprisingly cost a hefty sum of money to the developers for presenting and selling their product. Resources as mentioned below in table 1 stack up to a cost of approximately Rs. 93,000 whereas on the aisle side the VR technology takes up a one-time investment on Oculus Quest - VR headsets which can help clients take a walk-through of the actual properties sing VR technology which can ultimately help them conclude on whether to or no to invest in the property. From Table 2 we can clearly observe the adoption of virtual reality by different domains falling under the AEC domain. The team of stakeholders and design support team has adopted 33.902 % which is tagged as complete implementation whereas the least value of 7.944 % depicts the non-implemented slots. If we formulate the average of adoption according to the categories listed above, we can see that the average value for non-implementation is equal to 15.272%, similarly 15.216% of adoption is involved in the early phase of testing. 24.708% of adoption can be seen by all the domains for the purpose of primary implementation and 33.212% for partially using the technology. From Table 2 we can clearly observe the adoption of augmented reality by different domains falling under the AEC domain. The team of stakeholders and design support team has adopted 33.902 % which is tagged as complete implementation whereas the least value of 10.853 % depicts the non-implemented slots. If we formulate the average of adoption according to the categories listed above, we can see that the average value for non-implementation is equal to 15.403 %, similarly 21.892% of adoption is involved in the early phase of testing. 29.389% of adoption can be seen by all the domains for the purpose of primary implementation and 33.566% for partially using the technology.



4a: Complete villa in VR

4b: Close up view of villa in VR

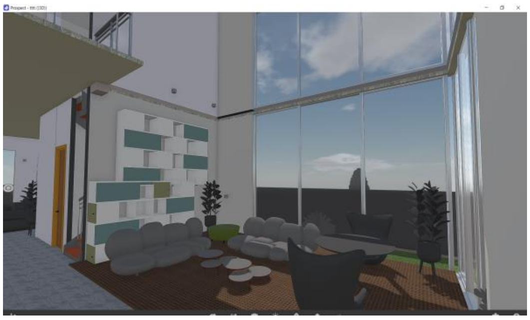
4c: Side elevation of villa

4d: Poolside view of villa

4e: Lawn and backyard of the villa

4f: Front entrance door of a villa

4g: Interior of the main hall inside villa



4h: Main Hall of the villa

4i: Foyer

4j: Interior of a living room inside the villa.

4k: Kitchen with elemental details

4l: Staircase from ground floor

4m: Staircase leading to first floor

4n: View from the first floor

4o: Path leading to balcony

4p: Balcony view

4q: Interior of a bedroom on the first floor

4r: Balcony view from one of the bedrooms

4s: Front wall of the bedroom with TV Unit

4t: Closet area outside the Bathroom

Fig. 4. Three-dimensional view of various sections of a villa on virtual reality

Table1. Cost Comparison of traditional approach of sightseeing vs. VR technology used for sightseeing

Sr. No.	Traditional Method		VR Technology	
	Resources	Cost (approx. in INR)	Resources	Cost (approx. in INR)
1	Vehicle & Transportation	1,000	Oculus Quest – VR headset	38,000
2	Property (Sample Villa) maintenance	1,500	-	
3	Electricity	50-80	-	
4	Other Utilities	500-1000	-	
5	Total expense/day	3050	-	
6	Total expense/month	91,500 – 93,000	-	Can vary if bought in greater quantities.

Table 2. Adoption levels of virtual reality and augmented reality in six different use cases falling under the AEC domain [75]

Categories	Not implemented/used		Early testing phase		Primary implementation		Partial usage		Complete implementation	
Stakeholder	VR adopt	AR adopt	VR adopt	AR adopt	VR adopt	AR adopt	VR adopt	AR adopt	VR adopt	AR adopt
Design support team	7.94	10.853	7.944	15.888	18.909	25.846	33.79	32.895	33.9	33.9
Design review team	10.9	12.867	10.965	19.804	20.923	27.972	31.888	33.902	33.9	33.9
Construction support	10.9	12.979	10.853	21.93	21.93	28.867	33.902	33.902	NA	NA
Operations and Management team	19.9	17.902	19.804	24.951	28.867	30.881	33.902	33.902	NA	NA
Training team	23.9	18.909	23.832	24.839	30.769	32.895	33.902	33.902	NA	NA

To get a breakdown on adoption parameters inside the particular premise of different use cases of AEC domain, refer to the enlisted Figure 5a & 5b which depicts the complete adoption of both the technologies by stakeholders and the design team itself by incorporating 33.902%. Followed by the Figure 5c & 5d which depicts the primary level of implementation of both augmented reality and virtual reality. The donut chart values for early testing phase adoption of AR and VR by the six different use cases is described in Figure 5e & 5f. In the last set of Figure 5g & 5h we observe that around 9-12% of stakeholders have abandoned the adoption of these platforms. Around 12-14 % of design team members as well as design review team have abandoned the adoption of augmented reality and virtual reality in their use. The construction supporting agencies shows an abandonment rate of 22% for virtual reality and 19% for augmented reality. The operational management team reflects stats of 26% abandonment for VR and 21% abandonment for AR. Lastly, the training department exhibits the values of 19% abandonment in adopting virtual reality platforms while 20% abandonment in adopting augmented reality platforms. The series of figures attached show the adoption percentages of augmented reality as well as virtual reality by different teams which come under the AEC i.e., Architectural - Engineering - Construction domain. Figure 5a & Figure 5b shows that the design support team and the team of stakeholders have incorporated equal percentage i.e., 5o% respectively of both Augmented Reality as well as Virtual Reality. Followed by Figure5c & Figure 5d represents the partial adoption percentage levels of both virtual reality and augmented reality. The foremost implementation percentage levels of these technologies can be seen in Figure 5e & Figure 5f, operation & management team incorporates 21% for virtual reality platform in their usage whereas on the parallel end it incorporates 19% for augmented reality for their work. Figure 5g and Figure 5h attached above depicts the adoption level of VR and AR in the early testing phase. The adoption level range in the early testing phase is similar to that in the primary implementation phase. The operation & management team subsumes 26% accompanied by the construction support team that subsumes 22% of virtual reality platform. On the aisle side, both operation & management team as well as construction support team subsume 19% of augmented reality platform. The percentage adoption level numbers of not adopting AR and VR are marginally similar to those in the early testing phase. Figure 5i and Figure 5j are the proofs showing how different teams have different incorporation levels of virtual reality and augmented reality in their work.

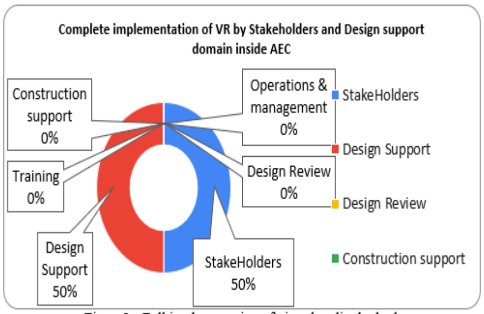


Figure5a: Full implementation of virtual reality by both stakeholders and design support team.

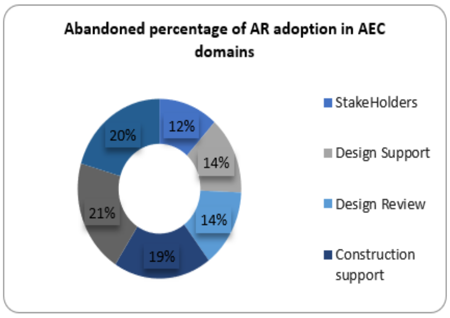


Figure 5b: Full implementation of augmented reality by both stakeholders and design support team.

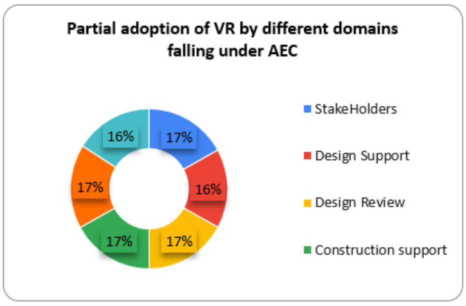


Figure 5c: Partial adoption of virtual reality by different domains under AEC.

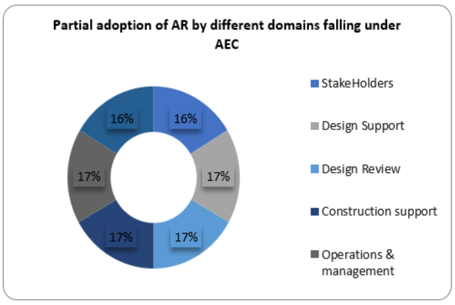


Figure 5d: Partial adoption of augmented reality by different domains under AEC.

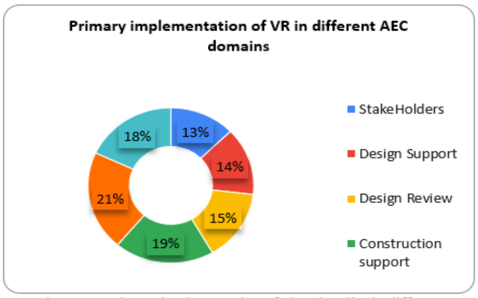


Figure 5e: Primary implementation of virtual reality in different domains under AEC.

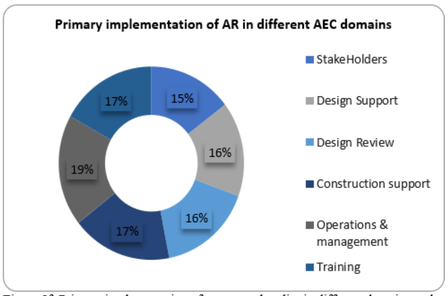


Figure 5f: Primary implementation of augmented reality in different domains under AEC.

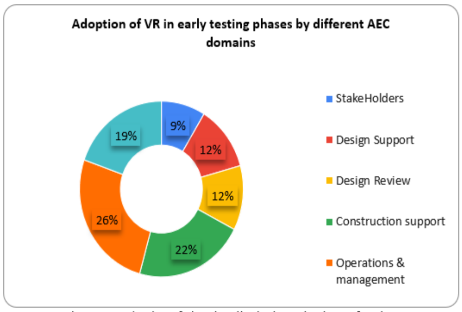


Figure 5g: Adoption of virtual reality in the early phase of testing.

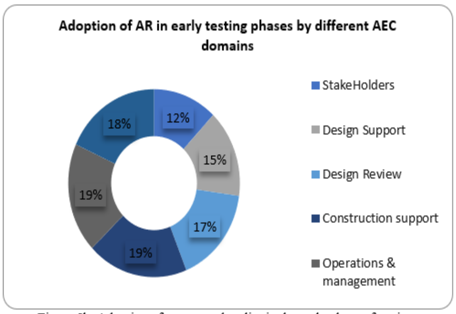


Figure 5h: Adoption of augmented reality in the early phase of testing.

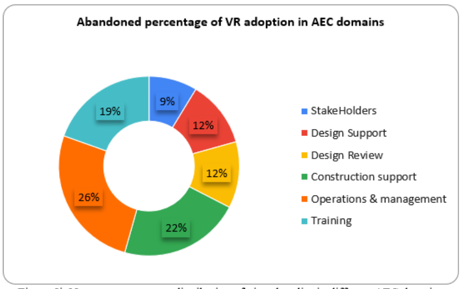


Figure 5i: No usage percentage distribution of virtual reality in different AEC domains

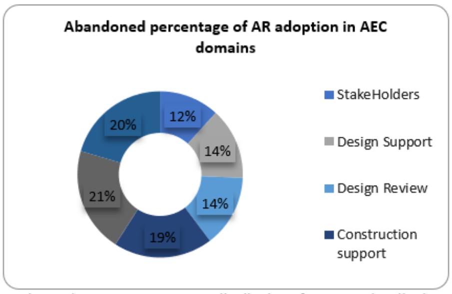


Figure 5j: No usage percentage distribution of augmented reality in different AEC domains.

Fig. 5. Comparison between adoption of Virtual Reality and Augmented Reality in the domains of Architectural-Engineering and Construction

5. DISCUSSIONS AND FUTURE OUTCOMES

Since now we know that these marvellous technologies can do wonders and create opportunities for the parties involved in the deal, it is not only limited as a helping hand to the sales and marketing process but also has an impact on different firms intricating their ideas. Taking into the account

Incorporating this approach in near future can help save time for both client and organization when undergoing the displaying, buying and viewing of their property. Making the task hazel free and smooth for both the parties to deliver precise results.

The customer can design their own interior on the VR platform with the architect, and the changes made by the architect will be reflected in the ongoing VR meeting in real-time.

1. This esteemed technology is in the emerging phase and seeks add-ons from potential developers which tends to unlock the real time customization support and built-in tool palette that would help the client to make the changes as per their requirements. Regular or periodic bug fixing OTA updates can resolve the bugs and these technologies can be implemented on numerous platforms without learning the operating parameters and usage technicalities.
2. Considering the next crucial area where virtual reality and its application plays a vital role is inside the school of civil engineering. Virtual Reality technology opens up countless new possibilities for the purpose of training, especially STEM in terms of hands-on lab work. This helps in cost-cutting and reducing environmental damage from that big lab equipment. It also helps in making a few experiments more accessible to the general public than ever before. At present, colleges and universities are struggling to find places to conduct experiments and probably have damaged the lab equipment. Experimentation could be expensive as well as risky at times and hence building virtual laboratories which can help students conduct, operate and understand experimentations more effectively and safely.
3. There are various benefits and characteristics of the virtual reality technique, as determined by the analysis and comparison method of research. Practically, virtual reality training and internships only require a small amount of room to complete the programme. Investing in computer hardware, software, and a virtual reality headset can help the user get an immersive experience.
4. Immersion aspect: In the realm of immersion, the majority of students are always present during fieldwork, and because of gathering in groups they find it difficult to focus on the field-based

parameters. The observations and student feedback appear to suggest that undergoing site visits in groups while receiving instruction simultaneously from a single teacher leads to reduced level of concentration, which limits the number of students who are able to complete the report with a respectable level of quality. In this kind of situation, the internship organized through a virtual reality platform can help students understand the peculiarities of the field practice independently.

6. CONCLUSION

1. This research work proves that marvellous technologies like virtual reality and augmented reality can significantly improve the civil engineering domain thoroughly. These technologies hold the caliber for altering the standard methods and ideologies in order to layout new potent and exceptionally well managed ideas which can proficiently improve the quality standards of the educational courses, construction work, management and maintenance work.

2. Using these platforms while undergoing activities like designing, planning and reviewing can embed all the crucial personnel at same time which can promote the discussions and all the mistakes and errors are rectified on the initial stage itself which can help undergo a smooth construction process.

3. The cost comparison analysis shows that the idea of implementing a virtual reality platform in order to showcase the construction projects samples of flats, villas, row-house or any kind of property is economically feasible and can save up to around 43 - 45% of displaying samples / mock-ups. This can not only affect the organization with economical profit but also improve the ultimate timeline of the project.

4. Virtual reality in education is an exception and can be used to elaborate the fundamentals of the civil engineering principles. The CAVE facility tends to satisfy the needs of an immersive environment in the civil engineering schools. VR platforms can profusely solve the issue of site visits and practical’s by making the process much easier and convenient for everybody enrolled in the programme.

5. VR and AR can be named as nutrients for the civil engineering schools, real-estate, construction firms and organizations. These magnificent technologies hold power to change the face of the aforementioned domains significantly over a period of 2 - 3 years and can deliver exceptional results which are both sustainable and profitable.

6. 2D plans can be evolved into 3D models which can be then transmogrified into walk-throughs and then can be experienced using virtual reality platforms. This approach can be effective in saving client-owner time and energy. This is economically feasible with minimal amount to be invested for maintaining the VR equipment. It lays out a sustainable idea of experiencing, buying-selling or even marketing the products in the civil engineering domain.

ABBREVIATIONS

2D: Two dimensional
3D: Three dimensional
AEC: Architect, Engineering, and Construction
AR: Augmented reality
BHK: Bedroom Hall and Kitchen
BIM: Building Information Modelling
CAD: Computer aided design
CAVE: Cave Automatic Virtual Environment
CE: Civil Engineering
CEET: Construction Engineering Education and Training
dwg: Autocad Drawing file
HDMS: Head-mounted systems,
n: Number of rooms
REVIT: Revise-Instantly
STEM: Science, technology, engineering, and mathematics
VR: Virtual Reality

ADDITIONAL INFORMATION

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors confirm that they have read, understand, and agreed to the submission guidelines, policies, and submission declaration of the journal

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