T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

INVESTIGATING THE APPLICABILITY OF VIRTUAL REALITY MODELS IN CONSTRUCTION INDUSTRY

MASTER'S THESIS

Mohammed Ahmed M. ADWAN

Engineering Management Department

Engineering Management Master in English Program

JANUARY 2023

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Thesis Supervisor: Assoc. Prof. Dr. Redvan GHASEMLOUNIA

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İSTANBUL GEDİK ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (201281001) numaralı öğrencisi Mohammed Ahmed M. ADWAN'ın "Investigating the Applicability of Virtual Reality Models in Construction Industry" adlı tez çalışması Enstitümüz Yönetim Kurulunun 25/01/2023 tarihinde oluşturulan jüri tarafından *Oy Birliği* ile Yüksek Lisans tezi olarak *Kabul* edilmiştir.

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1) Tez Danışmanı: Doç. Dr. Redvan GHASEMLOUNIA

2) Jüri Üyesi: Dr. Öğr. Üyesi Hasan Bozkurt NAZİLLİ

3) Jüri Üyesi: Dr. Öğr. Üyesi Gökhan KAZAR

DECLARATION

I, Mohammed Ahmed ADWAN, hereby certify that this thesis entitled "Investigating the Applicability of Virtual Reality Models in Construction Industry" is my original thesis for the award of Master's Degree in Engineering Management at the Faculty of Engineering Management. I further certify that this thesis or any part thereof has not been submitted and presented for any other degree or research thesis at any other university or institution (25/01/2023)

Mohammed Ahmed M. ADWAN

PREFACE

Foremost, I would like to express my profound gratitude to my supervisor A Assoc. Prof. Dr. Redvan GHASEMLOUNIA for his valuable guidance and continuous support during the process. I would also like to thank the rest of my thesis committee, Assoc. Prof. Çiğdem Üstün and Asst. Prof. Şadan İnan Rüma for their insightful comments and contributions. I owe great debt to my family, especially my father, my mother my wife, for unequivocally supporting me in all that I do and always being there for me. I also want to extend my appreciation to Kemal for bringing joy and standing by me in every sphere of my life - both academically and personally.

January 2023 Mohammed Ahmed ADWAN

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ABBREVIATIONS

VR	: Virtual Reality
BIM	: Building Information Modelling
CAD	: Computer-Aided Design
2D	: 2 Dimensional
3D	: 3 Dimensional (Design)
4D	: 4 Dimensional (Time)
5D	: 5 Dimensional (Cost)
6D	: 6 Dimensional (Life cycle)
7D	: 7 Dimensional (Sustainability)
8D	: 8 Dimensional (Safety)
AEC	: Architecture, Engineering, and Construction
GIS	: Geographic information system
GDP	: Gross domestic product
AR	: Augmented reality
CAVE	: Cave Automatic Virtual Environment
ACCE	: American Council for Construction Education
HMD	: Head-Mounted Display
SHM	: Structural health monitoring
HTC	: High Tech Computer Corporation
SWOT	: Strengths, Weaknesses, Opportunities, Threats
POV	: Production-Oriented Views
SPSS	: Statistical Package for Social SCI

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INVESTIGATING THE APPLICABILITY OF VIRTUAL REALITY MODELS IN CONSTRUCTION INDUSTRY

ABSTRACT

During the past years and decades, the construction processes have become more complex and fuller of details, especially when talking about giant projects. It becomes very difficult to work for the purpose of reaching the desired goal in a way that guarantees safety and quality of construction within the specified budget and time.

This research aims to analyze the methods necessary to apply virtual reality technology within modern construction projects and what are the challenges facing the use of this technology with finding solutions and how it can be linked with various technologies and models to create an environment of construction Industry and a virtual model that enables both the client and the work team within the project to understand the projects and delve into all its details.

Through the virtual reality system, we can access information quickly and reliably. For example, when a certain defect occurs during the implementation process, it can be solved in a virtual way and ensure the appropriate work mechanism in order to achieve security and safety for the project.

The technology has an advantage that distinguishes it from other technologies in that it enables the customer to participate in the design and implementation process within a complete environment virtual and give the customer opinions without a prior engineering background, which adds more flexibility and effectiveness and provides quick engineering solutions, which helps us save the time and money needed to finish the project. The aim was also to provide complete homogeneity during the implementation phase of the project for the stakeholders. In addition, the subject of learning the theory of virtual reality and getting acquainted with it theoretically within the specialized centers, especially for company owners, investors and university students, was addressed.

Keywords: *Virtual Reality; Technology; Construction Industry*

SANAL GERÇEKLİK MODELLERİNİN İNŞAAT SEKTÖRÜNDE UYGULANABİLİRLİĞİNİN İNCELENMESİ

ÖZET

Geçtiğimiz yıllar ve on yıllar boyunca, inşaat süreçleri, özellikle dev projelerden bahsederken, daha karmaşık ve ayrıntılarla dolu hale geldi. Belirlenen bütçe ve süre içerisinde inşaatın güvenliğini ve kalitesini garanti edecek şekilde istenilen amaca ulaşmak amacıyla çalışmak çok zor hale gelmektedir.

Bu araştırma, sanal gerçeklik teknolojisini modern inşaat projelerinde uygulamak için gerekli yöntemleri ve bu teknolojinin kullanımının karşılaştığı zorlukların neler olduğunu ve çözüm bulmayı ve inşaat endüstrisi ortamı yaratmak için çeşitli teknolojiler ve modellerle nasıl ilişkilendirilebileceğini analiz etmeyi amaçlamaktadır. hem müşterinin hem de proje içindeki çalışma ekibinin projeleri anlamasını ve tüm ayrıntılarına inmesini sağlayan sanal bir model.

Sanal gerçeklik sistemi sayesinde bilgiye hızlı ve güvenilir bir şekilde ulaşabiliyoruz. Örneğin, uygulama sürecinde belirli bir kusur meydana geldiğinde, sanal olarak çözülebilir ve proje için güvenlik ve emniyet sağlamak için uygun çalışma mekanizması sağlanabilir.

Teknolojinin kendisini diğer teknolojilerden ayıran bir avantajı, müşterinin tasarım ve uygulama sürecine eksiksiz bir sanal ortam içerisinde katılmasını sağlaması ve daha fazla esneklik ve etkinlik katan ve daha hızlı sonuçlar veren daha önceki bir mühendislik altyapısı olmadan müşteriye fikir vermesidir. projeyi bitirmek için gereken zamandan ve paradan tasarruf etmemize yardımcı olan mühendislik çözümleri. Projenin uygulama aşamasında da paydaşlar için tam bir homojenlik sağlanması amaçlandı. Ayrıca, özellikle şirket sahipleri, yatırımcılar ve üniversite öğrencilerine yönelik olarak uzmanlaşmış merkezlerde sanal gerçeklik teorisinin öğrenilmesi ve teorik olarak tanıtılması konusu ele alınmıştır.

Anahtar Kelimeler: *Sanal Gerçeklik; teknoloji; Yapı sektörü*

1. INTRODUCTION

Current global environmental conditions are the result of human activity, which has led to a decline in productive capacity, from which major consequences have begun to appear, which have greatly affected the social and environmental character of the world. The importance of the issue led to the emergence of global discussions and international agreements in order to achieve a stability between the various forces, including society, the environment and the economy (Langston, 2001).

On the other hand, built facilities are the most important economic, social and environmental investment of humankind (Langston, 2001**)**. The built environment is usually a nation's largest asset, as the nation's residents live, work, and generate GDP. According to Newton et al. (2009).

Looking at contemporary industrial societies, approximately 95 percent Population employed in the built environment Design, planning, building, and operation of the built environment are crucial to the productivity and competitiveness of the economy, the quality of life of inhabitants, and the environmental sustainability of the continent and planet.

The globe is still seeing an ongoing evolution of the built environment, which plays a significant part in this ongoing evolution.

As a country's economic progress necessitates a rise in the construction of factories, office buildings, and residences. As the economic status of the society continues to rise, the demand for architectural resources such as land, buildings or building goods, energy, and other resources for the construction process also continues to rise (Haghighat, 2009). However, new building projects need resource consumption and site alterations, which often decrease environmental wealth while increasing capital wealth (Langston, 2001).

When the construction sector is examined, it becomes clear that it is not suitable compared to the different sectors (Dehlin, 2008). Where it becomes clear that in the absence of the possibility of integrating the construction industry with advanced technology. Then many different problems may arise in different sectors. An illustration of project management, construction, and design.

Within the building industry, occupational safety risk analyses are generally performed on 2D drawings, despite the development of technology. In large projects, controlling risks through 2D graphics reduces the visibility of risks. In order to solve these problems, planning for the automation of occupational safety procedures in an integrated manner with BIM (Building Information Modelling) has begun. With BIM working style, the project design, construction and maintenance process has reached a level that can be planned and controlled.

In the twenty-first century, virtual reality technologies have achieved important and effective developments in the construction industry (Rahimian, 2014)Where the traditional methods have been abandoned in many different parts of the world. For example, the United States, China, England and others. Moreover, BIM standards have begun to develop in many countries (Eastman C. T., 2011)**.**

More recently, BIM has been incorporated into the design and construction processes of construction projects, along with augmented reality (AR) applications. Using AR applications, control processes during project creation can be improved and real-time access to project information can be provided.

Virtual reality technology It is used in several industries and activities, including education, design, manufacturing, entertainment, healthcare, and others. Despite being one of the least digital businesses, the construction industry is gradually embracing more and more computer-based technology. All of this is done to improve performance across the different phases of building and conceptualization projects.

Moreover, these modern technologies may bring considerable benefits to the advanced building sector via visualization. The construction industry's growing need for visualization technologies such as virtual reality resulting from the industry's complexity and the increasing need for information access for assessment, communication and cooperation.

Many scientific studies have contributed to drawing attention to the benefits and uses of virtual reality technology in architecture, engineering, and construction (Chi HL, 2013) (Wang X, 2013). But although the effective use of virtual reality in the construction industry is not easy at all. However, this technology has shown different areas in the construction sector where it has been considered a effective application of needed technology (Ahmed S. , 2018). The researchers were interested in compiling research activities on the applications of virtual reality technology in the construction industry (Delgado JMD, 2020) (Wang P, 2018). As these technologies have made a substantial contribution to the improvement of this industry in many areas such as cost and time management, defect management, safety management, education and training, progress monitoring and tracking, and information collecting, they deserve to be recognized.

Moreover, virtual reality technology positively influences the way design and construction parties comprehend, assess, and finish construction projects. VR provides novel capabilities such as walking inside a 3D model of a building at the early phases of design and navigating interactive components in the virtual world. Designers, contractors, and owners may now exchange data and make key choices even before the model is deployed on a building site, thanks to these new options.

The world has witnessed tremendous modifications in a wide variety of aspects in the construction sector during the past years. There have been major transformations construction industry around the world. The construction industry has revolutionized the various methods, techniques, and strategies in the construction industry. Furthermore, in order to address the scarcity of suitable workforce, extended duration, and poor work, the construction industry has devised new means of hiring employees as well as new methods of maintaining the construction profession. (Escamilla, 2016, pp. 51-71)

Virtual reality (VR) technology is one of the technical instruments utilized in the building business. A computer-generated simulation of a three-dimensional picture or scene with which a person may interact in an apparently real or physical manner utilizing a proprietary digital technology is referred to as virtual reality. This comprises a helmet with an internal display screen or gloves with sensors. (Whyte, Industrial applications of virtual reality in architecture and construction. Journal of Information Technology in Construction (ITcon), 8(4),, 2003a, pp. 43-50)**.**

The main objective of this study is to clarify the possibility of applying virtual reality and its possibilities in the construction industry. And providing a field of communication and cooperation that helps in verifying the project in its complete form in the construction industry process (Studio, 2016, p. 50)**.**

On the other hand, the current study also aims at several other secondary objectives, including them. Example Explore and provide insight into the way virtual reality models are understood. In addition to demonstrating their use by AEC professionals in their daily work. In addition to the above, the study will also aim to analyses the applications and benefits of using the BIM-VR methodology in the AEC industry.

1.1 Research Questions

1. What is virtual reality technology and what are its classifications and scope of work within the different construction systems
2. How can we use BIM technology with virtual reality technology?
3. What are the obstacles that we may encounter while using the two technologies together during the construction phase?
4. What are the additions that the process of combining virtual reality technology and BIM technology can provide in the fields of industry and education?
5. What is BIM technology, what is the importance of its work within the scope of construction work, and how is it fully applied?
6. What are the limitations and challenges of integrating VR in the Construction industry?

1.2 Research aim and Importance

The purpose of the case studies offered here is to investigate and provide knowledge of how (Virtual Reality) models are seen and utilized by AEC professionals in their daily work, as well as an analysis of the applications and advantages of employing BIM-VR methodology in the AEC sector. The two instances were as follows:

1. A quantitative questionnaire regarding how experts participating in the construction of a big building project experienced and evaluated Virtual Reality models, as well as the degree to which Virtual Reality may supplement the usage of traditional 2D CAD drawings. The key goal in this context was the practical usage of Virtual Reality on the construction site.

2. Point out the possibilities of the virtual Reality Modelling for improving construction communication and coordination and provide live source of information (real-time data). In the result there is the provision of workflows and guidelines for future improvement plan of using the methodology in the industry.

1.3 Method and Technique

1.3.1 Methodology

Research methodology, one of the most essential chapters in and of itself, gives the underlying rationale and arguments for following the selected study technique, which governs the total research being described in the thesis. This component of the thesis offers the total study a sense of purpose and comprehension. As the section progresses, it discusses the reasons for picking the approach described below and why it was best suited given the course that the study took toward completion. A quantitative technique was employed in this research to get information on the knowledge of virtual reality usage in the construction business. The data is gathered using an online questionnaire survey.

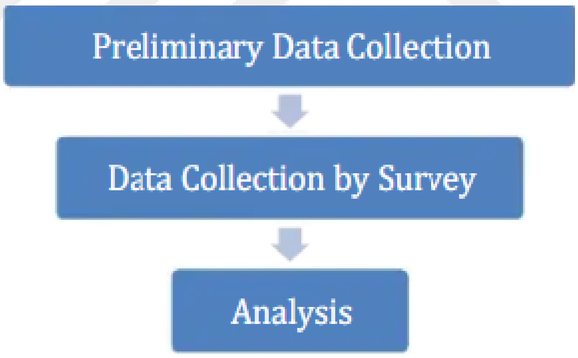


Figure 1.1: Methodology Process Chart

1.3.2 Preliminary Data Gathering

The preliminary data for questionnaire design were derived from a survey of the existing accessible literature. on BIM-VR technology in AEC industry and then, analysis of different cases-studies where BIM-VR technology to perceive better communication and coordination, minimize risks between different participants and provide real-time data., paper published in various publications regarding VR in construction industry and understanding current scenario of technology enhancement and practicality in construction industry.

1.3.3 The total sample

The total sample amounted to 121 Engineering working in different country around the world, and they were chosen specifically within disciplined of specific terms. which contributes to the formation of an accurate perception of the distribution and composition of the study sample

1.3.4 Data Collection by Survey

As stated before, Google Forms were used to gather data from an online survey form. The primary objective of the questionnaire was to get responses from building experts in order to comprehend and draw conclusions from the study. The intended participants are civil engineering and architecture graduates with prior construction industry experience. Among the responses, construction management, structural engineering, and architecture are the fields of expertise. Tabular representation of respondent demographics (Table 1.1).

A questionnaire comprising of questions or statements will be used to examine how various sorts of individuals viewed and evaluated the project's usage of Virtual Reality (VR). The survey was targeted to civil engineers, architects and consultants. A total of 121 respondents were obtained from the survey and their responses were recorded. The first three questions pertained to individual characteristics including age, profession and computer skills.

Table 1.1: Demography of the Respondents

Position	Field of Specialization	Years of Experience
Assistant Site Engineer	Construction Management	4
Site Engineer	Construction Management	5
Structural Design Engineer	Structural engineering	4
Structural Engineer	Structural engineering	3
Structural Site Engineer	Structural engineering	5
Contractor	Freelancer	5
Architectural	Architectural engineer	4

Participants in the survey will be required to respond to all questions based on their experience and the type of their degree. they have obtained, in addition to their full knowledge of the subject. The arithmetic mean, Cronbach's Alpha coefficient test and the standard deviation for the participant group as a whole will calculate for each statement.

1.3.5 Data Analysis

After collecting data using a questionnaire survey, the data must be analysed. Using Google forms, the opinions of experts were gathered via questionnaires including a series of questions. Here, data collection is followed by data analysis. The proportion of respondents is ascertained by comparing collected data to the whole sample. It is determined via data analysis which elements have the most impact on the adoption of VR in the construction business.

1.3.6 Tool analysis

Utilizing quantitative methods for data collection and analysis, IBM SPSS and Microsoft Excel were used for data analysis. Each kind of respondent's responses were converted to Excel sheets, and then the data was loaded into SPSS to generate statistics. Using descriptive statistics will enough for broad information. It will conduct demographic statistics for general information about responders.

1.3.7 Study procedures

- After reviewing the educational literature and previous studies related to the subject, the researcher built the study tool.
- • The researcher gave the questionnaire to a panel of arbitrators with specialized knowledge. in Canada, Palestine and Turkey; To ensure the validity of their paragraphs and the extent to which they belong to its dimensions, and its integrity in terms of linguistic formulation.
- The questionnaire was administered to an experimental sample of thirty (30) engineers by the researcher. To guarantee the questionnaire's validity and reliability.
- The researcher applied the questionnaires to the total study sample in a resaecher.

1.3.8 Statistical processors used.

The data was processed using a computer using the SPSS program in order to answer the study's questions, using the following statistical methods:

- Means and standard deviations, In order to find the responses of the study sample to the items of the questionnaire, its dimensions and its overall degree.
- Frequencies for all data
- Cronbach’s alpha equation; To find the stability of the tool.
- Chi-Square Tests

1.4 Literature Review

1. **Aly, H. (2020)**

Virtual reality applications in construction management and control are the focus of the research. The study focused on the use of virtual reality at several stages of building, including design, planning, and implementation.

The study also discussed the necessity of using virtual reality technology in the construction process, as well as the problems it faces. The aim of the research study is to analyze and implement modern technology such as BIM and VR in the construction business, as well as the difficulties associated with transforming BIM models into virtual models utilizing a virtual reality environment.

In his research, the researcher devised a strategy for improving the construction work required to adopt virtual reality technology on a big scale in the construction business. The study also discovered a framework for implementing in construction enterprises, virtual reality and remote collaboration are used.

The study also discovered a framework for implementing virtual reality in construction enterprises and catastrophe management using remote technology. Virtual reality technology is also a distinct new technology and a new model in the building and construction process, according to the study. It can also be used to meet the demands of various projects.

2. **Sampaio, A. Z. (2018)**

The study article discussed how virtual reality technology could be used to improve the bim approach.

The article explained the value of BIM technology and how to integrate it with virtual reality technology in collaborative interactive projects, in addition to the description of BIM technology. Aside from that, the research article discussed the benefits of employing virtual reality technology.

The purpose of this essay was to develop and clarify the full integration of virtual reality technology and BIM technology by boosting the efficiency of solving facility problems before they occur. The study also investigated how to use or adapt Virtual Reality devices, as well as how to make links to display information from the BIM model.

In addition, the study concluded that the interactive capabilities inherent in virtual reality technology should be paired with BIM technology to improve the technology's future use in the right context and with the right projects.

3. **Chen, L., & Luo, H. (2014)**

The topic of building quality management using BIM technology was covered in the research paper. Furthermore, the research report discussed BIM's many uses. It explains how to use 4D BIM to apply quality based on building codes by creating a high-quality model using a mix of BIM and the present high-quality POP model. The definition of product, organization, and process (POP) data is included in its structure. The article presented a case study to validate the usage of the proposed (4D) BIM application for quality control throughout the Wuhan International Exhibition Canter’s development phase.

It also mentioned the advantages of adopting BIM technology to help engineers improve the quality of their job. This is accomplished by using visual data formatting to assist project participants in better understanding quality progression and collaborating more efficiently.

The goal of the study was to create a comprehensive, instructive, and practical 4D BIM-based application for building quality monitoring, as well as to investigate how it fits into existing construction practices. The study also analyses and suggests solutions to potential issues with combining BIM technology with conventional quality management systems. Using national, industry, and local quality standards and norms, quality models comprising process, organization, and product (POP) information were developed during the research.

The scheduling and quality models were then merged into a virtual application using 4D BIM to create during the building phase, quality control requirements and duty assignments are established.

The study came to several conclusions, including a discussion of the benefits of employing bim to attain the highest possible quality by utilizing various building regulations.

4. **Ahmed, S. (2018)**

The problem of reviewing virtual and actual reality in project management was discussed in the research paper. The study looked at how we may use current technology to improve our lives by giving correct information .In addition, the research study demonstrated how to use virtual and augmented reality in construction management difficulties with excellent quality and efficiency.

Furthermore, it explained how the technology of worker training, quality management, and control during the workflow is applied in project management. The research also discovered that augmented reality is useful in the construction sector for project scheduling, progress monitoring, worker training, safety management, time and cost management, and quality and defect control. The goal of the research paper was to clarify the areas where virtual and actual reality might be used successfully and profitably in the construction process to save time and money while improving quality.

In comparison to current methodologies and models, this report outlines several researchers' efforts to employ augmented reality and virtual reality in building efficiently .The significance of the research study stems from the fact that it can assist authorities in determining the usability and efficacy of various augmented reality and virtual reality technologies in solving a variety of administrative issues in construction management .The study discovered that the incredible advancements in (Argument Reality and Virtual Reality) technologies have a substantial impact on the construction industry in a variety of ways.

5. **Liu, Y., Lather, J., & Messner, J. (2014)**

The goal of research is to use virtual reality to help with integrated design processes. For many years, virtual reality technology has been employed in building design and construction, according to the report, as it was widely used in the design and review processes, employee training on the subject and how the work mechanism was clarified, and a full demonstration of the work mechanism using 3D technology.

The study also looked at how to employ a virtual reality system in an energy retrofit project and what the problems and benefits are, with the goal of coming up with a more acceptable and effective display system as a consequence of the research and analysis The goal of the research study was to develop engineering construction mechanisms, particularly because they lack the importance of virtual reality technology, as well as the necessary tools, expertise, and display systems, which delays their rapid adoption and application.

The study discovered that this technology can be used for greater productivity and more effective revisions and designs, but only with advanced models of models that meet the required level of detail and functionality.

6. **Whyte, J. (2003)**

The research focused on the use of virtual reality in the building and architectural industries. The study's general goal was to follow the multi-case system and the actual and strategic motivation for using virtual reality. The study also discussed customer interface support, as well as the development of new markets and patterns in the use of virtual reality technology.

Demonstrating efficiency and capability, reviewing designs, simulating the dynamic process, and planning construction .The goal was to analyze the impact of using virtual reality technology in construction and the two and the surrounding environment in what differentiates them from each other. Also, measuring the impact of project size and re-design on strategies for implementing and utilizing virtual reality, as well as what commercial benefits have been realized.

The study also discovered that virtual reality is viewed as a global interface for all construction applications; however, the study predicted that in the future, there will be competition among families of different designs to achieve the best possible result.

7. **Sirajuddin, M. F., Thabeet, W., & Bowman, D. (2004)**

The research focused on the usefulness of virtual settings for inspecting 3D building models.

The study focused on how two-dimensional graphics techniques are used when planning and starting the construction process, which provides what is required in the project and what they need in construction, where the work team exchanges information in the form of clear drawings for everyone, but this is likely to cause problems between the construction process and the design.

As a result, the research focused on using 3D modelling technology to create a virtual environment in which we can review and modify the design goal during virtual interactive sessions, thereby reducing and resolving conflicts.

Following the study, which included the use of various architecture and construction topics divided into several models, I discovered that it is necessary to restrict the work and define restrictions on the planning category using two-dimensionality and replace it in a three-dimensional way and display it on screens that allow the work team in all its forms to visualize it intuitively immersed with comparison what Between technologies and devices, choosing the best.

8. **Ahmed, S. (2018)**

The focus of study is on the use of virtual and actual reality in construction management. The study aimed to assess the influence of virtual reality technology and actual reality on our everyday lives, as well as the benefits it has brought to construction management in recent years.

And I concluded that the actual reality demonstrated its efficacy in project scheduling, safety management, time management, cost, quality, and defects, as well as executing intense worker training courses.

The investigation also revealed how virtual reality was employed as a safety and training tool for working cadres and management for quality and defect management.
Furthermore, it was revealed how virtual and virtual reality technology might assist potential regions in efficiently using these technologies as lucrative methods to save money.

9. Sacks, R., Perlman, A., & Barak, R. (2013)

The focus of study is on construction safety instruction utilizing virtual reality technologies. The study focused on how workers deal with virtual reality and immerse themselves in it in a similar environment to reality, but it turned out that its full application is more like a fantasy, and it has become somewhat threatened because the cost of the necessary equipment is high, but with the technological revolution that has occurred in the world, particularly in smart phones, digital equipment, and so on.

We can see how virtual reality has been changed into a reasonable cost that can be employed, followed by the creation of appropriate applications for this. During the building era, the research also analysed the nature of the fields that joined the virtual world, such as the electronic games business, driving lessons, and promotional activities for shopping malls and safety training centers.

The study's stated goal was to determine how to promote virtual reality around the world, as well as the benefits of using virtual reality in the building process, taking into consideration the application of the protected life of tools in various nations.
When building is in its early phases, safety, training, and construction are all priorities.

10. Bastug, E., Bennis, M., Médard, M., & Debbah, M. (2017)

In terms of potential, problems, and essential enabling variables, we are moving toward an interconnected virtual reality .The study focused on the experimental usage of virtual reality technologies use of fifth generation networks in order to keep up with the latest technologies and modern technological developments, as well as the development of search and storage operations in conjunction with industrial development and artificial intelligence that is currently available in the world.

The research also explored the fundamental criteria for implementing virtual reality technology, how to enable and develop it, and what the obstacles are considering the extraordinary surge of interest in many circles.

The study also found how the notions of virtual and actual reality spread widely across fifth generation networks, as well as the magnitude of the growth that happened. As a result, the success of the virtual reality experience is dependent on solving a large number of major challenges, which include studying the limits of human perception prior to the paradigm shift by linking virtual reality with Relevant technological requirements and drawing conclusions to discuss whether a coherent ideal can be achieved and what its full implications.

11. Sampaio, A. Z., Henriques, P. G., & Ferreira, P. S. (2006, February)

The research focuses on virtual reality models used in civil engineering education.

The study concentrated on the influence of employing virtual reality technology to enhance the educational process and what this technology may contribute to acquiring various models to visually imitate the client.

Furthermore, how can these models contribute to the growth of the work while adhering to the order of intended construction and visualizing the form of each of the work's numerous elements. The study's intended goal was to investigate the kind and technique of operating the materials required for building operations.

In addition to preparing the essential resources for how to use and use virtual reality technology, professionals should consider teaching students the value of each part of virtual modelling and how to interact with the virtual model in a way that helps learning.

12. Sampaio, A. Z., Henriques, P. G., & Ferreira, P. S. (2004, June)

The research focuses on the use of a virtual reality environment to portray engineering building procedures.

The study focused on the application of reality in the field of construction training, where the diagram can be used to put visuals in the construction, where you can use planning this simulation with the ability to project the project with the ability to change the project dynamically to reach the best participation possible without problems or errors.

The primary goal of the research is to develop models that provide a comprehensive visual simulation and contribute to the application of virtual reality theory to aid in the visualization of construction progress in parallel with the various stages of engineering construction in order to achieve the best possible ways for the development of the construction process.

13. Sun, G., & Wang, X. (2021, May)

The use of computerized virtual reality technology in the practical teaching of structural engineering surveys. The study focused on virtual reality and linked it to the subject of structural engineering survey, where the subject is characterized using strong practical applications, especially in the field of training teaching, but the problem is that not all times are suitable for taking students to the training site.

The study's objective.

How can learners have equitable access to a continuous learning process in which they feel as if they are standing in front of the teacher, assuring the learning effect and the fairness of each student?

And how to deliver learning to students is the same as the sequence of establishing a construction site, and how virtual reality provides an environment for practicing simulation at any moment without any impediments.

14. Wang, W., Lv, Z., Li, X., Xu, W., Zhang, B., Zhu, Y., & Yan, Y. (2018)

The project focuses on a GIS analysis platform for virtual reality based on spatial queries.

The study focused on how the proposed platform can serve a three-dimensional digital city in addition to supporting the integrated VR GIS functions, such as spatial analysis and three-dimensional visualization of the spatial process, because this three-dimensional procedure and the massive visualization of the city are entirely done on the platform.

The research also examined the vast quantity of information that can be visualized using this system, as well as how GIS can give the essential flexibility to access various data sources, knowing that there are algorithms developed to facilitate the distribution and query of geographical data.

By way of example, the primary goal of the research is to determine how the specially created query algorithm substantially increases the performance of the suggested system. Within the framework of the concept of big data, with the tools that the system possesses capable of optimizing the system via enormous size, predictability, and real it.

2. VR TECHNIQUES

Affecting the industry on two levels: integration of enabling technologies or tool sets in both the design and construction processes, and integration of the two processes, design and construction. Virtual reality will play an important role at both levels, serving as a testing and modelling medium in both design and construction. Furthermore, it will allow the building process to be addressed at the concept design stage, analysing the design for buildability.

VR will therefore be seen as the technology that will aid in the abolition of the conventional lines that separate design and construction. According to the survey findings, most of the work being done by researchers in this subject is still not being adequately disseminated and used by practitioners in the business.

The survey showed there is a widespread lack of knowledge of new enabling technologies such as VR, owing in part to the expense and in part to the amount of practitioner participation in the research and development process. This should guide future work by supporting more industry-led research to shorten the gap between research and practice.

2.1 Virtual Reality: Definition and Characteristics

Depending on the setting in which it is used, virtual reality (VR) can be defined in a variety of ways. The term "virtual reality" refers to a computer-generated environment that gives the observer a compelling illusion and a strong sense of immersion in a made-up world that only appears on the screen. Thus, immersion technology is a term frequently used to describe virtual reality. Virtual reality systems are mostly assessed based on how fully immersible and interactive they allow the user to be. The development of greater spatial abilities is said to benefit from immersion and interaction as well as other aspects (Trindade, 2002).

According to Trindade (2002), immersion is advantageous when using VR to convey ideas that don't have a real-world equivalent. Since they transition from being passive observers to active thinkers when they can participate, pupils learn more effectively (Trindade, 2002).

Depending on the degree of immersion created, there are three other classifications of virtual reality systems:

- Immersive systems that employ big screens or head-mounted displays to completely fill the viewer's field of vision.
- Non-immersive systems, such as small screen monitors that don't fill the entire field of vision.
- Augmented systems, which place a virtual display on top of the user's real-world perspective.

2.2 Categories of VR

According to the amount of immersion, VR categories may be classified into three tiers. (Fries, 2007)

- **VR platform with full immersion**

Users are given a 360-degree perspective of the virtual environment through the technology. A head-mounted display (HMD) makes it simple to attain total immersion. The Cave Automatic Virtual Environment is a tool that is offered in the AEC sector to create a completely immersive environment (CAVE). A 1:1 scale representation and a strong sensation of presence are provided by the fully immersive technology.

- **VR platform with some immersion**

The device provided a limited VR experience and was referred to as projection-based VR. Several projectors and enormous screens make up the system. It provides a less immersive experience than desktop VR.

- **VR platform without immersion**

A three-dimensional scene may be seen through a graphics monitor and explored through using a mouse in non-immersive VR, often known as desktop VR. The system's mobility and affordability are its two biggest benefits. Autodesk Navisworks is an example of a desktop virtual reality system.

Virtual reality (VR) technology is a key tool for visualizing the finished product, with significant potential for interface use. VR may be used to validate design processes, visualize construction activity, and improve collaboration between various parties.

Then consider the creation procedure. There is a contention that the appropriate usage of virtual reality in different stages of building is not evident. Considering the advantages of employing model-based information BIM, this may have a reasonable explanation, since the development processes of VR in the manufacturing business inspired the widespread usage of the VR model in the AEC industry. The advantages of virtual reality are typically described as cost savings, risk mitigation, and enhanced stakeholder communication. We can see the intricate pipe system and the precisely described geometry by using the VR model.

The primary factor driving VR's increased attention is that it provides a variety of advantages for a wide range of applications in the building sector (Woksepp, 2007)

2.3 Structure and Infrastructure Engineering

Autonomous condition evaluation of large-scale structures has drawn a lot of interest in recent years due to the development of more complex infrastructure. By implementing prompt risk and hazard reduction, data-driven structural health monitoring (SHM) approaches preserve the safety and uninterrupted usage of the structures under a variety of operational situations. Traditional approaches, however, are inadequate to monitor a substantial quantity of SHM data and make maintenance decisions in a methodical manner.

In this study, Building Information Modelling (BIM) is used as a prospective computing environment and integrated digital representation platform of structural health management (SHM) that can organize and visualize a large quantity of sensor data and subsequent structural health information over an extended period. The suggested visualization tool for a long-span bridge is developed using a BIM-enabled platform, which also enables automatic sensor data inventory in the BIM environment.

A solution like this one automates routine maintenance and risk management while preventing human mistake brought on by ocular examination of the buildings. The suggested approach may be viewed as an affordable and user-friendly framework for assessing the state of structures and mitigating disasters using long-term observed data.

2.3.1 Enhanced infrastructure monitoring data visualization using building information modelling.

According to (Fanning, 2004) structural health monitoring (SHM) is regarded as a useful method for identifying critical reactions in a structure and for monitoring any unexpected symptoms, the serviceability, and the safety of the structure. (Carden, 2004) Natural calamities, severe operating demands, cyclical freezing and thawing, corrosion, and many other causes can cause a building to degrade over time. Early damage detection makes catastrophic failures easier to avoid (Lynch, 2016)

The integrity of these structures is generally evaluated manually by maintenance engineers Nonetheless, a network of sensors can instantly assess the structure's strength and locate the damage, which may drastically save operational costs while enhancing public safety (Somwanshi, 2016) Output-only vibration testing (Sadhu A. N., 2017) (Friesen, 2017)is one approach that employs reaction data from accelerometers that have been strategically positioned (Sadhu A. &., 2017)throughout the structure to ascertain the structure's current state.

There are several instances of large-scale constructions, like bridges, exhibiting long-term SHM. For instance, sophisticated bridge safety evaluation and technologies were suggested by Zhou, Li, Xia, Yang, and Zhang (2017) for a long-span bridge in China. A long-span bridge was instrumented and monitored by Catha's, Susoy, and Frangopoulos (2008) who then assessed the resilience of a structure to environmental effects.

Omenzetter and Brownjohn (2006) utilized several time series analysis methods already in use, such as univariate (2006) used a SHM system for a highway ridge equipped with several sensors to offer data for planning and maintenance tasks as well as notify the future development policies for cable-supported bridges. In their 2005 article, (Ko, 2005)examined current procedures for monitoring bridge health as well as the SHM's ongoing difficulties.

The research cited above emphasizes the necessity for a comprehensive solution for reliable and accurate data fusion and visualization for SHM. Utilizing augmented reality (AR) or virtual reality, there have been considerable advancements in the visualization of SHM systems during the last several years (VR). For instance, (Malkawi, 2005)presented a system for immersive real-time data visualization of computational fluid dynamics. The study's developed human building interaction model allows users to see and interact with buildings and their thermal conditions.

An immersive and highly interactive AR environment enables fast processing and data transfer. By developing a digital process that allows for the visualization and access of SHM data and metadata in 3D, (Napolitano, 2018)) revolutionized the way that SHM data is currently visualized. Such an interactive approach used information modelling and spherical imagery to incorporate SHM data into a VR experience. Ballor et al looked at how AR may be used to lessen the downsides of visual infrastructure inspections (Ballor, 2019)

It improved human inspectors' capacity to take precise 3D measurements of infrastructure. For effective SHM data management, Glisic, Yarnold, Moon, and Aktan (2014) established a distinctive strategy. The effects of various data consumer characteristics on visualization and the rules for presenting SHM data both historically and now were examined. (Glisic, 2014)

2.3.2 Infrastructure for VR technologies

A virtual reality environment is one created by a computer. High-tech information is used to create this atmosphere. It makes use of both hardware and software components to build the environment. High-performance display systems for graphics are part of the hardware. The program is a game design that creates a virtual immersive environment using three-dimensional technology. The VRAR Association's illustration of the VR system parts is shown below.

System Components for VR the Vara, 2017. (Boland, 2017)

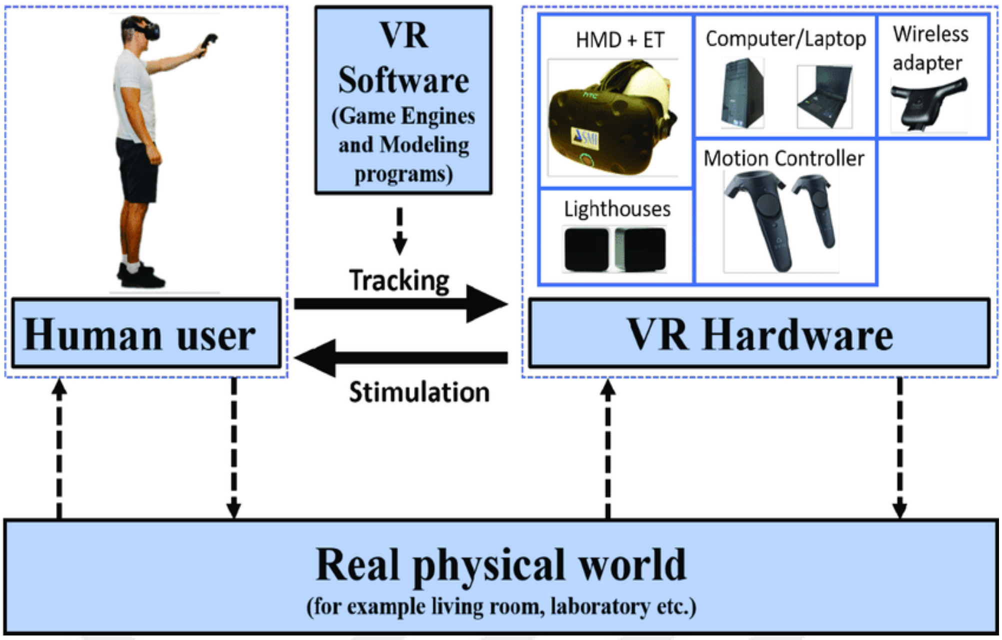


Figure 2.1: System Components for VR

Source: (Thevrara, 2017)

- **Hardware**

2.4 Automatic Virtual Environment for Caves (CAVE)

A. What is an Automatic Virtual Environment for a Cave?

The CAVE's main use is for imaging in three dimensions for virtual reality. Although the CAVE is immersive, the user is not cut off from the outside world. The user sees the entire 3-D image surrounding them when they are standing within the CAVE. Some people may feel uneasy and maybe dread running into a wall in this kind of setting, but it doesn't take long for users to feel totally at ease. Rear projectors beam computer-generated images onto the three walls, while a fourth projector located overhead projects images into the floor. After synchronizing all of the computers and other devices, the program determines the right perspective for each wall and floor. The 3-D model appears to be suspended in midair in front of the user. When users are inside the CAVE, a visually accurate, large-scale depiction of the model immerses them in first-person

Figure 2.2: LCD Shutter Glasses and Infrared Emitter

Source: Googles Photo

A. How The Cave Works

This technological advancement could make the buyer wonder a little bit about how the product functions. Each component has a certain task to accomplish for the system to work. While some of the components have extensive technological histories, others just have little roles to perform. There are several components that must come together for the CAVE to function successfully. Shutter or active stereo glasses must be used if the user wishes to truly feel three-dimensional. To achieve this look, these spectacles alternately block the left and right eyes.

The stereo LCD shutter glasses and projectors work together to provide a realistic stereo image at a frame rate of 60 frames per second. For each eye, this translates to thirty frames each second. Wearing these glasses will ensure that each eye only sees the image that has been created just for it. When this occurs, the image is formed as planned since the brain believes that each eye is only seeing the image that eye is supposed to view. When the picture from the other eye is being presented, the glasses cause the lens of one eye to become opaque, and the opposite is also true.

B. Why The Cave Works

Why does the picture seem the way it does now that the most crucial components of the CAVE have been revealed? Why does the picture have color? How does the picture know when to animate? These are querying that client regularly ask.

People observe things from two distinct points of view or angles since they have two eyes. Try closing each eye separately; you'll notice a little change in the picture that emerges. This is due to the gap between a person's two eyes on their face. The brain combines these two pictures into one without any conscious effort. The depth perception is located here. In the CAVE, pictures are given from two separate angles so that the eyes may combine them into a single image, much as they would in the outside world.

The user's impression of depth is what gives the image the appearance of coming to life in front of their eyes. Standing in the center of the CAVE, the user may see past the picture for certain applications or down the road as though he were gazing at cars.

The shutter glasses recover and transmit the depth information that has been encoded in the CAVE's virtual picture to the eyes. Similarly, to video games, where the player can peer behind corners, the CAVE user can do this as well. The user may experience traveling 360 degrees around the object thanks to the various visuals and viewpoints. The picture spins very instantly along with the user's head movement. These two features together with the depth perception feature give the user the impression that they are inside the image.

Figure 2.3: Cave Automatic Virtual Environment

Source: Googles Photo

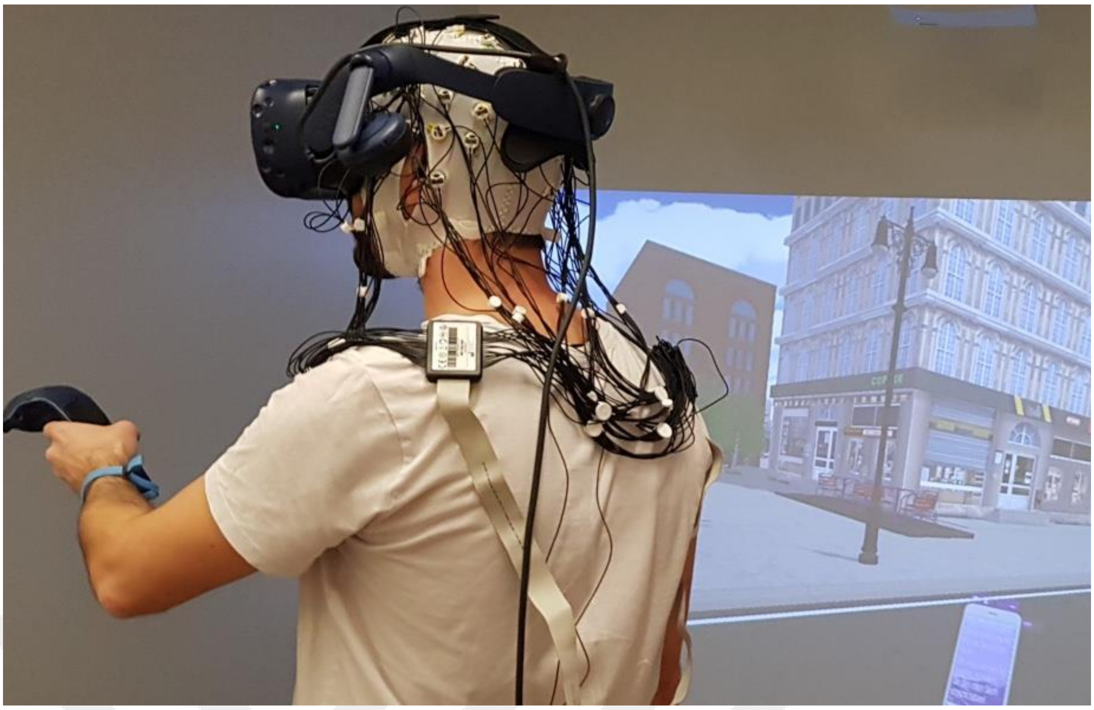
C. Cave Systems

- Computer System
- Graphic System
- Sound System
- Tracking System

So, we can say cava was initially introduced at the ACM SIGGRAPH meeting in 1992. The University of Illinois in Chicago established the Electronic Visualization Laboratory. It is a virtual world with four displays, three on the walls and one on the floor, tracking cameras, and speakers. CAVE offers a large field of vision, head16 and hand-followed interaction, three-dimensional audio, and off-axis stereo projection. However, it is expensive in terms of expense (Visbox, 2020).

2.5 Head Mounted Display (HMD)

With the use of headphones and glasses, an HMD is a helmet that enables the user to become completely immersed in a virtual environment. The employment of trackers and joysticks enables the user to move, walk, and interact with virtual objects in a virtual world. The manipulation area is determined by the base station. The HTC Vive may be used as a base station if the user can roam about in a scaled-down area, which is one of two scenarios for experiencing VE while wearing an HMD. The Oculus Rift may also be used as a base station if the user is in a fixed position. Because of its affordability and adaptability, HMD is utilized in building. The two kinds are depicted in the following figure. HMDs must fulfill several characteristics in order to provide the user a sense of immersion. One of the top businesses in the VR hardware market, Oculus, has conducted research and outlined the essential factors for hardware immersion.



Tracking
Six degrees-of-freedom (ability to track not only rotation but movement through 3D space too), 360-degree tracking (ability to track 6DOF no matter which direction the user is facing)
Sub-mm accuracy, no jitter noise (no shaking while the tracked object is completely still)
Comfortable tracking volume (the space within which the headset can be tracked in 6DOF)
Latency
Less than 20ms from when motion happens to when the last photon is emitted from the display
Minimized loop: tracker → CPU → GPU → display → photons
Low persistence
Currently, less than 3ms to turn pixels on then off (to reduce smearing)
90Hz+ refresh rate to avoid visible flicker
Resolution
Correct stereoscopic (3D) rendering
At least 1,000 x 1,000 pixels per eye
No visible pixel structure
Optics
Wide field of view: greater than 90 degrees horizontal
Comfortable eyebox (the minimum and maximum eye-lens distance wherein a comfortable image can be viewed through the lenses)
High-quality calibration and correction (correction for distortion and chromatic aberration that exactly matches the lens characteristics)

Figure 2.4: The VR system of HMD of HTC Vive

Source: Google Photo

- **VR – Software**

A PC may serve as the foundation for a VR system. You are submerged in a three-dimensional virtual environment thanks to the computer's handling of several various sensory display technologies. Headsets for 3D audio and HMD for 3D visual are the most widely used sensory displays. Extra processing power in the form of add-on 3D graphics cards and 3D sound cards is often advantageous for displays that must be refreshed more than twenty times per second. A virtual reality system must be able to monitor the position and orientation of your head in order to present the correct views. In addition to hands, feet, and prehensile tails, any additional body parts that will be employed actively in the virtual world must be monitored. Surprisingly, the gadget that does this is known as a tracking device. The third type of VR gear is input devices. You could want to utilize a keyboard, speech recognition, an instrumented glove, a joystick (also known as a wand in VR systems), or other methods of input to interact with the virtual environment. can move about the virtual environment with these tools, interact with items, and maybe even add to the virtual world. In order to provide input devices' operation a spatial (3-dimensional) component, tracking devices are occasionally utilized in conjunction with them. For constructing the items that go into the virtual environment and configuring their properties, auxiliary software frequently demanded when building virtual environments.

Using three-dimensional modelling tools, you may build the item's geometry and determine some of its visual characteristics. Using two-dimensional graphics tools, you may edit textures and apply them to objects, which typically significantly enhances the visual fidelity of the objects. Using digital sound editing software, you may mix and manipulate the sounds that objects produce. There is a wide range of software packages available since they all have business applications outside creating VR. All the parts come together thanks to the simulation program. It collects information from trackers and input devices, uses it to modify the built-in objects, and refreshes the sensory displays. You create the rules that the virtual world adheres to by programming how the items behave in the simulation software.

Software includes:

- 3D Modelling
- 2D Graphics
- Digital Sound Editing
- VR Simulation
- Three-Dimensional Modelling Software

Because virtual reality is a three-dimensional medium, the elements of a virtual environment must be constructed such that they may be seen from any angle. A simple depiction of a product is inadequate. Utilizing 3D modelling software, the real geometry of the items must be determined before being imported into the virtual setting. For a more thorough examination of modelling software.

Figure 2.5: Three-Dimensional Modelling Software

Source: (Noghabaei, 2020)

- **Two-Dimensional Graphics Software (**2D)

As there is a limit to the geometric complexity of things in a virtual world, it is usually advantageous to be able to "paint" the surfaces of the items with additional detail. This procedure, known as texture mapping, calls for two-dimensional graphics tools sometimes referred to as paint programs . The geometric framework built by 3D modeling software may then be stretched over photographs created with this application. Or photographs that are digitally captured and then modified with this software to create intricate, intriguing creations.

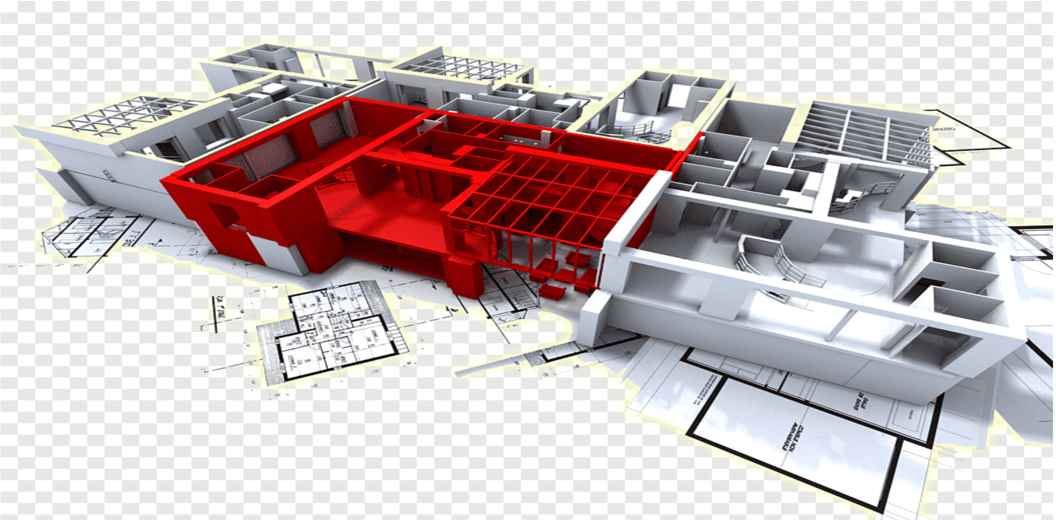


Figure 2.6: Two-Dimensional Graphics Software (2D)

Source: (Dorsey, 2010)

2.6 Understanding the Differences between 3D AND VR

- **Understanding OF 3D AND VR**

Because of how rapidly the digital world is evolving, we are always being marketed to by the promise of novel and interesting experiences. Like how playing games no longer only involves watching a screen and clicking a mouse, movies are no longer just moving visuals. It might be challenging to grasp the tiny variations between the principles of the many different digital experiences available today.

- **Difference Among 3D AND VR**

The idea of 3D and its effects have been around for a while. It is a rather ancient technique that, in essence, employs a second layer of content video, picture, poster, etc. to give the viewer a sense of depth. As our eyes focus on various regions of the environment around us, the brain combines the two viewpoints to give us a larger peripheral vision, 3D makes use of this physiological mechanism of the human body to produce the alleged third dimension. By overlaying a second movie or picture over the first in an over-under or side-to-side format, 3D really tricks your brain into combining the views from each eye to produce an image that appears to have layers and depth. This false sense of depth gives us the impression that something is approaching us or that we are a part of the action. You feel as though you are perceiving additional angles rather than a level area.

On the other hand, VR, or virtual reality, affects more than just your ability to see; it also emphasizes interaction. VR demands you to physically blend with what you are seeing as opposed to simply sitting in a chair with the odd bounce to the left or right. In contrast to 3D, where you are only a viewer, virtual reality casts you in a tale, assigns you a role, and wants you to interact with it. A multitude of sensors observe your movement as you view via your VR glasses and react accordingly.

The digital environment follows you in every direction as you turn, run, wave, and engage, giving you a true experience rather than simply a tale to look at. Technically speaking, 3D before virtual reality, thus since every VR format already supports the third dimension, 3D is present by default; you just get an upgraded version. A multitude of sensors observe your movement as you view via your VR glasses and react accordingly. The digital environment follows you in every direction as you turn, run, wave, and engage, giving you a true experience rather than simply a tale to look at. Technically speaking, 3D is really the forerunner of virtual reality; since every VR format already has the third dimension, you just receive the upgraded version of it.

2.7 Adding 360 to the Virtual Dimensions

While researching VR and 3D, you may encounter several references to 360. As it can be used to both 3D and VR, this is more of a technological potential than an idea. Before the digital age, 360-degree films included the cameraman rotating a full 360 degrees to capture the actor's surroundings. If he performs it now in 3D, the scene will have the previously specified circular perspective with depth. You may do it yourself by recording a video at the entrance, rotating it, and then scrolling from left to right to capture the whole area. VR, however, cannot be separated from 360, since it already utilizes it by default — you spin, and the digital world follows.

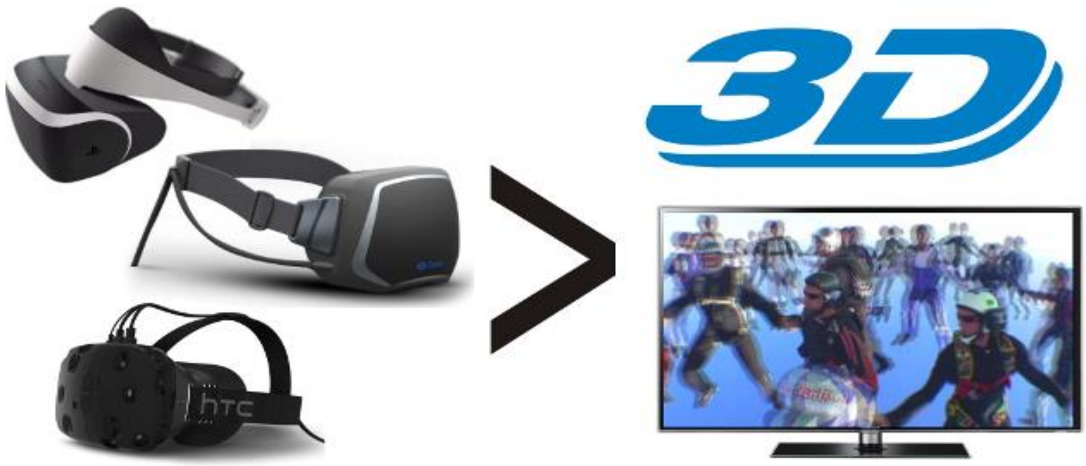


Figure 2.7: Three-dimensional immersive virtual worlds

Source: (Hew, 2010)

2.8 Capabilities of BIM-VR Methodology

Virtual reality (VR) technology assists everyone in comprehending a project by enhancing design visualization and communication amongst key players in the construction sector. When evaluating difficulties and debating possible solutions, team members must be familiar with the many kinds of data that may be related to the parameters that define each parametric object, the process that is the foundation of BIM modelling. Using the BIM model to visualize the geometry of the components and consult the parametric data facilitates the collaborative development of a project. The acceptance of virtual reality in the construction business is increasing. In virtual reality, a 1:1-scale, manipulable 3D/BIM model may be utilized to immerse the viewer and give them a sensation of presence in a future place. Professionals in the sectors of design, engineering, and construction management are aware that virtual reality (VR) applications help customers visualize concepts early on, therefore reducing material prices and staff requirements. For instance, a VR tour may be used to a BIM model to assess the maintenance schedule from a facility's point of view. management 7D/BIM model or from the standpoint of the project team 4D/BIM model, aiding decision-making.

1- Walkthrough: the most popular method is because it allows users to view the 3D model in real time from various angles of the building, including from the inside and outside.

2- Consulting data: refers to the capability of retrieving information centralized in a BIM model, specifically, data associated with parameters that make up the parametric objects used in the modelling process.

2.8.1 Walkthrough

Virtual reality may improve the creation and analysis of any project detail, as well as design phases, since it is easy to include the whole team and a rational decision can be made about prospective solutions or problem-solving strategies. Scale computer models may be used to test a structure's viability, but human analysis is not always valid, and these models cannot fully simulate the environmental conditions to which a structure is exposed. VR provides more realistic possibilities due to the capacity to create the result in 3D and the team member's ability to explore the location as if it were a real world.

By going around the outside and inside and seeing everything around them, a user may explore an artificial environment using VR technology. They can also reach out and touch items in real time. Computer graphics technology and specific hardware with superior viewing and interaction capabilities are required to create an immersive VR experience. Today, the 3D virtual environment utilized to assist the various facets of building activity is constantly expanding. The usage of VR applied over the BIM model is now viewed as a beneficial and innovative contribution, to increase the efficiency of the construction industry. This perspective is documented in research works and on commercial websites. Recently, VR technology has advanced and been used in the disciplines of architecture, engineering, and construction. The checklist may be easily created, saving both the customer and the business important time and resources.

Architects, engineers, and other construction professionals are now researching the integrated RV BIM technology's full reach. (Figure 5). Right present, there are approximately 50 VR software and hardware technologies that can completely change how BIM is used and understood.

Figure 2.8: Virtual Reality Tour of a BIM Model inside and Out, Supporting a Group Gathering

Source: (Sampaio A. Z., 2018)

Architects, engineers, and other construction industry experts are already learning about the benefits of combining BIM with VR technology. To specify the interaction and interoperation of BIM models, there are several VR software and hardware options. Three methods are available for experiencing VR: non-immersive on a desktop or PC, semi-immersive with an HMD like the HTC Vive, and fully immersive with Cave Automatic Virtual Environment (CAVE). Various VR applications are currently being used in the construction sector to assist architects and engineers.

- **Oculus Rift**

Is an interactive real-time viewer program created by the Oculus Company that can be used with Revit as a plugin. Oculus may be used to depict a full building and provide a greater understanding of the true scale of the project with the correct technological know-how, which is not possible with only conventional monitor-oriented solutions. It has a large viewing angle that may reach 110°. With the use of these VR headsets, you can see and interact with 3D models, 360-degree panoramas, and virtual mock-ups over BIM models. Due to the far more seamless integration of physical touch and display updating with Oculus Rift, the minimum interactivity requirements are often greater.

In order to identify how the user's head is positioned in the outside world, the gadget has a gyroscope, an accelerometer, and a magnetometer. It also offers stereoscopic 3D viewing. With the Rift, split-screen rendering is used to produce the stereoscopic

3D vision, with the left half of the screen representing the left eye and the right half representing the right eye.

Figure 2.9: Enhancing BIM methodology with VR technology

Source: (Sampaio A. Z., 2018)

- **Samsung Gear VR**

A virtual reality tool called the Samsung Gear VR lets users explore virtual worlds while working on a project or attending meetings (Figure 2). A BIM model and photographs of the building site are required in order to implement virtual reality by using Gear VR for facilities management reasons. The user should have experience with BIM software such as 3ds Max for rendering and Revit for visualization. To go inside and outside of the BIM model in a virtual environment, game engines such as Unity3D with Android Studio are necessary. For studying panorama photographs, panoramic photography equipment and editing tools to convert such shots to the 3D world are required.

Figure 2.10: Gear VR

Source: (Reference Google)

- **The Smart Reality**

Application offers more realistic capabilities for interacting with customers, engineers, contractors, and other construction industry experts. A genuine 3D world is immediately shown to the user, providing a feeling of scale, depth, and spatial awareness as well as a more accurate view of the object and its surroundings. For an improved mobile depiction of building projects, builders created a VR smartphone app that mixes 2D blueprints with 3D project models.

This app's VR functionality is starting to add a new level of assurance to the design and construction processes as well, assisting stakeholders in having a more complete understanding of the BIM model and providing an unhindered, in-depth perspective of projects for planning, design, and construction management. It is intended for use in the AEC industry and integrates with BIM software like Autodesk's Revit. Smart Reality can be utilized to assist the owner or architect in better understanding spatial awareness of the planned result prior to the start of construction because the design process is time-consuming.

The Smart Reality app is available for both iOS and Android, and it can be used to quickly and collaboratively evaluate and analyses various project components wherever you are and with any team member. Utilizing virtual reality (VR) headsets like the Oculus Rift and Epson's Move Rio BT-200 smart glasses can improve the viewing experience even further.

Figure 2.11: Smart Reality

Source: (Reference Google)

- **Prio VR**

The PrioVR real-time motion capture technology for virtual reality may potentially be used to the construction sector. In lieu of using a keyboard and mouse, the PrioVR motion capture device enables the user to experience a virtual reality environment via natural body movement. Using PrioVR, it is possible to realistically open and close doors, switch on and off the lights, move objects, alter the wallpaper and flooring, and experiment in real time with a range of environmental parameters such as the weather, lighting, and surroundings. The device is powered by body sensors that provide information about the user's movements to the VR software. The user wears either a full-body suit with 12 sensors or an upper-body outfit with eight sensors. The Prio VR sensors need to be properly calibrated in order to produce a virtual reality environment of a building site and enable practical interaction with the design elements. With this modification, the user may precisely record motions and modelled objects in the VR environment. It enables 360-degree observation of the virtual space.

Figure 2.12: Construction sites use the PrioVR capturing system

Source: (Sampaio A. Z., 2018)

- **Enscape3D**

A Revit plugin enables the user to tour a fully rendered project and show customers several design options. It is compatible with several BIM programs, including Revit, SketchUp, ARCHICAD, and Rhinoceros. The project's views, geometrical item features, and modifications are all reflected in the Escape tour. It is possible to program a preplanning walkthrough to produce a collection of films. The project team can collaborate and communicate with stakeholders in an accurate and effective manner thanks to the real-time visualization and rendering. Without leaving the BIM model, Escape delivers a live and direct design change generator.

Figure 2.13: Enscape Dynamic Visualization

Source: (Reference Google)

- **Escape benefits**

✓ Real-time visualization walkthrough

✓ Virtual reality extension

✓ Collaboration platform

✓ Range of visualizations

✓ Asset library

2.8.2 Consulting data

Materials, lighting, furniture, and other minute details that contribute realism to the VR experience are added once the model is placed into the VR environment. This is the concept of walkthroughs, but because BIM includes data, it makes sense to examine it while navigating a virtual model. VR may play a key part at every stage of the design-to-construction process, from evaluating design options and displaying proposals to designing out defects and addressing construction and usability problems before breaking ground. Integration of BIM data into a VR environment necessitates additional technical capabilities for model-data retrieval.

By offering centralized access to BIM models, collaboration for BIM tools is intended to assist project teams in overcoming the obstacles of corporate firewalls and geographic location. Models housed on cloud servers are accessible to and usable by team members in all disciplines from several businesses or locations throughout the world. Project teams may access the model from any location, and access to project data is dependent on permissions. As a result, when organizations discuss joint projects, they refer to BIM data in models stored in the cloud. Additionally, applying VR technology directly over the BIM model can increase the capacity of reviewing BIM data.

From the perspective of facility management or maintenance, a virtual reality (VR) tour may be integrated into a 7D/BIM application to improve decision-making. It provides facility management professionals with a new perspective by integrating the usage of VR devices over a BIM model with real site inspection. Virtual reality has the potential to improve project managers' and construction workers' access to virtual data. During the real site visit, any data-rich virtual information may be accessed, read, and assessed from the BIM model. Real-time construction issues may be addressed, and internal assets can be viewed to facilitate installation and planning while preserving resources. Thanks to a new category of accessible smartphone apps, project teams may now explore 3D building blueprints. Multiple plugins or BIM viewers make it possible to review 3D/BIM model data.

- **Viewer Revit plugin**

A viewer Revit plugin is supported by Autodesk Revit to offer an integrated design environment. When a user first opens the Add-Ins tab in Revit, a 3D graphical representation appears in a new window. The user has the option to move about the model, retrieve the needed data with a mouse and keyboard on a desktop computer, or enhance the VR experience by connecting to an Oculus HMD device. The user is exposed to the complete underlying BIM database as a result of being fully immersed in the model, which starts the data consulting process. In addition to interacting with the model as if they were using VR, the user may access the model's database or the parametric object that was used in the modeling process while Revit is open.

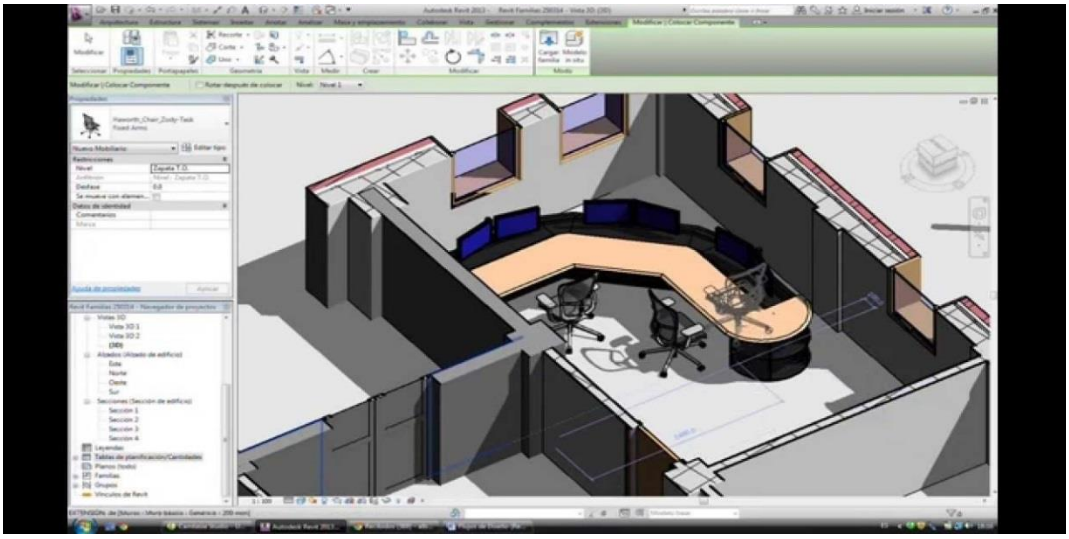


Figure 2.14: The viewer plugin interface in Revit

Source: (Reference Google)

- **Autodesk 360**

because every change made to a BIM model is visible to everyone in a convenient timeframe, it enables the team's incorporation into collaborative projects. For examining BIM material, Autodesk creates a comprehensive web-based solution. Each Autodesk 360 participant must be invited to the project for them to be able to see and download any files posted in the relevant project discipline. Autodesk 360 displays the 3D model as well as each sheet that was integrated into the uploaded Revit model. Users of the 3D viewer may isolate items by categories and inspect every element's attribute. In order to improve the project in a collaborative setting, any data may be accessed, examined, and altered.

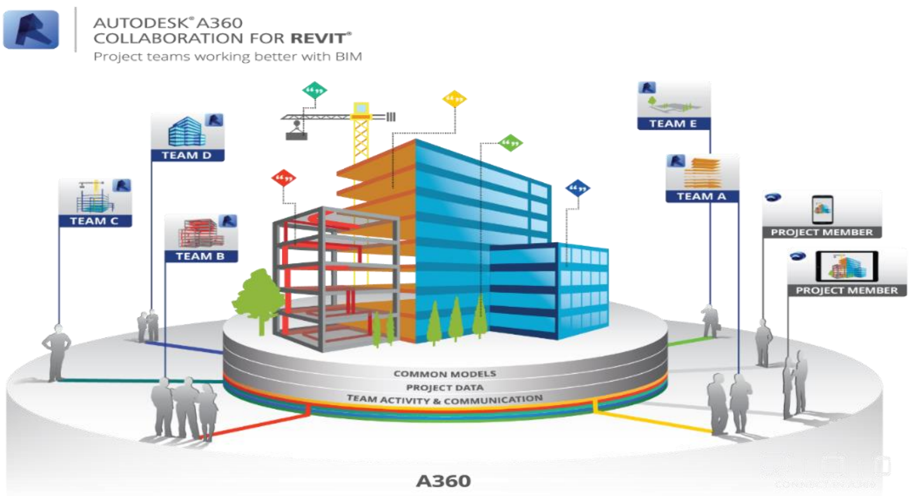


Figure 2.15: BIM Project 100% Free BIM for Revit & ArchiCAD

Source: (Reference Google)

- **Escape plugin of Revit**

With the help of Escape, a VR plugin for Revit, a BIM model may be visualized and experienced in virtual reality in an approachable manner. Only the walkthrough capability was previously described but escape additionally permits data consultation with Revit. The Escape plugin may be used from within Revit, and users can view both models there and in Revit. The user may engage in a virtual area in Escape and reference the rich data included in the 3D/BIM model in Revit. Therefore, Escape can promptly analyses any modifications made in Revit. It is feasible to access the data associated with each parametric item used in the BIM model since Revit lets the user interact with the model. The facilities manager in a 7D/BIM domain may look around the facility, assess the state of the equipment, and collect pertinent information from the BIM model using the Revit interface thanks to a virtual tour created using Escape. For instance, the facilities manager may better comprehend what is put underneath the ceiling tile by seeing the BIM model of an MEP system in a virtual tour on a tablet PC. Therefore, integrating consultation capabilities with virtual reality walking capabilities is a crucial advancement in the use of BIM methodology. Escape may also be used in conjunction with the Oculus Rift to enhance the VR experience. The user may easily explore many design possibilities supporting a collaborative project team with Escape. Escape will instantly display any other solutions or design modifications made by the designer in the project using Revit.

Figure 2.16: Enscape Plugin of Revit to Access Data

Source: (Sampaio A. Z., 2018)

- **Augment**

Downloadable on a smartphone or tablet, Augment is augmented reality (AR) software that enables users to examine the 3D/BIM model in a realistic environment. BIM data may be consulted while taking a real-time tour of the building thanks to AR and BIM technology. A collection of 2D project designs may be converted into a 3D build space with the use of augment. The customer may examine the 2D drawing in 3D using the Augment app when the design team uploads it to the website, which helps them better comprehend the project's specifics. The Augment app is also compatible with the software packages AutoCAD, Revit, and SolidWorks. The user may review data in Revit and engage in a VR environment in Augment.

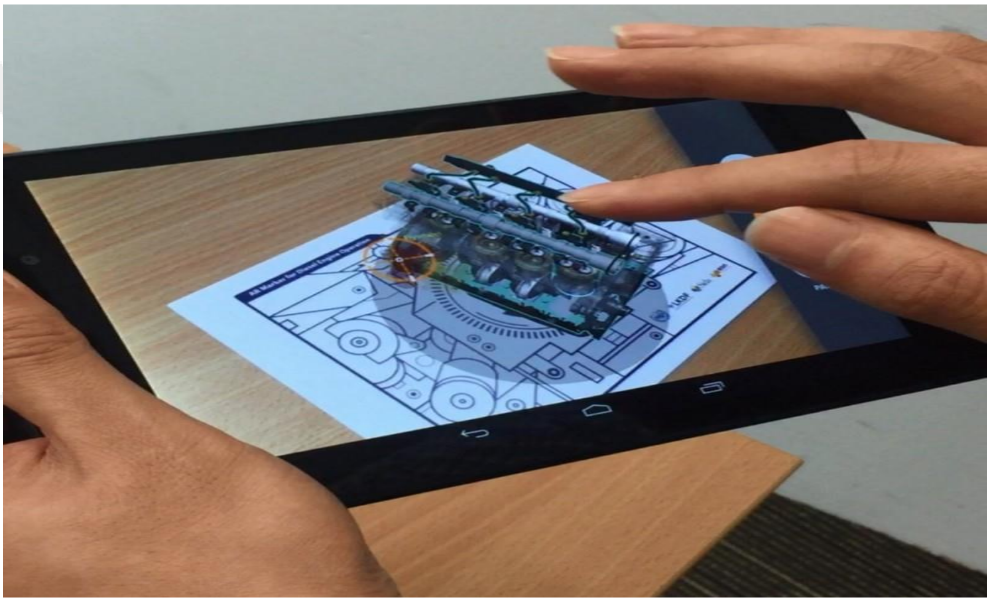


Figure 2.17: SPADA: All Courses

Source: (upi.edu)

- **Autodesk Stingray**

By hovering their mouse over objects in a Revit model, users of Autodesk Stingray may access the underlying attribute data. By connecting external BIM data sources into Autodesk's Stingray interactive engine, the VR gadget enables the user to produce high-quality, interactive estimates and schedules in VR. For this reason, BIM data is exported from the Revit program into an external data source, where it is sorted and categorized before being used in various ways by Stingray to build interactive, immersive worlds. Customers may therefore view many design, financial, and scheduling choices in VR. The members' team will be able to access 5D estimates and 4D site logistics drawings, allowing them to compare different design and material alternatives and their related costs. Additionally, Stingray makes it simple to export BIM data to an external data source. Realistic design visualization and real-time decision making are advantages of estimating and scheduling in VR.

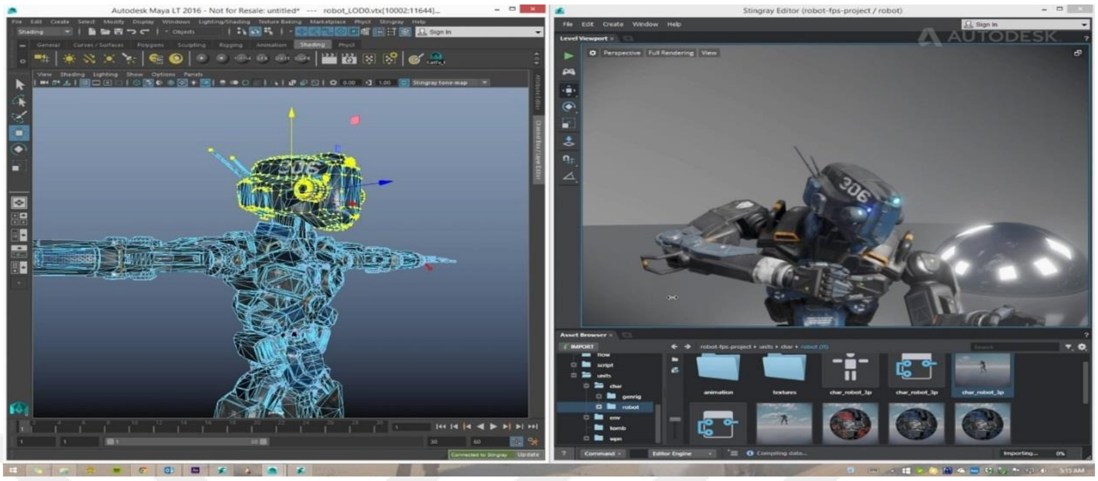


Figure 2.18: Stingray Autodesk

Source: (Reference Google)

- **Covise**

Direct collaboration is somewhat constrained because BIM software is typically operated on lone workstations. The goal of Kiefer and Wesner’s study was to integrate Revit with the VR program Covise in order to provide a platform for the development and improvement of BIM and VR. They were able to develop a variety of interactions, although they found certain procedural limitations.

Utilizing Covise to display and reference the project's 3D model and related data enhances teamwork even during distant team discussions. The Covise program immediately updates any modifications performed in Revit, and vice versa.

This innovative method has the potential to encourage two-way data flow between the systems. This may be viewed as a development in VR BIM technology when compared to other applications.

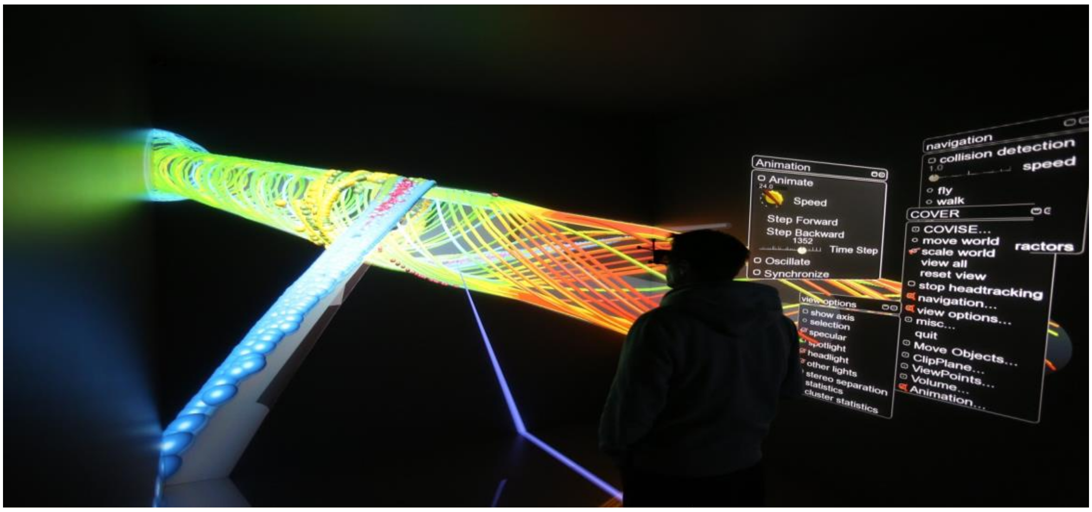


Figure 2.19: Visions du Reel (visionsdureel.ch)

Source: (Reference Google)

- **Web3D**

While VR approaches have made some development, the connection to BIM methodology has only just been established. For the purpose of assisting multidisciplinary users throughout the building lifecycle, a VR system should be used in conjunction with existing applications. An environment using web3D, BIM, and BSNS is presented by Jiao et al. as a prototype cloud framework (Business Social Networking Services). System coordination and constructability review activities are two BIM uses for the AEC sector where Web3D may be use. In order to address important problems like composition, publication, and writing, technical solutions are developed. As a result of the suggested environment's seamless integration with current information systems, it is more usable.

Figure 2.20: MEP Clash Detection Services

Source: (Reference Google)

- **Unity**

3D real-time application, which is regarded as the top real-time development platform in the world. It was used to the production of 3D, audio, and video interactive content. Designers, engineers, and contractors utilize Unity increasingly frequently and broadly in the construction sector to visualize and create interactive and virtual experiences.

Features of Unity include:

• Rapid programming and production

• Unparalleled platform support

• Access to the most significant market assets

• Ideal graphical output

• Connecting design and construction with Unity Reflect

Figure 2.21: Building Model Shown in Navisworks and Unity Reflect Viewer

Source: (Alizadehsalehi S. H., 2020)

3. DESIGN WITH BIM

Both the incorporation of enabling systems or toolkits in the design and construction processes as well as the integration of the two processes, design and construction, are having an impact on the industry. Virtual reality will be a crucial component on both levels, serving as a testing and modelling medium for both design and construction. Additionally, it will make it possible to take the building process into account when evaluating a design for buildability at the concept design stage.

Then VR will be seen as the technology that will help do away with the current distinction between design and construction. The survey's findings make it clear that industry professionals are still not adequately using and disseminating much of the research being done in this area.

According to the poll, new enabling technologies like virtual reality (VR) are not well understood. This is partly because of their high cost and partially because of how little practitioners are involved in the research and development process. In order to shorten the gap between research and practice, this should encourage more industry-led research in the future.

3.1 Design and build with BIM.

3.1.1 What is BIM?

BIM is primarily a three-dimensional digital representation of an environment, structure, or building with its inherent characteristic. It is made up of intelligent building components or environmental characteristics such as data attributes and parametric rules for each object (Hergunsel, 2011) . According to the National BIM Standard-United State Project Committees (NBIMS-US),

BIM A digital representation of a facility's physical and functional characteristics, as well as a is shared knowledge resource for information about a facility that forms a reliable basis for decisions throughout its life cycle; defined as existing from conception to demolition (Saeed, 2013)

About the different between BIM and CAD we observe that CAD get the information from the external sources, in a BIM, they rely on three-dimensional actual constructions and assembly rather than the two-dimensional drawings found in CAD (Krygiel, 2008)

The BIM technology be able to manage the information not only graphic and can be control data to avoided data (Bynum ,2010). redundancy

The basic possibilities of BIM are numerous which aim to develop the following, construction and maintenance management, strategy of building project, ensure that integration between informational data flow and management of graphical, Individual executors are transformed into teams, and tools are decentralized into sophisticated solutions, resulting in individual tasks being implemented as complicated processes. perform construction project life cycle processes more effectively, faster, and at a lesser cost (Popov et, 2008).

3.1.2 The BIM components

Components, or parametric objects contained in object libraries, are the foundation of a BIM. Steel beams, concrete slabs, framing, drywall, ducts, windows, and other real-world components are software equivalents of the actual real-world things used to create the physical structure. The parts are shown in three dimensions, and extra data is kept making them "intelligent." (Eastman C. M., 2008)

BIM is defined as a computer-aided modelling system for managing and generating building information, together with processes for creating, exchanging, and analyzing building information models, in The BIM (Handbook, 2008)

Building components have information explaining what they stand for since building information models are object-oriented. For usage in operations like analyses and work processes, building components can be attached with parametric data that characterizes their features.

When data in one view of the model is changed, other views connected to the model are updated in a consistent, coordinated manner.

BIM has numerous different interpretations, hence there is no single agreed-upon definition. The National Building Information Modelling Standards provide the following definition of BIM:

- Digital illustration of the specific structural and operational elements of a facility. When making choices regarding a facility across the course of its life cycle, which is defined as starting with original conception and ending with destruction, it is important to have a shared knowledge base of data about the facility. The cooperation of diverse stakeholders at different phases of the life cycle of a facility to input, extract, update, or modify information in the BIM to support and represent those stakeholders' activities is a core BIM concept. (NBIMS., 2007, p. 21)

- Jernigan (2008) asserts that there are numerous widespread misconceptions about BIM and that the best approach to comprehend it is to first recognize what it is not.

- The idea that BIM only comprises of one model or database is among the most common misconceptions about it. This is not actually the case, however, as BIM is made up of numerous linked models and databases.

- It's critical to remember that BIM cannot take the place of humans. Although BIM streamlines information processing and eliminates repetitive, menial chores, individuals are still needed to obtain and input data into the model. Another misconception is that BIM is error-free, however errors do happen occasionally because of human error when inaccurate data is added. However, data is only inserted once, reducing the likelihood of errors.

3.2 Technical aspects of BIM

3.2.1 Clash controls

The most prevalent issue in the AEC sector is inconsistencies in the geometric designs of the many disciplines of a structure (Eastman C. M., 2008)

Due to overlap between the various plans, this occurs. The architectural information models from several disciplines are combined and examined for geometrical design errors using clash controls.

When models from many disciplines are combined, overlaps between them are found and can then be fixed. The only practical way to handle this problem is to use BIM to combine all the designs in the cloud, identify any differences, and make the necessary corrections.

3.2.2 Time estimation (4D)

The elements of a building information model are connected to the time plan via time estimation, which is frequently referred to as 4D. Users can simulate the building site and construction at any point in time thanks to the connectivity to the time plan, which allows for a graphic visualization of the project timeline. This kind of simulation offers a great deal of insight and enables the early identification of planning mistakes. Errors can be minimized during the design phase rather than finding out about them later in the construction phase and having to deal with issues on the job site, which can be quite expensive (Eastman C. M., 2008)

The logistical factors can also be optimized by using time estimation. Different alternative methods of carrying out the building might be simulated and compared to one another.

3.2.3 Cost estimation (5D)

The elements of a 3D design can be connected to price lists for various materials using cost estimating, often known as 5D. Price lists can also contain labor and equipment expenses for more precise cost predictions. Price lists are mostly based on volumetric material costs. This makes it possible to estimate costs accurately at any stage of the design process and fosters an awareness of the financial effects of design choices. Therefore, materials and construction methods can be assessed from an economic standpoint (Eastman C. M., 2008)

3.2.4 Analyzes

By connecting a building information model to tools that assess a building's ability to isolate outside noise and evaluate energy use for heating and cooling during peak hours, energy analyses can be carried out. Buildings can now be produced that use less energy overall thanks to energy analyses (Eastman C. M., 2008)

The analyses of light and acoustics are some examples of analyses that can be carried out with the use of BIM.

3.3 BIM Dimensions

A dynamic method for constructing a data-rich construction project lifecycle model. is known as building information modelling (BIM). A distinct level of development in a BIM model, such as LOD 100, 200, or 300, is required during the various project phases. Depending on the complexity and stage of the project, the BIM model can be utilized for tasks, known as use-cases. The present BIM model is enhanced with specific attributes. BIM dimensions are a term used to define these extra parameters. With the advancement of technology, BIM technology has evolved from simple 3D dimensions to more complicated 4D, 5D, 6D, 7D, and 8D dimensions that are poised to transform the AEC industry's future (United, 2019)

- **3D visualization in modern construction projects**

One of the primary objectives of engineers in general, and architects, is presentation method since it allows concepts to be conveyed as simply and attractively with as many information as feasible.

Engineers must thus strive to achieve some sort of intellectual balance in order to satisfy all of the clients we serve, and this is necessary because of the diversity of those clients.

Engineers, particularly architects, have become an essential component of 3D imaging technology as a result of technological advancement and technical support. With all its advantages, this technology has incorporated into the fundamentals of engineering work. It cannot be disregarded if one wants to live and prosper in the building and engineering industries.

- **4D (Time)**

To put it simply, BIM is used to create graphical information models or data sets. and information that is not graphical as a Common Data Environment (CDE). The primary goal

The timely delivery of the project to the client or end user is a goal of this information model.

The BIM model is usable. to create project scheduling, project management, and step-by-step development visualization The BIM model's consideration of time is helpful.

construct and depict construction timelines and relationships to the environment. It is a major benefit to boost site effectiveness and reduce the total construction schedule (Shelbourn, 2016)

- **5D (Cost)**

Cost is at the heart of the construction sector. Any cost estimate's data accuracy determines how accurate it is.

BIM makes cost estimation possible by supplying specific component amounts. Considering that the capital expense of components is all based on information related to a specific component.

Cost estimators can rapidly calculate Using the graphical model and its properties, calculate the quantity of a particular element. Cost may be obtained in 3D thanks to the advantages of tying cost to model. Geta reminder in case components need to be changed or counted automatically.

The ability to query the data throughout the process is the primary advantage of extrapolating cost from the data model. updates are made to the data that feeds cost reports for the project.

- **6D (Energy Performance and Sustainability)**

The ability to combine several elements makes it imperative to include the installation information, element configuration Facilities management and operations are aided in driving successful construction outcomes by this integration. Accessibilities and a better understanding of buildings are provided by the 6D BIM. (Ayasta Cachay, 2016)

- **7D (Life Cycle Management and Maintenance)**

Operations and facilities management for the facility are the focus of the 7D BIM approach. owners and managers. The dimension makes it easier to monitor and evaluate building data. such as the present situation, technical details, and information regarding the equipment's warranty,

Includes instructions for use and upkeep. 7D BIM dimension is an original strategy.

for the facility management procedure, in which all pertinent data is compiled at a one location in the BIM model. This might facilitate better service provision during the cycle of a project (United, 2019)

- **8D (Safety)**

The construction industry's occurrence rate for occupational accidents and injuries is still almost twice as much as all other areas combined. There has been strong evidence supporting a During the project's initial design phase, numerous safety threats are created. Eliminating dangers at their source is one of the best strategies to prevent them.by Designing for Prevention (PTD). (Kamardeen, 2010)

3.4 Using Virtual Reality and Building Information Management Together During Construction

3.4.1 VR-BIM in the industry

There are numerous applications for BIM in the building sector. BIM is used for more than just creating a three-dimensional (3D) visualization of the project (Azhar, 2011)It can be used during the entire project life cycle (Ahn, 2016)As construction projects get more complex, there is a requirement for greater collaboration, more efficient communication, and documentation (Eastman C. M., 2008)

BIM converted the outdated paper-based construction tools into a virtual setting, increasing productivity, collaboration, and joint effort (Lee C. , 2008) .It is regarded as the best remedy for the issues with coordination across the building supply chain (Howard, 2017)The fourth dimension, time, is added to the 3D model when the schedule is included (4D).

In order to illustrate process and create a sequencing simulation that depicts the building being constructed in 3D from beginning to end, 4D models are crucial. Detecting early clashes and locating spatial conflicts in building will also be provided. (Hardin, 2015); (Azhar, 2011); (Eastman C. M., 2008) .The definition of clash detection in 2D designs is the easy identification in BIM of components that overlap in the same place. (Osland, 2014)

(Sampaio F. P., 2012) developed a project for building planning utilizing virtual reality technology. By connecting the geometrical AutoCAD 3D model of various construction activity steps to the construction planning schedule, a 4D model is produced. With the use of this application, building partners may better coordinate while also removing flaws and mistakes.

The 4D model is expanded to incorporate the cost, making it a 5D model. By generating take-offs, counts, and measurements directly from a model, BIM decreases the manual take-off, which reduces the time and efforts needed for cost estimating ((Azhar, 2011); (Nassar, 2012). (Eastman C. T., 2011) (Bryde, 2013) concluded through their thorough research that project cost was most positively impacted by the introduction of BIM, followed by time. According to contractors, implementing BIM has the following top benefits: less rework, shorter project duration, and fewer document errors (McGraw-Hill, 2012)

The ordering and delivery of building materials for prefabrication will be made easier and more efficient with the inclusion of all the necessary information in the model. That will cut down on a project's price and time (Ahn, 2016); (Azhar, 2011) (Eastman C. M., 2008)

In the previous two decades, VR technology has significantly increased its potential in a variety of fields for both industrial and academic communities. The first large-scale virtual projection system, CAVE (CAVE Automatic Virtual Environment), was created in the early 1990s and allowed computer scientists to present their findings on cutting-edge interactive workstations (Cruz-Neira, 1993)

Although VR technologies have been employed in the AEC sector, its main applications have been for marketing, visualization, and educating AEC professionals (Bullinger, 2010) Pour Rahimian, et al., 2014). Applications for Virtual Reality offer an immersive, spatial, real-time platform for project model simulation that encourages productivity, safety, and error-free building projects (Whyte, 2003) .In order to assess and validate construction activities and operations without running the risk of injury, VR has been utilized for safety training for construction workers (Shi et al., 2006; Sacks et al., 2013). It can also assist designers in understanding how their designs affect safety (Sacks R. W., 2015)

A VR-based training program for construction equipment has proven effective for electrical system design and installation as well as steel erection (Zhao, 2015) (Le, 2015).Training programs using virtual reality for cranes, excavators, and other construction machinery are dependable and tried-and-true technology (Fang, 2014) (Hilfert, 2016). The usage of VR aids in the designer's comprehension of the model and improves team involvement, collaboration, and evaluation throughout all design phases, leading to a better comprehension of complicated designs and the detection of design flaws (Paes, 2017). In-depth visualization using VR technology can help improve the planning, tracking, and management of field construction (Kamat, 2010)Virtual reality technology has greatly simplified and improved defect management.

Here, it cannot be disregarded. Physical work is not required for this operation. Because of this, this method of defect and quality control is labor and time efficient (Ahmed S. H., 2017); (Shen, 2010)Additionally, the application of virtual reality to comprehend occupant-system interactions involving temperature changes (Ozcelik, 2017)

BIM experts can use VR to interact with the detailed information contained in a BIM model in real-time. Throughout the course of a project, this visualization aids in fostering shared understanding among the key stakeholders, minimizing design revisions (Alizadehsalehi S. H., 2019) (Balali, 2020) .By combining the benefits of BIM models, which allow users to quickly evaluate alternate design possibilities in the models, and pre-construction prototypes, which offer users a sense of presence.

3.5 VR-BIM In the Education

BIM has not been consistently included into AEC instruction in recent years. Academic programs in architecture, engineering, and construction use BIM the most (Arashpour, 2017)- (Aranda-Mena, 2017)As of 2008, fewer than 1% of construction schools offered a stand-alone BIM course, while 9% included BIM in their already existing curriculum (Sabongi, 2009)). As of 2013, 54 percent of construction programs featured BIM courses on their curricula, and 52 percent reported that BIM content was incorporated into traditional courses, these statistics grew (Wu, 2014)

BIM integration in education has proven to offer many advantages. The primary advantage of employing BIM in education is improving accessibility to information and visualization (Zolfagharian, 2013); (Lu, 2013), although there are many more advantages for students than visualization. Students were able to work on more complicated projects and apply a variety of management techniques thanks to the usage of BIM management tools in project management lessons (Peterson, 2011)

Teaching BIM techniques for measuring and costing huge constructions can help students better comprehend the estimation process because university students lack construction experience (Sylvester, 2010) (Kim, 2010)

A multidisciplinary team made up of students from several fields also uses BIM as a collaborative design tool. The multidisciplinary setting fosters the growth of students' teamwork abilities (Ghosh, 2015); (Peterson, 2011).BIM was proven to improve design abilities, fundamental concept comprehension, and the construction process (Gledson, 2016)It is a useful tool for educating pupils about basic structural ideas and enhancing their comprehension of the structure's whole behaviour (Nawari, 2014).When students are exposed to BIM 3D models, as well as HVAC system components, research by Irizarry et al. (2012) revealed an increase of around 10% in the number of right responses linked to concrete construction (Mokhtar, 2019)

Buildings with lower energy use may be designed using energy analysis related to sustainability (Agirbas, 2020).Students' comprehension of construction sequencing challenges has increased because to the use of 4D CAD models in the classroom (Messner, 2003)

Educational institutions have been embracing BIM either by offering classes in a single subject and instructing students in the usage of BIM software or concepts with students in the same course and background. Alternatively, interdisciplinary courses can be taught using BIM in conjunction with students from other disciplines at the same institution or from different universities (Barison, 2010)

3.5.1 Application of virtual reality technology in university education

Since virtual reality relies on a variety of user systems, including multimedia technology, sensor technology, computer graphics, virtual imagination, simulation technology, as well as many other related disciplines, it has become more widely known as the world's technologies have progressed. Creating a virtual environment where individuals may express their emotions and treat them digitally as a form of amusement is also required. Regarding education, virtual reality technology is one of the most often studied areas due to its distinct advantages, particularly with the advancement of science and technology. Additionally, by utilizing virtual reality technology in engineering instruction, can observe and replicate the situation from many angles, which fosters creativity and enhances our understanding of engineering.

3.5.2. Benefits of using virtual reality technology in university education

Additionally, by utilizing virtual reality technology in engineering instruction, we are able to observe and replicate the situation from many angles, which fosters creativity and enhances our understanding of engineering. Speaking of the advantages of using virtual reality technology, users can engage all of their senses while viewing objects in a three-dimensional space as if they were physically present at the event. In addition, it is possible to create a multi-dimensional environment between people and the virtual environment that allows us to become aware of our surroundings and explore ideas to develop and come up with new ones.

3.5.3. Different techniques had been explored in higher education to integrate BIM into the curricula

Stand-alone course: This is accomplished by adding a new BIM course to the curriculum. Students often take a lower-level course where they learn the basics of BIM and particular modelling techniques. The course might serve as an elective or a replacement for the CAD course (Lee N. &., 2013) (Barison, 2010)There is no room to offer a stand-alone curriculum that teaches these approaches in construction management programs approved by the American Council for Construction Education (ACCE) since there are no specific requirements for BIM classes (Maghiar, 2013)Additionally, offering standalone BIM courses without continuity in other subjects does not support students' long-term learning (Clevenger, 2010).

- One more technique to teach BIM is by including it into a capstone project. Although it enables students to understand the BIM process throughout the project cycle, the course's constrained timeline limits the learning process (Zhang, 2016)
- Incorporating BIM into current courses by breaking down BIM information into smaller, easier-to-manage sections that are spread over all CM curricular years. The succeeding years concentrate on more complex BIM tasks, including as estimating and scheduling, whilst the first two years concentrate on fundamental

knowledge and modelling abilities (Sacks R. &., 2013).Additionally, interactive instructional modules are made using BIM. To assist students in understanding various topics given in the curriculum, these modules can be included into a variety of courses (Lee N. &., 2013).If teachers stick to the current core courses, which cover a lot of material, they won't have the time to fully explore BIM's possibilities (Clevenger, 2010).

Both: a standalone class and incorporation into the current curriculum. Combining these two approaches is advised by (Clevenger, 2010) so that students may study the fundamental BIM principles in a stand-alone course and get ready for more complex BIM concepts in the current courses.

3.6. Features of Virtual Reality

Virtual reality includes four main characteristics that emphasize the importance of the presence of the human element and the place it occupies within the virtual world environment

- **Imagination**

Refers to the user's capacity to move things in the simulated world and the level of environmental input that is naturally occurring.

- **Immersion**

When reaching the degree of complete realism, as it is difficult for users of the virtual environment to distinguish between what is right and what is wrong.

- **Multi-Sensor**

This feature refers to the multiple senses used within the different perception systems, which include sensory, auditory, visual, and tactile perceptions, as well as the perception of movement and different forces, in addition to the perception of smell and taste.

- **Conceptuality**

This feature refers to a mixture of different information related to the use of the virtual reality system in order to achieve the highest level of knowledge through which we seek to develop imagination, connection and thinking in depth.

- **In General**

Using the Building Information Modelling approach, project participants may build a virtual data model that aids in a better understanding of the project. The AEC business is experiencing a significant change toward upgrading BIM as a management tool by improving coordination and communication, eliminating uncertainty, and boosting efficiency.

BIM is concerned with the process of all development phases, including facility management, design, and construction. A three-dimensional model cannot be the only output of the BIM process. However, it can also apply the BIM model to virtual reality (VR) technology and integrate those two together (Chen & Luo, 2014). Participants in AEC may be able to experience the project in virtual reality before it is ever built. With the flexibility to reuse and utilize the data straight from the model, architects and engineers may construct and adapt their design to function more naturally. Virtual reality is regarded as a cutting-edge instructional tool for AEC professionals (Goulding, 2014)

However, VR narrows the communication gap between clients and architects as well as between visual and physical thinking (Zaker, Virtual reality-integrated workflow in BIM-enabled projects collaboration and design review: a case study. Visualization in Engineering, 6(1), 1-15., 2018) . White asserts that 2D drawings could be able to be obtained and extracted from the virtual models utilized in the design process.

4. CONSTRUCTION PLANNING

4.1 4D/VR/BIM Model

In several projects throughout the world, 4D CAD models have been utilized to depict the construction process by integrating real-world 3D features over time. 4D models have been utilized in the construction phase and have shown advantageous throughout procedures that cover the full project lifespan, such as stakeholder cooperation, design decision-making, project constructability assessment, and locating spatial disputes during construction. There are several research relating VR technologies to 3D geometric models that discuss the development of 4D apps as a support for following construction design. The first 4D model employs exclusively VR technology, whereas the second model makes use of BIM technologies without VR capabilities.

A- prototype based on VR technology used in building planning was implemented by Sampaio et al. A 4D model is created by linking the geometrical AutoCAD 3D models of various construction activity phases to the construction planning schedule. A significant tool for tracking the progress of the building activity is virtual reality (VR) technology, which enables interaction with and visualization of various construction phases. EON Studio and AutoCAD VR are all used in the prototype. By preventing inaccuracies and construction mistakes, the 4D/VR application accurately depicts the construction process, enhancing partner communication throughout the project.

B- Sampaio and Moat used Revit, MS Project, and Navisworks to produce a 4D/BIM model. The MS Project-established activity sequence for the building may be followed by the relevant job by connecting the 3D models that are organized into sets using the Navisworks program. The developed 4D model gives the 3D/BIM set components a time component, enabling a visual representation of the construction process. The ability to move around the model permits analysis of every angle and spot, as well as material take-off amounts for each desired building stage.

Additionally, Navisworks may be able to aid in the investigation and discovery of conflicts across specialty projects.

Figure 4.1: Enhancing BIM Methodology with VR Technology

Source: (Sampaio A. Z., 2018)

4.2 Interfaces of 4D/VR Model and of 4D/BIM Model

For a 4D/BIM model to be proposed, some elements that were developed as a single entity but consisting of numerous layers of materials must be broken down into their constituent parts. To support the 4D construction modelling processes, it is crucial that the BIM modelling software in use can divide parts, such a wall or floor, as necessary. It can put pieces together, in reverse. Two Revit categories were created in this context to facilitate workflows for construction modelling.

1- It permits breaking out a model element into separate components that may be individually scheduled, labelled, filtered, and exported.

2- It enables the creation of an assembly from any number of element instances, which may then be managed as a single entity and independently scheduled, tagged, and filtered.

Any changes to the element from which it is formed are immediately reflected in each of the smaller sections that can be subdivided from the larger part. Therefore, changing a component has no impact on the original component. As a result, any component, such as the floor's finishing layer or a wall system, may be connected to the appropriate MS Project activity.

This capability provided by the BIM tool is significant because, in a typical construction schedule, the building of a wall or a floor requires the definition of a series of activities corresponding to different time periods. By using VR software that can function over a 4D environment, these two BIM modelling software-enabled capabilities diving, and assembling may be enhanced.

When work is underway, actual confrontations frequently materialize on the construction site. Any potential inaccuracy at that point results in extra expenses and delays. Following each building stage with a 4D/BIM allows the team to identify any potential conflicts and make the required modifications on the BIM model. The analysis performance of BIM models may be enhanced by integrating VR capabilities.

Therefore, BIM + VR applications can help to save building costs and prevent on-site mistakes that result in material waste.

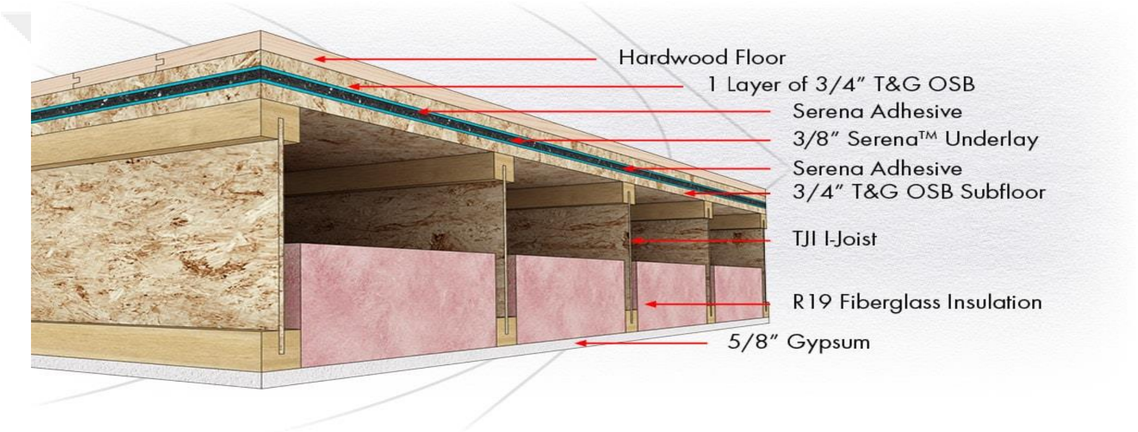


Figure 4.2: Instructions on Fitting Suspended Ceiling

Source: (Reference Google)

Parametric objects of a wall solution and a floor system

The use of interactive visualization in constructing BIM projects has been pushed by recent breakthroughs in VR. As it generates a shared immersive experience, Du feels that interpersonal connection in a VR environment is more important for successful communication in a construction project. As a result, he built a BIM-enabled VR environment to enable multiplayer tour in virtual buildings. With a shared, immersive walkthrough experience, the multiplayer virtual walk enables remote project stakeholders to participate in real time in the same setting.

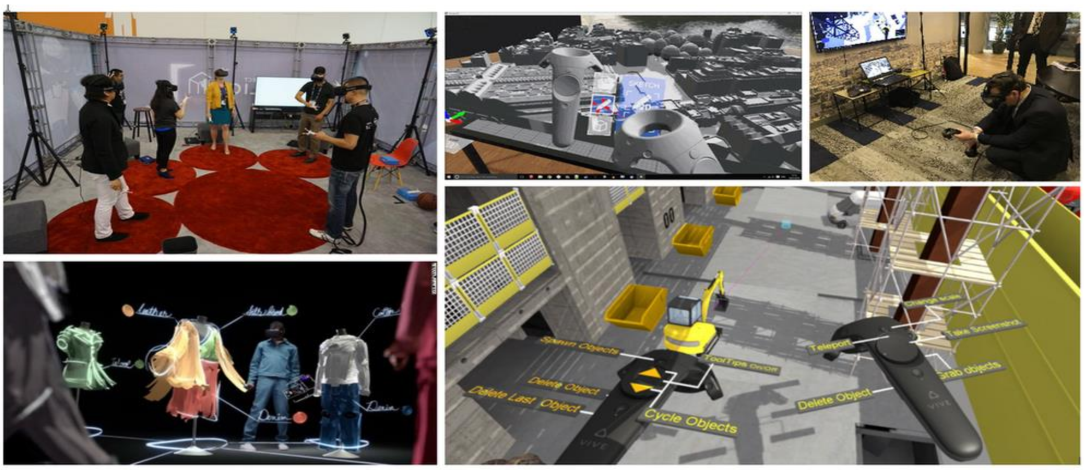


Figure 4.3: A virtual reality supported 3D environment for engineering design review.

Source: (Wolfartsberger J. Z., 2017)

Screen shots of 4D/VR/BIM simulation processes

BIM facilitates 4D analysis, allowing for the simulation and study of project schedule activities in order to optimize the order of construction. Users may view the timetable and improve sequencing on the building site by using a 4D model. In every stage of building construction, BIM may be combined with the cost factor to provide a 5D/BIM simulation. Building materials and component amounts are surveyed using the BIM, and these numbers are connected directly to cost databases.

As was previously noted, VR combines a device for interaction to create a virtual world. Considering this, software companies have been generating cutting-edge BIM/VR solutions that are also used to enhance 4D/BIM models. Some of the VR tools we've spoken about is also used for planning building projects as following.

- **Oculus Rift**

Customers may virtually stroll around the Enscape project and experience it as if it were already created when used in conjunction with the Oculus Rift. The user sees the corresponding building 4D/BIM step during the construction process and consults all the information they require to compare the progress building stage and the delay, or the advance realized in the construction area.

Figure 4.4: Oculus Rift S, the Most Accessible PC VR Headset for all by Jose Antunes

Source: (Reference Google)

- **Augment**

With the aid of Augment software, data-rich virtual information is instantly accessible on the spot via connected devices like a smartphone or tablet. It enables the user to compare the intended 4D/BIM model to the real construction progress of the job from a variety of angles and 74 State of the Art Virtual Reality and Augmented Reality Knowhow. Project stakeholders can examine information-rich virtual models created using BIM and VR to more clearly comprehend the building construction project. Building confidence between project participants and giving owners and users the chance to see and provide comments on the building process plans are now crucial, and utilizing BIM with VR, this goal is readily accomplished.

Figure 4.5: Robotics and Artificial Intelligence

Source: (Salardi, 2020)

Screen shots of augment software

- **EON Icube**

To complement the building activities, 4D/VR models have been created using the standard EON software. The EON Icube, a multi-walled system, always surrounds the user with music and pictures. The EON Icube gives customers a realistic view of a building's inside, particularly in terms of lighting and wall material texture. Several VR devices are compatible with the EON Icube data-gloves, joysticks, or motion tracking systems.

Figure 4.6: EON Icube Environment

Source: (Sampaio A. Z., 2018)

4.3 4D/VR Model And 4D/BIM Model

In several projects throughout the world, 4D CAD models—which gradually merge real-world 3D elements—have been utilized to illustrate the construction process. The usage of 4D models during the building phase has been demonstrated to have advantages over approaches that cover the full project lifecycle, such as stakeholder participation, design decision-making, project constructability assessment, and spotting spatial issues during construction.

Several studies have been done on the development of 4D apps as a support for following construction planning, tying VR technology to 3D geometric models and reports on the production of 4D/BIM models without the inclusion of VR.

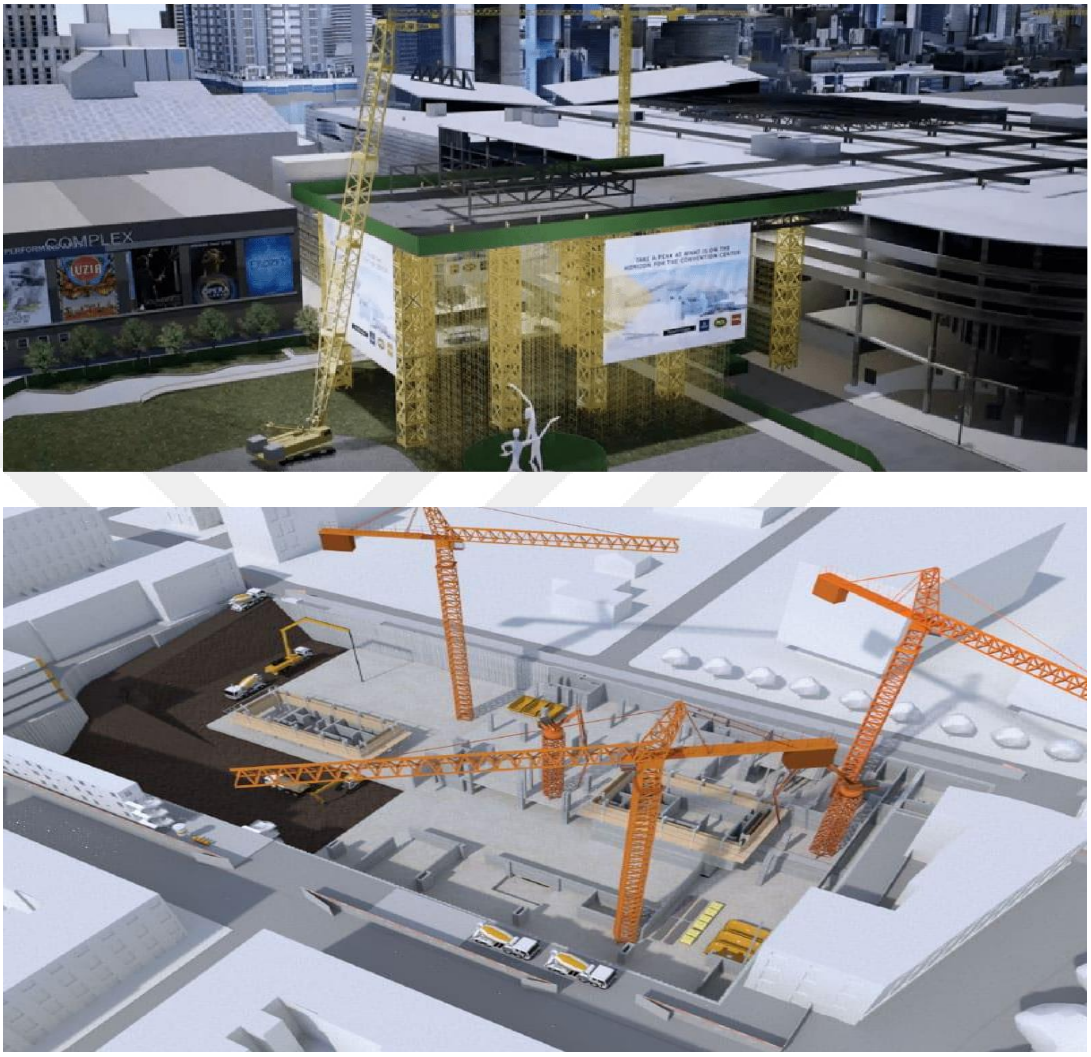


Figure 4.7: VR in Construction, Architecture & Engineering

Source: (Reference Google)

4.4 Screen Shots of 4D/VR Simulation Processes

According to Dawood et al. (2002), an integrated database was created to serve as the information resource basis for 4D/VR building process simulation. Utilizing a widely used categorization scheme Unclassy, a thorough core database of building components was created, and integrated interfaces between an MS Access database, AutoCAD drawings, and MS project schedules were created and put into use. The research team concentrated on creating a 4D/VR prototype simulator with VBA modelling and a database of AutoCAD 3D models as assistance.

A prototype using VR technology for planning construction was put into action by Sampaio and colleagues. In order to create a 4D model, the geometrical AutoCAD 3D model of various construction activity phases is connected to the construction planning schedule.

Virtual reality (VR) technology enables engagement with the construction process as well as the visualization of various phases of the building process, making it a useful tool for tracking the progress of the work. AutoCAD, MS Project, and EON Studio are all used in the prototype.

The 4D/VR application vividly depicts the construction process, preventing mistakes and inaccuracies, and so enhancing communication between parties in the construction process.

Using MS Project and Autodesk tools Revit and Navisworks, Sampaio and Mota developed a 4D/BIM model.

The 4D model enables the viewing and analysis of the activity sequence for the building by adding time connections to the 3D elements that are organized in groups connected to each task. The MS Project solution constructed the connectivity of 3D models with planning using the Navisworks software, which enabled links between the 3D models generated in the planning. Analysing every angle and spot on the model is made possible by the ability to travel through it.

Additionally, Navisworks has the ability to assist with conflict analysis and identification for the specialty projects.

4.5. 7D/VR/ Model

4.5.1 Facility management

- **How does 7D Facility Management help in Building Maintenance?**

Building information modelling services have revolutionized the industries of engineering, construction, and architecture. BIM promises to deliver accurate, timely, and pertinent information throughout the full life cycle of the building, not only during its design and construction. An efficient 7D Facility Management implementation makes this feasible.

- **What is Facility Management?**

BIM model is used in the 7D Facility Management process to manage the building. Here, 3D geometric models incorporate all the characteristics related to various architectural components. This aids facility managers in achieving their objective of creating a comfortable, effective, and energy-efficient building. In comparison to conventional approaches, it is also more economical. A data-rich geometric model is produced digitally by the BIM model and may be used to track and communicate information across the full building life cycle.

- A data-rich geometric model is produced digitally by the BIM model and may be used to track and communicate information across the full building life cycle. Facilities for a building that weren't made using an intelligent 3D model can also be managed using BIM. This can be accomplished through 3D laser scanning or a careful review of the original refit designs.
- BIM for Facility Management is a new field, and several studies are still being done in this area. However, there are other advantages that come with 7D Facility Management.
- **Benefits of BIM Facility Management**
- **Effective Space Management**

The facility manager must be aware of how every aspect of a place is used in a facility. Building managers may better plan and utilize the available space by using BIM, which enables a comprehensive depiction of the whole area. This aids in lowering real estate expenditures, expenses, and vacancies, which helps make the building more cost-effective.

- **Improved awareness of asset location**

A BIM model offers useful information on all the exposed and concealed parts of the structure. Therefore, BIM enables the ability to see what assets are hidden behind a wall or ceiling. As a result, the individual may quickly locate the needed spot for making any repairs or upgrades. Additionally, for quicker searches, each piece of equipment can have its own ID. To keep the BIM model current and accurate, it may also be updated to reflect any changes in element location during any refit or refurbishment.

- **Streamlined maintenance by providing asset information.**

All the building's components are specified in the virtual 3D model, as was already indicated. This indicates that the facility manager may obtain all information on the asset with the use of BIM, including data on its performance, condition, physical dimensions, and significant documents. Thus, facility managers may schedule maintenance and upgrades, learn more about products, and save time and effort compared to searching using more conventional techniques.

- **Saves Energy**

Any facility manager's job includes evaluating and contrasting various energy options. By assessing and contrasting all the important variables and metrics relating to energy and its usage, BIM may successfully assist decrease environmental impact. Additionally, it identifies high-energy consumption locations so that alternatives may be realistically tested on the 3D Model before being implemented in the building.

- **Enhances Lifecycle Management**

The owners and managers may make judgments about long-term investments in systems and materials using data on replacement cost and life expectancy of any product. Making an informed investment in construction items and components requires knowledge about the product's resistance, durability, and guarantee. This enhances people's quality of life and wellbeing while lowering operating expenses for a set period of the building's life cycle.

Finally.

BIM is important throughout the development process, and with 7D Facility Management Services, it can be used to make sure the facility is managed and operated efficiently. AEC business Tesla Outsourcing Services has collaborated with prominent international AEC companies for more than ten years. We are experts in producing BIM models that are ready for maintenance, which helps to increase building quality and prevent issues.

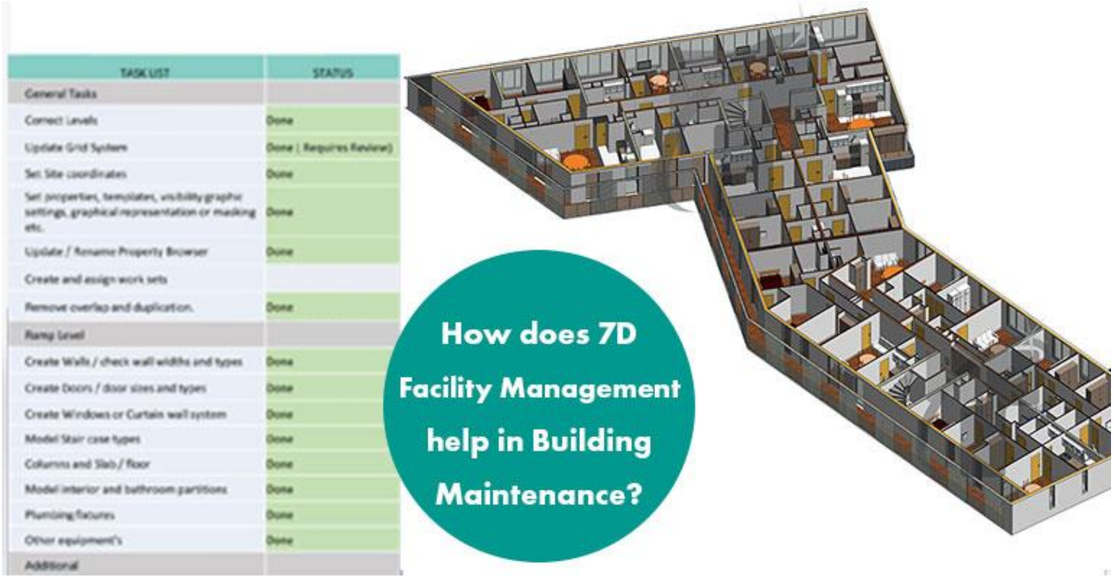


Figure 4.8: How does 7D Facility Management help in Building Maintenance

Source: (Reference Google)

4.6 Services Samples Contact 7D BIM.

Programming, record modelling, maintenance scheduling, and asset management services

4.6.1 7D BIM services

- **Facility Management Applications**

The greatest level for BIM is the seventh dimension (7D). It enables you to handle all you've accomplished in the previous six stages. In other words, 7D can assist you in creating a detailed 3D model of the building that is now being built. It's also useful for continuing facility management since it offers you a clear view of what needs to be done even after construction is finished.

- **Warranty Data**

Knowing knowledge regarding warranties will become essential for efficient maintenance. BIM software saves this information for you, saving you from having to maintain a paper file with hundreds of warranties at your office. You can observe once more how thorough BIM systems are at the 7D level. You may reduce the cost of repairs by conveniently accessing warranty data (even through a mobile device). This applies to both individual equipment and construction materials.

- **BIM for asset management**

It is entirely up to you whatever assets you manage with BIM modelling. You could wish to use more powerful systems, like HVAC, or you might want to include some of the different machines. The different assets may be included to the BIM models once you know where they are situated and what they are. This has the advantage of enabling you to share the models with facility managers, the finance division, and anybody else who may be in charge of overseeing the management of the different assets, inventorying them, or generally keeping track of them. Outsourcing BIM software might be advantageous because it can be difficult. Then, you may benefit from a knowledgeable outsider's information.

- **BIM For Repair And Renovation**

The renovation's primary goal is to make improvements. Before any work really starts, using BIM will make it simpler for contractors to depict precisely how the building will seem when the refurbishment is finished. This might make it simpler to get permission and make sure that everyone is in agreement regarding how the project will look when it is finished.

4.6.2 The need for sustainability

Investing in 7D BIM before your structure loses money due to inefficient procedure is a good idea even if the complexity and cost of the BIM process grow as you move through its five dimensions.

- **From Design to Demolition Management**

The idea of considering the complete life cycle of your building may seem intimidating. However, if you want to remain in the same building for a long time, it is crucial. You may manage operation and maintenance using 7D BIM technology all the way up to the point at which you could decide to sell or demolish the structure. Designing a "as-built" model that includes both what has been intended and what is being created is one of the elements involved in this. This is the first step in getting data into your BIM application for facility management in the future. The objective is to have a lot of data readily available so you can quickly extract and track pertinent data assets as necessary.

- **Variations**

BIM software will be helpful in the early phases of building your facility if you find that there are more differences than you anticipated. Working with a knowledgeable business that offers BIM assistance will enable them to add features to the program while the building is being constructed. You can keep a digital record of the things you're adding to the building as you go by storing data about the object's current state. When building is taking place, things don't always proceed as expected. Problems like geometrical and operational conflicts could arise, which would increase the value of your BIM platform. It will eventually contribute to the development of a simpler method for handling maintenance.

- **Technical Requirements**

BIM software may offer more to what you've constructed than just technical details. You can include further details on the technology you've included into the building or those you bring in after it opens. Your facility management job will function more effectively if you include additional elements and technological requirements. Your maintenance team will benefit from it as well when doing repairs. Any danger of downtime is decreased by having precise technical specifications available to assist with remodelling projects or mending on-site equipment.

- **Scheduling and upkeep**

Our BIM software incorporates maintenance scheduling to prevent mistakes when service is required, further enhancing how you perform maintenance. An experienced BIM team will handle it for you if you're unfamiliar with bringing in specifics like these. By using this, you may send notifications on what needs to be maintained to prevent unforeseen mechanical breakdowns or even structural issues.

4.7 VR in Worker Training and Construction Safety Management

Due to their natural risk and high level of uncertainty, construction sites are among the most dangerous workplaces. Given this reality, everyone involved in the building project needs to prioritize safety on construction sites. Construction sites were the scene of 20% of all fatal workplace accidents in the EU's 28 member states in 2017. (Eurostat, 2017).

VR technologies provide up a wide range of opportunities for safety management training, monitoring, and control in the construction industry. High accident rates in the construction sector cause delays and cost overruns in a dynamic and complicated environment. VR technology has the potential to significantly contribute to the construction industry's efforts to improve safety management through open learning platforms, training, and awareness (Ahmed, 2019).

Construction firms are looking to virtual reality (VR) to lower the number of avoidable incidents and provide a fresh perspective to the training idea in construction safety. It has the potential to be beneficial for construction operations and the long-term preservation of life.

using all high-fidelity computer models, whole operations may be learned in extensive real-world heavy machinery drills. The training process's safety is a benefit of 3D simulation and VR in the building project. When it comes to providing workers with safety training, using these models offers several advantages. Construction employees may experience many scenarios in the virtual world in a risk-free environment thanks to VR, which can reproduce and mimic complicated problems and give dynamic scenarios and processes (ANTYCIP, 2020).

4.7.1 Advantages of VR training for the construction

The user may fully experience the project in real life thanks to the accessibility of technical and instructional services. VR offers several important benefits for training in construction safety.

- **Avoid real-world risks and mishaps.**

The difficulty of applying information to practical situations is a challenge for conventional training approaches. With virtual reality, a construction business may develop and replicate authentic scenarios in a constrained work site or congested roadway. In order to provide students a complete understanding of what they could encounter on a building site, it also considers any exterior conflicts such inclement weather, breakages, and passers-by. By cooperating with other employees, the multi-user features also help to maximize the effectiveness of cooperation. It fosters user interaction and efficiency, especially at construction sites where heavy machinery and tools are frequently used.

- **Lower training costs and more retention**

The use of VR technology helps students and others who may not have any prior building site experience maintain their instruction. With solid supervision, a safe atmosphere, and no knowledge barriers, they can study. The learner can acquire the necessary information and develop the necessary skills through virtual site-based activities. It can lower the cost of safety training and prevent learners who lack the necessary credentials from entering dangerous locations until they do. It is simple and quick to keep track of and resolve all the process needs using the virtual training approach. The virtual training may be repeated without incurring additional costs or risks.

- **Preparing emergency procedures**

The requirement to teach personnel and project managers for any emergency operations, fire, and natural hazards like earthquakes to be carried out is a crucial safety factor that may be improved by VR.

The immersive training approach can mimic how someone might interact with protective gear and how to use it in an emergency. It is challenging to carry out this technique in a real-world setting without dangers. Virtual reality training gives operators a clear understanding of what to do in a high-risk circumstance and enables them to demonstrate and demonstrate their abilities under duress. All employees may learn what to do in situations by practicing emergency scenarios in real-time.

- **Improved efficiency**

Complex projects and training challenges can be simplified with difficulty levels and options, relieving the minds of both the trainer and the trainee. Training in a risky situation is not recommended. The ability to control anxiety in a safe and pleasant environment guarantees that the learner can provide their best effort and focus on the work. VR technology' immersive qualities also guarantee that the training process is not constrained. There are many challenges in traditional training. The virtual setting isolates the workers from the outside world and enables them to gather all the necessary data without being concerned about environmental factors.

5. ANALYSIS OF THE VR IMPACT ON THE CONSTRUCTION INDUSTRY

Overall, VR technology has a lot of potential for the construction industry because to its many applications and capacity to deliver a secure and dependable experience. To fully utilize VR capabilities, a thorough investigation is necessary to establish its potential contributions and problems.

5.1 BIM and Virtual Reality (VR) at the Construction Site

Structure information modelling (BIM) is a technique that allows architects and designers to create parametric, object-oriented 3D models that are packed with information to fully describe any building or facility. As a digital representation of a building's physical and functional qualities, a BIM serves as a storehouse for data that enables several design and construction-related applications, including cost estimate, energy analysis, and production planning. (Eastman C. T., 2011).

However, laws and the usage of traditional construction contracts mean that the major source of information transferred from design to construction is still 2D drawings (Abd Jamil, 2017) . Designers must work harder to create 2D drawings from the BIM as a result, and the rich data generated during design does not all make it to the building site.

Scandinavia has recently made more of an effort to abandon the conventional 2D drawings used on building sites. Examples of major projects where building information models (BIM) have been utilized as the main source of information include the Slussen project, Röfors bridge, and Oslo Airport Terminal 2 ((Cousins, 2017) (GÖTBORG, 2016) (Merschbrock, 2016).

Construction workers had immediate access to the BIM on tablets for the Röfors bridge project, which was totally accomplished without the use of traditional drawings. This allowed for a simple overview and knowledge of the project. Furthermore, BIM managers and designers stationed at the job site produced so-called Production-Oriented Views (POV) from the BIM in collaboration with the workers.

These views are simply augmented screenshots from the BIM and frequently include color-coded features, precise measurements and dimensions, item information, 3D-sections, or any other data the construction workers deem required to carry out the real work on the site. The views are created and then posted as pictures to a shared model repository where they may be viewed and utilized in conjunction with the full BIM on mobile devices like iPads. However, while being a very effective and successful concept, creating POVs now necessitates a designer or BIM-specialist on site, adding to the project organization's workload (Malmkvist, 2018).

The AEC industries are embracing Virtual Reality (VR) more and more as a result of rising BIM usage and a new wave of reasonably priced head-mounted displays (HMD). The necessary 3D data may be readily retrieved using BIM as opposed to being created from scratch, making it more practical. Virtual reality (VR) is frequently used nowadays for planning and training related to construction safety (Hafsia, 2018) (Ghaffarianhoseini, 2017) , production planning (Muhammad, 2019) and design review sessions (Roupé, 2016); (Zaker, 2018); (Wolfartsberger J. , 2019)Previous research on design review sessions has demonstrated that VR can make clear numerous design elements that are hard to understand from conventional design documentation, such as conflicts and a lack of room for installations and maintenance (Zaker, 2018).

Additionally, it has been shown that those who have less experience using desktop CAD/BIM viewers (such as MEP subcontractors and individuals who work in service and maintenance) prefer utilizing VR since it more closely mimics their actual working environment (Wolfartsberger J. , 2019) However, much like with BIM, VR is mostly used during the design stage and barely at all during actual building (Zaker, 2018).

In this section, a user-friendly Virtual Reality (VR) system designed for the office on a building site will be presented. The main use is to provide supervisors and workers in the construction industry with simple VR interface access to the BIM. They may enter and freely travel, inspect, and interact with the BIM in scale 1:1 using contemporary VR equipment, such as the Oculus Rift or HTC Vive, and extract information, take measurements, create section planes, and manage visibility of certain components or sub-models. Snapshots of the produced Production-Oriented Views may then be uploaded and accessed on mobile devices on the building site from within the VR environment.

The constructed VR-technical system's specifications will be presented, along with an analysis of the system's performance at four separate construction sites.

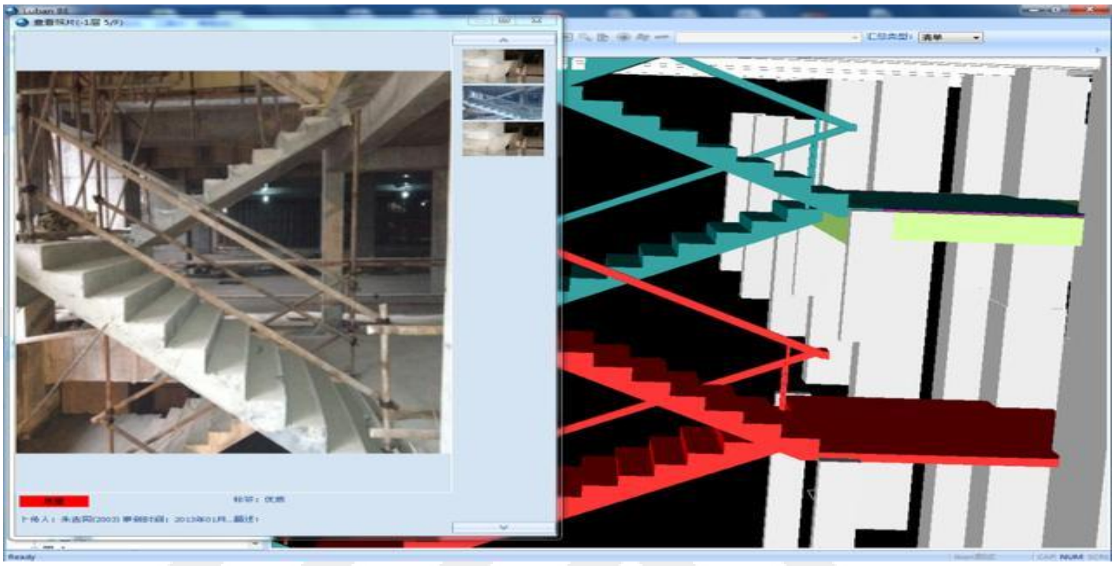


Figure 4.9: Example of Production-Oriented Views (POV) from the Röforsbron Project

Source: (Reference Google)

5.2 A VR Interface for On-Site Access to BIMs

We have utilized BIM Xplore as a platform and further adapted it to offer the capability to extract information and build POV directly in VR (BIM Xplore, 2019). A software program called BIM Xplore was created expressly to enable real-time VR viewing of big and complicated BIMs. Very big and complicated BIMs may be seen in VR by utilizing effective occlusion culling, eliminating the requirement for input dataset preparation or optimization (Shadram, 2016)It can import IFC files using the BIM Toolkit either as a standalone program or as a plugin for Revit (Lockley, 2017)

5.3 Type of Dangers is Most Typical at Building Sites

- **Utilities**

One of the main risks connected to many construction operations, such as excavation, is the presence of utilities. Gas and electricity are two really helpful utilities and services, but they are also quite dangerous and explosive. It is the goal of procedures like service finding and potholing to lessen the possibility of catastrophic strikes and problems.

- **Inappropriate tools and materials**

Like most businesses, the construction sector has greatly benefited from new machinery, supplies, and technology. They may save a ton of time and significantly lessen the physical strain of labor, but if they are not utilized and controlled appropriately, they can also be dangerous. Using tools and materials that aren't appropriate for the work or the process is the most frequent cause of equipment and material risks on construction sites.

- **Damage to property**

Construction site hazards can take many different forms, including safety risks, environmental concerns, business risks, and stakeholder risks. Property damage is one of the many distinct sorts of dangers that might occur on a building site. A construction site's buildings and surrounding property may sustain damage from deliveries and other events, the pre-existing structure may sustain damage, or recently finished work may sustain damage when other lots or areas are worked on. In addition to being a costly construction site risk, property damage is also extremely troublesome when it affects neighboring properties, public highways, and the neighborhood. For practically all businesses with this subject, maintaining appropriate dilapidation records and processes is essential.

- **Mishaps and accidents**

On construction sites, safety concerns are the most frequent outcome of accidents and incidents, but there can also be environmental spills, severe weather disruptions, and other mishaps. One of the objectives of the building game is to prevent accidents and mishaps, although it is quite challenging to do so. The best course of action for businesses is frequently not to completely prevent accidents and catastrophes, but rather to make sure that they have the proper systems and procedures in place to deal with these problems rapidly.

- **Site access**

Construction site access puts both employees and the general public at danger. The entire site's safety depends heavily on making sure that the appropriate individuals may enter and exit the area at the appropriate times.

- **Security**

Construction sites face security risks the same as other buildings and commercial establishments. To protect their products and services, as well as the safety of visitors who shouldn't be there, construction projects and businesses must maintain the security of their workplaces and locations.

- **Bad behaviour and negligence**

Poor behaviour and negligence are the danger on the building site that every organization wishes to remove. It is possible to avoid problems that result from carelessness and improper behaviour, which makes them much more painful. There is a very wide range of poor behaviour and neglect, from not strictly adhering to the rules to truly screwing about and acting foolish. Building a strong and positive culture where all employees feel required to perform job properly and safely always is one of the best weapons businesses can use to combat this construction site danger.

- **Chemicals**

Hazardous materials and chemicals are frequently utilized on construction sites to facilitate operations. Of course, they may be quite harmful when not managed or treated appropriately, despite being strong and beneficial agents. The simplest method to keep chemicals where they are safe is to make sure that they are all correctly labelled, monitored, and recorded using material safety data sheets, and that they are moved and managed by the right individuals wearing the appropriate PPE.

- **Poor safety procedures**

On construction sites, safety doesn't just "happen," it takes a lot of deliberate thinking and work. The firms with the finest safety practices are frequently the ones with the best safety records and outcomes. Once more, there is a rather wide range of insufficient safety measures, from a little procedural error or lack of paperwork to having virtually no safety procedures at all.

- **Lack of resources**

Lack of resources can result in hurried and uncontrolled labor, which is the major reason why it poses a risk on construction sites. Many activities and professions in the construction industry benefit from the input and supervision of several individuals, and when these people aren't present or don't exist, accidents tend to occur more frequently.

- **Poor communication**

While less preventable than bad behaviour and neglect, problems brought on by poor communication can nevertheless be extremely painful. A lack of communication or a delay in communication from the office to the site or vice versa might result in poor communication between two employees who work on the same project. The speed and effectiveness of communication between internal and external parties on construction sites may be significantly improved by putting the correct communication tools and technology in place.

- **Long-term exposure**

The hazards that are most evident at construction sites are those that happen rapidly and cause disruption, but many of the most harmful dangers there are those that arise slowly and have negative repercussions over time. Construction workers and other stakeholders may be seriously endangered if they are exposed for an extended period to noise, vibrations, sunlight, dust, and other consequences.

- **Working at height**

In addition to the general dangers connected with working on construction sites that we have discussed above, there are also certain very particular activity risks that many (or most) employees are exposed to when working on construction sites. Attempting at heights is one of the most frequent and dangerous dangers associated with construction sites, Governments, authorities, corporations, and workers continually try to mitigate this risk.

- **Slips, trips, and falls**

While less catastrophic than falls from great heights, slips, trips, and falls are nonetheless quite prevalent and problematic on construction sites. Numerous injuries are caused by slips, stumbles, and falls, and thousands of project hours are lost as a result. The greatest and simplest method to reduce this danger is to keep sites free and clean, even if all these sorts of accidents will never be completely eradicated.

5.4 The Best Way to Manage the Site Risks

There are certain high-level recommendations and techniques that businesses may use to decrease risk across all their construction sites, but we have drip-fed many of the micro-level methods related with most of the above construction site concerns as we cycled through them. Among the significant adjustments businesses might make are:

- **Boost or enhance your training.**

Lack of expertise and inadequate training are two of the construction site issues that increase risk in nearly every area of a site. These two dangers raise the dangers of using the wrong tools, being hurt while handling objects manually, acting negligently, and other dangers. The process of increasing or upgrading training doesn't have to be too formal or expensive. Enhancing tiny details like toolbox discussions and pre-starts may make a significant difference in how prepared workers are to carry out their tasks and supervise others on a construction site.

- **Improve the culture.**

Not only can a positive workplace culture make individuals happier and more in love with their jobs, but it may also have a significant positive effect on employee productivity. A strong culture where management drives safety and employees pull it can increase the likelihood that people will report hazards and incidents; one where other stakeholder are treated with respect reduces noise complaints before work should start, for example, and one where people feel held to high standards always lowers poor behaviour and negligence. All the construction site dangers may be significantly reduced by having a positive and safe workplace culture.

- **Implement improved tools and procedures.**

Finally, many of the challenges and dangers that occur on construction sites are the result of inadequate paperwork, protocols, and communication.

While none of these procedures will ever be flawless or fool proof, replacing bulky paper, PDFs, Excel spreadsheets, and emails back and forth with real-time software's is a terrific and simple beginning to substantially enhance your present operations.

Most of these software's are now free to use and can be simply updated as you migrate more of your operations to a digital and automated structure.

A smart information management system is the greatest approach to enhance the flow of information and the communication of risk on your building sites.

5.5 SWOT Analysis

SWOT analysis of VR implementation in the building industry as show in table 5.1

Table 5.1: SWOT Analysis of VR

Strengths	**Weaknesses**
Improvements in interactivity and visualization throughout the design review process	High standards for 3D modelling
Improving collaboration and communication between clients and project teams	The absence of streamlined software applications
Enhance project management and contractor coordination	Issues with image quality and rendering
Mock-ups in virtual reality	Many experts prefer and utilize traditional methods.
Give instruction in a low-stress atmosphere.	
Improve clash detection	
Tool for risk management in large projects	

Opportunities	**Threats**
Time and money saved	Subcontractors' lack of VR and BIM expertise
Reducing adjustments and rework prior to construction	Inadequate VR knowledge and capabilities
Improving client collaboration for future work	VR infrastructure system cost
High potentials are expected following COVID 19.	
High potentials are anticipated by combining laser scanning with drone photogrammetry.	

Source: (Reference Google)

6. RESULTS AND DISCUSSION

6.1 Reliability Test of the Questionnaire

Before starting to analyse the results of the questionnaire, it is necessary to ascertain the extent of the reliability of that questionnaire, and the Cronbach's Alpha coefficient was used to ensure the reliability. Table 6.1 contains the value of Cronbach's alpha coefficient, which was obtained using the statistical program SPSS.

Table 6.1: Reliability Statistics (Cronbach's Alpha)

Reliability Statistics	
Cronbach's Alpha	**No. of Items**
0.837	17

6.2 Statistical Analysis

Analysis of continuous variables was done with SPSS packet program (28.0). Frequencies of the category variables are calculated with cross tabulations and the relationship between dependent and independent variables was investigated with **Cronbach's Alpha coefficient** test. $P > 0.8$ is considered significant.

Table 6.2: Frequency Table of Participants' Age Reference

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	26-30	29	24.2	24.2	24.2
	31-35	31	25.8	25.8	49.9
	36-40	28	23.3	23.3	73.2
	>45	33	26.6	26.6	99.8
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.2, the frequencies of participants' age are summarized. Accordingly, the frequency of participants who aged between >45 is recorded as the highest frequency (26.6%) however, 36-40 age group was found to have the lowest frequency (23.3%).

Table 6.3: Frequency Table of Participants' Education Level

Frequency	Percent	Valid Percent	Cumulative	Percent
MSc	69	57.5	57.5	57.5
Undergraduate	45	37.5	37.5	95.0
Ph.D.	7	5.0	5.0	100.0
Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.3, the frequencies of participants' education level are summarized. Accordingly, the frequency of participants with an education level of graduate is recorded as the highest frequency (57.5%) however, the Ph.D. group was found to have the lowest frequency (5.0%).

Table 6.4: Frequency Table of Participants Reside Country

	Frequency	Percent	Valid Percent	Cumulative Percent
Turkey	32	25.8	25.8	25.8
Palestinian	53	44.2	44.2	70.0
Iraq	27	22.5	22.5	92.5
UAE	2	1.6	1.6	94.1
Libya	1	.8	.8	94.9
Saudi Arabia	2	1.6	1.6	96.5
Malaysia	1	.8	.8	97.3
Belgium	1	.8	.8	98.1
USA	1	.8	.8	98.9
Jordan	1	.8	.8	99.7
Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.4, the frequencies of participants reside country are summarized. Accordingly, the frequency of participants who reside in Palestinian was higher (44.2%) than the frequency of participants who reside in Libya, Malaysia, Belgium, USA and Jordan (.8%).

Table 6.5: Frequency Table of the Job Sector by the Participants

		Frequency	Percent	Valid Percent	Cumulative Percent
	Private	82	68.3	68.3	68.3
	Public	39	31.6	31.6	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.5, the frequencies of park selection to go are summarized. Accordingly, the most of participant select private sector was (68.3%) compared to public sector was (31.6%).

In this study we notice that the people who is working in private company using BIM technology more than government because private company because cash flow of private company is almost high.

Table 6.6: Frequency Table of Where the Participants Work Specialization

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Civil	64	53.3	53.3	53.3
	Mechanic	9	7.5	7.5	60.8
	Architecture	34	27.5	27.5	88.3
	Electric	9	7.5	7.5	95.8
	Biomedical	1	0.8	0.8	96.6
	Environment	2	1.6	1.6	98.2
	Project management	1	.8	.8	99.0
	Petroleum	1	.8	.8	99.8
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.6, the frequencies of places where participants work are summarized. Accordingly, the most of participant (53.3%) of the participants are Civil engineer compared than the frequency of participants who work as Project management, Petroleum engineer, and Biomedical engineer was (0.8%).

Table 6.7: Frequency Table Position of Participants in Them Firm

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Executive engineer	47	39.2	39.2	39.2
	Consultant	7	5.8	5.8	45.0
	Contractor	9	7.5	7.5	52.5
	Coordinator manager	6	5.0	5.0	57.5
	Designer	27	21.6	21.6	79.1
	Professor	3	2.5	2.5	81.6
	Chief Engineer	9	7.5	7.5	89.1
	Lecturer	8	6.67	6.67	95.77
	General manager	5	4.2	4.2	99.9
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.7, the frequencies of places where participants work are summarized. Accordingly, the most of participant (39.2%) are Executive engineer compared than the frequency of participants (2.5%) is Professor.

Table 6.8: Frequency Table Years of Experience the Participants

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5	51	42.5	42.5	42.5
	6-10	22	18.3	18.3	60.8
	11-15	14	11.6	11.6	72.4
	16-20	29	23.3	23.3	95.7
	>25	5	4.2	4.2	99.9
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.8, the frequencies years of experience the participants are summarized. Accordingly, the frequency of participants who is experience between (0-5) years is recorded as the highest frequency (42.5%) however, who has experience >25 was found to have the lowest frequency (4.2%).

Table 6.9: Frequency Table the Percentage of Engineering That Using BIM Technology

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Daily basis	22	18.2	18.2	18.2
	Weekly basis	24	19.8	19.8	38.0
	Monthly basis	42	34.7	34.7	72.7
	Never use any BIM models	33	27.3	27.3	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.9, the frequencies of percentage of engineering that using BIM technology are summarized. Accordingly, the frequency of participants who is using Monthly basis is recorded as the highest frequency (34,7.0%) however, the frequency of participants who is using Daily basis is recorded he lowest frequency (18,2%).

In this question the majority of respondent more than 72% said they use BIM tools at least one day on the month and notice the daily repot is lowest percentage because in this country use the report as monthly

Table 6.10: Frequency Table Experience of the Engineering with BIM Tools

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**1-3 years**	19	15.7	15.7	15.7
	3-7years	28	23.1	23.1	38.8
	More than 7 years	37	30.6	30.6	69.4
	Never	37	30.6	30.6	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.10, the frequencies of experience of the engineering with BIM tools are summarized. Accordingly, the frequency of participants who have experience between (3-7) years is recorded as the highest frequency (37%) however, the frequency of participants who have experience between (1-3) years is recorded he lowest frequency (16.6%).

The second question about the familiar using BIM tools. 69,7% of those surveyed said they had some familiarity using BIM tools and there are 30,6% don't have an experience because its consider new technology in the same time It has become a goal for engineers to stay up with progress to receive better employment possibilities, therefore those with basic experiences make up more than 48%.

Table 6.11: Frequency Table of VR Devices They Are More Familiar With and Recommend to be used

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Microsoft	76	63.3	63.3	63.3
	Samsung Gear	24	18.3	18.3	81.6
	Oculus Rift	13	10.8	10.8	92.4
	HTC Vive	9	7.5	7.5	99.9
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.11, the frequencies of VR devices they are more familiar with and recommend to be used are summarized. Accordingly, the frequency of participants who devices they are more familiar is Microsoft is recorded as the highest frequency (63.3%) and, the frequency of participants who devices they are less familiar was HTC Vive.

The result gives an indication most of engineering feeling comfortable when they use Microsoft company products in the same time its easily to make combination between BIM technology and Microsoft.

Table 6.12: The Frequencies Growth Indicates There Has Been A Significant Increase in Integration of (Argument Reality/Virtual Reality) Tools Within Architecture, Engineering, and Construction (AEC) Industry Projects

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Hardly at all	13	10.7	10.7	10.7
	Extremely well	24	19.8	19.8	30.6
	Average	76	62.8	62.8	93.4
	Not very well	8	6.6	6.6	100.0
	Total	121	100.0	100.0	

In table 6.12, the frequencies growth indicates there has been a significant increase in integration of AR/VR tools is summarized. Accordingly, the frequency of growth as (average) is recorded as the highest frequency (63.3%) and the frequency of growth as (hardly at all) is recorded as the lowest frequency (10.8%).

Table 6.13: Frequency Table of Beliefs VR / AR Usage on all Majority of the Projects within 5 to 10 Years

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	May be (0-35) %	59	48,8	48,8	48,8
	May be (35-70) %	49	40,5	40,5	89,3
	Definitely 100%	4	4,1	4,1	95,4
	Definitely not	8	6,6	6,6	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.13, the frequencies of beliefs AR/VR usage on all/majority of the projects within 5 to 10 years is summarized. Accordingly, the frequency of usage between (0-35%) is recorded as the highest frequency (48,8%) and the frequency of usage as (Definitely 100%) is recorded as the lowest frequency (4.,1%).

The majority of engineering believe the future will be consider for AR/VR technology as the world development every day rapidly especially in the last years. and at the same time the world needs to be easy for everything.

Table 6.14: Frequency Table of Sector has the Most Growth in the Future and Has the Highest Potential for Growth in (Virtual Reality) Utilization

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Commercial Building	33	27.5	27.5	27.5
	Healthcare Facilities	27	22.5	22.5	50.0
	Heavy Civil	30	25.0	25.0	75.0
	Construction Building	30	25.0	25.0	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.14, the frequency of sector has the highest potential for growth in virtual reality utilization and has the most growth in the future is summarized. Accordingly, the frequency of Commercial building is recorded as the highest frequency (27.5%) and the frequency of healthcare facilities is recorded as the lowest frequency (22.5%).

Table 6.15: Frequency Table of about Project Sizes Get the Most Advantages from AR/VR when we Use it

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small project	16	13.2	13.2	13.2
	Medium size project	44	35.5	35.5	48.8
	Large size project	48	40.5	40.5	89.3
	Mega project	13	10.7	10.7	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.15, the frequencies of about project sizes achieve the highest benefits from AR/VR when we use it is summarized. Accordingly, the frequency of large size project is recorded as the highest frequency (39.2%) and the frequency of small project is recorded as the lowest frequency (13.3%). The result found medium and large size project large initiatives received the most support. Comparing with small and medium project

Table 6.16: Frequency Table of Limitations Further Increase the Adoption of AR/VR Technologies in (AEC) Industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Lack of knowledge of design teams	34	28.1	28.1	28.1
	Lack of budget	41	33.9	33.9	62.0
	Lack of understanding of upper management	35	28.9	28.9	90.9
	communication among software	11	9.1	9.1	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.16, the frequencies of limitations further increase the adoption of AR/VR technologies in (AEC) industry is summarized. Accordingly, the frequency of lack of budget is recorded as the highest frequency (33,9%) and the frequency of lack of communication among software is recorded as the lowest frequency (9,1%).and notice the same percentage twice of Lack of knowledge of design teams and lake of understanding of upper management which consider normal because without management can't do any things.

Table 6.17: Frequency Table of the Cost and Time Savings by Utilizing AR/VR During the Design and Construction Phase

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not effective at all	11	9.1	9.1	9.1
	May be more effective than BIM (over 5%)	39	32.2	32.2	41.3
	Not much (less than 10%)	35	28.9	28.9	70.2
	That will be effective more than (30%)	36	29.8	29.8	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.17, the frequencies of the cost and time savings by utilizing AR/VR during the design and construction phase is summarized. Accordingly, the frequency of That will be effective more than (5%) is recorded as the highest frequency (32.2%) and, the frequency of Not effective at all is recorded as the lowest frequency (9.1%). The result showing more than 90%answered cost and time savings by utilizing AR/VR during the design and construction phase is summarized at least 5% and over.

Table 6.18: Frequency Table of the Time and Costs Savings by Utilizing AR/VR throughout the Planning and Implementation Stage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not effective at all	6	5.0	5.0	5.0
	May be more effective than BIM (over 5%)	37	30.6	30.6	35.5
	Not much (less than 10%)	39	32.2	32.2	67.8
	That will be effective more than (30%)	39	32.2	32.2	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.18, the frequencies of the cost and time savings by utilizing AR/VR during the design and operation phase is summarized. Accordingly, the frequency of That will be effective more than (30%) is recorded as the highest frequency (32.2%) and, the frequency of (Not effective at all) is recorded as the lowest frequency (5.0%).

The result showing more than 95% answered cost and time savings by utilizing AR/VR during the design and operation phase is summarized at least 5% and over .as the private question.

Table 6.19: Frequency Table of the VR Meetings from During COVID-19, the Interdisciplinary AE Company (Merrick) will be in Many Places

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Nearly (10-30%)	27	22.3	22.3	22.3
	Nearly (30-60%)	60	49.6	49.6	71.9
	At almost (60-90)	22	18.2	18.2	90.1
	Certainly (100%)	12	9.9	9.9	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.19, the frequencies of the VR meetings from different locations for multidisciplinary AE firm Merrick during COVID-19 is summarized. Accordingly, the frequency of Nearly (30-60%) is recorded as the highest frequency (49,6%) and the frequency of Certainly (100%) is recorded as the lowest frequency (9,9%).

The study showed almost completely that virtual reality technology replaced daily work through remote work, with a rate of 77,7%, according to what the study showed during the covid 19.

Table 6.20: Frequency Table of the Future of the Virtual Reality in the Construction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Its need a lot of many so we didn't use it	20	16.5	16.5	16.5
	We will use this technology just in the argent action	21	17.4	17.4	33.9
	Uses it in some sensitive stage of project	55	45.5	45.5	79.3
	Uses it from the first stage until the final stage of project	25	20.7	20.7	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.20, the frequencies of the future of the virtual reality in the construction are summarized. Accordingly, the frequency of Uses it from the first stage until the final stage of project is recorded as the highest frequency (45.5%) and the frequency of (Its need a lot of many so we didn't use it) is recorded as the lowest frequency (16,5%).

The study showed that money is not the biggest problem to benefit from virtual reality technology in the construction which the percentage reach 17,4 %. Additionally, the study demonstrated that the use of virtual reality technology offers the biggest benefits in a number of areas, such as emergency situations, which made up a total percentage of more than 83%, indicating the significance of employing virtual reality technology in construction .

Table 6.21: Frequency Table of the Relationship VR Which Be Good to use in the Future

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Artificial intelligence	27	22.3	22.3	22.3
	military industries	26	21.5	21.5	43.8
	Business	29	24.0	24.0	67.8
	education, medicine	39	32.2	32.2	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.21, the frequencies of the relationship which be good to use in the future are summarized. Accordingly, the frequency of (VR with any benefit field in the life future education, medicine is recorded as the highest frequency (32.2%) and, the frequency of VR with military industries is recorded as the lowest frequency (21.5%).

The study revealed that the use of virtual reality technology is anticipated to be widespread, especially in sensitive areas like medicine and military technology, which highlights the significance of this technology, the context in which it will be fully implemented, and the advantages that will result from its application.

Table 6.22: Frequency Table of Percent of the Safety Will Be Useful If We Used the (VR) In the Construction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Reduce the injuries and accident nearly (30%)	28	23.1	23.1	23.1
	Reduce the injuries and accident nearly (60%)	69	57.0	57.0	80.2
	Reduce the injuries and accident nearly (100%)	17	14.0	14.0	94.2
	Affect a little not reach to (10%)	7	5.8	5.8	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.22, the frequencies of percent of the safety will be useful if we used the (VR) in the construction is summarized. Accordingly, the frequency of (Reduce the injuries and accident nearly (60%)) is recorded as the highest frequency (57%) and, the frequency of Affect a little not reach to (10%) is recorded as the lowest frequency (5.8%).

One of the most crucial considerations throughout the building phase, regardless of whether it relates to the employees or the instruments employed in the process, is safety. With the help of this technology, we can decrease the number of injuries and accidents that could happen during the work period through careful review or anticipation of their occurrence, providing an environment that is as safe as possible by more than 75 %. This percentage is a high indicator to maintain a work environment free of accidents as much as possible, as this matter helps in many ways, for example, reducing time and cost and avoiding things that lead to disasters before they happed virtual reality technology is significant and required nowadays. In building projects, particularly large-scale one.

Table 6.23: Frequency Table of the Best in the Future VR and Related Technologies Instruction Engineering Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desktop-based VR	21	17.4	17.4	17.4
	based 3D game- VR	28	23.1	23.1	40.5
	BIM-based VR	53	43.8	43.8	84.3
	Augmented Reality	19	15.7	15.7	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.23, the frequencies of the best in the future VR and related technologies instruction engineering education is summarized. Accordingly, the frequency of (BIM-based VR) is recorded as the highest frequency (43.8%) and, the frequency of Augmented Reality is recorded as the lowest frequency (15.7%).

The study dealt with more than one topic related to the nature of the relationship between virtual reality with several diverse topics, but it was found that building information management technology is the most interconnected compared to other technologies of 3D and actual reality and its importance, but the building information management technology remains the most integrated with a percentage of more than 40%.

Table 6.24: Frequency table of the best during construction Utilization of Virtual Reality in Construction Engineering Education and Training

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architecture Visualization and Design Education	42	34.7	34.7	34.7
	Construction Safety Training	30	24.8	24.8	59.5
	Equipment and Operational Task	20	16.5	16.5	76.0
	Structural Analysis Education	29	24.0	24.0	100.0
	Total	121	100.0	100.0	

Source: (Adwan, 2023)

In table 6.24, the frequencies of the best VR Application in Construction Engineering Education and Training are summarized. Accordingly, the frequency of Architecture Visualization and Design Education is recorded as the highest frequency (34,7%) and, the frequency of Structural Analysis Education is recorded as the lowest frequency (16,5%).

Since virtual reality in architecture relies heavily on imagination, and the majority of the factors in this section of the study are close to each other, it is only natural that there would be a gap between the architect's perception factor and the other factors, which in this case was greater than 35%.

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Through the study, it finds that with the accelerating scientific development every day, modern construction methods must be in conformity with the requirements of the times and development. Provide an appropriate scientific environment for this matter.

It also finds through the study that the owners of large companies and investors do not have sufficient experience to deal with virtual reality technology, so in order to avoid any loss, the first defect, especially since there are no complete studies that show the extent of investment feasibility of using virtual reality technology and what is the expected return from this matter in projects for that They resort to avoiding working with virtual reality technology.

By reviewing the literature, books, and case studies, and with the development we are witnessing today, there was a need to conduct a study that opens the horizon to shed light on virtual reality technology while opening the horizon for companies and investors to invest in digital technology and its tools, especially after the reports that proved the success and efficiency of virtual reality technology in various sectors and to block the road For any technical doubts as follows:

- What is BIM technology, what is the importance of its work within the scope of construction work, and how is it fully applied?
- How can we use BIM technology with virtual reality technology?
- What are the additions that the process of combining virtual reality technology and BIM technology can provide in the fields of industry and education?
- What is virtual reality technology and what are its classifications and scope of work within the different construction systems
- What are the obstacles that we may encounter while using the two

technologies together during the construction phase?

- What are the limitations and challenges of integrating VR in the Construction industry?

7.2 Recommendations for Future Work

While working on this research, the aim was to shed light on the technological technologies that can be linked to virtual reality technology for application in the design and construction processes and to adopt them mainly in construction companies, especially for special projects.

In the beginning, since the virtual reality technology is new and rarely used, the following things must be done

1. Conducting integrated courses for employers that show the importance of using virtual reality technology, how the use of virtual reality technology reflects on work performance and progress, and what are the advantages and gains that the use of virtual reality technology can add
2. Through the study and with the technological development in the world, it is necessary to implement more special studies and researches that deal with virtual reality technology, especially due to the lack of complete information related to this technology and its full working mechanism as follows:

Within the systems that seek to develop the construction and building processes, it was noticed that the construction and construction processes faced various problems and events, so there was a need for an auxiliary technology in this matter to be worked on and linked to virtual reality technology, especially after many reports that proved how the existence of BIM technology caused a resounding revolution Within the construction community, which encouraged many to be open to adopting digital technology and its tools, by integrating virtual reality technology with BIM technology within the unique construction sectors, we can achieve the following:

1. Conducting integrated feasibility studies on the investment feasibility and expected returns from using virtual reality technology over other technologies, while working on determining the scheduling for a group of projects that will be applied simultaneously under different conditions that

give an addition to the value of time, cost, quality and safety within these projects and compare them with projects established under the same conditions using other techniques.

2. Is it possible to work on small projects within a group of investors or through partnership between the state and the owners of private companies through which virtual reality technology is implemented and linked with several modern technologies and the economic and investment feasibility is extracted within precise conditions
3. There are many related fields that still need to be linked to virtual reality technology, such as artificial intelligence in all its forms, augmented reality, laser scanning, and mixed reality, in addition to genetic and atomic research systems.

It is recommended that the effect of the using of VR on the project cost investigated.

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RESUME

Mohameed Ahmed ADWAN

OBJECTIVE:

As a civil engineer, I aspire to be a manager for the largest engineering and real estate companies in order to achieve quality and safety for clients in line with the requirements of the modern area.

EXPERIENCE:

Sck company 08_06_2018 - 01_09_2019 Manager
The field of work of managing the production and manufacturing department of the perfume manufacturing plant, with supervision of exits and imports.
AREN REAL ESTATE 01_02_2020 - 01_11_2021 Call center
I'm Working as call center representative.
Number one 01_11_2021 - 02_06_2022 Call center
I'm Working as call center representative.
Advice consultant 02_06_2022 - Until now Call center.
I'm Working as call center representative.

EDUCATION:

Palestine university 2012_2017 Civil engineering Very good
Gedik university 2020_2023 master's degree

PROJECTS:

Foundation company Establishing many companies from the starting point, entering competition in the labor market, promoting closed companies, introducing them again to the labor market, and competing vigorously.

SKILLS:

Sales Team
Building working under pressure
Solving problem
Program skill MS project Office
Auto cade CRM

LANGUAGES:

Arabic language as native
English 75%
Turkish 25%