Thesis Work

Innovation Engineering Program/Bachelor's Thesis in Product development and innovation leading with scientific method 22.50 HP

Virtual Reality Startup Guide

Navigating the New Product Development Process for Successful VR Sessions

FIH (Business, Innovation and Sustainability)

Halmstad 2023-05-28
Written by Lovisa Brenne and Oskar Naij
Examinator: Leif Nordin
Mentor: Fawzi Halila

HÖGSKOLAN I HALMSTAD

Abstract

The use of new technologies is important in new product development and virtual reality is a technology that companies today are trying to find use for in their organizations. The problem present today is that there are tools ready to be used that are not because organizations are at different maturity levels of understanding how to work in virtual reality (VR). VR could not only make development cheaper but also greener. This thesis aims to bridge the gap within Volvo Construction Equipment (VCE) to make the use of VR more present in product development. That is why the thesis crafted a startup guide on how to work with VR. The value of this is to inform all stakeholders within VCE of the value of VR at a basic level as a tool. The guide explains the benefits of virtual reality as well as a general step by step guide on how to use it to replace some physical prototypes. It is targeted to project leaders and product developers.

Preface

This thesis was written by Oskar Naij and Lovisa Brenne, students at Halmstad University pursuing their degree in Innovation Engineering. Both were in Korea for exchange studies in the spring of 2022 at Korea University and Hanyang University. This sparked an interest in conducting their bachelor's thesis in connection with Korea in some capacity. Contact was made with VCE Korea to see if collaboration was possible, and it seemed feasible. VCE Korea was willing to help, and through the support of VCE Sweden, who had a firm grasp of the common practices of students writing their thesis work in collaboration with companies. The topic to cover was decided upon during the fall semester.

Acknowledgment

We would like to really thank VCE Changwon and VCE Eskilstuna for providing us with this opportunity. For VCE Korea, it was the first time working with bachelor students and taking a chance. We would really like to thank Na Chanju (나찬주) for providing the opportunity and our mentor Jang Jinho (장진호) for guiding us from the other side of the world. From Sweden, we would like to thank Pia Wessman for her enthusiastic support and Anna Sannö for always having the answers to our questions. Joakim Carlberg was also very helpful when we contacted him out of the blue to bounce ideas.

We would also like to thank our school mentors Fawzi Halila and Leif Nordin, for guiding us throughout the process of this project, especially when they were available to answer our questions around the clock.

Overall, we thank everyone who we talked to and supplied us with support throughout this journey.

Index

1. Dictionary 6
1.1. Key Phrases 6
2. Introduction 7
2.1. Background 7
2.2. Problem formulation 7
2.3. Concept 8
2.3.1. What 8
2.3.2. How 8
2.4. Purpose 8
2.5. Goal 8
2.6. Limitations 8
2.7. Requirement specification 9
3. Frame of reference 10
3.1. Theory 10
3.1.1. VR background & use in product development 10
3.1.2. New product development in global teams 10
3.1.3. Knowledge gaps 11
3.1.4. Resistance to change 11
3.1.5. 70-20-10 11
3.2. Project Model 12
3.2.1. Agile product model 12
3.2.2. Dynamic product development 12
3.2.3. Stage-gate process 12
3.3. Tools 13
3.3.1. Gantt chart 13
3.3.2. Cross-reference 13
3.3.3. Pilot study 13
3.3.4. Brainstorming 14
3.3.5. Stakeholder analysis 14
3.3.6. FMEA 14
3.3.7. VR Headset 14
3.3.8. User stories 15

3.3.9. Digital tools 15
4. Method 16
4.1 Project method 16
4.1.1 Project start and planning 16
4.1.2 Primary Data 17
4.1.3 Secondary Data 17
5. Development process 18
5.1. Process 18
5.2. Changes 20
6. Project solution 21
6.1. Product 21
6.2. Product Process 22
6.3. Business analysis 22
6.3.1. Summary 22
6.3.2. Cost Breakdown 22
6.3.3. Estimates 23
7. Discussion and Reflection 24
7.1. The Project 24
7.2. Comparing to goals 24
7.3. Future opportunity 25
7.4. Conclusion 26
8. References 27

1. Dictionary

XR: Stands for Extended reality, which is an umbrella term for Virtual reality, Augmented reality, and Mixed Reality

VR: Stands for Virtual reality which uses special glasses with a screen on the inside of them to immerse the user into a virtual world or program. It may also include headphones and hand controls.

VCE: Volvo Construction Equipment

NPD: New Product Development

R&D: Research and Development

NDA: Non-disclosure agreement

1.1. Key Phrases

Virtual reality, New Product Development, Industrial Industry, Volvo Construction Equipment

2. Introduction

2.1. Background

The field of product development is where most new technological advancements occur. However, some technologies with great potential may take longer than expected to break through and find their place in businesses. This can be due to various reasons, such as the technology's maturity and its users' proficiency. Additionally, businesses need help to implement new technologies due to knowledge gaps between the technology, management, and workforce. (Gravenhorst & Veld, 2004)

Virtual reality (VR) is an example of one of these technological advancements that industries see much value in but need help to integrate into their organizations. (Lasi et al., 2014)

For some, testing with the help of VR does not have the same authority as a physical prototype. This means that tests conducted with the help of VR have a hard time being accepted. Currently, VR has areas where it is unable to test, but there are areas where it is ready to be used. It is just not applied. (Cañas et al., 2021)

In July of 2022, the first contact between students from Halmstad University and VCE Changwon was initiated, where the students, Jinho Jang and Na Chanju, got to know one another. They discussed the possibility for a collaboration and framework for a bachelor's thesis in Sweden and what future work together could be like. The reason for interest in doing the thesis work with Korea comes from the students' mutual interest in the country.

This was VCE Korea's first time doing a bachelor thesis together with international students. To help the students and VCE Korea, contact with VCE Eskilstuna was established. A Teams meeting was set up between VCE Korea, VCE Sweden, and the student group to create a plan for how the project would be conducted in practice.

2.2. Problem formulation

Volvo Construction Equipment (VCE) uses VR in the new product development (NPD) phase. This is a new technology, and in Eskilstuna, it has become a problem to know how and what to use VR for. For this, a startup guide on what to do before you start a session of developing in VR would help as a steppingstone. The mission of this project is to provide the company with a guideline they can follow.

2.3. Concept

The concept is to work with VCE in Korea and Sweden who both has a big market share in their respective countries. To look how their current work with VR and how it is implemented in their NPD phase. By looking at both locations and the current situation, the project organization will try to create a startup guidebook for working in VR in the VCE organization. This from interviews and interactions with the people working in that environment and combining a guide, in which the most effective way is presented.

2.3.1. What

Create a step-by-step process of what steps are necessary to get started with working in VR and what opportunities it brings.

2.3.2. How

Workshops and interviews with different parts of the VCE organization about the use of VR, its challenges at the different locations, and what needs to be done to improve the situation.

2.4. Purpose

To find the ways VR improves NPD and make it more accessible in the NPD process at the VCE organization as well as increase the number of people using it in their workflow, specifically in Eskilstuna and Changwon. Making a steppingstone for getting into VR work and an easy guide in what is needed to get started working in it and what its strengths are, and how to utilize them best to save time and money on projects.

2.5. Goal

To create a startup guideline on how to get started with working in VR in early NPD phases.

Find the best practices for using VR and present what is required to start working in the environment through a guidebook engineers can use to get started with VR within VCE.

2.6. Limitations

This project stretches over the course of 29 August 2022 to 28 May 2023. Communication will primarily be through email due to regional limitations.

The guidebook that is produced will be limited to the product development phase.

2.7. Requirement specification

Due to this project's explorative nature, a traditional requirement specification is not made.

3. Frame of reference

3.1. Theory

Here theories that are relevant to the project are presented. This involves the technology, methods used in the project and how it affects it.

3.1.1. VR background & use in product development

The use of VR is not a new concept. The idea was first introduced in the 1960s, but the usage of VR in industries did not bloom until the 2010s. This was also when VR became more available to society through Oculus Rift and HTC Vive. (Sutherland, 1968) (Berni & Borgianni, 2020)

Using VR is slowly changing the way how product development is done in a plethora of ways, such as prototyping and product reviewing. Creating an environment where you can test products without building a physical product. (Siltanen et al., 2021)

So far, the response to VR is mixed. Many are intrigued and find the technology interesting, while others might not understand why they would move on from a program such as Computer Aided Design (CAD).

The positive benefits are things such as cultivating innovation for people who do not have access to a physical prototype and for a product with no real prototype yet. (Siltanen et al., 2021) It allows workers in different time zones to work on the same digital prototype and leave notes for one another. (Siltanen et al., 2021)

The limitations of the technology that must be improved before broader adoption, is for example the ease of transfer of work between CAD and VR programs, more precise controls for sketching in VR, and just general user experience improvements like the aforementioned controls. (Siltanen et al., 2021)

3.1.2. New product development in global teams

VCE is a significant global company. It is the seventh-largest construction equipment company in the world. With this, it naturally works with people worldwide as they are stationary on different continents. This means that the NPD teams might sit in different countries. (Daswell, 2022)

Solving problems through global teams has some advantages, such as always getting the right person for the job as well as being able to customize the result for local markets. (Balzerkiewitz & Strechert, 2020)

The problems of working in globally distributed teams can be disagreements between team members. These can be avoided by face-to-face meetings, but they are often avoided due to the high costs associated with them. There are

alternative communication channels such as E-mail, Live chat, phone calls, and video calls, but they all miss out on crucial parts of face-to-face meetings. (Balzerkiewitz & Strechert, 2020)

3.1.3. Knowledge gaps

A knowledge gap, or K-gap, refers to the missing information or skills required to complete a project successfully. This gap is often identified at the start of the project and is filled over time through education, expert consultations, or self-directed research. By recognizing the K-gaps, project teams can plan and provide necessary training to all relevant individuals, ensuring that all necessary knowledge and skills are acquired for the successful completion of the project. (Roundtable Learning, n.d.)

3.1.4. Resistance to change

Resistance to change is a well-researched concept common within organizations, especially regarding new working methods. (Ali et al., 2016) This is because decisions to change often come from the top management and do not have broader support within the organization. An essential part of a change to be successful is that people from all levels of the organization are involved in the change management process and working in collaboration towards a common goal and that the changes reflect this work. (Gravenhorst & Veld, 2004) (Ali et al., 2016)

To make changes in organizations successful, members must work together in the change process, focus on the process instead of contents should be applied to make change most effective. (Gravenhorst & Veld, 2004)

3.1.5. 70-20-10

The 70-20-10 model is built from three learning methods, experiential, social, and formal. It is important to know that even though this method is more of a guideline. Most of the learning comes from experience and social learning rather than formal class learning.

70% is from experiential learning. This is hands-on learning, where you do daily tasks and challenges. This part can be divided into four parts: a concrete experience, which is the hands-on experience. A reflective observation, which is learning from previous experience. Abstract conceptualization is how you plan how to be successful in the future, and active experimentation is when you test your theory to see if it is successful.

The 20% comes from social learning. This is where we learn from other people by observing, asking questions, and being taught by previous workers. This is the more spontaneous learning that might come from conversation and discussion rather than formal learning.

Last is the 10% which is formal learning. Even though it only covers a small part, it is equally important. This is what builds the backbone for all knowledge. This is where all the theories and facts originate from. It also amplifies what has already been taught in first-hand experience. (Growth Engineering, 2022)

3.2. Project Model

The group determined that success in the project requires the use of three complementary work models: The agile project model, dynamic product development, and stage-gate process. The group worked in an agile way to be able to stay flexible in what the project was meant to produce, using mostly a dynamic product development method with stage gates in the form of big deadlines and meetings. These will be used in parallel, but the usage ratio will vary in different phases. The choice of these models was driven by the absence of a physical product and the uncertainty regarding the technology's potential, as they offer the necessary adaptability for handling changes.

3.2.1. Agile product model

The agile product model is a flexible and collaborative approach to product development that prioritizes customer satisfaction. It follows the agile methodology and involves delivering working product increments in short sprints, with close collaboration between the development team, customer, and stakeholders. The team continuously adjusts to changing customer needs and market conditions, resulting in a constantly improved product. This approach is suitable for projects with high uncertainty, as it enables quick adaptation to changing requirements. (Tonnquist, 2018, p.189)

3.2.2. Dynamic product development

Dynamic product development is a fast-paced, agile product creation approach emphasizing speed, flexibility, and innovation. It involves rapid prototyping, cross-functional collaboration, and a customer-focused mindset. New and emerging technologies, such as digital manufacturing and AI, are often utilized to increase efficiency. Dynamic product development aims to quickly bring new products to market and respond to changing customer needs and market trends. This approach strongly emphasizes innovation and finding creative solutions to product development challenges. (Holmdahl, 2009)

3.2.3. Stage-gate process

The stage-gate process is a structured project management methodology that divides projects into stages or phases and evaluates them at significant decision points. It comprises several phases, including idea generation,

concept development, business analysis, development, testing and validation, and launch, each with corresponding gates like idea screening, business case assessment, development testing, market testing, and post-launch review. This approach is beneficial for organizations in managing risks, enhancing communication and collaboration, and improving the probability of successful project delivery by providing a structured and systematic approach to project management. (Elmansy, 2022)

3.3. Tools

3.3.1. Gantt chart

A Gantt chart is used to plan, schedule, and track the progress of the research project. By creating a Gantt chart, the task required can be defined to complete the project and set a timeline for each one. This helps the project stay organized and on track, ensuring that work is completed in a timely and efficient manner. The Gantt chart can also communicate the research schedule to the advisor, committee members, or other stakeholders, providing them with a clear understanding of the project timeline. Additionally, the Gantt chart can monitor progress and identify any potential roadblocks, allowing one to make necessary adjustments and stay on track to complete the thesis work successfully. (Tonnquist, 2018, p.178)

3.3.2. Cross-reference

Due to much of the information gathered from online sources for the project, the group wanted to ensure that the information they gathered was as authentic as possible. To manage this, articles will be cross-referenced with one another. This will also apply later in interviews, where information is gathered and cross-referenced to isolate problems and solutions.

Additionally, the group recognizes the importance of ensuring the information's validity; therefore, cross-referencing will be a crucial step in the process. The group aims to minimize the risk of inaccuracies and provide the most reliable information by cross-checking the articles and, later, the information collected during interviews.

3.3.3. Pilot study

A pilot study is made at the beginning of a project to assess ideas, needs, and underlying factors to form a formation for a project. The reason is to unravel all the conditions and, to a degree, see if it is possible to do. A pilot study presents all the requirements and presents a plan that reassures that the crucial resources are available to finish a project successfully. (Pearson et al., 2020)

3.3.4. Brainstorming

Brainstorming is often used at the beginning of the project because it is a creative problem-solving technique that generates many ideas in a limited time. The ideas need not be realistic and should be met with an open mind with no criticism. This is because the goal is to encourage the participants to be creative and find possible solutions later on for the problem.

Brainstorming is done in a group where the members share their thoughts and ideas. The method in how the ideas is shared varies from either having a group discussion to writing them on post-it notes or a whiteboard.

The brainstorming process inspires creativity and collaboration within the team to identify possible solutions. The encouragement that involves the free flow of mind and ideas helps individuals and to teams overcome creative roadblocks and discover fresh and inventive solutions. (Wikberg Nilsson et al., 2021, p.137)

3.3.5. Stakeholder analysis

A stakeholder analysis is a tool to map the different stakeholders and how the project affects them, and how they affect the project. All stakeholders share a different amount of interest in the project, and they are, because of this, divided into smaller groups of primary and secondary stakeholders. The primary stakeholders are those directly impacted by or impacting the project, while secondary stakeholders have a lower level of interest and do not affect the project. The core stakeholder is the most affected stakeholder of all. The goal is to maintain a balance among stakeholders, ensuring satisfaction for all in the end. (Tonnquist, 2018, p.104)

3.3.6. FMEA

Failure Modes and Effects Analysis (FMEA) is a tool used to assess the risk of failures in designs or systems. It can be used to evaluate the potential failures of a design and determine the impact of those failures. The steps involved in FMEA include defining the system, identifying potential failures, assessing impact, evaluating the likelihood of occurrence, determining corrective actions, and prioritizing failures. FMEA helps ensure product quality and reliability and improve design and manufacturing processes. The results can inform design changes, process improvements, and risk mitigation strategies and provide a basis for further research and development. (Tonnquist, 2018, p.244)

3.3.7. VR Headset

VR Headsets are what are called head-mounted displays (HMD) and are currently the main way to use VR in most applications. There are two different kinds of HMDs, there are what are called standalone VR headsets

which are battery powered headsets that run the software in the headset with cameras on to track their position. There is also PC/Stationary VR which are headsets connected to a PC and uses its hardware to run its applications, sometimes these setups use sensors and cameras set up in the location they are used for more accurate tracking. An easy comparison to make is to that of stationary computers and laptops, one is more powerful, and one is more convenient.

The benefits of standalone headsets are improved mobility and convenience of not needing wires to use and cheaper to buy. The cons are that they have a more limited battery life and can run less powerful hardware. (The Differences Between PC VR and Standalone VR, 2011)

There are two different movement options: 3 DOF and 6 DOF VR headsets. DOF stands for degrees of freedom which describes how many ways it is possible to move within the program. 3 DOF headsets only allow for rotational movements around the x,y, and z-axis, so in other words, you cannot move only look around from one location, whereas 6 DOF allows for rotational as well as translational movements along the earlier mentioned axes, so you can move and look around. (Degrees of Freedom | Google VR, 2018)

3.3.8. User stories

User stories are a tool in the agile development model used to describe requirements from the customer's perspective, usually in the format "As a [user], I want [feature], so that [reason/benefit]." This helps align development with user needs, facilitates communication, and breaks down complex requirements into manageable pieces. (Tonnquist, 2018, p.121)

3.3.9. Digital tools

Digital tools and software include both hardware devices like computers and software applications such as various programs. They serve to improve communication and optimize processes by utilizing the features of computers and the Internet. (Almi, n.d.)

Some common examples of digital tools that can be employed in such projects are video conferencing platforms like Teams, creative software like Adobe, project management tools like Asana, collaboration platforms like SharePoint, and cloud storage solutions like Google Drive. These tools offer an easy and efficient way for team members to collaborate, exchange information, and work together on projects, even from separate locations.

4. Method

4.1 Project method

4.1.1 Project start and planning

The project began with a student reaching out to VCE in Korea to inquire about potential bachelor thesis projects. A meeting was arranged with the Head of Engineering Support, an engineer, and HR from VCE Korea. This was the first time VCE Korea had worked on a bachelor's thesis with international students, so they reached out to VCE Sweden, who had more experience with thesis projects. The plan the group and VCE discussed working on was to focus on VR in product development and to begin with a focus on NPD in global teams.

Due to the long process of finding the frame of reference and limitations for the project, the planning for the project needed to start even before the project was decided. A Gantt schedule was included in the project to keep track of deadlines that would be relevant during the project. An FMEA was also made to find potential risks and how these would affect the project. It was early on known that communication and workshops would mostly be through online means. This meant that digital tools were used like Teams - for digital meetings, Messenger - for communication, Google Drive - for files and documents, Google Docs - for writing reports, Google Sheets - for Gantt and FMEA, Gmail - for mail communication, Volvo Software - Volvo internal database for information and documents. Other tools used by the group were VR headsets. They visited the Digital Laboratory Center (DLC) at Halmstad University, getting an opportunity to try VR themselves to build a better understanding of the technology. Through the stakeholder analysis all of the vital stakeholders were identified. A communication plan was initiated with both the mentors from Halmstad University and VCE Korea however, due to sick leave and slow progress in the beginning, these were not followed through regularly. An NDA contract was written between the students and VCE to be able to work on this project as well as get access to Volvo’s database. During the duration of the project, three meetings were scheduled with VCE that were face to face. One in which Anna from VCE Sweden discussed the layout of a report, and the other two were visits to VCE Eskilstuna and VCE Changwon.

The initial plan for a working method was to perform interviews to grasp the potential problems and compare previous cases where VR has been used. What part worked well and what was lacking from there, researching k-gaps and making a combination where the best way of working was combined to make the most effective working method. The plan later evolved from this

to a more open free-form discussion at both locations while visiting, focusing on user stories, brainstorming solutions to the group's challenges, and coming up with plausible solutions due to the fact of the group wanting to keep a user focus and learn from the experiences of the people in both parts of the Volvo organization.

4.1.2 Primary Data

At the beginning of the project, the primary data was collected through science articles and published papers that were cross-referenced for accuracy. The idea was then later to interview workers with the help of Kvale interviews. However, a more relaxed method was approached instead by having open-ended conversations and collecting fundamental information that was discussed. The people talked to were bosses, users, and mentors.

The reason for using conversations as primary data is because it would provide a more insightful look at the actual situation of usage of VR as of now. Also, to hear the relevant concerns that the organization and user have. By having an open conversation, the project's end goals will be more in line with what the consumer actually wants.

4.1.3 Secondary Data

Once the data has been collected from VCE through interviews, the articles selected would act as secondary data. The articles selected for this purpose will be impartial and neutral in their viewpoint. This will provide context and background information to supplement the results of the primary data collected through interviews and first-hand observation. The articles selected will be carefully chosen to ensure they are impartial and neutral in their perspective and fact-checked through multiple sources, providing a balanced and proven view of the subject. This combination of primary and secondary data will give a comprehensive understanding of the current state and future potential of VR technology.

5. Development process

5.1. Process

When the students reached out to VCE and got acquainted with the organization, mentors from both VCE Korea and Sweden were assigned to the group. The plan for the project was to work on XR technology and how it would help save costs for the company. Shortly after, a meeting was set up with VCE Korea to narrow the scope to a feasible level achievable in the timeframe given. VCE Korea requested the group after narrowing its scope to research the current uses of the technology in the industry. Due to this flexibility requirement the students knew they would need to approach this with a dynamic product development method. The students researched the current situation by reading scientific articles and other thesis work on the area. Thus, the students built a better understanding of the subject.

In October, the students put together a one-pager (attachment 7) that was sent to VCE Eskilstuna. This served as one of the projects stage gates. It needed to be rephrased multiple times at first because it was written in Swedish with no real conclusion on what the project would present (attachment 10) and later again because the scope was still too broad (attachment 11). After multiple rejected one-pagers, the student had a Teams meeting with VCE Eskilstuna to find a way to narrow the scope even more. The scope became “The potential benefits of using VR/AR in an engineering support application, working in distributed teams considering a Sweden – Korea context,” which focused on how a collaboration would be able to function between two different countries within VR.

This one-pagers information was used to make the ad on Volvos' website where the students could apply officially for their thesis work in November. The student applied and got accepted while continuing to research articles about XR, mostly VR. At the end of November, the Changwon team visited Eskilstuna to discuss XR-related materials. The students got the opportunity to sit in on these meetings through Teams to partake in the information sharing.

During December the student worked on the next stage gates of the project this being the concept report as well as the concept presentation. The presentation was made deliberately vague to ensure no confidential information would be presented. As well because the concept was still big and hard to grasp.

During this period the students had to be very agile in the way they worked both because they knew their project could change a lot once they got access to Volvos internal network and the projects nature being very broad in general.

In the middle of December, the NDA contract was sent out to the student to sign so the student could access Volvos´ internal network and the material it could provide. The access for the student came in the middle of January, where they could remotely access Volvos network.

At the end of January, the student was able to meet one of the mentors, Anna, face to face when they were visiting the students' school. Anna provided information and helped with how a report would be written and how to think when writing one. With that help, the students finished another stage gate in the form of their concept report and the project plan and thus handed it in to the examinators. The concept report was also sent to the mentors, that later provided feedback.

Around this time, the mentor from the University went on sick leave, so the students adapted to less contact from the school.

At the beginning of February, the student got in contact with a Ph.D. student that is working together with Volvo regarding XR and has done both questionnaires, research, and seminars. The students watched a seminar that was available and continued to ask for more insight about XR.

A meeting was scheduled in the middle of February to let the students visit Eskilstuna and present their current progress on their work and get comments and guidance from a group of people, including mentors, the Ph.D. student, and workers involved in the VR at VCE Eskilstuna. After the presentation, feedback was given that the area might be hard to focus on as well as the scope was still too broad, and the students were helped in finding a suitable focus and got contact information for people who might be able to assist them in progressing further in their work. This process was made easier by the students' agile way of working. Thus, the thesis was further limited to just VR and the NPD phase. With the title "VR Collaboration Unlocked: A Thesis Guide for Distributed Teams in Sweden and Korea."

The students planned a visit to Korea during March and informed their Korean mentor of their visit and asked if it would be possible to visit the factory in Changwon. A meeting was subsequently scheduled for when the students were in Korea. The student spent a whole day at the facility and met the people working with VR, walked the factory, and tested using the VR system.

Around the end of March, the student got in contact with an expert on using VR in Volvo and scheduled meetings and information sharing. After an informative meeting with the expert and the school mentor, the thesis was narrowed down for the last time to make a product that could be presented within the given timeframe. These meetings and the research helped reframe the issue and helped the students see that the situation might not be about technical limitations with VR but more of a K-gap in the organization. The

title for the finalized version was “Virtual Reality Startup Guide: Navigating the New Product Development Process for Successful VR Sessions,” which would focus on making a startup guide for the beginning of the project to present what would be needed to know and what process to take when using VR for a project. The student would provide the startup guide and the written thesis report explaining how they got there.

5.2. Changes

The project changed for almost its entire duration as the group got more information and understood the problem better, and this was made a lot easier with the groups continuous use of a dynamic product development throughout the project. During the fall semester the group worked through narrowing the scope of the thesis to get a better idea of what to focus on. The most pivotal moments of the project were the following:

The group was asked to make a one-pager summarizing what the thesis was intended to cover. This led to the group needing to be a bit more specific than the original subject of looking at the potential economic benefits of all different kinds of XR, the evolution from this subject took three different one-pager versions and a meeting with all involved. The scope was thus decided to be: “The potential benefits of using VR/AR in an engineering support application, working in distributed teams considering a Sweden – Korea context.”

In February, the students visited Eskilstuna and presented their current progress to mentors and VR users at that location. The contents the group shared was a PowerPoint (attachment 5) with talking points on what they had read about in articles on working in VR and the goal was to get helpful feedback on how the research lined up with the situation at VCE. After this presentation, the students and the group discussed problems surrounding VR and what the students should focus more on in their thesis. The subject was further limited to producing a resource for collaborating remotely with VR.

After this meeting, the group mentioned the intended change in scope to their mentor in Korea. He highlighted the concern that the different locations the students were collaborating with were not working on the same things and lifted this as one of the main challenges with the pilot study.

In early April, the students had a meeting with their mentor at Halmstad University, who had just got back from sick leave, and in trying to catch him up on what had happened when he was gone, he managed to help the students make the project more straightforward and rephrased what they wanted to highlight in their resource to “A startup guide in VR.” That would focus more about helping with the K-gap rather than with the VR Technology.

6. Project solution

6.1. Product

The product is a Word document that is five pages long (attachment 9). The first page is titled “Startup Guide: How to use Virtual Reality (VR) for the best outcome,” giving the reader a direct idea of what they are going to read about. Page 2 contains two titles, “VR” and “Why use VR.” ’VR’ explains briefly what VR is to give people who have not worked or heard about it an idea of what it is. ‘Why use VR’ explains the benefits of using VR, including how it can save cost, reduce physical prototypes, and be a greener alternative. Pages 3 and 4 explain by a step-by-step guide of 5 steps on how to successfully plan a project in which VR helps in the development phase. Each step has three subheadings explaining what action to take, why the action is necessary, and examples of what could be achieved at that step.

Step 1 is evaluation. To check if and which of the tests are relevant to do. The guide's purpose is to help and promote the usage of VR but not encourage it when it is unnecessary.

Step 2 is to create a checklist. This is to make sure that the user knows what data they are trying to collect and what is needed. This step encourages the user to be very specific and detailed in what they want to get from the session.

Step 3 talks about VR, CAD, or a physical prototype. This is where the users need to identify which of their tests can be used with the help of VR or if a physical prototype is needed. Examples where the VR can help are ergonomics parts, how people are standing or sitting when using or working on the product. Ergonomics is also included in the physical where weight may be a factor. This means that some tests can be done with either VR or a physical prototype, while others may need both.

Step 4 tells the user to evaluate once again. This time from the result that they got from the tests that have been done.

The final step, Step 5, tells the user to repeat steps 1-4 through all the new prototype builds.

The final page is a flowchart showing visually the steps in order.

The document is short and concise to keep the potential user interested. It also is very generic so that multiple departments can use it and build their version from it. The design and wording are also kept simple, making it easy to follow.

6.2. Product Process

The first idea of how the product would look was not recorded. It existed as a mental image among the students. The concept of the report was a guide on how a person would work in VR. However, as the students learned more about VR and after discussion with VCE and getting a better understanding of the company's way of working with VR, the realization was that the technical usage of VR was not the main problem. The biggest concern was to make people open to using VR and informing them of its existence. People who were working in the program understood its value well.

Nevertheless, a challenge was getting people within the company not currently using it to understand its value, how and why to use the available tools, and their limitations. The idea of still doing a guide was left but not with the same subject. The project moved toward how to utilize VR as a tool and not the more technical parts of it. The first idea included just making a checklist with a step-by-step solution on how the user would use VR. The realization of why that could not work was due to all the departments not looking for the same thing, and a guide would not fit them all if a checklist with specific instructions were done. The student does not have the necessary knowledge of what questions would be needed to be asked in the development of each department. This did not include the reasons why the usage of VR has advantages. This created the version in which information about VR was made, as well as a step-by-step guide on how to utilize it. The first version (attachment 6) included a first page, index, explanation about VR and three steps for the step-by-step model. This finished version (attachment 9) kept the first page, the explanation about VR, and step by step. The step-by-step became five instead of the previous three.

6.3. Business analysis

6.3.1. Summary

The primary goal the project is trying to achieve is increasing the use of prototyping in VR, thus reducing the amounts of physical prototypes required. This will save money in the product development phase and save on materials needed to make prototypes. The business benefit of our work is reducing the cost of and improving product quality and, by doing that increasing the profit margins of the products developed by VCE.

6.3.2. Cost Breakdown

The different costs associated with making a physical prototype can be broken into three different categories: material cost, design cost, and manufacturing cost. The material cost part is affected by how many prototypes are manufactured directly, and design and manufacturing costs are affected by how much time is necessary for these stages.

VR prototyping reduces the number of physical prototypes necessary, thus reducing both material spent and machine time manufacturing the prototypes. In addition to this, it also reduces the time of development and reduces design costs as well.

6.3.3. Estimates

Two product development projects are never the same. However, suppose salaries are expected to be the same for designers of virtual and physical prototypes. In that case, the difference in cost is decided by how large of a part the material cost and machine time are of the product's development.

In the worst-case scenario for our project, material and machine time costs are not a big part of the cost, and it is a small saving of producing less (relatively cheap physical prototypes).

In the best-case scenario for our project, material and machine time costs are the majority of the cost and help save vast amounts of (making multiple expensive prototypes).

7. Discussion and Reflection

7.1. The Project

Throughout the project, the use of agile project model, dynamic product development, and stage gate process has been interchangeably used. Dynamic product development has been used to give a rough plan with key activities that would be helpful. The Agile part has helped with the short-term part of planning. as well as the surrounding uncertainties that followed with this project. Lastly, the stage gate part was because we had certain complex gates we could not move past at moments like before we signed our NDAs and when we refined the project scope.

The members of this project are very alike in how they work. Making it easy to communicate with one another but harder to divide what each person needs to do to proceed. None of the members stepped naturally into the project leader role, making some decision-making hard. Contact with the mentors has also been lacking, mostly because of the students and the fact that no constant contact was decided. This meant that steps took longer than needed. Much of the focus lay on understanding the subject and getting the needed basic knowledge, communicating ideas and potential ways to do the project.

The project has relied a lot on different people and scientific articles. As much help the different people gave, limiting the project when trying to please the different ideas and opinions took much work. Ultimately, the decision that pleased the most while still being durable was decided. In hindsight, using multiple mentors and people was more harmful than helpful.

The students have created a vast network domestically and internationally through all the connections and meetings. Opening up the idea of collaborating more between the different organizations. This also showed people that materials that can help users already exist. By working on this project together with people who will use it, the group is optimistic that the project will continue to develop as time passes.

7.2. Comparing to goals

The goal for this thesis was to “create a startup guideline on how to get started with working in VR in early NPD phases.” which the group achieved. The goal and its initial idea of how it would have looked have changed, but the students managed to create a product that could be used in the intended scenario.

The project's goal to “Create a step-by-step startup guidebook on how to utilize VR in the best possible way” was reached but not tested. From gathering information and talking with people, this would, in theory, be the best way to create a guidebook. The group would have liked to do a pilot study with it, but the timeframe did not allow for this.

The next goal of “Find the best practices for using VR and present what is required to start working in the environment through a guidebook engineers can use to get started with VR within VCE.” was further developed so that project leaders can also read it and see if they want to include it in the process of their product development. There was a realization that VCE already has a good idea of how to use VR but a challenge in implementing it best. The guidebook explains when and where VR can be used without getting technical, making it easy for people who may not have worked with VR before to understand its usefulness.

The first effect goal was to “Find the ways VR usage improves NPD.” This goal is more shown in the report than in the product. The product is more for encouraging people to use VR and improve the new product development phase. The report explains how the company can save money and become greener while using VR.

The goal of “Creating a workflow in which the usage of VR improves NPD.” was reached by the step-by-step solution. Also, making more people aware that the VR tool can be used in NPD improves the prototypes made.

The last goal of “Decrease either time or money spent on projects.” is a consequence of using the startup guide but is not something the group can take credit for. Timewise, the project may take around the same time as a project that is not using VR, and the money saved depends on the project size. The cost saving comes in the extra amount of things that can be tested with fewer physical prototypes.

Overall, the goal for the project was reached but not put to the test.

7.3. Future opportunity

The future goal would be to make a pilot study in which the guide is tested in a real scenario. This would test if the guide would work in practice as much as in theory. We would also then be able to gather the opinion of the users and further improve the guide. The guide would also not be a general guide, but one fitted for each department. Giving them more relevant examples of things, they need to look for and elements that are relevant to them.

Another option is for a new group to pick up where this group did not have time to continue further and expand, given the limitations this group has

identified. Those limitations are that the issue not necessarily lies in the VR technology but in the understanding of why it should be used.

7.4. Conclusion

The state of VR in product development is not hindered mostly by the technology’s maturity but more by the understanding of usage areas. The project group's startup guide seeks to be a simpler introduction to the company's other resources for VR usage.

8. References

Ali, M., Zhou, L., Miller, L., & Ieromonachou, P. (2016). User resistance in IT: A literature review. International Journal of Information Management, 36, 35-43. http://dx.doi.org/10.1016/j.ijinfomgt.2015.09.007

Almi. (n.d.). Digitalisering 2020 - För små och medelstora företag | Almi. Almi. Retrieved February 1, 2023, from https://www.almi.se/vara-tjanster/vill-du-vaxa/digitalisering/

Balzerkiewitz, H.-P., & Strechert, C. (2020). Use of Virtual Reality in Product Development by Distributed Teams. Procedia CIRP, 91, 574-579. Google Scholar. doi: 10.1016/j.procir.2020.02.216

Berni, A., & Borgianni, Y. (2020). Applications of Virtual Reality in Engineering and Product Design: Why, What, How, When and Where. Electronics, 9(7). https://doi.org/10.3390/electronics9071064

Cañas, H., Mula, J., Díaz-Madroñero, M., & Campuzano-Bolarín, F. (2021, 4 30). Implementing Industry 4.0 principles. Computers & Industrial Engineering, 158, 17. https://doi.org/10.1016/j.cie.2021.107379

Daswell. (2022, November 25). World's Top 10 Construction Equipment Manufacturers. DASWELL. Retrieved February 5, 2023, from https://daswell.com/blog/top-10-construction-equipment-manufacturers/

Degrees of freedom | Google VR. (2018, September 21). Google Developers. Retrieved February 5, 2023, from https://developers.google.com/vr/discover/degrees-of-freedom

Elmansy, R. (2022, May 15). Stage Gate Process: The Complete Practice Guide. Designorate. Retrieved April 4, 2023, from https://www.designorate.com/stage-gate-new-product-development-process/

Extended reality. (2022, September 24). Wikipedia. Retrieved September 27, 2022, from https://en.wikipedia.org/wiki/Extended_reality

The differences between PC VR and Standalone VR. (2011, May 24). UnboundXR. Retrieved February 5, 2023, from https://unboundxr.eu/zakelijk/standalone-vr-vs-pc-vr-wat-zijn-de-verschillen

Gillis, A. S. (n.d.). What is FMEA (Failure Mode and Effects Analysis)? A Definition from TechTarget.com. TechTarget. Retrieved February 1, 2023, from https://www.techtarget.com/searchcio/definition/FMEA-failure-mode-and-effective-analysis

Gravenhorst, K. B., & Veld, R. (2004). Power and collaboration: methodologies for working together in change. Dynamics of organizational change and learning,. 317-341.

Growth Engineering. (2022, February 9). What is the 70:20:10 Model for Learning & Development? Growth Engineering. Retrieved February 5, 2023, from https://www.growthengineering.co.uk/70-20-10-model/

Heilig, M. (2020, October 5). A brief history of Augmented Reality. Numerized. Retrieved October 17, 2022, from https://numerized.com/augmented-reality/history-augmented-reality/

Holmdahl, L. (2009). Produktutveckling. Lars Holmdahl. Retrieved February 2, 2023, from http://www.larsholmdahl.com/pdf/Product%20Development.pdf

Kvale, S. (1996). Kvale Steinar Interviews 1996 PDF | PDF. Scribd. Retrieved February 2, 2023, from https://www.scribd.com/document/398289907/Kvale-Steinar-Interviews-1996-pdf#

Lasi, H., Kemper, H.-G., Fettke, P., Feld, T., & Hoffmann, M. (2014, 6 19). Industry 4.0. Business & Information Systems Engineering, 4, 4. https://doi.org/10.1007/s12599-014-0334-4

Pearson, N., Naylor, P.-J., Ashe, M. C., Fernandez, M., Yoong, S. L., & Wolfenden, L. (2020, October 31). Guidance for conducting feasibility and pilot studies for implementation trials - Pilot and Feasibility Studies. Pilot and Feasibility Studies. Retrieved February 1, 2023, from https://pilotfeasibilitystudies.biomedcentral.com/articles/10.1186/s40814-020-00634-w

Roundtable Learning. (n.d.). What Is A Knowledge Gap? Less Than 100 Words. Roundtable Learning. Retrieved February 5, 2023, from https://roundtablelearning.com/what-is-a-knowledge-gap-less-than-100-words/

Siltanen, S., Heinonen, H., Burova, A., & Turunen, M. (2021). Reimagining innovation for remote, distributed teams with collaborative virtual reality. The International Society for Professional Innovation Management (ISPIM).

Sutherland, I. E. (1968, December). A head-mounted three dimensional display. In Proceedings of December 9-11. fall joint computer conference, part I, 757-764.

Tonnquist, B. (2018). Projektledning upplaga 7 (7th ed.). Sanoma Utbildning. 978-91-523-5498-8

Wannerberg, P., Löfvendahl, B., Larsson, F., & Stridell, E. (2019, March). The Challenges With Implementing XR In the Industry. RISE. Retrieved October 3, 2022, from https://www.ri.se/sites/default/files/2019-09/MAXAT%20report.pdf

Wikberg Nilsson, Å., Törlind, P., & Ericson, Å. (2021). Design - Process och metod (Vol. 2:1). Studentlitteratur AB. 978-91-44-14339-2

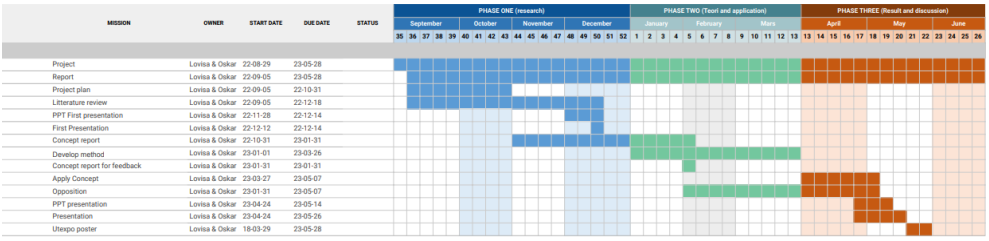
Zington. (n.d.). VR, AR och MR: vad är skillnaden, egentligen? Zington. Retrieved October 3, 2022, from https://www.zingtongroup.com/artiklar/vr-ar-och-mr-vad-ar-skillnaden/

9. Attachments

9.1. Attachment 1: GANTT

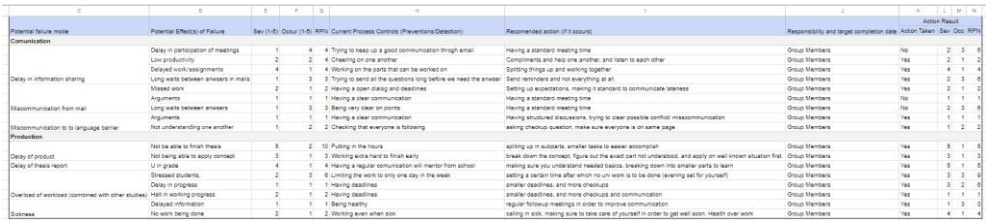
GANTT-DIAGRAM

PROJECT NAME	Batchlor thesis	COMAPANY	VCE
STUDENTS	Lovisa Brenne & Oskar Naij	DATUM	22-08-29 TO 23-05-28



MISSION	OWNER	START DATE	DUE DATE	STATUS
Project	Lovisa & Oskar	22-08-29	23-05-28	
Report	Lovisa & Oskar	22-09-05	23-05-28	
Project plan	Lovisa & Oskar	22-09-05	22-10-31	
Litterature review	Lovisa & Oskar	22-09-05	22-12-18	
PPT First presentation	Lovisa & Oskar	22-11-28	22-12-14	
First Presentation	Lovisa & Oskar	22-12-12	22-12-14	
Concept report	Lovisa & Oskar	22-10-31	23-01-31	
Develop method	Lovisa & Oskar	23-01-01	23-03-26	
Concept report for feedback	Lovisa & Oskar	23-01-31	23-01-31	
Apply Concept	Lovisa & Oskar	23-03-27	23-05-07	
Opposition	Lovisa & Oskar	23-01-31	23-05-07	
PPT presentation	Lovisa & Oskar	23-04-24	23-05-14	
Presentation	Lovisa & Oskar	23-04-24	23-05-26	
Utexpo poster	Lovisa & Oskar	18-03-29	23-05-28	

9.2. Attachment 2: FMEA



Potential failure mode	Potential Effect(s) of Failure	Sev (1-5)	Occur (1-5)	RPN	Current Process Controls (Preventions/Detection)	Recomended action (if it occurs)	Responsibility and target completion date	Action Result: Action Taken	Sev	Occ	RPN
Comunication											
	Delay in participation of meetings	1	4	4	Trying to keep up a good communication throgh email	Having a standard meeting time	Group Members	No	2	3	6
	Low productivity	2	2	4	Cheering on one another	Compliments and help one another, and listen to each other	Group Members	Yes	2	1	2
	Delayed work/assignments	4	1	4	Working on the parts that can be worked on	Splitting things up and working together	Group Members	Yes	4	1	4
Delay in information sharing	Long waits between answers in mails	1	3	3	Trying to send all the questions long before we need the answer	Send reminders and not everything at all.	Group Members	Yes	2	3	6
	Missed work	2	1	2	Having a open dialog and deadlines	Setting up expectations, making it standard to communicate lateness	Group Members	Yes	2	1	2
	Arguments	1	1	1	Having a clear communication	Having a standard meeting time	Group Members	No	1	1	1
Missacommunication from mail	Long waits between answers	1	3	3	Being very clear on points	Having a standard meeting time	Group Members	No	2	3	6
	Arguments	1	1	1	Having a clear communication	Having structured discussions, trying to clear possible conflict/ missconmunication	Group Members	Yes	1	1	1
Missacommunication to to language barrier	Not understanding one another	1	2	2	Checking that everyone is following	asking checkup question, make sure everyone is on same page	Group Members	Yes	1	2	2
Production											
	Not be able to finish thesis	5	2	10	Putting in the hours	splitting up in subparts, smaller tasks to easier accomplish	Group Members	Yes	5	1	5
Delay of product	Not being able to apply concept	3	1	3	Working extra hard to finish early	break down the concept, figure out the exact part not understood, and apply on well known situation first	Group Members	Yes	3	1	3
Delay of thesis report	U in grade	4	1	4	Having a regular communication will mentor from school	making sure you understand needed basics, breaking down into smaller parts to learn	Group Members	Yes	5	1	5
	Stressed students.	2	3	6	Limiting the work to only one day in the week	setting a certain time after which no uni work is to be done (evening set for yourself)	Group Members	Yes	3	3	9
	Delay in progress	1	1	1	Having deadlines	smaller deadlines, and more checkups	Group Members	Yes	3	2	6
Overload of workload (combined with other studies)	Halt in working progress	2	1	2	Having deadlines	smaller deadlines, and more checkups and communication	Group Members	Yes	1	1	1
	Delayed information	1	1	1	Being healthy	regular followup meetings in order to improve communication	Group Members	Yes	1	3	3
Sickness	No work being done	2	1	2	Working even when sick	calling in sick, making sure to take care of yourself in order to get well soon. Health over work	Group Members	Yes	4	1	4

9.3. Attachment 3: Stakeholder Analysis

	Stakeholders	Interests	Estimated want (1-5)	Prio-nr
Primary	Project organization	Expand Knowledge	5	2
		Bring value to the company	5	
		Achive excellent academic results	3	
		Build contact with the industry	4	
	VCE Sweden	Get value from the result of thesis	5	1
		Get measurable data how XR improves NPD	4	
		Explore XR differences between Swe/Kor	3	
	VCE Korea	Build connection with students	4	1
		Get value from the result of thesis	5	
		Explore XR differences between Swe/Kor	3	
	Supervisors	Supporting the Project Organization through the thesis	4	3
Secondary	Competitors	Developments in the field as a whole	2	8
	Researchers	Opportunities to continue research in area after thesis is completed	4	6
	Teams in different geographical locations	Better methods of working together in remote teams	5	5
	Halmstad University	Having students graduating into succesful fields	5	4
	Customers	Better products through more efficient product development	2	7

9.4. Attachment 4: Older version of Stakeholder Analysis

6. Stakeholders and Stakeholder Management

Core Stakeholders

- Project group
- VCE Sweden
- VCE Korea
- Supervisors

Primary Stakeholders

- Heavy Machine Industry
- Researchers
- Teams in different geographical locations

Secondary Stakeholders

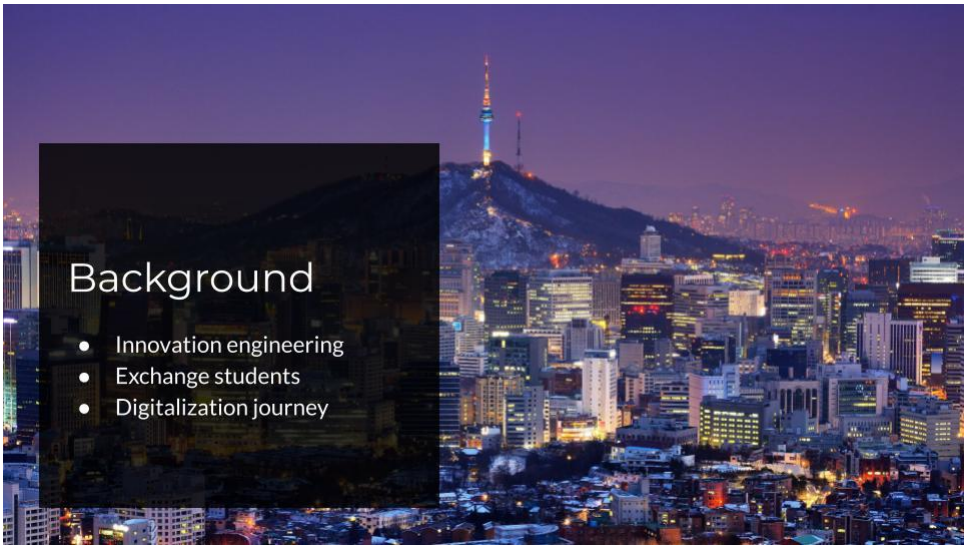
- The Public
- Halmstad University

The core stakeholders have a great interest in the project with varying levels of influence on it. VCE has a large interest in the project and are affected by the project's result and therefore have a lot of influence in the project. The supervisors, both from VCE and from Halmstad university, have interest in the result and will support the project group throughout the project.

The primary stakeholders have a similar high interest in the project and its result but do not have the same influence on it.

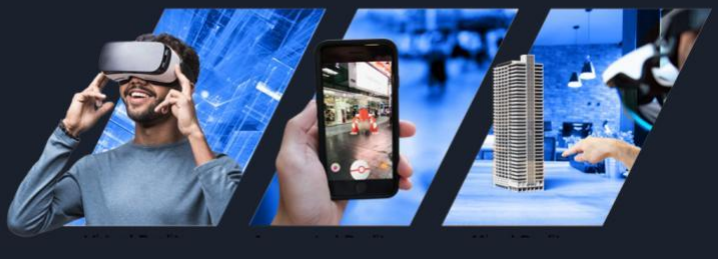
The secondary stakeholders have a low interest in the project but can nonetheless benefot from its results.

9.5. Attachment 5: Current Progress Presentation



Challenges

- VR/AR Underutilized
- Data transfer
- Clunky controls



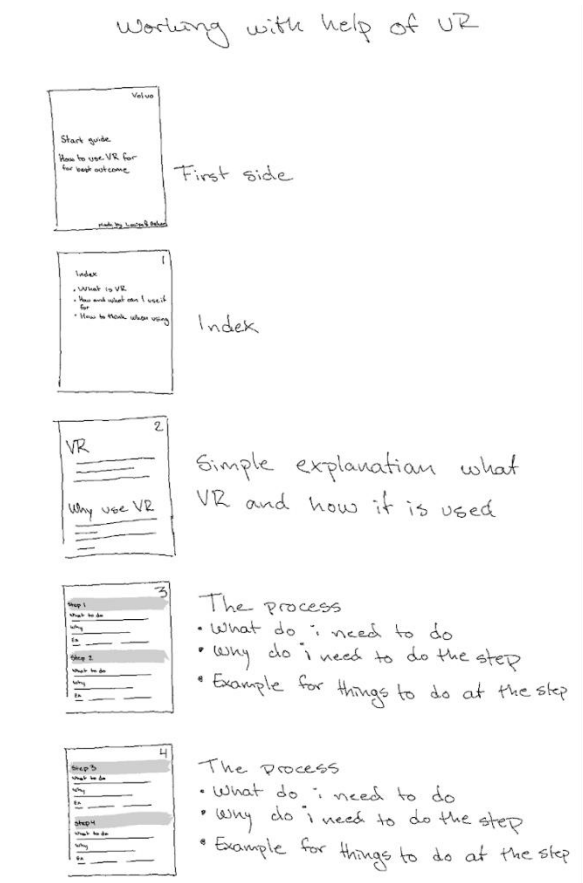
How

- **Published papers discuss:** CAD to VR transfer issues, Better remote collaboration ect.
- Conduct Kvale **interviews.**
- Qualitative good because it focuses on **experience**, Important if switch is to be successful

Sweden/Korea - Perspective

- Are there any differences present? Why?
- Is the other locations methods applicable at other location
- Why

9.6. Attachment 6: Layout of the guidebook



9.7. Attachment 7: One-pager final draft

Bachelor thesis "The potential benefits of using VR/AR in an engineering support application, working in distributed teams considering a Sweden – Korea context"

The project is about XR where we want to focus on streamlining stages of working in XR thus reducing the cost during the product development phase. The thesis would like to look at ways to reduce the time spent in this phase by optimizing the use of XR.

Execution of thesis project

Much of the work is theoretical, to start a literature review on trends and how XR is being used today within multiple industries will be conducted. The results will be analyzed and applied within the context of product development. To continue we will follow two specific cases chosen from VCE Korea* about recurring problems with the current XR working environment.

This will provide an understanding of what needs to be changed within VCE to increase efficiency. The end result of the thesis work should be improvements on the cases for the current work in XR in the context of product development that can be implemented and evaluated within VCE.

Lastly the method would be applied, the results would be quantified and evaluated

Korea part vs Sweden part

The job will take place in collaboration between Korea and Sweden, where Korea is responsible for the main subject of the degree project, i.e. questions and support regarding the use of XR within the product development phase. Sweden is responsible for the framework of the thesis itself as they have a better idea of how thesis projects are usually structured and developed. Sweden can also help us as they have access to the same development environment as Korea and we can get some on site experience of how the work is done.

Much of the information exchange will take place online because we are positioned in Halmstad but are available to be able to work on site on a few occasions.

*Specific cases will be suggested from VCE Korea (Discussed during meeting 7/11).

9.8. Attachment 8: Layout of the guidebook version 2

Working with help of VR

First side

Simple explanation what VR and how it is used

The process
- What do i need to do
- Why do i need to do the step
- Example for things to do at the step

The process
- What do i need to do
- Why do i need to do the step
- Example for things to do at the step

Steps

1. Evaluate if and which tests are relevent to do.
2. Create a checklist for what data is needed
3. VR, CAD, or Physical prototype. What needs to be done in what program or physical prototype
4. Evaluate the results from the sessions
5. Repeat the process 1-4

9.9. Attachment 9: The final startup guide.

Startup Guide:

How to use Virtual Reality (VR) for the best outcome

Made by Lovisa Brenne and Oskar Naij

VR

VR or Virtual Reality is used to make virtual simulations (usually from a first-person perspective). This is a more immersive experience than a traditional way of working and can have benefits over that style of working in some applications. Working in VR can be different from working in a more traditional sense. However, it's important to think of VR models just like prototypes that they should be used to make tests previously using physical prototypes. There are areas where CAD can be a more efficient application for doing tests, and there will be areas where VR cannot fill the same role as a physical prototype. But many tests can now be done in VR, saving a lot of money, time, and material.

Why use VR

Prototypes are used in almost every company dealing with product development and they can serve multiple different functions such as design, visualization, proof of concept and safety. These can often serve as milestones for products before they can be released on the market.
Every prototype made has a cost associated with it being the cost of the material and machine time it takes to produce them and the work needed to design its parts.
It's very important to test the products and ideas before they are released. To get the most significant profit out of products developed it's essential to reduce the cost of development as much as possible. One way to do that is by doing as much prototyping digitally as possible and trying to limit the number of physical prototypes. A beneficial tool to achieve this is VR.
VR has the economic benefit of not needing raw materials to be made and the environmental benefit of making it greener.
Product developers need to determine what parts of the prototype are able to be tested in VR in the early stages of the project. Some examples of usage areas where VR is beneficial are: Better understanding the scale of your prototypes/ seeing your prototypes in a 1:1 scale and trying many more iterations without adding extra costs in the form of material and machine costs.

How to implement VR

Step 1. Evaluate

Action:
Evaluate if and which of the tests is relevant to do.

Why:
VR might be interesting and new but should only be used for its intended purpose.

Step 2. Create a checklist

Action:
Have a list of what needs to be controlled throughout the process. The checklist needs to be detailed to get as specific responses as possible.

Why:
It is essential to have a plan and a course of action. With a detailed plan, it's easier to organize and execute a prototype.

Example:
Set up geometry securance like height and weight limits.

Step 3. VR, CAD, or Physical prototype

Action:
Classify what can be done in VR, which needs a physical prototype, and what needs to be done in CAD to make everything happen.

Why:
VR needs CAD files to follow, and some tests can only be done on physical objects.

Example:
Few examples that you can check with VR. Interface fixed or float, access, ergonomics, probability internal/ external. Small things such as how you stand when working ergonomic wise or how long a cable needs to be are relevant situations to test in a VR.

Few examples that you can check with a physical prototype. Interface fixed or float, access, ergonomics, tolerances, producibility internal/external. Here things such as max capacity or sound limit are better suited for a physical prototype.

Step 4. Evaluate

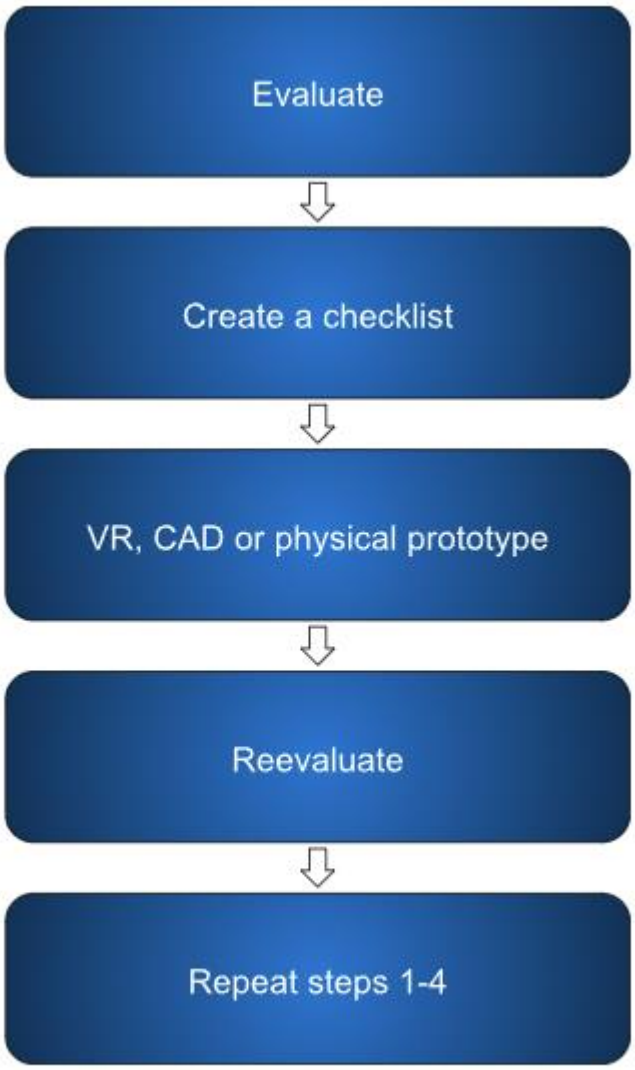
Action:
Evaluate the results from the test to the checklist.

Why:
During/after the test, write down the result of the test to be able to evaluate the outcome and record improvement.

Step 5. Repeat

Action:
Repeat steps 1-4 throughout A, B, C, and P-build.

Why:
All models must be tested and evaluated to improve in each step.


Evaluate
Create a checklist
VR, CAD or physical prototype
Reevaluate
Repeat steps 1-4

9.10. Attachment 10: One-pager first draft

Examensarbete
Vi är två studenter från Högskolan i Halmstad som läser 3:e året på Utvecklingsingenjörsprogrammet. Vårt examensarbete är inom XR där vi vill fokusera på effektivisering av arbetsprocess och kostnadsbesparingar under produktutvecklingsfasen vid jobb med XR.

Utförande av examensarbete
Mycket av arbetet är teoretisk lagt där man jämför tidigare cases för att därefter kunna skapa en arbetsmetodik som gör att XR utnyttjats till dess fulla potential för effektivisering. Vi kommer observerar hur arbetet utförs i dagsläget för att lokalisera flaskhalsar där en ny innovation kan effektivisera dessa.
Vi kommer även vilja diskutera med personer som arbetar i miljön i hur de jobbar.

Korea delen ut vs Sverigedelen?
Jobbet kommer ske i samarbete mellan Korea och Sverige där Korea är ansvarig för huvudämnet av examensarbetet d.v.s. frågor och stöd kring användningen av XR inom produktutvecklingsfasen. Sverige är ansvarig för utformningen av arbetet i sig då dem har en bättre uppfattning hur examensarbeten vanligtvis är utformade och brukar utvecklas. Sverige kan även hjälpa oss då de har tillgång till samma utvecklingsmiljö som Korea och vi kan få en uppfattning om hur det går till i praktiken på plats.

Mycket av informationsutbytet kommer att ske via online pga att vi är positionerade i Halmstad men är tillgängliga att vid fåtals tillfällen kunna arbeta plastbelagt.

9.11. Attachment 11: One-pager second draft

Bachelor thesis
The project is about XR where we want to focus on streamlining stages of working in XR thus reducing the cost during the product development phase. The thesis would like to look at ways to reduce the time spent in this phase by optimizing the use of XR.

Execution of thesis project
Much of the work is theoretical, to start a literature review on trends and how XR is being used today within multiple industries will be conducted. The results will be analyzed and applied within the context of product development. Following this the thesis work will focus on observing how the work is currently carried out within VCE in order to locate bottlenecks where a new innovation can make them more efficient. To get even more data we also want to discuss with people who work in the environment how they work and potential problems with the current XR working environment.
This will provide an understanding of what needs to be changed within VCE to increase efficiency. The end result of the thesis work should be a framework for working in XR in the context of product development that can be implemented and evaluated within VCE.
Lastly the method would be applied and evaluated.

Korea part vs Sweden part
The job will take place in collaboration between Korea and Sweden, where Korea is responsible for the main subject of the degree project, i.e. questions and support regarding the use of XR within the product development phase. Sweden is responsible for the framework of the thesis itself as they have a better idea of how thesis projects are usually structured and developed. Sweden can also help us as they have access to the same development environment as Korea and we can get some on site experience of how the work is done.

Much of the information exchange will take place via online because we are positioned in Halmstad but are available to be able to work on site on a few occasions.

9.12. Attachment 1: Project Plan

Project plan

The potential benefits of using VR/AR in an engineering support application, working in distributed teams considering a Sweden – Korea context

Students: Lovisa Brenne & Oskar Naij

Mentors:Fawzi Halila, Jang Jinho, Pia Wessman

Company: Volvo Construction Equipment (VCE)

Submitted: 07-02-2023

1. Introduction **3**
1.1. Background 3
1.2. Problem formulation 4
1.3. Concept 4
1.3.1. What 4
1.3.2. How 4
1.4. Goal 4
1.5. Purpose 4
1.6. Limitations 5
1.7. Project goals 5
1.8. Effect target 5
1.9. Requirement specification 5
1.10. Project model 5
1.10.1. Agile project model 5
1.10.2. Dynamic product development 6
1.11. Tools 6
1.11.1. Pilot study 6
1.11.2. Brainstorming 6
1.11.3. Gantt - Diagram 7
1.11.4. Stakeholder Analysis 7
1.11.5. FMEA 7
1.11.6. VR Headset 7
1.11.7. Kvale Interviews 8
1.11.8. Reference group 8
1.11.9. User Stories 9
1.11.10. Digital tools 9
1.11.11. Cross reference 9
2. Project Organization **10**
3. Activity-,Resource- and Timeplan **10**
4. Budget and financing **11**
5. Stakeholders and Stakeholder Management **11**
6. Risks and possibilities **11**
7. SWOT **12**

1. Introduction

1.1. Background

Lovisa and Oskar are students at Halmstad University pursuing their degree in Innovation Engineering. As part of their academic journey, they have embarked on a thesis project in collaboration with Volvo Construction Equipment. This work aims to showcase their technical expertise and apply the knowledge gained during their education in a practical setting. With Volvo being at the forefront of technological advancements in the automotive and heavy machinery industries, the students have a unique opportunity to contribute to the field of innovation engineering.

During the spring of 2022 both students were pursuing exchange studies at Korea and Hanyang University respectively through their degree in Innovation engineering at Halmstad University. This sparked an interest to conduct their bachelor's thesis in connection with Korea in some capacity. Contact was made with VCE Korea to see if collaboration between the two parties seemed feasible. Through the support of VCE Sweden who had a firm grasp of the common practices of students writing their thesis work in collaboration with companies a topic to cover in their thesis was decided upon during the fall semester.

The landscape of Product Development is often in the forefront of new developments in technology and progress. Sometimes however businesses have a difficult time implementing new technologies within them because of knowledge gaps between the management trying to implement the technology and the workforce itself. (Gravenhorst & Veld, 2004, p.320)

Previous research has been done around product development in global teams and VR as a solution to the challenges it entails e.g. effective communication and more specific VR problems. (Balzerkiewitz & Strechert, 2020,) (Siltanen et al., 2021,)

But no study has specifically looked at the context of collaboration between Sweden and South Korea.

It's interesting to look at the Sweden and South Korea collaboration because of their long history of economical, political and cultural relations. (Armanini et al., 2020, p.70-77)

Both Sweden and South Korea are incredibly innovative countries with enormous investments in R&D. (Dayton, 2020, p.55-56)

A perfect illustration of Sweden and South Koreas different strengths comes from the 'Smart cities' sector. According to Sweden's trade commissioner in South Korea, "when it comes to smart cities, Korea is strong on the technology side, while Sweden is thinking more sustainably. There I think we can cooperate and complement each other". Similarly with VR the organization believes Sweden and South Korea have different strengths and weaknesses

as well as business cultures and therefore can learn a lot from each other. (Armanini et al., 2020, p.71)

1.2. Problem formulation

Volvo Construction Equipment (VCE) is a big player in the construction equipment industry and wants to use new technologies in their production. VR and AR technologies have been improving quickly over the last decade and businesses all over the world in multiple different fields are trying to find cases where they can use it. The project group's goal is to, from the cases presented by VCE, find improvements for working in the new more digital way as opposed to the older traditional way.

1.3. Concept

The concept is to work with VCE both in Korea and Sweden and look at how their current work in XR in the NPD phase is being conducted and the challenges they face. From looking at both different locations information and current situation the project organization will try to extrapolate what could be learned from each other and through looking at similarities and interviews form a method of working in XR more efficiently.

1.3.1. What

Finding similar and different use cases and attitudes towards conducting work in VR across the Swedish and Korean teams.

1.3.2. How

Conducting interviews with both teams and finding what is similar and what is different as well as investigating what works well and the reason for it.

1.4. Goal

Create a method to improve the current way of working in XR technologies that will minimize the time to market for each project.

1.5. Purpose

To make the use of XR technologies in the product development phase more effectively.

1.6. Limitations

This project stretches over the course from 29 of August 2022 to 28 of May of 2023. Due to the regional difference in which everyone is located, communication will mostly be through email. There is also a time difference due to the student being located in Sweden and one of the mentors being located in South Korea.

This project will not produce any physical product. Instead a report regarding benefits of using VR in product development will be provided to VCE. It's also limited to the product development phase.

1.7. Project goals

- Find and create a work model in which the benefits of VR are more used.
- Present measurable data difference in traditional product development and product development with help of VR.

1.8. Effect target

- Create a model in which the usage of VR improves NPD.
- Decrease either time or money spent on projects.

1.9. Requirement specification

Due to this project's explorative nature a natural requirement specification is not made. Instead the use of user stories are in focus. The project is interested in what the user wants to have from this and what their inputs are.

1.10. Project model

The group determined that success in the project requires the use of two complementary workmodels: Agile project model and Dynamic product development. These will be used in parallel, but the ratio of usage will vary in different phases. The choice of these models was driven by the absence of a physical product and the uncertainty regarding the technology's potential, as they offer the necessary adaptability for handling changes.

1.10.1. Agile project model

The Agile product model is a flexible and collaborative approach to product development that prioritizes customer satisfaction. It follows the Agile methodology and involves

delivering working product increments in short sprints, with close collaboration between the development team, customer, and stakeholders. The team continuously adjusts to changing customer needs and market conditions, resulting in a constantly improved product. This approach is suitable for projects with high uncertainty, as it enables quick adaptation to changing requirements. (Tonnquist, 2018, p.189)

1.10.2. Dynamic product development

Dynamic product development is a fast-paced, agile approach to product creation that emphasizes speed, flexibility, and innovation. It involves rapid prototyping, cross-functional collaboration, and a customer-focused mindset. New and emerging technologies, such as digital manufacturing and AI, are often utilized to increase efficiency. The goal of dynamic product development is to bring new products to market quickly and respond to changing customer needs and market trends. This approach places a strong emphasis on innovation and finding creative solutions to product development challenges. (Holmdahl, 2009)

1.11. Tools

1.11.1. Pilot study

A pilot study is made in the beginning of a project to assess ideas, needs and underlying factors to form a formation for a project. The reason is to unravel all the conditions and to a degree see if it's possible to do. A pilot study presents all the requirements and presents a plan that reassures that the crucial resources are available to successfully finish a project. (Pearson et al., 2020)

1.11.2. Brainstorming

Brainstorming is used often in the beginning of the project due to it being a creative problem-solving technique that generates a large amount of ideas in a limited time. The ideas don't need to be realistic and should be met with an open mind with no criticism. This is because the goal is to encourage the participants to be creative and find possible solutions later on for the problem.

Brainstorming is done in a group where the members share all of their thoughts and ideas. The method in how the ideas are shared varies from either having a group discussion to writing them on post-it notes or a whiteboard.

The brainstorming process encourages creativity and collaboration within the team to identify possible solutions. With the encouragement that involves the free-flowing of mind and ideas it helps individuals and teams overcome creative roadblocks and discover fresh, inventive solutions. (Wikberg Nilsson et al., 2021, p.137)

1.11.3. Gantt - Diagram

In this thesis work, a Gantt chart is used to plan, schedule, and track the progress of the research project. By creating a Gantt chart, the task required can be defined to complete the project and set a timeline for each one. This helps the project stay organized and on track, ensuring that work is completed in a timely and efficient manner. The Gantt chart can also be used to communicate the research schedule to the advisor, committee members, or other stakeholders, providing them with a clear understanding of the project timeline. Additionally, the Gantt chart can be used to monitor progress and identify any potential roadblocks, allowing to make necessary adjustments and stay on track to complete the thesis work successfully. (Tonnquist, 2018, p.178)

1.11.4. Stakeholder Analysis

A Stakeholder Analysis is a tool to map the different stakeholders and how the project affects them and how they affect the project. All stakeholders don't share the same amount of interest in the project and they are, because of this, divided into smaller groups of primary and secondary stakeholders. The primary stakeholders are those directly impacted by or impacting the project, while secondary stakeholders have a lower level of interest and do not affect the project. The core stakeholder, in this case the students, is considered primary due to their significance. A stakeholder analysis was conducted to determine the importance of the project for each individual, which will inform future decisions. The goal is to maintain a balance among stakeholders, ensuring satisfaction for all in the end. (Tonnquist, 2018, 104)

1.11.5. FMEA

FMEA (Failure Modes and Effects Analysis) is a tool used to assess the risk of failures in designs or systems. It can be used to evaluate the potential failures of a design and determine the impact of those failures. The steps involved in FMEA include defining the system, identifying potential failures, assessing impact, evaluating likelihood of occurrence, determining corrective actions, and prioritizing failures. FMEA helps ensure product quality and reliability and improve design and manufacturing processes. The results can inform design changes, process improvements, and risk mitigation strategies and provide a basis for further research and development. (Tonnquist, 2018, p.244)

1.11.6. VR Headset

A VR set, In particular, Meta Quest 2 has been used to give the student a better feeling in how VR works and feels. VR Headsets are what are called HMD's which is short for head mounted displays and is today the main way to use VR in most applications. The Meta Quest 2 is a standalone headset meaning it runs off a battery and has cameras on the outside to track its position. As opposed to having them set up in the space where the VR is being used and having the headset connected to some sort of power supply.

The benefits of this are:

- the improved mobility and convenience of not needing wires to use.
- cheaper to buy and

And the cons are:

- having a limited battery life
- Less powerful hardware.

(*The Differences Between PC VR and Standalone VR*, 2011)

There are 3 DOF and 6 DOF VR headsets. DOF stands for degrees of freedom which describes how many ways it's possible to move within the program. 3 DOF headsets only allow for rotational movements around the x,y and z axis, whereas 6 DOF allows for rotational as well as translational movements along the aforementioned axes.(*Degrees of Freedom | Google VR*, 2018)

1.11.7. Kvale Interviews

Kvale Interviews is a qualitative research method that involves in-depth, semi-structured interviews to gather information from individuals about their experiences and perspectives. The interviews are typically conducted one-on-one and are guided by a set of predetermined questions, but also allow for some degree of flexibility and exploration. The method is named after its originator, Steinar Kvale, and is used in various fields, including psychology, sociology, and education, to gain insight into complex phenomena and subjective experiences. The goal of Kvale Interviews is to obtain rich, detailed data that can provide a deeper understanding of the topic being studied. (Kvale, 1996)

1.11.8. Reference group

A reference group serves as a platform for evaluating concepts, finding solutions, and showcasing partial solutions. When utilized properly, it can serve as a valuable aid for the project manager in ensuring the project stays aligned with both the plans and stakeholders' expectations. The input from the reference group can contribute to refining the specifications and plans. The members of the reference group may include potential users, targeted customers, and business partners. (Tonnquist, 2018, p.41)

1.11.9. User Stories

User stories are a tool in the Agile development model used to describe requirements from the customer's perspective, usually in the format "As a [user], I want [feature], so that [reason/benefit]." This helps align development with user needs, facilitates communication, and breaks down complex requirements into manageable pieces. (Tonnquist, 2018, p.121)

1.11.10. Digital tools

Digital tools and software include both hardware devices like computers and software applications such as various programs. They serve to improve communication and optimize processes by utilizing the features of computers and the internet. This is especially crucial in a global project where the participants, including mentors, engineers, and students, are located in different locations. (Almi, n.d.)

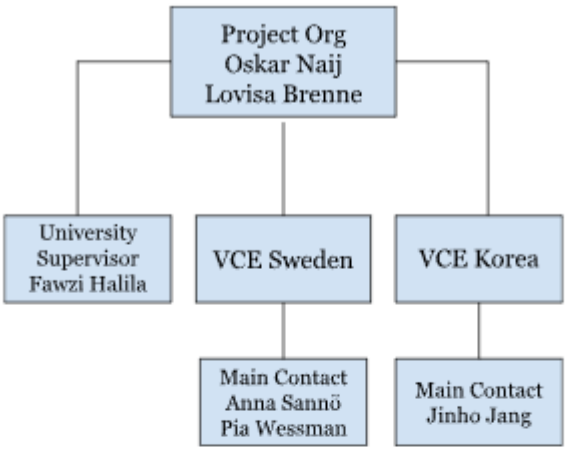
Some common examples of digital tools that can be employed in such projects are video conferencing platforms such as Zoom, creative software like Adobe, project management tools like Asana, collaboration platforms like SharePoint, and cloud storage solutions like Google Drive. These tools offer an easy and efficient way for team members to collaborate, exchange information, and work together on projects, even from separate locations.

1.11.11. Cross reference

Due to much of the information gathered from online sources for the project, the group wanted to make sure that the information they gathered was as true as possible. To manage this articles will be cross referenced with one another. This will also apply in interviews later on where information is gathered and cross referenced so isolate problems and solutions.

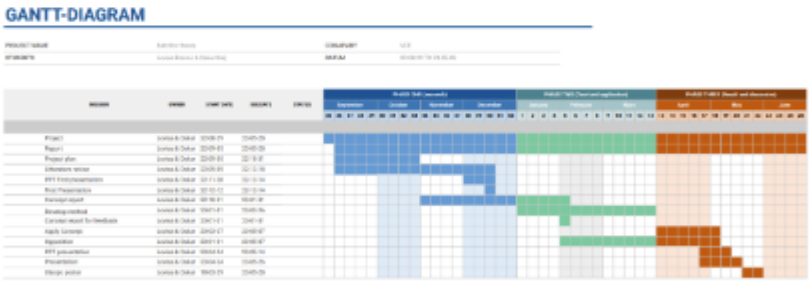
Additionally, the group recognizes the importance of ensuring the validity of the information gathered and therefore, cross-referencing will be a crucial step in the process. By cross-checking the articles and later, the information collected during interviews, the group aims to minimize the risk of inaccuracies and provide the most reliable information possible.

2. Project Organization



The project organization consists of the project group members Oskar Naij and Lovisa Brenne. To support the project Fawzi Halila will act as the supervisor from Halmstad University as support to the project group's thesis work. In addition to that Anna Sannö will act as the main contact person to the project helping familiarize VCE Korea with how Swedish thesis work tends to be conducted. Jinho Jang will act as the groups main contact from VCE Korea which is the main partner for the thesis work and the most relevant contact in regards to the project's actual contents.

3. Activity-,Resource- and Timeplan



A timeplan was made with the help of a Gantt schedule in which the schedule was divided into three categories. All the known deadlines were also filled in and an estimated time to work on the project. No activity nor resource plan was made because the only resource so far is a computer and the determination when people need to be available has yet to be decided.

4. Budget and financing

This project does not have a special budget. However, the students get a salary that matches the amount of hours they put into the project that comes from the school as well as access to a computer at Volvo. In the contract it's also mentioned that VCE is allowed to use the work the student does.

5. Stakeholders and Stakeholder Management

Core Stakeholders

- Project organization
- VCE Sweden
- VCE Korea
- Supervisors

Primary Stakeholders

- Heavy Machine Industry
- Researchers
- Teams in different geographical locations

Secondary Stakeholders

- The Public
- Halmstad University

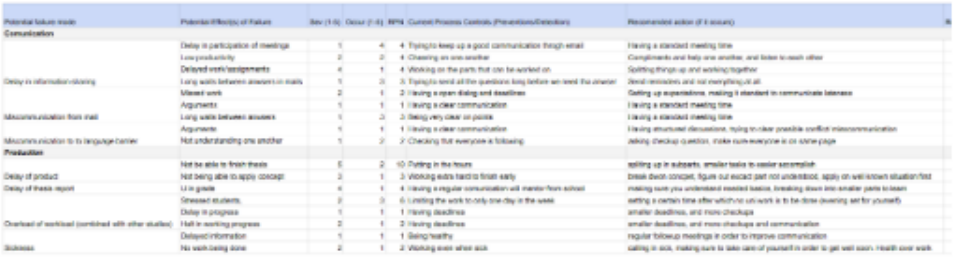
The core stakeholders have a great interest in the project with varying levels of influence on it. VCE has a large interest in the project and are affected by the project's result and therefore have a lot of influence in the project. The supervisors, both from VCE and from Halmstad university, have interest in the result and will support the project group throughout the project.

The primary stakeholders have a similar high interest in the project and its result but do not have the same influence on it.

The secondary stakeholders have a low interest in the project but can nonetheless benefit from its results.

6. Risks and possibilities

For risks in the project a FMEA was made. Here all the risks for the project were written up. Much involved with communication as being in different locations made it harder to have regular contacts and communication in a second language can lead to miscommunication. Others were related to delays as a big potential for failure.



Potential failure mode	Potential Effect(s) of Failure	Sev (1-5)	Occur (1-5)	RPN	Current Process Controls (Preventions/Detection)	Recommended action (if it occurs)	R
Comunication							
	Delay in participation of meetings	1	4	4	Trying to keep up a good communication though email	Having a standard meeting time	
	Low productivity	2	2	4	Cheering on one another	Compliments and help one another, and listen to each other	
	Delayed work/assignments	4	1	4	Working on the parts that can be worked on	Splitting things up and working together	
Delay in information/missing	Long waits between answers in mails	1	3	3	Trying to send all the questions long before we need the answer	Send reminders and not everything at all	
	Missed work	2	1	2	Having a open dialog and deadlines	Getting up expectations, making it standard to communicate lateness	
	Arguments	1	1	1	Having a clear communication	Having a standard meeting time	
Miscommunication from mail	Long waits between answers	1	3	3	Being very clear on points	Having a standard meeting time	
	Arguments	1	1	1	Having a clear communication	Having structured discussions, trying to clear possible conflict miscommunication	
Miscommunication to to language barrier	Not understanding one another	1	2	2	Checking that everyone is following	delaying checkup question, make sure everyone is on same page	
Production							
	Not be able to finish thesis	5	2	10	Putting in the hours	splitting up in subparts, smaller tasks to easier accomplish	
Delay of product	Not being able to apply concept	3	1	3	Working extra hard to finish early	break down concept, figure out exact part not understood, apply on well known situation first	
Delay of thesis report	Lt in grade	4	1	4	Having a regular comunication will mentor from school	making sure you understand needed basics, breaking down into smaller parts to learn	
	Stressed students	3	3	6	Limiting the work to only one day in the week	setting a certain time after which no work is to be done (evening set for yourself)	
	Delay in progress	1	1	1	Having deadlines	smaller deadlines, and more checkups	
Overload of workload (combined with other studies)	Halt in working progress	2	1	2	Having deadlines	smaller deadlines, and more checkups and communication	
	Delayed information	1	1	1	Being healthy	regular followup meetings in order to improve communication	
Sickness	No work being done	2	1	2	Working even when sick	calling in sick, making sure to take care of yourself in order to get well soon, Health over work	

7. SWOT

Strengths	Weakness
• Don't have to build prototype thus saving costs • Immersive technology might give better visualization • Helps reduce waste • Better remote collaboration	• Upfront investment costs • Few people know how to use it • Technical difficulties such as non interactive controls and low latency causing motion sickness
Opportunity	**Threat**
• Being ahead of the curve on a new standard • Diverse use cases	• Highly competitive market • Rapid developments in the field

7.1. Strengths vs Weakness

It's important to consider the cost upfront might be covered by the savings of using VR and therefore might be valuable. It's also important to use the technology in areas where it shines, so focus on things such as visualization and collaboration, not things that lean heavily on the controls in the VR itself such as sketching.

7.2. Strengths vs Threats

The strengths of today might not persist for long, it's important when working with new technologies to be proactive and stay up to date with the newest developments with the tech as not to implement outdated methods or products.

7.3. Strengths vs Opportunity

Being early in adopting new technology holds the power of shaping where the industry moves. This is naturally a powerful and desirable position to be in, it's important not to be complacent in a situation like this and stay honest and self critical of steps made.

7.4. Weakness vs Opportunity

It's important to carefully consider if it's possible to get ahead of the curve by investing in VR early and weigh its many diverse use cases against the upfront cost of investing and also keep the current limitations of the technology and limited competent user base in mind.

7.5. Weakness vs Threat

The virtual reality market faces significant challenges, including high competition and rapid advancements in the field. One of the major weaknesses of virtual reality is the upfront investment costs involved in developing and deploying VR technology. This can be a hindrance for companies looking to enter the market. Additionally, few people currently have the skills and knowledge to effectively use virtual reality, further limiting its potential adoption.

Another challenge is the technical difficulties associated with virtual reality, such as non-interactive controls and low latency, which can cause motion sickness in users. These issues can detract from the user experience and limit the potential for widespread adoption.

Taken together, the upfront investment costs, lack of knowledgeable users, and technical difficulties represent significant weaknesses against the threats posed by a highly competitive market and rapid developments in the field. To be successful, Volvo must overcome these challenges and deliver innovative solutions that address these limitations.

7.6. Opportunity vs Threat

With it being a highly competitive market shows that it's an opportunity market. Volvo being out there in the beginning of this trend can form how the market is going to change and develop what's going to happen. But it also means that there ain't alot of different options or maybe the technology that is needed out there.

The diversity in the usage to begin with and the opportunities that exist in the future are endless. Not just thinking in a NPD perspective but it has gaming, social, teaching ect. opportunities. Volvo might excellence in the usage of the program in industrial industry and NPD or even develop to educational, there will be a competitive market to do this but by competing with other technology develops.