VIRTUAL REALITY
IN ARCHITECTURE
PROJECT REPORT

A DISSERTATION REPORT

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Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report "**VIRTUAL REALITY IN ARCHITECTURE**" is the Bonafide work of SREENIDHI who carried out the project work under my supervision.

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ACKNOWLEGEMENT

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Thank you

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VIII semester

311318251137

ABSTRACT

IMMERSING ARCHITECTURE BEFORE ARCHITECTURE THROUGH VIRTUAL REALITY

A BRIEF ABOUT THE PROJECT

The importance of the use of advanced technology, such as the popularity of virtual reality in the architectural space, is increasingly necessary. There is an ongoing need to put the use of this technology at the professional level.

Virtual reality (VR) refers to a computer-generated environment in which a person participates and determines the performance of the space.

The advantages of using this immersive experience is in the way they can be used early in the stages of thought and till the execution phase in order to further explore the relationships between different spaces, light, construction, and physical. The use of focused representation allows for the opportunity to quickly understand and comprehend these design elements, as opposed to just looking at a scale model or visual presentation. People who may not be associated with the work of a designer or architect may not be able to understand the relationship of space and scale if they look at a two-dimensional supply, however, the use of virtual reality is very common and can evoke positive responses in the same way physically. properties can.

This paper examines how VR is used in architecture. It is a process-driven study that enhances its extensive function as a cognitive function and research aimed at understanding the implications of understanding spaces in VR.

It concludes by identifying vr as an exciting new phenomenon, with its own set of rules, pros and cons very helpful to the industry. This approach therefore enhances user experience as it becomes a major part of interacting with the environment while designing.

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CHAPTER 1 – INTRODUCTION

AIM :

The development of the tech industry has lead to its role play in producing productive workflow . the effective utilisation of tools like virtual reality and its potential contribution in architecture is going to be the next great leap after the transition of manual to digital process . This paper aims to understand the high fidelity architectural visualisation that is significantly contributing to the design industry .

OBJECTIVE :

Judge the practicality of VR in architecture

Applications of VR in architectural education

How to effectively increase the communication between architect and his client with its impact

RESEARCH QUESTION :

What is the Role of VR in architecture in understanding spaces better ?

How to use VR to design effective solutions for presentation and communication ?

how is the complexity reduced in the design process and decision making process ?

is VR more effective than 3d models and 2d drawings ?

SCOPE AND LIMITATIONS

The research will cover the implications and benefits and the potential of virtual reality in the use of architectural design .

LIMITATIONS:

Paper will not be exploring solutions to induce VR into architectural field rather focus on analysing its potential and giving an immersive experience in design process paper doesn’t involve the use of AR and only talks about role play of VR

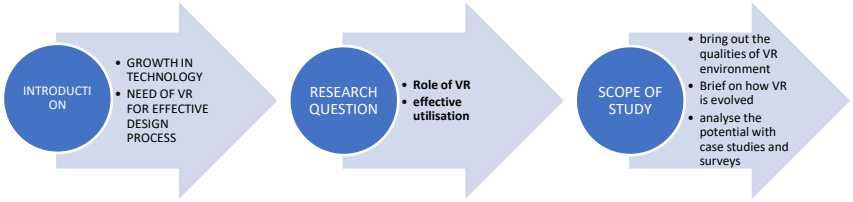
SCOPE :

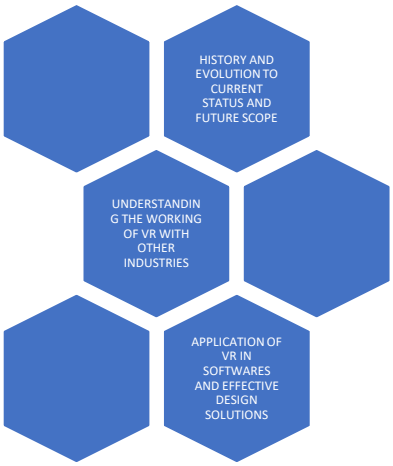
Research and bring out the qualities of VR environment .

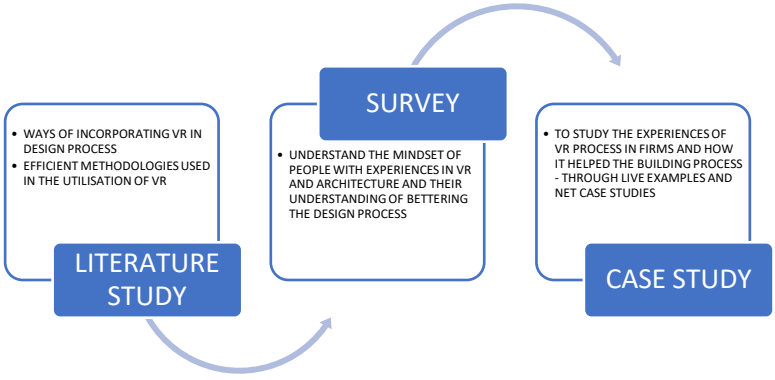
Brief on how VR is evolved today and its existence in the professional field .

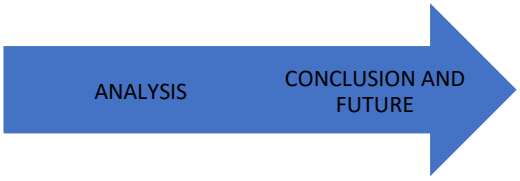
Show the use of VR and how can it be fitted in architecture world

METHODOLOGY









RESEARCH WORKFLOW CHART

CHAPTER 2- LITERATURE REVIEW

COMPLEXITIES AND UNIQUENESS IN PROJECTS

understanding how vr is implemented in the design process with the help of case studies

OVERVIEW OF VR IN ARCHITECTURE

development of virtual reality vr system components benefits and potential of vr in architecture types of vr increasing immersivity and interactivity through vr

CURRENT PRACTICES WITH CASE STUDIES

challenges in design decision process early design decision and design review engagement of end users and stake holders in project

1. CASE STUDY 1: Explains how vr is used during the design review and the design approval for a railway tunnel projects in norway
2. CASE STUDY 2: Explains how vr implemented as a decision-making tool in pelletizing plant in sweden
3. CASE STUDY 3: Explains how vr used for understanding the spatial arrangements in university project in brazil.

IMPORTANCE OF DESIGN DECISION:

Decisions are an important part of the construction industry at every stage. As there are a few phases involved from the concept phase to project delivery, the decision-making process tends to be complicated. In the context of such decisions, it is advisable to use “different support mechanisms ”. High project costs, poor quality, delays and inadequate production are the result of poor planning and management, according to the conclusions of a few studies previously conducted . The tasks followed in the construction process are design, development, integration and construction. Even though some aspects may differ greatly from one project to another, the tasks and decisions are essentially the same. “The decision-making process is crucial to the success of any construction project. Wrong decisions can be costly in terms of time, quality, cost and relationships ”. This means that in a real construction environment, making informed decisions rather than relying on self-understanding and assumption is important. Architectural practitioners and stakeholders must be trained in the decision-making process to come up with a better design .

So there is a visible lack of the right decision-making platform which creates a huge change . people view VR as a tool that brings value to design updates, conveys the purpose of design and improves the efficiency of meetings. Compared to standard offers and standard drawings, the tool allows users to navigate the structure and understand its beauty in a more malleable manner. Using virtual reality to visualise a space or the building allows individuals to quickly navigate with current design features and programs. Creating a common level of familiarity allows people to collectively view the model and enhances interdisciplinary interactions, expertise and technical interactions. It has been noted that the review of 20 projects including VR has raised serious questions that have raised unexpected design issues, which could be easily seen in renders or traditional models. Hence there is a explicit need to bring about effective frameworks for the effective implementation of decision-making theories. The VR concept brings, in fact, a set of new possibilities and solution with its impressive technological capability . This technology allows professionals to find a virtual environment, providing a VR capture environment. Their aim will be to see if the adoption of VR can influence employees' perceptions of how to use it to make construction decisions.

Complexities :

Recently, the size and complexity of the project has seen an enormous increase. Some of the things that add to the complexity of a project include timelines, unexpected domain conditions, structural problems and much more. In addition to the impact of the difficulty and its features, employees often face difficulties in understanding what is expected. A few studies have also shown that traditional project management tools are lacking in dealing with project complexity. This clearly means that decision-making strategy contributes to resolving difficulties in working groups. So this study is focused on reducing the barriers to decision-making.

Uniqueness :

A study conducted by Nam and Tatum (1988) compares construction with the manufacturing industry on five factors: complexity, immobility, costliness, durability and continuous improvement. The authors identify these five elements as critical success factors for the successful working of the construction sector.

VR IN DESIGN DECISION :

If the project is complex like the ones that involves a work flow connecting different stakeholders and that's a huge project on track which takes time for a productive outcome , it is very difficult to maintain contact records and communication within the flow. This complex situation might lead to information inflow and a lost flow of information among participants. Loss of information in a traditional work program is often due to a lack of trust or inadequate communication tools. Two crucial factors can increase communication and remove technical and social barriers which includes increasing trust between affected stakeholders and increasing the confidence and credibility of data transactions that is the proper information about the space in this context . VR can close the communication gap between the design team and the client by producing a more accurate representation of the quality of design that can make a significant contribution to output assessment .

Looking at a case study that's been studied before , To support city planning decision makers, a team of researchers researched the possibility of integrating VR with the Geographic Information System (GIS). The goal from the study was to find out how VR and GIS can provide solutions and ideas to city planners and authorities in the Gaza Strip, Palestine. Provide new processes from existing tools that can support decision makers. The authors argue that using VR in urban planning can improve the way engineers, designers and decision-makers understand a project. They can get real-time design results in the project environment. They can deal with different situations and compare them in a short time. Researchers have used the case to prove the point of using VR via GIS. The study planned a railway line that would connect between several cities in the Gaza Strip. They built several models as alternatives to rail design without focusing on the details of the rail itself. Along with the case study, the researchers compiled a questionnaire of a group of designers, urban planners, and the responsibility for decision-making in the region. satisfaction of participants. For example, 90% of participants announced that a tool is useful to show or add an idea. In addition, the question of decision-making using the traditional method compared to VR and GIS, 63% of participants indicated that they prefer VR with GIS rather than the standard method. The results highlight the potential for VR in urban planning and especially when integrated with GIS. It enhances the designer 's ability to express design ideas. When participants met the city model in VR, they could easily identify the city and become familiar with the streets and neighbourhoods. There were some participants who faced management issues and exploits within VE and some of them pointed out the need for training before implementing the program.

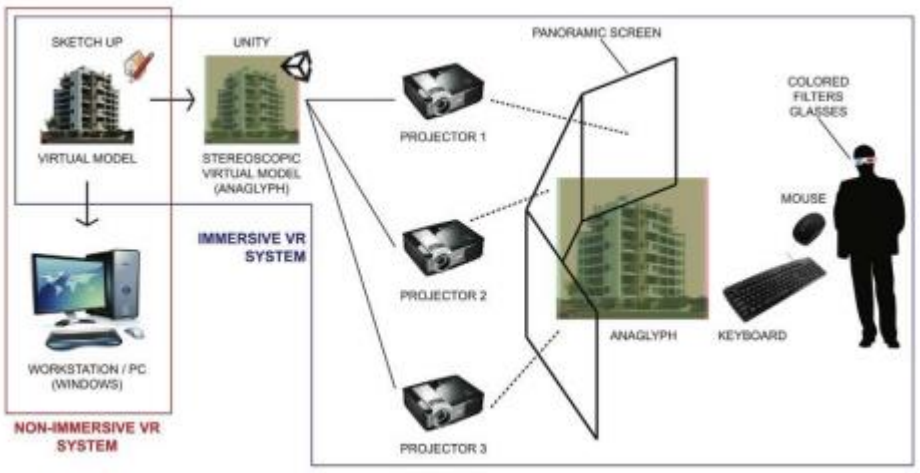


FIGURE 1 : IMAGE : IMMERSIVE VR SYSTEM

FIGURE 2 : IMAGE : NORMAL AND VR IMMERSIVE DESIGNING

OVERVIEW OF VR :

VIRTUAL REALITY , is a 3 dimensional space created by computers and software simulations that recreates an artificial environment which is believed and accepted by the user as real . VR can be enjoyed physically with devices such as special helmets with screen inserted inside of it , sensor gloves or other sensorial electronics that manipulates one of the five human senses.

Virtual Reality (VR) is an emergent computer technology for full 3D-simulations, which has a natural application in the architectural work, due that activity involves the complete definition of buildings prior to its construction. Although the profession has a long tradition and expertise in the use of 2D-plans for the design of buildings, the

increasing complexity of projects and social participation requires better media of representation. However, the technological promise of Virtual Reality involves many sophisticated software and hardware developments. It is based on techniques of 3D-modelling currently incorporated in the majority of drawing software used in architecture, and also there are several tools for rendering, animation and panoramic views, which provide visual realism. But other capabilities like interactivity and sense of immersion are still complex, expensive and under research. These require stereoscopic helmets, 3D pointers and trackers with complicated configurations and uncomfortable use. Most advanced installations of Virtual-Reality like CAVEs involve much hardware, building space and restrictions for users. Nevertheless, diverse developers are working in Virtual-Reality user-friendly techniques and there are many initial experiences of architectural walk-throughs showing advantages in the communication and development of designs. Then we may expect an increasing use of Virtual Reality in architecture

VR offers a more realistic approach . It is especially useful during the conceptual stage where it helps the architect to comprehend key elements if the project and deliver more a realistic message . The virtual simulation allows the individual to interact and explore the VR as if it was real . This gives the user a 3D environment by using headsets , and this allows a better understanding of objects in space , materials perception and more accurate calculations .

Immersive vs. Non-Immersive VR :

Both immersive and non-immersive VR were useful in the design process. Immersive VR, with a tracked HMD and wand, offered the designer a better perception of space and the opportunity to see the design from the inside. At the scale of a person within the building, the designer was able to examine details and connections more intuitively with an easy-to-control viewpoint. This became very useful later in the design process, as the designer was able to detect minor flaws in the model. Non-immersive VR, with a monitor and spaceball, offered higher resolution and higher frame rates, both of which became necessary as the model increased in complexity. The non-immersion offered easier and quicker manipulation of the viewpoint. This was useful for moving around the exterior of the building for fly-throughs for presentations.

Level of Detail :

Once a critical threshold of detail was represented in VR, the designer was able to perceive spatial characteristics of the design that may not have been apparent with other design media. Before the complexity of the model reached a certain level, the use of VR as a design tool seemed to be a viable, but not a unique, tool of representation. The real-time simulations became more useful as a design tool as the level of detail of the model (color, transparency, and geometric complexity) increased. However, the level of detail needed to be kept in check to keep the frame rate at an acceptable level.

The challenge presented by this conflict required both the generation of a second, more detailed model, and the skills of the designer to abstract the models. Although more powerful geometry engines are continually being developed, it is unlikely that we will ever be satisfied with the level of detail that can be simulated in real time. This may indicate a need for new ways to display complex geometry to the viewer, both in terms of rendering algorithms and in terms of the arrangement of the database. New algorithms need to be developed such that complicated objects can be displayed with a certain level of abstraction. Currently, designers and modelers must make decisions about which aspects of a design are most critical to its character, and remove polygons which are not. This process is time consuming and subjective, relying on skills and intuitions of the designer or modeler. It would be more beneficial to design in digital media if there were algorithms to simplify geometry yet maintain its aesthetic character. In addition to such abstraction in the display of complex geometry, the database could be arranged in a "hypergeometry" format. Such a format could be developed so that higher levels of detail are represented only when a specific portion of a design is being studied. With the database arranged in such a manner, a designer in a room, for example, could pick a specific object or detail, and be presented with more information (geometric and alphanumeric) about that particular condition of the design. Such a "hyper-geometry" format would be consistent with the way architects are accustomed to representing their designs, with overall views as well as blow-ups and studies of typical and atypical details.

Immediacy of the Medium :

Because the simulations were performed weekly, after exporting and translating files from the CAD database, there was no immediate feedback from the walk-throughs. Although VR was useful for evaluating the three-dimensional model, it was not useful during the conceptualization of the design. Instead, the design was developed using a combination of sketching and three-dimensional CAD modeling, followed by simulations in real-time. If an inclusive modeling package was available to designers during conceptualization of design ideas, digital models A Critique of Virtual Reality in the Architectural Design Process 7 could be generated in much the same way that physical models are constructed to enhance the perception of a design developed by drawing. If the VR medium could provide the immediate feedback of CAD or more traditional design media, it is entirely possible that VR could replace "modeling" as CAD is replacing (or has replaced) "drafting." Two-dimensional media offer a limited means of representing three-dimensional space. Three-dimensional media enhance the perception of three-dimensional space. Designers need a digital design medium which allows them immediate, direct, and more intuitive control over their three-dimensional design, and VR can help. An inclusive, three-dimensional, world-building toolkit that matches the sophistication of today's CAD software would supplement, but not replace, other design media. Such software is sorely needed before VR can significantly enhance the design process.

Presentation Tool

The videos of the walk-throughs to present this project gave design critics the opportunity to visualize the design as it developed. They replaced the need for physical models and made clear what was not apparent in CAD drawings. The response from design juries was very positive, much more so than expected. Design critics often found the taped "walk-throughs" very convincing and conveyed that the design would make a very believable building. This says much about VR as a presentation tool; professionals and design critics, not just clients and laypersons, are able to visualize ones design intentions more clearly with VR than with traditional means of representation. However, several design critics and jury members commented that they would have gotten more out of the experience had they been able to walk or fly through the design themselves rather that depend on views from a particular path flown for the presentation. A VR system was unavailable to them because of the high cost and complexity of moving it to the place of presentation. Even if the system was available to them, it would have been time consuming for each of them to walk through the design individually, and awkward to discuss the design with others not experiencing the simulation in three-dimensions. Clearly, this problem could be addressed by the introduction of an inexpensive, multiple-participant VR system.

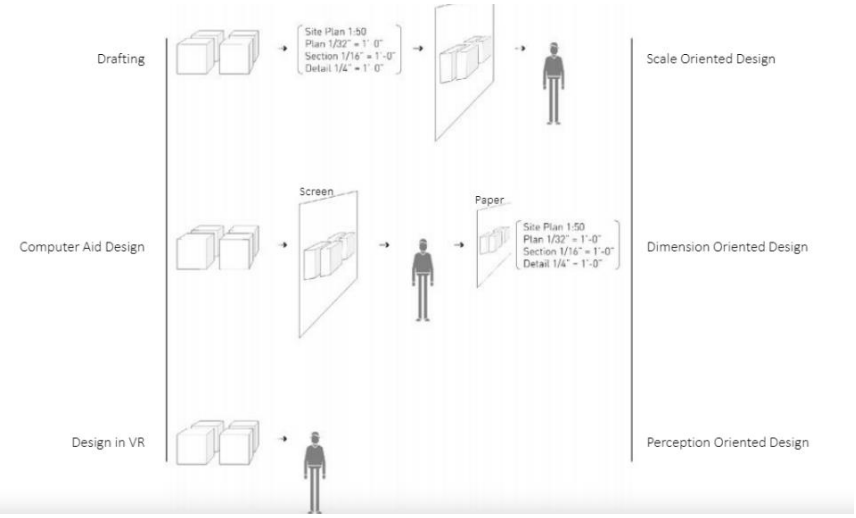


FIGURE 3 : IMAGE : DIFFERENCE OF VR AND TRADITIONAL WORKING SPACE WITH RESPECT SCALE

Experiencing a project spatially rather than abstractly also allows for the designer to better understand the physical experience of the building, which allows for them to make more accurate assessments of the comfort level of the space, by judging things such as lighting or spatial characteristics, before presenting their designs to clients.

FIGURE 4 : IMAGE : TYPES OF VIRTUAL REALITY

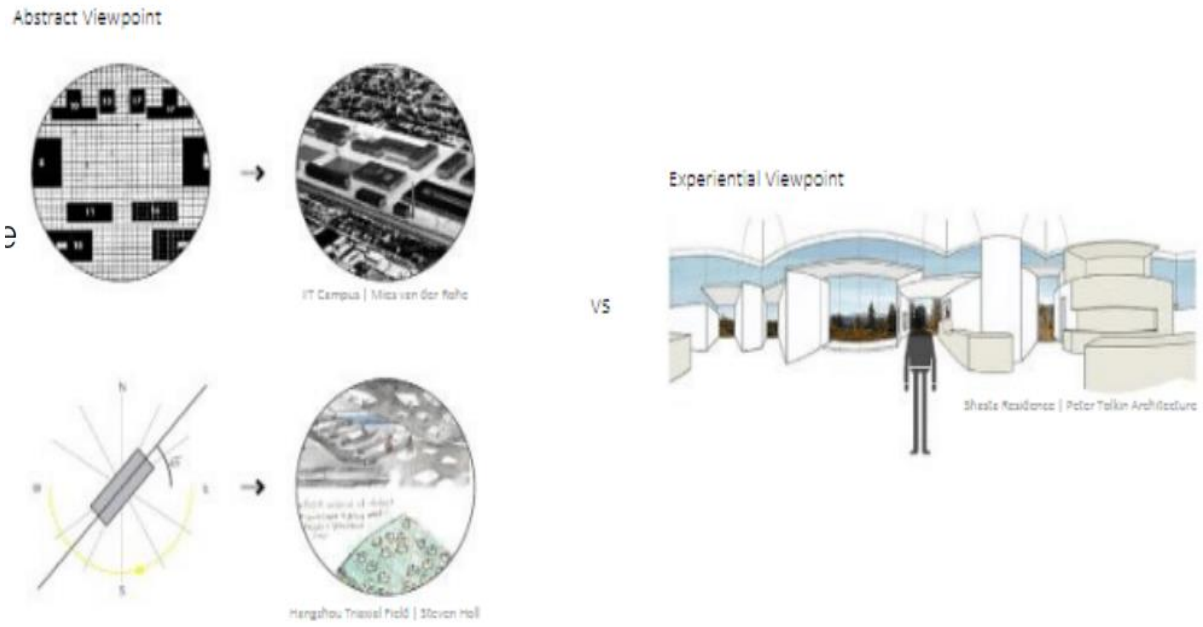


FIGURE 5 : IMAGE : DIFFERENT VIEWPOINTS OF THE VIEWERS

WHERE WE ARE NOW :

CURRENT STATUS IN TECHNOLOGY :

The first fifteen years of the 21th century has seen major , rapid advancement in the development of virtual reality . Computer technology and 3D graphics capabilities has enabled has continued to drive the development of consumer virtual reality unabated. Depth sensing cameras sensor suites, motion controllers and natural human interfaces are a part of human computing tasks. This technical definition states that virtual reality is a simulation technology implemented through the use of headsets and physical props, such as controllers and sensors, to impose a realistic multi-projected environment on a user. VR stimulates and brings a user into a rendered scene by allowing them to look around, navigate and interact with objects in the artificial environment.

Virtual reality previously existed solely in the laboratory sector, specifically as a medium for research and development purposes in the educational, medical and rehabilitative fields. In the past decade, the breakthrough of accessible virtual reality into the public realm has spurred a deep interest in the technology by designers, architects, and visualization specialists. Any room can be created as a virtual environment into which a user can step, and which can simulate the presence of actually being within that environment. Hence, VR is now seen as a technology to be heralded in the next decade with a transcendent impact on the way human-beings work, perceive entertainment and communicate ideas. As VR closes a user off from the physical world by commandeering sight, it can be used to conceive any space virtually, regardless of whether or not the architectural space exists in the present. Hence, this makes it more diversely applicable to the entire range of work in the architectural realm

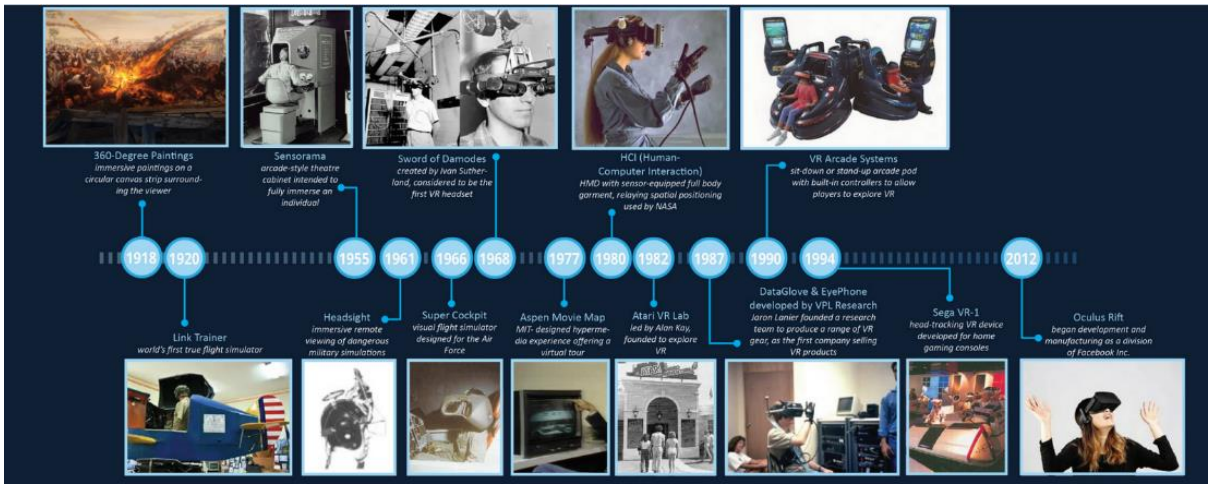


FIGURE 6 : IMAGE : TIMELINE OF VIRTUAL REALITY DEVELOPMENT

VIRTUAL WORLD :

IMMERSIVITY :

For a successful architectural visualization, it is also important to make sure the audience obtains a proper sense of presence .It provides more chances to audiences to act as if they are in the physical world, keeping the audience acquire more accurate mental sense of visualized space. Virtual Reality is the only visualization medium available to significantly increase the realistic effect of architectural visualization, transforming architectural visualization into an immersion experience. It can help architects, clients, and other participants in architectural design understand the design idea more accurately and make a more informed decision.

INTERACTIVITY :

The relation between people and the physical world is a kind of interactive connection.This interactivity makes up an important part of the experiencing in the physical world.In the experience of virtual reality, the audience can walk through the space, rotate the viewpoint, open the door, move objects, play videos, turn off the lights, and many other interactions.

SENSORY FEEDBACK :

Better than other traditional visualization media, virtual reality also offers sensory feedback to the audience. 49 In most cases, visual feedback is the main sensory feedback in architectural virtual reality. However, aural feedback is also useful to architects in keeping the audience obtain a more realistic virtual experience. The proper sound can be simulated for opening the door or playing a video. Haptic, olfactory, and gustatory feedback need high-speed computers and an advanced interface

Case Study 1 : Design Review And Approval Of Tunnel

Ulriken Tunnel is a part of a 500 km railway road between two big cities in Norway, Oslo and Bergen.The project's main challenge was to construct the new tunnel without disturbing the trains flow in the old tunnel beside the commitment of the project time and budget . In the traditional design, the method of testing and approving the signaling system requires a long time after the signals are installed. Therefore, the design team implemented VR and combined it with the BIM model to enable the train operators to drive and test trains in the VE and before even the tunnel being built . The surrounding terrain environment was created using a drone and then combined with the VR model.

Improving the design process will reflect positively on the construction • Using VR for simulating operation on infrastructure projects could facilitate and speed up design approval

• Design engineers could understand the infrastructure operation better when watching simulating the operation process

• Involving the operation team could help in enhancing the design and finding better alternatives

• The maintenance team could simulate infrastructure maintenance plan even before the project completion.

FIGURE 7 : IMAGE : : PICTURE FROM THE VR MODEL FOR THE DRIVER'S SIGHT. SOURCE: (VANNE, 2017)

case study 2: decision making in mk3 plant , Sweden

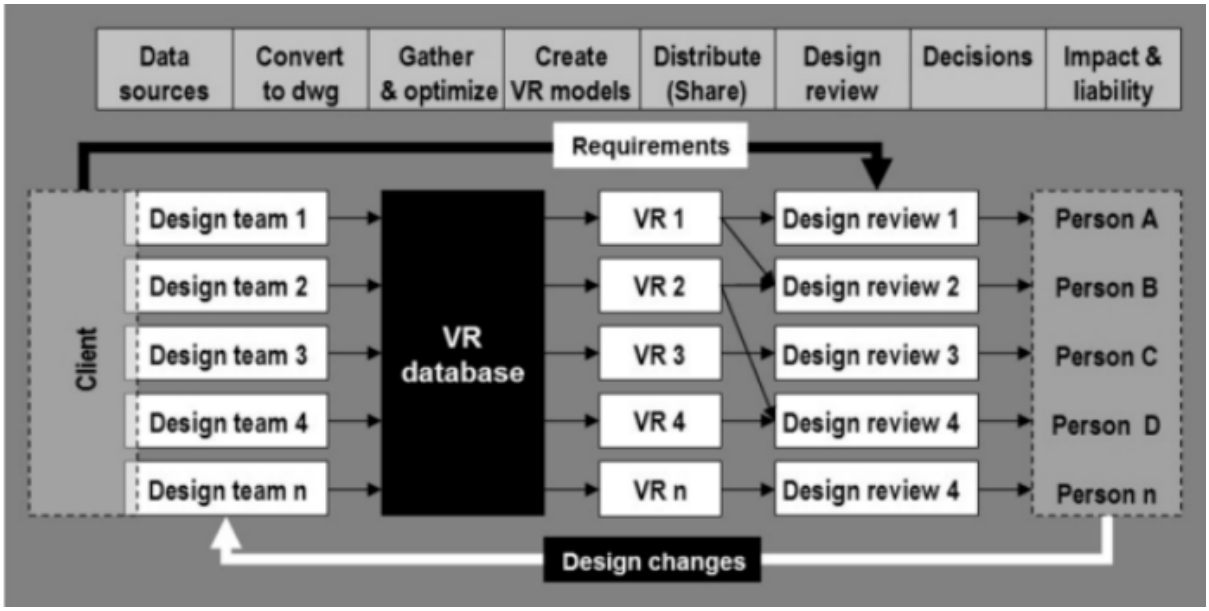


FIGURE 8 : IMAGE : : VR DATABASE WORKMODEL AND FLOW

In the north of Sweden, the Swedish mining company LKAB was planning to build a pelletizing plant called "MK3". The client's priority for the design and planning was the manufacturing process then the layout with the surroundings and finally the construction of the plant, which lead the project team to focus more on the manufacturing process as a priority than the real construction. Because of the complexity of the project and the need to meet the client's requirements, the contracting between all parties formed as Partnering and the project team used CVE in the design process. The CVE implemented directly from the beginning in the design process aiming for improving the communication between partners, reducing the risk, and achieving the goals of stakeholders. The project team produced different VR models for multiple reasons For instance, there were models for planning the spatial space, understanding the facility and machines inside, training the workers, and simulating the production process. Using VR models increased the understanding of information during communication. One example about the use of VR model during the design; sometimes a design team needed to take a decision quickly regarding the design, but the timetable was limited to consult the other teams, as an alternative they could use VR to see exactly the consequences of their design decision on the other discipline.

Access to correct and up-to-date information facilitates client's decision process and positively influences outcomes

- Efficient data exchanging tools such as VR can lead to precise earlier decisions

• Team working, sharing responsibility and trust within a CVE increase transparency and clarity

• Involving clients in daily design activities through VR models reduces the time needed for making decision.

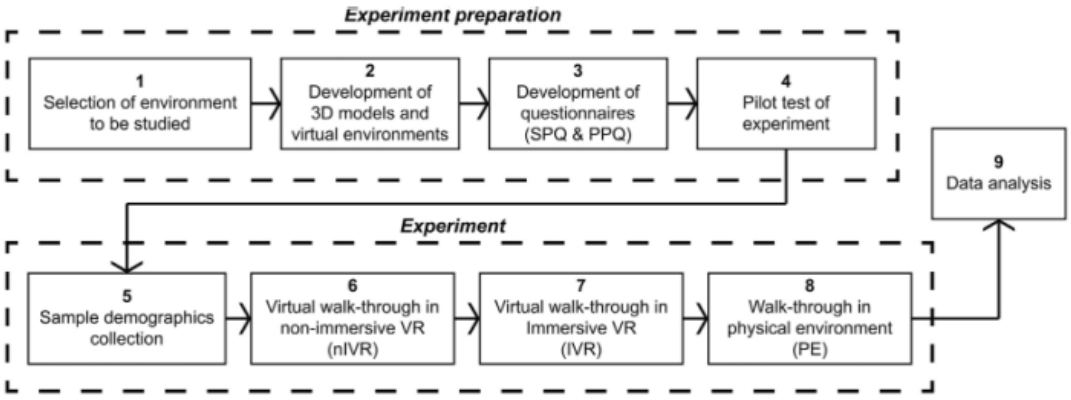


FIGURE 9 : IMAGE: PROCESS OF PRODUCING VR CONTENT THROUGH DIFFERENT METHODOLOGIES

CASE STUDY 3 : SITE PLANNING FOR CAMPUS BUILDING IN CYPRUS

A group of researchers performed a case study in university building in Cyprus to check the benefits of VR in site planning. The main idea from the case study was to compare three different approaches for site planning; 2D drawing, 3D model, and VR model. After the selection of the site, the researchers proposed two different scenarios for planning logistics in the construction. The construction management of the project created the first scenario based on previous experience. For the second scenario, they did some modifications for site access, materials locations, number and location of cranes, waste location, site office, and site orientation. The building selected is approximately 9,000 square meters with a budget of $4.5 million and should complete within a tight schedule of 11 months. . After the selection of the site, the researchers proposed two different scenarios for planning logistics in the construction. The construction management of the project created the first scenario based on previous experience. For the second scenario, they did some modifications for site access, materials locations, number and location of cranes, waste location, site office, and site orientation.

FIGURE 10 : IMAGE : THE SELECTED CONSTRUCTION SITE. SOURCE (MUHAMMAD;YITMEN;ALIZAEDHSAEHI;& CELIK, 2019)

Creating the VR Models The researchers created different models for different scenarios with the help of Autodesk Revit, SketchUp, and Lumion software. Revit used for creating the structural model then the models exported to SketchUp. . Then the model exported to Lumion for final rendering, after that the model was ready for VR experience .

After analyzing the answers of the questionnaires for the participants of this experiment, the researchers discovered that a 2D drawing in site planning is easy to understand and less time-consuming compared to the virtual environment. However, the participants believe that VR increased the understanding of the site planning, the ability to detect collisions, and predicting the site constraints through better evaluation of different scenarios . The researchers recommended that the construction managers have to practice more using the visualization tools, visualize better the site planning and increase the level of details for the site space

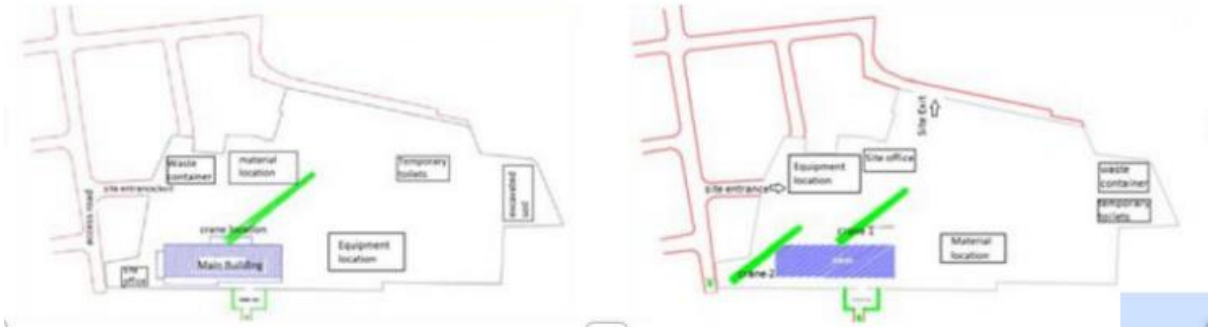
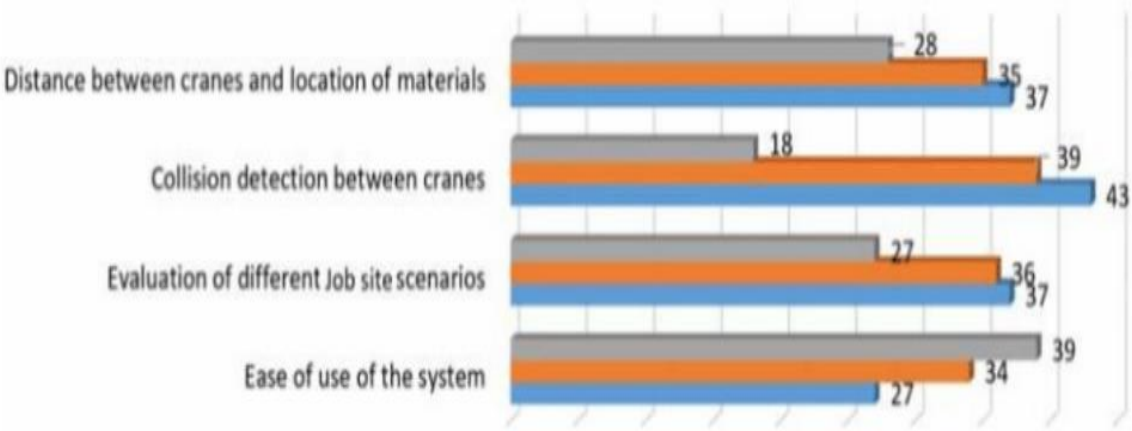


FIGURE 11 : IMAGE : COMPARISON OF 2D , 3D AND VIRTUAL REALITY PLANNING PROCESS

VR is more effective than 3D model and 2D drawings regarding planning the site components and placing materials

- VR is more effective than 3D model and 2D drawings regarding detection of future collisions of construction equipment and testing different site planning scenarios

- VR is difficult to use and handle compared to 2D drawings and 3D models, which means training needs to be considered when using VR.



CHAPTER 3 – RESEARCH STUDY

Virtual reality in architecture can be supported by its immense attribute to the technological innovation shift and its helpfulness in the human designs and understanding qualities.

Methods adopted for data collection and its justification :

Research methods have been explored to provide the basis of collection and analysis of data which is necessary in satisfying the objective of the study . a systematic method of collecting and analysis of the information was done and established to recommend the issues inferred by the whole paper .

Various methods to obtain the data for research study :

Net referencing

Questionnaire

Papers written before

Participant observer

Library study

IDENTIFYING USER GROUP / PARTICIPANT GROUP:



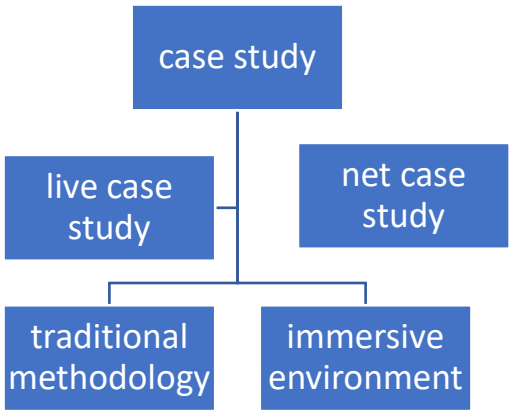


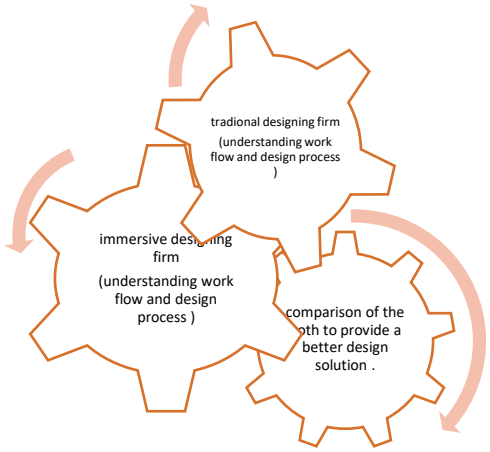
ARCHITECTS BUILDERS PROJECT MANAGERS ENGINEERS STAKE HOLDERS

DESCRIPTION OF THE DOCUMENTATION :

In order to compare the methods of the traditional work environment and the virtual reality induced work environment , both the type of work process were studied through live case studies of 2 chosen firms – walllab architects and LNT constructions . the documentation was done based on the design process that

was followed by each type of firm and whose methodology turned out to be better in terms of design output .





Collecting and Validation of Data :

The first phase of the experiment was data collection and validation. The main purpose of this phase was to measure the reliability of implementing VR in the construction site planning. The researchers used a sample comprising 6 professionals working in the construction industry. I selected participants from different specializations in construction such as construction management, design management, architectural design, and structural engineering who has experience in working with an architect who has worked with the virtual reality in their design process . The participants were from different positions such as BIM specialists, site supervisors, site engineers, architects, design managers, construction managers, and structural engineers. The participants were asked to assess, monitor, compare, and rate three different approaches for site planning 2D drawings, 3D model, and 3D in VR. The rating scale was from one (highly ineffective) and five (highly effective). The researchers categorized the overall rating of the participants as high if it was over 80%, medium if it was between 60-79% and low if it was less than 59%

QUESTIONNAIRE :

ROLE OF VIRTUAL REALITY IN ARCHITECTURE

NAME , JOB POSITION AND COMPANY :

LAKSHMI - HVAC CONSULTANT, L&T

Adithyan- VDC coordinator . L&T

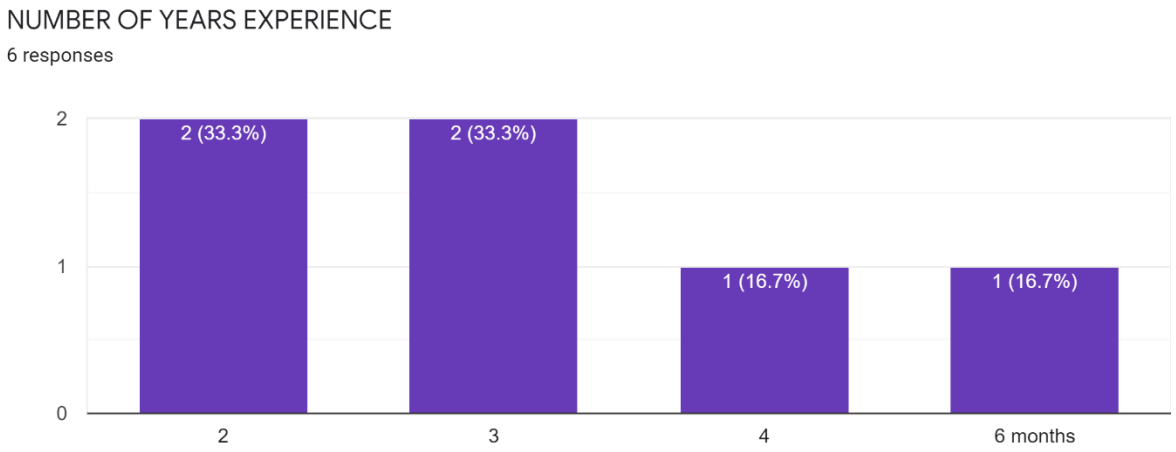
Jagadish Babu Baskar - Construction Analyst / Faithful Gould Inc.

Bharath Venkatachalam - Student assistant at Virtual Review Assist

Usama Kharodia - Intern- VRA

Rohan- Research Assistant, Design for Interaction @ UNStudio

NUMBER OF YEARS EXPERIENCE :



FOLLOWING THE BASIC UNDERSTANDING OF THE VR THROUGH THE STATEMENT QUESTION , THIS QUESTIONNAIRE IS DIVIDED INTO 3 STAGES OF DESIGN PROCESS AND THE EEFECT OF VR IN THESE STAGES

QUESTIONNAIRE :

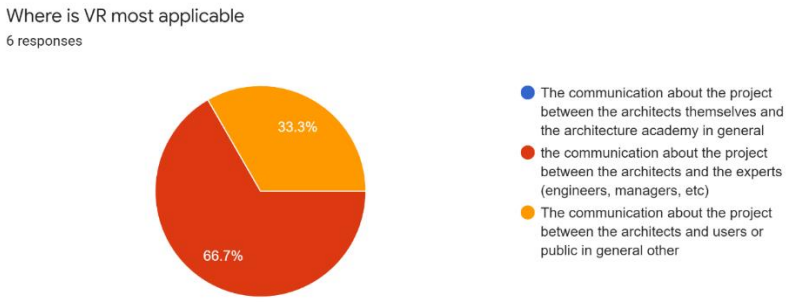
1 . HOW IMPORTANT IS VIRTUAL REALITY IN:

THE COMUNICATION OF THE PROJECT BETWEEN THE ARCHITECTS THEMSELVES AND THE ARCHITECTURE ACADEMY IN GENERAL

THE COMUNICATION OF THE PROJECT BETWEEN THE ARCHITECTS AND THE EXPERTS (ENGENEERS, MANAGERS, ETC)

THE COMUNICATION OF THE PROJECT BETWEEN THE ARCHITECTS AND USERS OR PUBLIC IN GENERAL OTHER

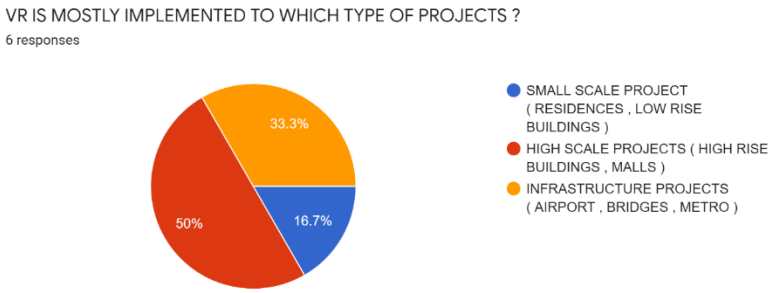
RESULTS :



2. VR IS MOSTLY IMPLEMENTED TO WHICH TYPE OF PROJECTS ?

- SMALL SCALE PROJECT (RESIDENCES , LOW RISE BUILDINGS)
- HIGH SCALE PROJECTS (HIGH RISE BUILDINGS , MALLS)
- INFRASTRUCTURE PROJECTS (AIRPORT , BRIDGES , METRO)

RESULTS :



3. WHAT MADE YOU CONSIDER USING VIRTUAL REALITY FOR THE PROJECT

RESULTS :

-Easier understanding of project goals and issues
-Visualization

-The ability to visualise better in identifying the utility clash
-Small projects require more details
-Ability to visualize and synchronized work flow
-VR provides designers and architects the freedom and flexibility in aiding users visualize and -experience designs that aren't restricted to a physical model.

4.WHAT STEPS WERE TAKEN TO PRODUCE VR CONTENT

_____

RESULTS :

-Outline goal, create assests, assess costs, proceed with algorithm
-BIM models pushed inside VR using enscape
-Making the model BIM complaint and making them available to VR
-3d modeling and rendering
-Understanding target audience and their expectations, Design prototyping - 3D modelling, Integration of IEs (Interactive Elements), Rendering to a VR Game Engine.

5.WHAT WERE THE GOALS SET TO ENDURE BY USING VR

_____

RESULTS :

-Creating HVAC layout for a building
-Coordination review and constructibility analysis
-To experience a real time visualisation
-3d walkthrough videos
-To minimize the time and errors
-Provide the client an immersive experience with interactive elements in a virtual environment.

6.HOW WAS IT DIFFERENT FROM NOT USING VR ?

_____

RESULTS :

-In terms of paper it was more difficult to work, more time taking, VR although difficult to master has made it extremely easy once it has been learnt
-VR allows better visualization and hence better understand the project

-Difficult to make any design changes during construction due to change in scope. This often resulted escalation of in cost factor
-Get a overall idea about the project
-Very time consuming and not accurate
-The client could visualize an almost finished project in virtual reality, provide critical feedback that was to be implemented in designing the final model.

7.HOW DO YOU THINK VR IS GOING TO CHANGE THE ARCHITECTURE

to visualize the project

to the conception of the project

for the communication with the client

for the communication between architects and other experts

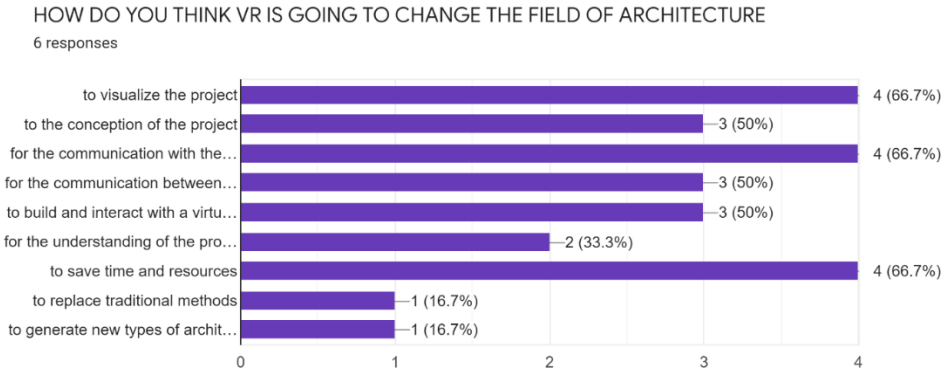
to build and interact with a virtual world

for the understanding of the project to the student

to save time and resources

to replace traditional methods

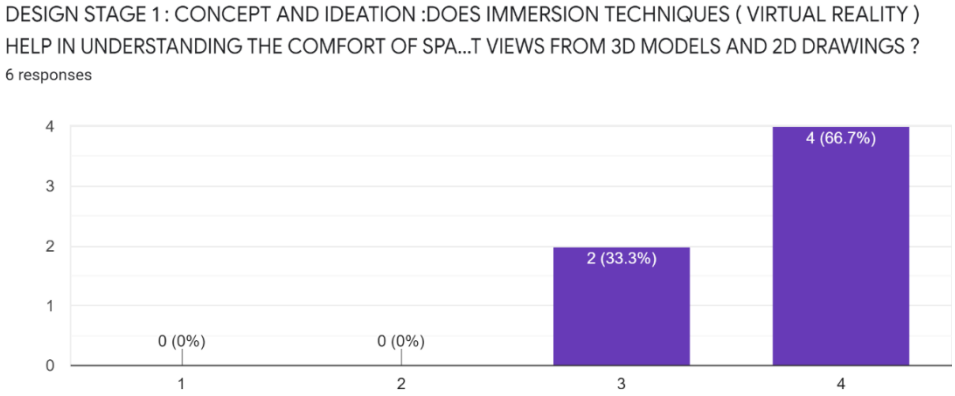
to generate new types of architecture



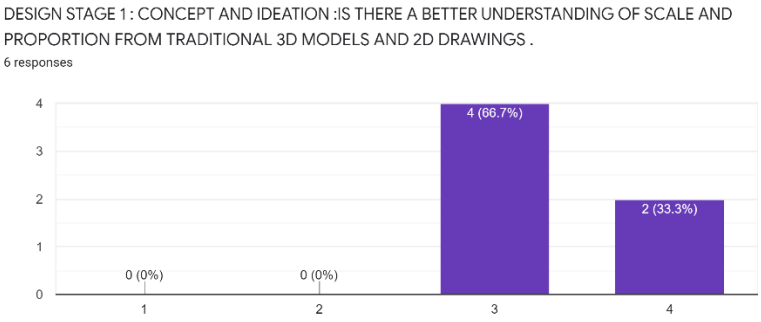
(THE INCRESING QUANTITIES OF NUMBER SIGNIFIES THE EFFECT OF POSITIVE CHANGE FROM THE TRADITIONAL TO THE EXPERIENCE IN VR)

DESIGN STAGE 1 : CONCEPT AND IDEATION

3. DOES IMMERSION TECHNIQUES (VIRTUAL REALITY) HELP IN UNDERSTANDING THE COMFORT OF SPACE BETTER THAN ABSTRACT VIEWS FROM 3D MODELS AND 2D DRAWINGS ?

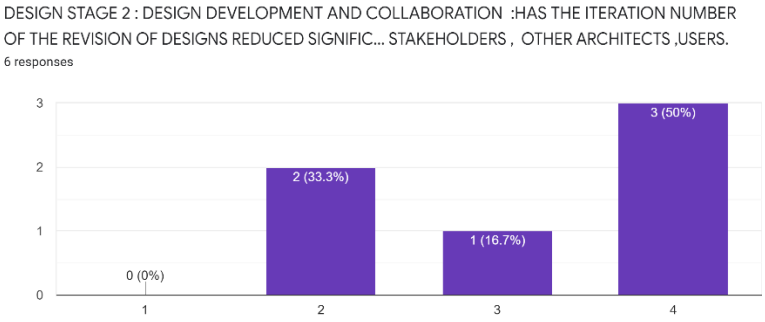


4. IS THERE A BETTER UNDERSTANDING OF SCALE AND PROPORTION FROM TRADITIONAL 3D MODELS AND 2D DRAWINGS .

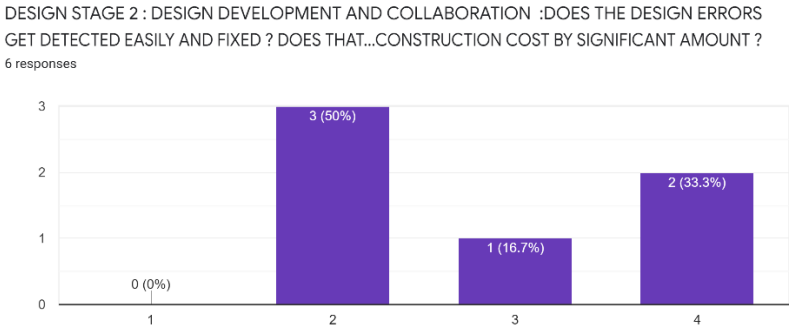


DESIGN STAGE 2 : DESIGN DEVELOPMENT AND COLLABORATION

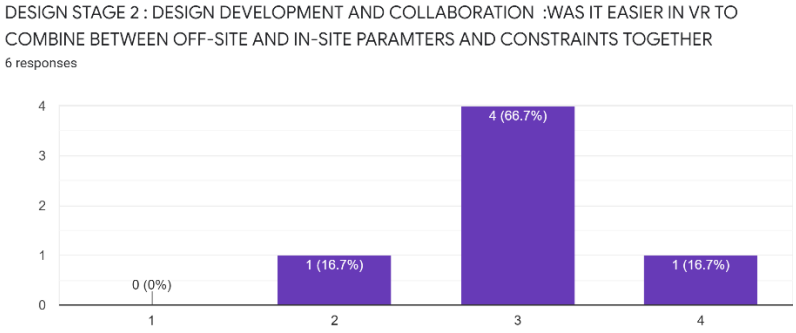
5. HAS THE ITERATION NUMBER OF THE REVISION OF DESIGNS REDUCED SIGNIFICANTLY AFTER THE INCLUSION OF VR IN THE PROCESS OF COLLOBORATION WITH THE STAKEHOLDERS , OTHER ARCHITECTS ,USERS.



6. DOES THE DESIGN ERRORS GET DETECTED EASILY AND FIXED ? DOES THAT REDUCE THE CONSTRUCTION COST BY SIGNIFICANT AMOUNT ?

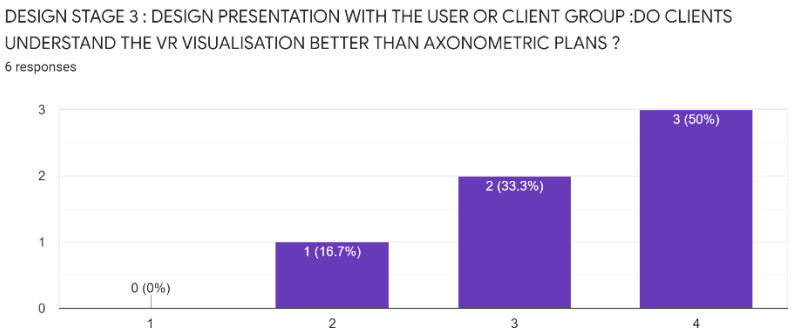


7. WAS IT EASIER FOR VR TO COMBINE BETWEEN OFF-SITE AND IN-SITE PARAMTERS AND CONSTRAINTS TOGETHER

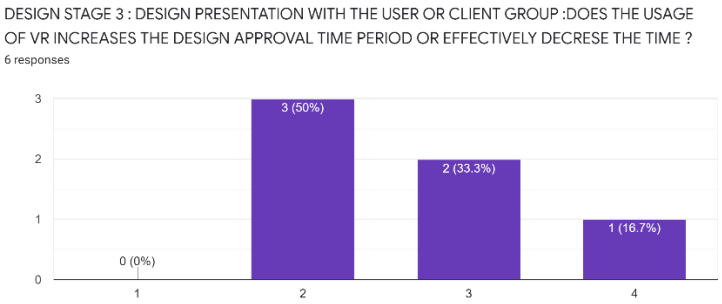


DESIGN STAGE 3 : DESIGN PRESENTATION WITH THE USER OR CLIENT GROUP

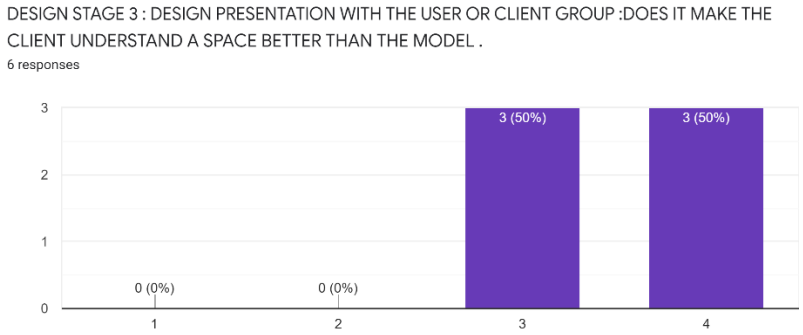
8.DO CLIENTS UNDERSTAND THE VR VISUALISATION BETTER THAN AXONOMETRIC PLANS ?



9.DOES THE USAGE OF VR INCREASES THE DESIGN APPROVAL TIME PERIOD OR EFFECTIVELY DECRESE THE TIME ?

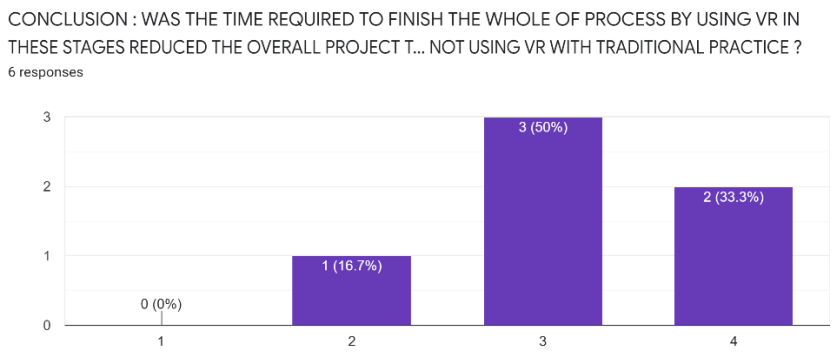


10.DOES IT MAKE THE CLIENT UNDERSTAND A SPACE BETTER THAN THE MODEL .



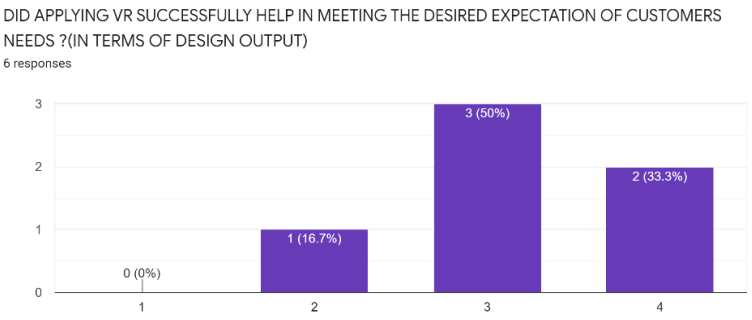
CONCLUSION

11.WAS THE TIME REQUIRED TO FINISH THE WHOLE OF PROCESS BY USING VR IN THESE STAGES REDUCED THE OVERALL PROJECT TIME AS COMPARED TO NOT USING VR WITH TRADITIONAL PRACTICE ?

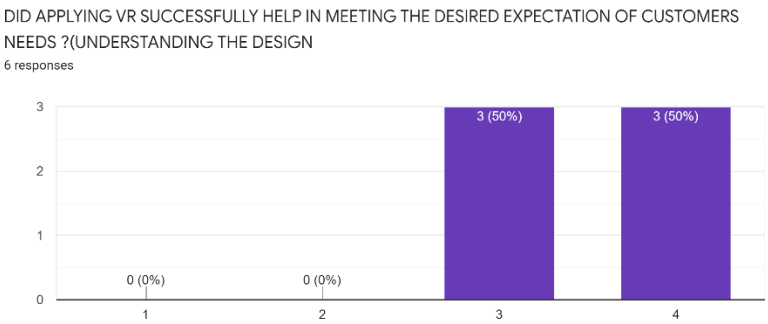


12.DID APPLYING VR SUCCESSFULLY HELP IN MEETING THE DESIRED EXPECTATION OF CUSTOMERS NEEDS ?

IN TERMS OF DESIGN OUTPUT

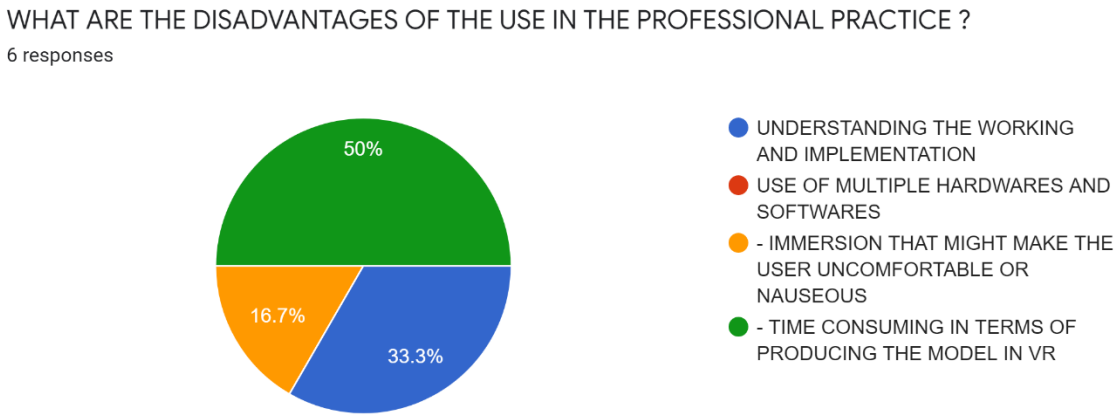


UNDERSTANDING THE DESIGN



13.WHAT ARE THE DISADVANTAGES OF THE USE IN THE PROFESSIONAL PRACTICE ?

- UNDERSTANDING THE WORKING AND IMPLEMENTATION
- USE OF MULTIPLE HARDWARES AND SOFTWARES
- IMMERSION THAT MIGHT MAKE THE USER UNCOMFORTABLE OR NAUSEOUS
- TIME CONSUMING IN TERMS OF PRODUCING THE MODEL IN VR



Results and Discussion:

The participants answered all the questions and provided rates for the design planning for both scenarios in the three different environments and their effect in 3 different stages : 2D Drawings, 3D Model, and 3D in VR. In 2D Drawings, the average rate was 4.5 out of 5 regarding the ease of using the 2D document. However, the participants provided a rating 1.9 out of 5 regarding the sufficiency of the information in 2D drawings for example the possibilities of collision between the cranes was difficult to detect in 2D drawings only. According to the participants' responses, the 3D model increased the understanding of the design plan. This was clear when comparing the overall rating for 2D and 3D; the 3D model was 3.9; However, the 2D was 3.0. The participants provided an overall rating for the 3D model when using in the VR environment by 4.4, which shows that VR enhanced the understanding of the site planning. The participants rated the ease of using VR by 2.9 out of 5, which shows that training might be needed before implementing such a technology .After analyzing the answers of the questionnaires for the participants of this experiment, the researchers discovered that a 2D drawing in planning is easy to understand and less time-consuming compared to the virtual environment. However, the participants believe that VR increased the understanding of the site planning, the ability to detect collisions, and predicting the site constraints through better evaluation of different scenarios . The research recommended that the architects that practice more using the visualization tools ,will help them, visualize the planning better and increase the level of details for the site space. Comparison between the answers of professionals in 2D, 3D, and 3D within VR.

Conclusions :

- VR is more effective than 3D model and 2D drawings regarding planning the site components and placing materials

- VR is more effective than 3D model and 2D drawings regarding detection of future collisions of construction equipment and testing different site planning scenarios

- VR is difficult to use and handle compared to 2D drawings and 3D models, which means training needs to be considered when using VR.

TRADITIONAL WORK ENVIRONMENT :

Location : walllab constructions , office

In this documentation , there is a focus on finding the work flow of a certain design project and how its carried out with 2D plans and 3D models . During the documentation every pain point was identified and and the points where the role play of virtual reality with its tools and applications can make a significant change in the quality of design decision .

Virtual environment system displayed on monitors which is typically categorised as desktop virtual environment (DVE) . The DVE has evolved animated CAD The user interacts with the environment and objects generated by personal computer (pc) through input devices such as mouse , keyboards or joystick .At the same time , the computer will give feedback through several media such as vision from screen , auditory from speakers or touch sensation from tangible interfaces .

Non-Immersive virtual design environments are becoming very common in modern architectural practice. Representation of the design idea usually starts using traditional design media such as sketching and physical models followed by a more detailed phase using CAD on a workstation. Finally, 3D models are built using 3D modelling software outside the virtual world, interacting with the mouse in a graphical user interface of menus and palettes. These 3D models are then experienced on the same computer screen using a VR viewer which supports a more or less photo-realistic display. The keyboard and mouse are used to interact with the virtual environment. The computer screen becomes a window on the virtual world. The designer benefits from the sophisticated interface of the CAD and 3D modelling software packages involved offering a few hundred functions and commands for creating, manipulating and representing design objects. This setup helps improve visualization and exploration of design ideas. It offers a high level of scalability allowing the designer to work on scaled representations such as building layouts then to zoom-in to work on 1:1 details. The designer has the choice between 2D and 3D representations displayed on the screen.

Some packages also include simulation capabilities which help predict environmental performance aspects for example. A significant drawback of this setup is that it includes most of the limitations discussed earlier which are associated with traditional tools and with CAD. However, more recent developments are improving the effectiveness of non-immersive environments. On the hardware side, wide-screen and stereoscopic displays are widening this window on the virtual model and enhancing the 3D experience. On the software side, free-form technologies such as DDDoolz and Sketch-Up facilitate 3D computerized sketching during the early stages of design. non -Immersive Decision Support Environments This setup is common whenever an immersive environment facility is available for shorter periods of time. In this approach the designer works in a conventional non-immersive design environment and takes the design to the immersive virtual environment when the design is almost finished or at distant intervals during the design process. The immersive sessions are helpful for group decisions .Since most of the work is done on a conventional workstation, this approach requires from the designer the least level of adaptation to the new concept of immersive design and offers a very strong decision support tool. However, it does not exploit the full potentials of immersive design. The immersive environment is used as a presentation tool during the final evaluation stage rather than a design environment throughout the entire design development.

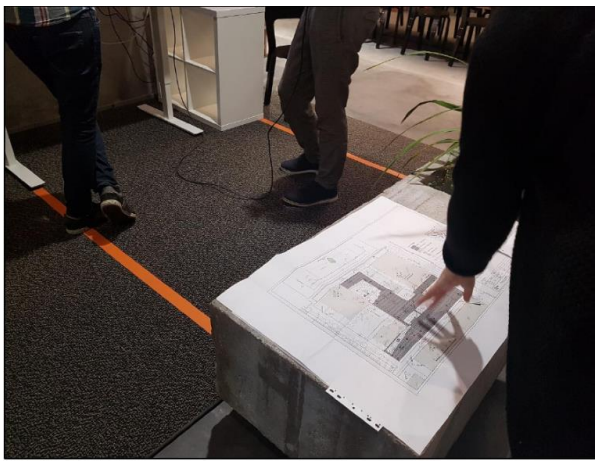


FIGURE 12 : IMAGE : SITE DRAWINGS USED IN THE FIRM

In design , traditional communication approaches may not reveal the details of a clients concerns or requirements . without the full understanding of the client's intention , correcting and adjusting a design can be slow and a painful process . Although designers often use CAD to help visualize potential solutions, clients with limited technical skill cannot be expected to properly use these advanced digital tools .To solve that problem , this dissertation tries to propose a web based tool VR system that could be employed to enable professionals and non- professionals to view and manipulate 3D graphics using regular wed browser . Given the access to an interactive 3D environment , clients would be able to express their design intention through assembling a virtual design using standard design components created by interior

designers . Based on the information collected through communication approaches such as conversation and questionnaire , the interior designer prepared a series of digital design materials and categorized them into catalogues to be displayed on the website . The client then previewed different design options in a virtual environment rendered on a web-page .

Each option was built using the virtual object from the catalogs provided by the designer.This process would allow the client the sufficient time to communicate with the designer .To implement the VR application in the proposed communication Framework this firm presented a specific methodology. the first step was to prepare the virtual design materials used online . They introduce X3D the ISO standard its XML based file format for representing 3D Computer Graphics over the internet and illustrated the web the workflow in converting a CAD based computer model into the X3D format used online . The second step goes was to operate with these design materials in an interactive virtual environment and this firm produced a web-based face and specified the script support required for this interface to function . to examine the feasibility of this methodology a proof of concept 3D was created enabling a client to design interior scene complete with furniture .Having multiple viewpoints allowed the allowed the client the opportunity to preview the design option and desired with solution best satisfying their requirement .

VR IMMERSIVE WORK ENVIRONMENT :

Location : LNT constructions , virtual reality lab

In this documentation , there is a focus on the applicability of implementing VR in a full 3d immersive design environment enhance communication, collaboration, and coordination within the project team itself and with the client. Furthermore, and because of the overseas project, there is a need to overcome challenges regarding the project location and possibility to use VR with photogrammetry instead of visiting the actual site. The main goal of the documentation was to explore and practice the integration between VR, laser scanning, and photogrammetry technologies to enhance the communication and collaboration with the client during the design process. Therefore, the client can be involved in the daily design tasks, which will reflect positively on the time, cost and quality of the project.

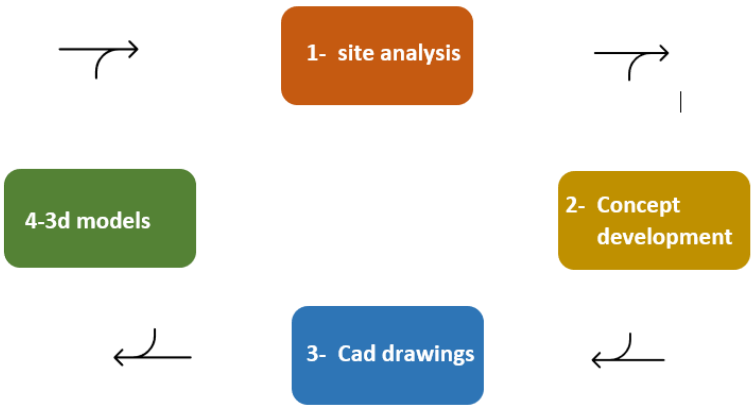
UNDERSTANDING WHERE WAS THE USE OF VR APPLIED :

Communication : Within a VE, the client can have access to the VR model from the office and communicate directly in realtime with the designers. The client can visualize the facility elements in real scale similar to the reality without need for engineering background to be involved in the design.

Collaboration: In each phase, the project team commits a different level of collaboration with the client. VR can influence positively on the collaboration within the design process. For instance, it allows multiple users at the same time within CVE where the client can virtually walkthrough with the engineers and influences the design.

Coordination: The understanding and background for each engineer differs from the other. For instance, structural engineers can easily understand structural elements, materials, and loads however, for architecture engineers it is easier to understand finishing materials, colors, and facade. VR can visualize the project different details regarding structural elements, architecture finishes

Project location: Insufficient information about the site can lead to significant delays. Some sites involve hazards issues and materials, which could be dangerous for humans. With the help of laser scanning, photogrammetry, and drones, it is possible to create a VR model where engineers can walkthrough and investigate the site without a need to visit the site in the nature.



Stages of traditional methodology in which use of VR and its effects can be introduced in every stage

WORK THEY WERE DOING :

The plant needed maintenance and designing for a new heat exchange. The area of the factory is 1200 m², and they created the 3D model of the project using a high quality laser scanner see figure (45). The average point density in the high focus area was 3 mm. The specialists scanned the entire plant within six hours using 60 scan stations with 32 hours of processing time to create the 3D model.

FIGURE 13 : IMAGE : VIRTUAL MODEL VIEWD IN THE VIRTUAL REALITY MODE

SETTING UP THE SYSTEM: SOFTWARE AND HARDWARE:

Participants of the meeting set up the HTC Vive for VR system with the connection of the headset, controllers, and base station to the laptop.

Design Space Software is software developed by 3D TALO (a company located in Finland) that was used by this company to produce the VR content . The software enables the user to export CAD model to a VR environment with multiple editing tools. After the user optimizes the project, it is possible to send it back to the CAD model. The software allows combining between different models such as an architectural, HVAC, scanned data, etc. Multiple users from different locations can use the same model with the ability to edit in the real-time. Within the immersive environment, the user can select useful tools such as measuring and scaling, flying and walkthrough, drawing pipes or cubes, writing notes, and taking pictures. In addition, it is possible to adapt the software for multiple purposes.

After setting up the hardware and installing the software, the participants occupied the room . The groups started to locate the base stations in the room in which they were facing each other in the diagonal line of the room. The trainees made sure that the distance between the stations was 68 not less than 1.5m and not over 3.5m, as specified in the instructions. Subsequently, the trainees calibrated the controller and the headset. The calibration was done by moving the controllers and headset in the area between the two base stations and locating them on the floor. At the beginning, all teams faced

difficulties in setting up and calibrating the tracking area. The problem was because there were two teams in the same room and the base stations were wireless conected that interfered between the two groups.

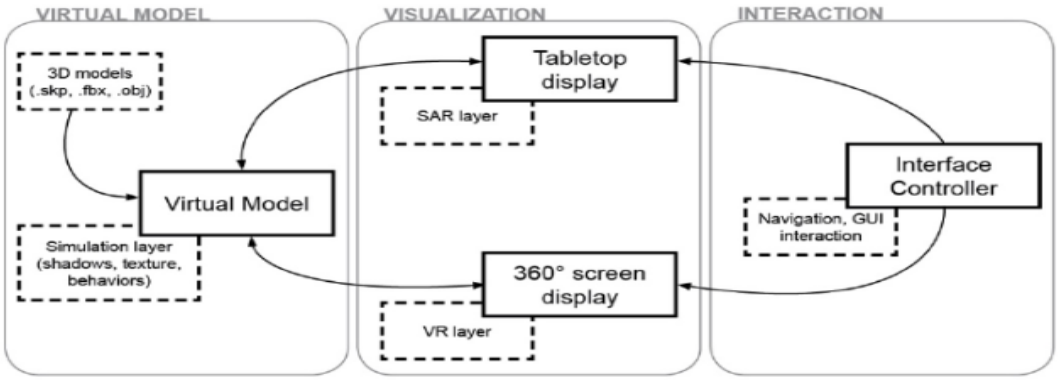
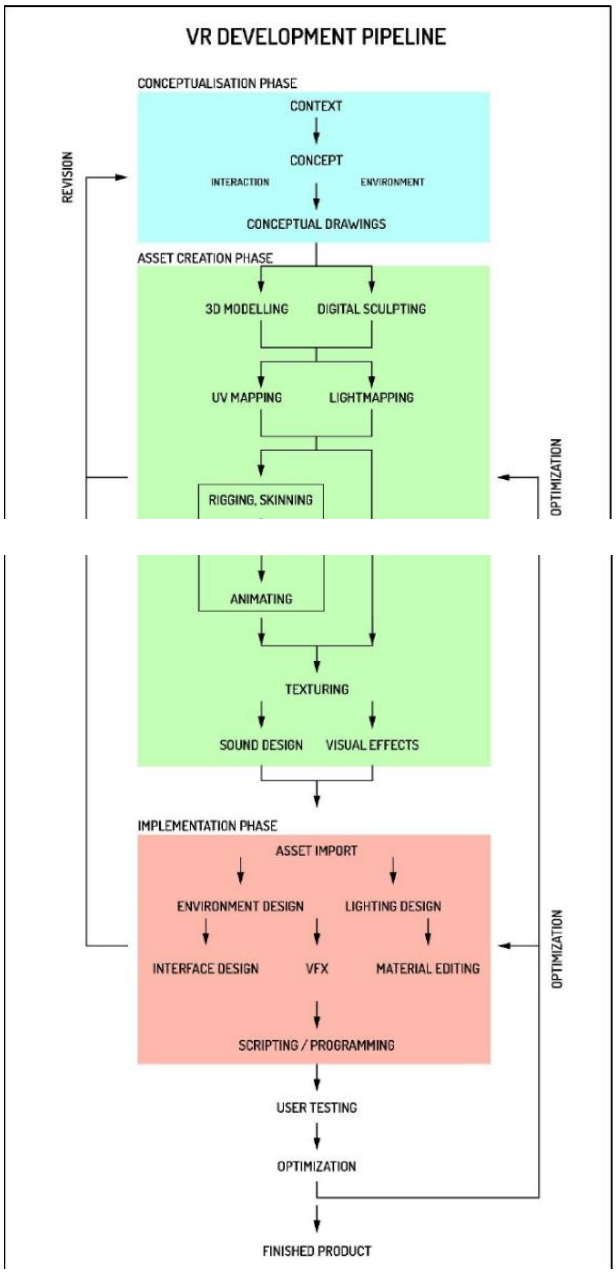


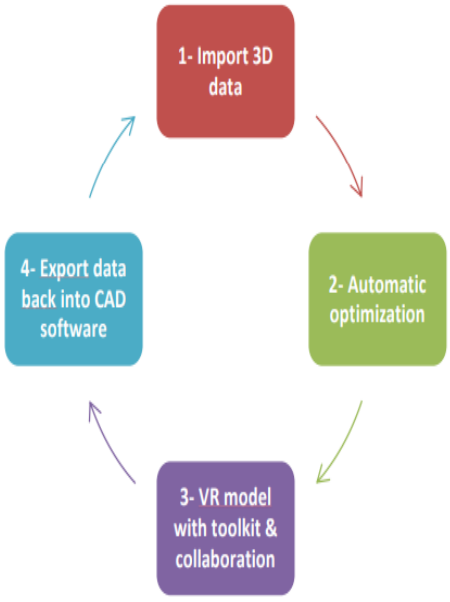
FIGURE 14 : IMAGE : VIRTUAL MODEL TO VISUALISATION TO INTERACTION

WORKFLOW OF DESIGN SPACE SOFTWARE :

The software automatically converts 3D-CAD into VR environment using attribute reader. The process and workflow are straightforward and timesaving. The workflow starts by exporting the 3D-CAD data to a polygon model such as exporting from Navisworks as FBX format. When the file is imported into Design Space software, the software automatically optimizes the file. Then the VR model is ready for editing, collaboration, and communication. After finishing the modification and reviewing the model, the software sends the changes back to the CAD model. In addition, drawing drafts, adding safety instructions, and taking pictures are possible while navigating in the VR model.

The supervisors instructed each group how to use the headset and the controllers to navigate in the VR model. At the beginning, it was important to learn how to maintain balance while wearing the headset. In the VE, the software provides a network represent the obstacles in the room such as walls so that the user can avoid hitting the wall while being immersed in the VR model. The software contains many features that help the user make changes and to navigate smoothly in the model. shows the main features and function.





WORKFLOW OF HOW VR CONTENT IS PRODUCED

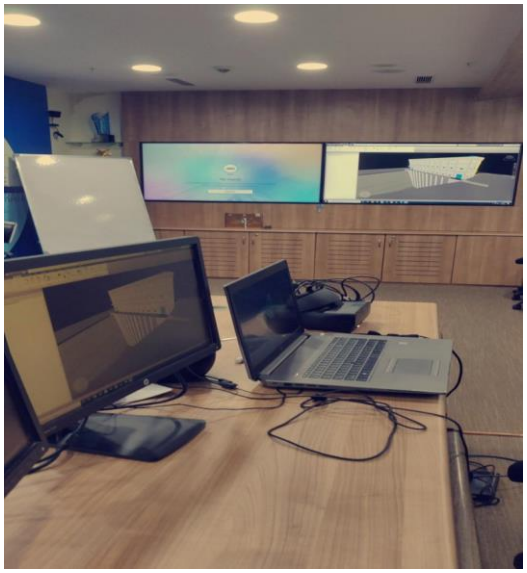


FIGURE 15 : IMAGE : VIEWING THE MODELS IN VR DURING CONCEPTUAL DEVELOPMENT STAGE

FIGURE 16 : IMAGE : DISCUSSION WITH THE CLIENTS

OBSERVATIONS :

- When the model was viewed in the 1:1 scale , the glitches in the plans and clashes between different disciplines seemed to e not be identified but when with viewing the same with VR content , they were fixed immediately .
- The attributes like the space required and provided , for every design feature were causing troubles in making the design understandable by the stakeholders and clients , which was made easier with VR being introduced at this stage .

  For example – How much head room was required Is the feature provided accessible like a valve that passed all standards of easy service access .

- Identifying the construction process called the pre construction planning phase which when viewed in Vr makes the designer understand the flow of how

efficiently it can be built which is a major flaw identified in 2D as these considerations are left unresolved .

- Safety checks are better considered and identified with the VR more than any 2D or 3D models as they don't let us experience it with the real 1:1 scale to actually feel the pain .

  For example – identification of sharp corners , clashes in the design

- With this better identifation and understanding of flow of design has made the supply chain flow easier and not get disrupted as easily as identified in the traditional methodologies .

Conclusion from the study :

- Safety planners could simulate the construction and identify potential collisions.

- VR can provide simulation for the construction equipment and allow predicting future clashes in the site.

- Applying VR in site planning could help to predict the collisions between construction equipment

- VR with the help of laser scanning and photogrammetry could be useful for investigating hazardous sits

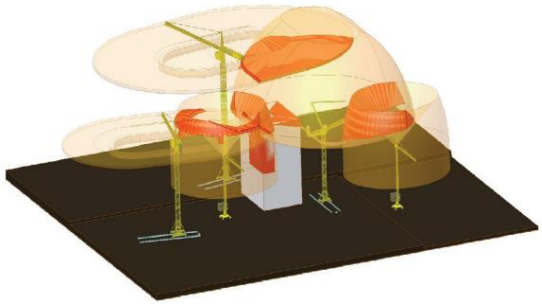


FIGURE 17 : IMAGE : Source: (Ebner;Kammergruber;Horenburg;& Günthner, 2012) 3D MODEL SHOWS POTENTIAL COLLISIONS BETWEEN CRANES AT THE CONSTRUCTION SITE

CHAPTER 4 – CONCLUSION

SUMMARY OF RESEARCH :

Comparison of 2D plans and 3D immersion :

The design process is tracked down and the comparison between the different effect of each stage in making a quality design decision is marked .

SNO	FEATURE	2D PLANS	3D	3D IMMERSION
1	SITE ANALYSIS AND SITE PLAN			
2	CONCEPTUAL DEVELOPMENT			
3	CONCEPT DECISION MAKING			
4	CONSTRUCTABILITY TESTING			
5	DRAWINGS GENERATION			
6	TESTABILITY BETWEEN DISCIPLINES			
7	REVIEW MEETING			
8	SAFETY CHECK			
9	CLASHES AND GLITHCHES INDENTIFICATION			
	(BETWEEN DIFFERENT DISCIPLINES)			
10	CLIENT MEETING			
11	USER TESTING TO THE DESIGN			

The research findings provide a comprehensive understanding of the problems stated in the dissertation . the main question in this paper is determining the efficiency of contribution of vr in the field of architecture . the objective was to bring out the qualities through different modes of study on theories and practises to establish a good understanding of the issue .

- First the complexity of a decision making process in the field of architecture is addressed with a need of a better platform to be introduced to produce effective decisions . it is explained by how Vr can effectively bring about a change in this gap that's been identified to pull down the growing industry . the usage of VR in the different design process phases can thus make increase a more responsible decisions made .
- Furthermore , the role of VR is well established by doing practical researches on the virtual reality labs in companies that use them for design process for a variety of projects . studying about its effects and implications on the designer and the whole system as such , the study is held strong from a positive response observed the users who has seen the shift from traditional designing methodologies .the engagement of VR with different aspects can be used to create a well designed space that has got a value than ever before .
- Virtual reality has not only enabled new possibilities but also added value to existing possibilities in architecture . VR used in architecture may not be as convincing as the real, due to the present Software and Hardware Technology constraints .

- however it does enable us to perform task that were not possible before or treated as to do them more efficiently while much can be expected from future technology development. the problems are not likely to disappear anytime soon your from our research we found that even with it current limitations VR has a potential impact on the way we conventionally think and design are built environment pushing it beyond space and time constraints.

RESEARCH OBSERVATIONS AND ITS SIGNIFICANCE :

Over the last seven decades, VR has developed rapidly and has proven its efficiency in many industry sectors; however, its application and implementation are still limited in the Architecture industry. The main causes of this limitation are the unique character of the construction projects and the high cost of VR technology in the past.

- The construction projects and especially infrastructures involve multi-disciplined engineers, stakeholders with different interests and background, clients with high influence, and end-users cautiously looking for the project. Therefore, lack of communication, collaboration, and coordination in such projects generate mistakes and problems during the design and the construction processes.
- In addition, clients and stakeholders without an engineering background may face difficulty in understanding the design and particularly at the early design phase where the information is still limited. The project can face claims during the construction caused by the misunderstanding of the end-users or stakeholders.
- On the other hand, the VR technology has witnessed a huge improvement not only in hardware and in software but also in the technology's cost, which has dramatically decreased compared to 15 years earlier. Therefore, many developers are working on adapting VR in the Architecture industry. In the design process, the design team can use VR within CVE to improve the design review and design approval by increasing the communication and collaboration and reducing the revision and approval time.
- rIn addition, understanding the space and design elements can increase when the designer becomes immersive in a real scale 3D model. The facility operation and maintenance teams are able within CVE to simulate operation, maintenance, and even evacuation plans with the ability to leave feedback and comments on the design. The client and decision-makers can have access to the right and up-to-date information within a VE, which enables them to take earlier, reliable, and precise decisions. Stakeholders and end-users within a VE can see the future effects of the projects on the surroundings and even walk around trying to use the facility virtually. A sufficient design should always consider the method and

the ability to construct the facility. Before the beginning of the construction phase, VR can be applied to simulate hazardous areas in future sites and provide safety training for workers in advance.

- In addition, architects can identify and correct potential collisions that might cause accidents. Based on construction stage management, designers can simulate the construction elements sequence. Architects can simulate the dynamic process in the construction site when preparing site planning and before the beginning of the execution phase. This could maximize the benefits from the workplace and the resources.
- Through the literature study, investigated case studies, and participation in a documentation for implementing the VR in the design process, we can provide a framework and workflow to show the benefits and challenges from applying this technology in the architecture design process. It can be concluded that implementation can bring many benefits for the department. The VR model can be used for communicating with the client within the VE, where the client is able to see the up-to-date design and select between multiple alternatives. Meeting sessions can be recorded in the VE with the ability to take notes and comments, which can represent the meeting minutes. In mega-infrastructures projects, the VR model can be applied to engage the stakeholders in the design and increase the satisfaction of end-users.
- Designers and modelers could understand and manipulate better with the design components and communicate with each other within a CVE. Finally, the model can be used for planning the operation, maintenance, and as-built documentation.

LIMITATIONS :

The real implementation of VR still faces challenges regarding technology limitations or cultural aspects. VR still needs traditional odelling tools and cannot work independently from 3D odelling software. Creating a CAVE requires a permanent place and high cost, which limited the application only for high budget projects. The implementation may not cost efficient with simple and small size projects where traditional 3D models can be sufficient. In addition, some people feel sickness and dizziness when using VR headsets for a long time. Some clients feel comfortable using the headsets within a big group. Due to the lack of research time, there was a shortage in investigating the future approach proposal.

covering the needs of a wide range of participatory group :

- **Use several tools**: While designing a participatory urban design process, integrating several tools and methods is important. To include everyone targeted to participate, various case-specific informal tools and methods should

be used. Traditional methods should not be excluded from the process while using technological instruments. Participants who do not want to or are unable to use HMDs should not be excluded from participation. Today, 6 DoF HMDs are not a household commodity, but smartphones and personal computers are. For people who do not want to or are unable to use an HMD should be provided with a flat screen version of the experience.

- **Provide comfort modes and consider accessibility**. Participants who have a hard time with locomotion or other aspects of the experience should be allowed to choose easier alternative methods to navigate and participate. Individuals with disabilities should be thought of.

- **Accessibility modes** may be developed according to the aim of the participatory process. For example, color blindness may be considered during the conceptualization phase and colors may be chosen accordingly.

- **Use VR as early as possible**: VR is a very influential medium to present finished, polished environments with high realism. But at that stage of the design, important decisions are hard to alter. If a VR-based tool is going to be developed and used, it should not be left to last stages of the process, where important decisions are almost set in stone. Designers should see the VR medium as a way to introduce the body and therefore the reality of the participant to a designed environment, with the intention of including participants in the decision making process, instead of showing off an impactful visualization device.

- **Playtest:** Because every person has a different body and different experience with tools, natural and intuitive body centered interaction design for a wide audience can only be achieved through many test sessions. Testing and iterating is a long process, but it ensures that the design is easy to understand, even if it demands effort from the participant to use it.

- **Use frameworks, templates and built-in tools and alter them.** Developing an interactive tool built from ground up is a costly process. Using existing assets, frameworks, templates and tools significantly shortens development cost. However, such ready made material should be altered when needed, otherwise it is unavoidable that the content becomes generic. This warning is especially valid about the feature of teleportation in VR. Keep it short and allow participants to extend their experience duration. VR is an unusual medium for a lot of people. Having a display close to eyes or locomotion techniques may be tiresome for some people. Participants should not be forced into a long gameplay and should be allowed to extend their playtime if they want to.

- **Try to amplify presence using all 3 illusions**. Place Illusion, the illusion of being in a place that does not exist, is easily achieved with large, realistic environments and multi sensory hardware. Plausibility illusion, the illusion of what is happening is real, is trickier to achieve. Innovative methods should be developed that help create another reality, where everything obeys the rules of that reality. Physics of an object should be in compliance with the physics of another object. Everything should be coherent in the created (virtual) reality. Because the participant's virtual body is in that reality as a base point, its interactions should also comply, and perhaps even create the rules of that scenario. Body centered interaction techniques express such interactions. Body Ownership Illusion, the illusion of having a virtual body, can be achieved by tracking the body either in parts or fully. Its first step, implementing hand presence, is the industry standard in 6DoF applications. In location-based applications, body trackers may be used to create full body avatars, which generates full body illusion. IK may be used for home setups, either for full or half-body illusions. Bringing the (virtual) body into the created (virtual) reality brings a whole new level to its immersion. Believing that the virtual body is in fact their own body on a subconscious level allows emotions such as empathy have a bigger part in the experience.

To conclude, using a well-designed VR experience with multi-sensory modalities and human centered interaction design approach in a participatory project would increase interest in the proposed design and encourage participants to think about and provide input to the proposed design. If the participation process has a high participation level that allows the design to be changed by the participant, intuitive, natural body centered interaction is necessary. Full or partial virtual body not only increases the level of presence but also might provide interesting design opportunities for empathy in the community.

FURTHER RESEARCH AND CONCLUSION :

The subjects demonstrated the fallibility inherent in different virtual representations, be it CAD or VR, and through examining their design processes, we can better understand how CAD and VR

- Affect perceptions of scale

-Object relationships

-Materiality

-Open spaces.

VR naturally supports better intuitive understandings of scale and object spatial relationships, but does so in an experiential manner. CAD provides illusions to questions of scale, density, and immersion. Both no texture and realistic rendered textures can be deployed in VR, with a slight preference for realistic rendered textures.

Finally architects and novices, when self-evaluating their immersive 3d spatial imagination from a plan, perform almost the same, with architects performing slightly better. These conclusions demonstrate a space for VR as a unique and worthwhile new medium for architectural design. The experiment also allowed for some brainstorming and possibilities of future VR applications. Different subjects weighed in with the various uses of VR. One particularly interesting proposition was to design from the perspective of those who are not currently considered, such as views for children or for wheelchair users that have different lines of sight. Some found VR as a helpful tool. but not a replacement for traditional CAD modeling and there were many different opinions on its place and role in the design pipeline. On the broader scope, the next step for this project and this research would be to evolve the VR review tool into the VR editor tool. By taking the VR proof of concept and develop it into a full VR editing environment, we could make a more comprehensive comparison between designs in CAD and designs in VR. The beginnings of this research was interested in this possibility but the difficulties in creating flexible VR metaphors to edit space proved to be quite the challenge. One example of such a difficulty was how objects could be moved and manipulated far away from the body. The question of whether the user would have to move with the object in order to place it was one out of many object manipulating concerns. The metaphors that enable modeling would have to be reimagined for an immersive virtual reality environment. Doing so would transform design and the act of making and architectural modeling in virtual space.

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