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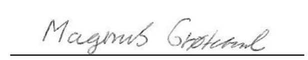
Reality training in manufacturing



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Preface

The completion of this thesis signifies the culmination of a five-year journey studying for a Master of Science in Industrial Economics at the University of Stavanger in collaboration with Advansia, our corporate partner. With a credit value of 30, this thesis has been diligently crafted during the period from 06 January 2023 to 15 June 2023.

Engaging in this thesis has provided me with valuable insights into reality training in manufacturing, addressing crucial matters within the realms of technology, risk, and financial considerations. Exploring such a pertinent and rewarding subject has been an honor, as its relevance will undoubtedly extend to my future professional endeavors.

I extend my heartfelt gratitude to Tone Bruvoll, my faculty supervisor at the University of Stavanger, for their exceptional guidance and valuable professional insights throughout the process. I would also like to express my appreciation to Hannah Perrens and Dinah Olivares Laland, my external business supervisors from Advansia, for their invaluable contributions.

I am grateful to Beyonder and Norske Skog Skogn for their collaboration and assistance in gathering the pertinent data for this thesis. Their support has been instrumental in enriching the research.

Lastly, I would like to extend my thanks to my family, friends, and colleagues for their unwavering encouragement and support throughout my academic journey. Their presence has been a source of strength and inspiration.

Reality Training

Abstract

This thesis aims to answer whether manufacturing companies should develop reality training for production based on analysis and comprehensive literature study. The thesis will investigate the analysis of reality training in technology, investment, risk, and financial aspects. Hence, it will answer the following research question: *What are the consequences of establishing reality training in manufacturing?*

To answer the technology and investment aspect of reality training, current research has been done from the research of literature, companies, and relevant investment support. There have been a Technology & Investment analysis of the current research's most critical drivers and barriers to creating a result. The result wants to find which one of the aspects is the most critical factors in reality training.

In terms of the risk aspect, the thesis will conduct a comprehensive risk analysis by comparing reality training with traditional training methods, focusing on critical operations. By examining existing critical operations in traditional training, the study aims to determine the impact level of risk when utilizing reality training in production settings. The risk analysis will specifically utilize a case study involving critical operations at Beyonder, a Norwegian battery manufacturing company. The findings from this analysis will shed light on whether reality training has an influence on the level of risk in production compared to traditional training methods.

In terms of the financial aspects, the thesis aims to conduct a comprehensive Financial Statement analysis comparing the utilization of reality training with traditional training methods, specifically focusing on Norske Skog Skogn. The analysis will be conducted through two distinct cases, with the objective of determining the total EBITDA over a six year period.

Case 1 will investigate the change in EBITDA between traditional and reality training for one year. This case will examine the implementation of virtual reality training to establish a new factory, considering an average training duration of 3 months to 1 year before the factory begins generating revenue. In Case 2, the analysis will focus on evaluating the cumulative net present value, specifically examining the investment benefits and costs related to the implementation of mixed reality over a period of five years. As part of this evaluation, the thesis will consider the impact of investment benefits on OPEX, comparing the changes in EBITDA between traditional and reality training.

By evaluating the outcomes of these two cases, the thesis will provide a Financial Statement analysis result of the changes in EBITDA over a six year period, specifically focusing on the transition from traditional training to reality training. This analysis will contribute to a better understanding of the financial aspect of reality training within the context of Norske Skog Skogn.

Abbrevations

AEC	Architecture, Engineering, and Construction
AR	Augmented Reality
BIM	Building Information Modeling
CAD	Computer-Aided Design
CAPEX	Capital Expenditures
EBITDA	Earnings Before Interests, Taxes, Depreciation's and Amortizations
HMD	Head Mounted Display
HPU	Holographic Processing Unit
MR	Mixed Reality
NPV	Net Present Value
OPEX	Operating Expense
R&D	Research and Development
SDG	Sustainability Development Goal
UK	United Kingdom
UN	United Nations
VR	Virtual Reality
XR	Extended Reality

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1 Introduction

1.1 Background

The UN's definition of sustainability is *"development that caters to today's needs without destroying the possibilities for future generations to meet their needs"*[52]. According to Sustainable Development Goal (SDG) 9, it means to *"Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation"*. One consequence of the UN's sustainability goals related to climate is that the manufacturing industry is in a reformation phase in cooperation with authorities [46]. In solving the problem of such a relevant topic, it has become pertinent to focus on the digital transformation of training in manufacturing since it involves the foster innovation to increase the resilient infrastructure in the training processes of manufacturing [29, p.938].

Due to the current situation regarding sustainable development goal 9, the COVID-19 pandemic has demonstrated the importance of creating innovative and resilient infrastructure in manufacturing. The scale of technology grade in unique manufacturing has been affected differently by the COVID-19 pandemic, shown in figure 1.1. The results shows that higher-technology manufacturing industries fared better than lower-tech industries during the pandemic and therefore recovered faster in production. In particular, high-risk and highly complex manufacturing require cost-effective training programs to minimize training risks, improve higher production efficiency, and reduce training costs [46].

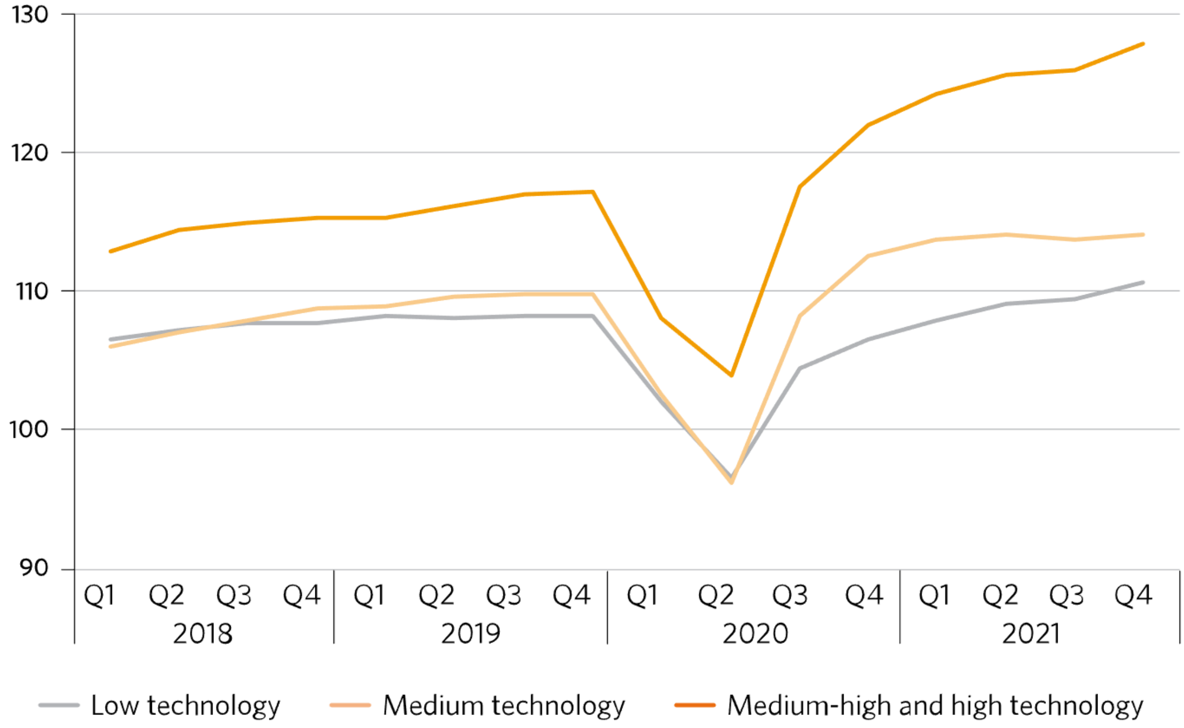

figure 1.1: Globally manufacturing production, first quarter of 2018 to the last quarter of 2021[46].

The Norwegian Government's green industrial initiative, as outlined in the report, emphasizes the country's ambition to become a leader in digital infrastructure and drive the digital transformation of its industries. To achieve this, the Government has initiated a national Industry 4.0 program to implement digital technologies [45, p. 51].

In 2022, the Labour and Welfare Administration conducted a business survey that revealed significant recruitment challenges across various sectors in Norway, as depicted in Figure 1.2. The analysis highlighted a notable shortage of skills, particularly in the manufacturing sector's machinery and equipment production. Insufficiently skilled operators can introduce risks and exacerbate issues that may arise during production. In response to these challenges, the Norwegian Government aims to enhance training programs, focusing on the manufacturing industry. The objective is to equip the workforce with the necessary skills to address industry-specific demands and ensure the industry's growth and competitiveness [45, p. 20-21].

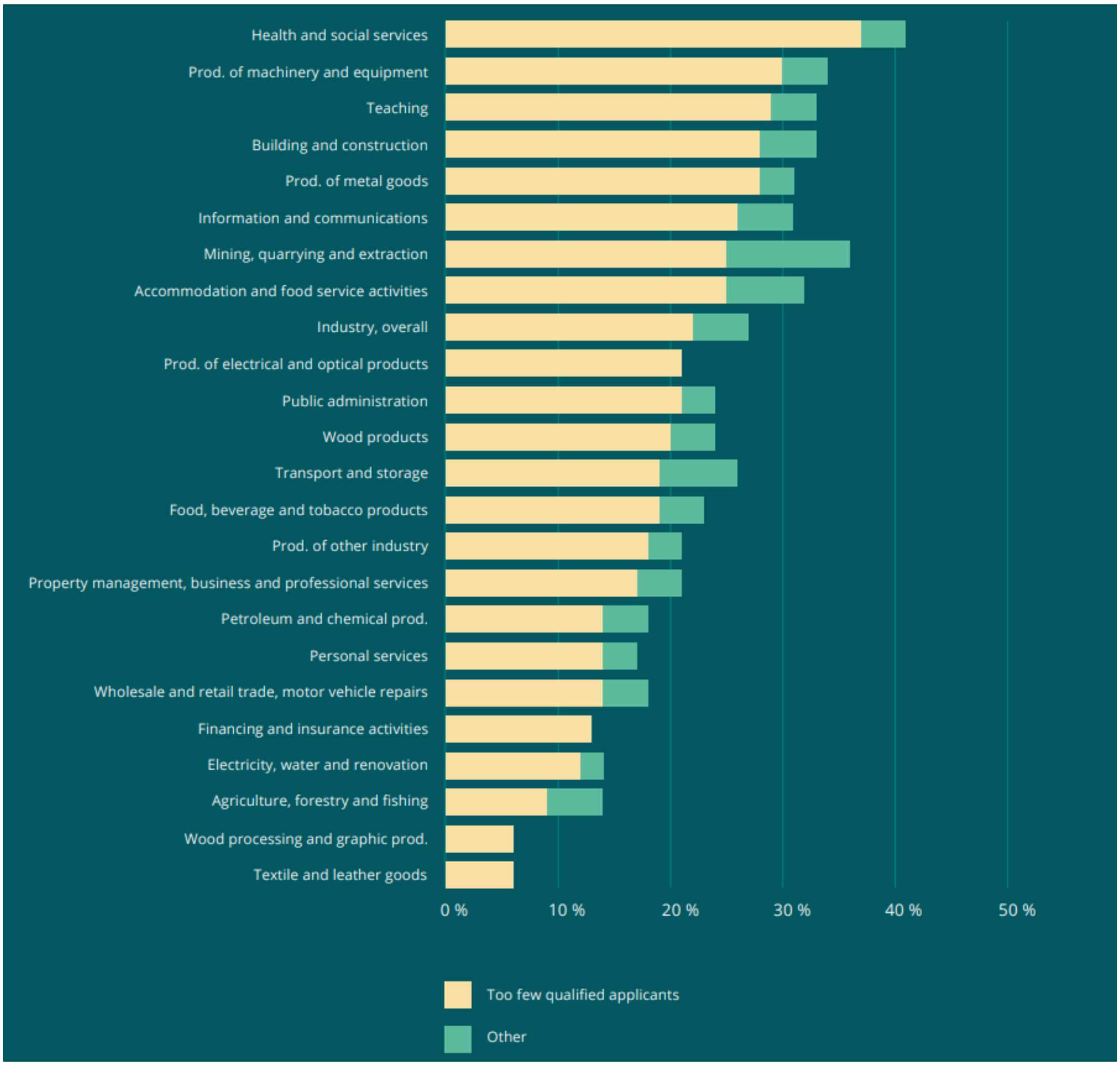

figure 1.2: Shortage of skills in several sectors in Norway [45, p.20].

1.2 Research gaps

Extensive research has been conducted on the digital representation of physical objects in manufacturing. However, most studies have focused on utilizing applications and system development for training. While digital representation has been extensively used for product design and assembly planning, there needs to be more emphasis on developing training systems to train industrial workers effectively. This research gap has created a disconnection between the analysis conducted during system development and the associated risks and financial costs [2, p.3744].

1.3 Research question

The objective of this master thesis is to examine and shed light on the implications of implementing reality training as a digital transformation in the manufacturing sector, in comparison to traditional training methods. The study aims to contribute to the understanding of the drivers and barriers associated with the development, risk, and financial effects of reality training. By investigating the consequences of different training approaches, the research aims to align with SDG 9 and the national Industry 4.0 program initiated by the Norwegian Government. The consequences of using reality training in manufacturing are unclear, which leads to the investigation of the thesis:

What are the consequences of establishing reality training in manufacturing?

The following sub-questions will be investigated to answer the main research question:

- What are the most critical drivers and barriers in the development of reality training?
- Does reality training affect the risk impact level upon production from traditional training?
- How does reality training affect EBITDA during six years compared to traditional training?

1.4 Constraints

The masters thesis has a scope of 30 credits, and has a limited time from 06 January 2023 to June 15, 2023. Therefore, the thesis is restricted to the following limitations below:

- Reality training includes three different training forms of virtual reality (VR), augmented reality (AR), and mixed reality (MR), which is described in theory chapter 2.1.2.
- Addresses a *Technology and Investment analysis* in implementing reality training.
- Addresses a *risk analysis* to assess the impact level of Quality, Health, Safety, and Environmental (QHSE) factors specifically for the Norwegian battery manufacturer, Beyonder AS.
- Addresses a *Financial Statement analysis* of two cases for the Norwegian paper mill manufacturer Norske Skog Skogn AS in finding total EBITDA between traditional and reality training during six years.

- Case 1 addresses the change in EBITDA of one year between traditional and reality training of using VR to establish a new factory with an average training time of 3 months to 1 year before producing revenue.
- Case 2 addresses a cumulative net present value (NPV) between investment benefits and costs of using reality training as MR over five years in comparing the changes in EBITDA from the two training approaches.

1.5 Structure of the thesis

The thesis comprises of following chapters, with their brief description:

Chapter 2 Theory:
This chapter provides a brief insight into the theory related to training, elements of reality training, digital transformation and investment support funds.

Chapter 3 Method:
This chapter overviews the method in research, data collection, Technology & Investment analysis, risk analysis, and Financial Statement analysis.

Chapter 4 Current research:
This chapter presents the research of literature, companies, and investment of the Technology & Investment analysis.

Chapter 5 Technology & Investment analysis:
This chapter presents the results of the Technology & Investment analysis from the current research.

Chapter 6 Risk analysis:
This chapter overviews the risk case and presents the risk analysis results.

Chapter 7 Financial Statement analysis:
This chapter overviews the financial statement case and presents the Financial Statement analysis results.

Chapter 8 Discussion:
This chapter discusses the method criticism and the result findings.

Chapter 9 Conclusion:
This chapter presents the conclusion of the research questions.

Chapter 10 Recommendations:
This chapters suggest some recommendations for further research.

2 Theory

This chapter serves as the theoretical foundation for training in the manufacturing industry, exploring the frameworks that connect various training approaches. It delves into the components of reality training and the framework of digital transformation. Furthermore, it includes the investment funds utilized in the thesis.

2.1 Training in manufacturing

Manufacturing production refers to the process of creating goods or products in a factory or industrial setting. It involves converting raw materials into finished products through a series of manufacturing processes such as assembly, fabrication, machining, and packaging, shown in figure 2.1. Training in manufacturing is an essential process for equipping employees with the knowledge, skills, and abilities required to perform their job functions effectively and safely. Manufacturing involves a wide range of technical skills, from operating machinery to assembling products. Training programs should focus on developing technical skills required for each specific job, such as operating equipment, quality control and safety procedures [33].

figure 2.1: Manufacturing production [65].

2.1.1 Traditional training

Traditionally, training methods commonly used in various fields include the utilization of technical manuals and practical training programs shown in figure 2.2. These methods have been relied upon for many years and typically involve face to face instruction, hands on exercises, and assessments to gauge progress and comprehension. For instance, when using technical manuals or multimedia films, operations may only be viewed from limited angles, as they are presented in a two-dimensional format. In a manufacturing facility, a new employee often receives initial training on safety protocols, quality standards, and equipment operation directly in the actual factory. Additionally, they may receive on-the-job training from a supervisor or experienced colleague who will provide guidance throughout the process of operating machinery and carrying out specific tasks [9].

figure 2.2: Traditional training [14].

2.1.2 Reality training

Extended Reality (XR) is an umbrella term that encompasses various reality training technologies, including VR, AR, and MR shown in figure 2.3. XR combines the real and virtual worlds to create immersive and interactive experiences for training purposes as reality training. It extends beyond individual reality technologies and aims to provide a comprehensive solution that blends elements of both physical and digital environments [67].

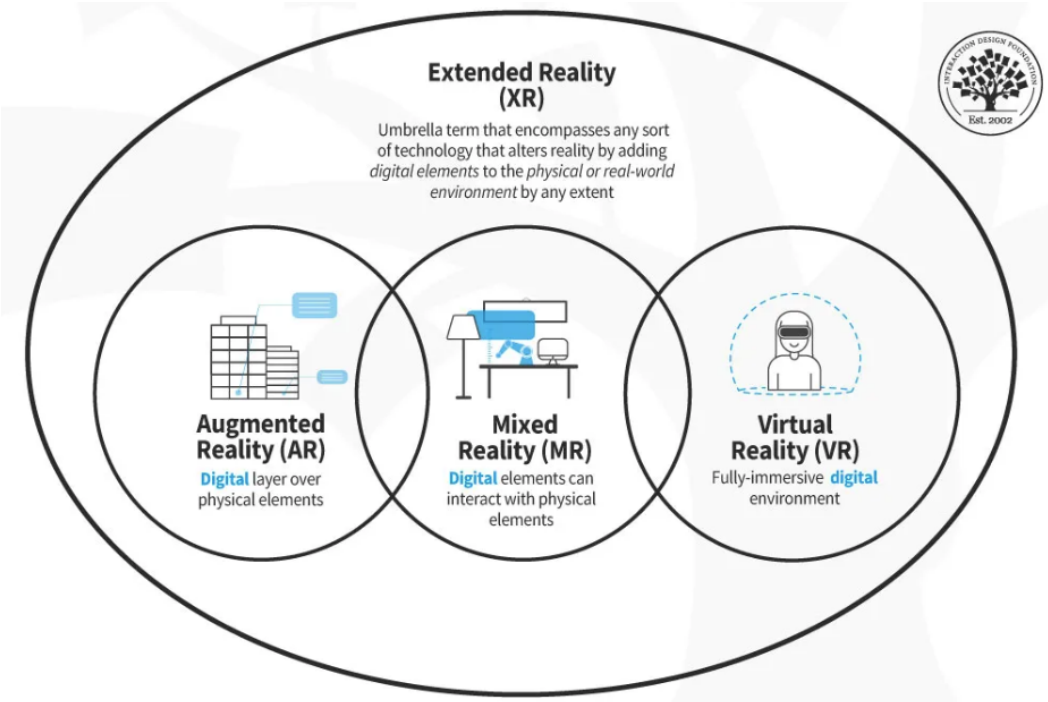

figure 2.3: Definition of XR as reality training [67].

Virtual reality

VR is a technology that creates a simulated environment, separate from the user's physical surroundings, through the use of digital elements. In VR, the entire environment is constructed digitally, including all objects and elements within it [57, p.2]. This is achieved through 3D modeling and integration with technologies like Building Information Modeling (BIM) and Computer-Aided Design (CAD) [32].

VR can be experienced using various devices, such as a Head Mounted Display (HMD), which immerse the user in a virtual world. The user wears the HMD and is transported to a fictional or simulated location, as depicted in figure 2.4. This technology originated in gaming and has since expanded to various fields, allowing users to have virtual experiences in natural environments or specific scenarios.The purpose of VR is to provide a virtual representation of an environment or scenario that can be interacted with and explored by the user. It offers a unique and immersive way to simulate experiences and environments that may not be easily accessible or feasible in the physical world. VR can be used for training, education, entertainment, and other applications where a realistic and interactive virtual experience is desired [57, p.2].

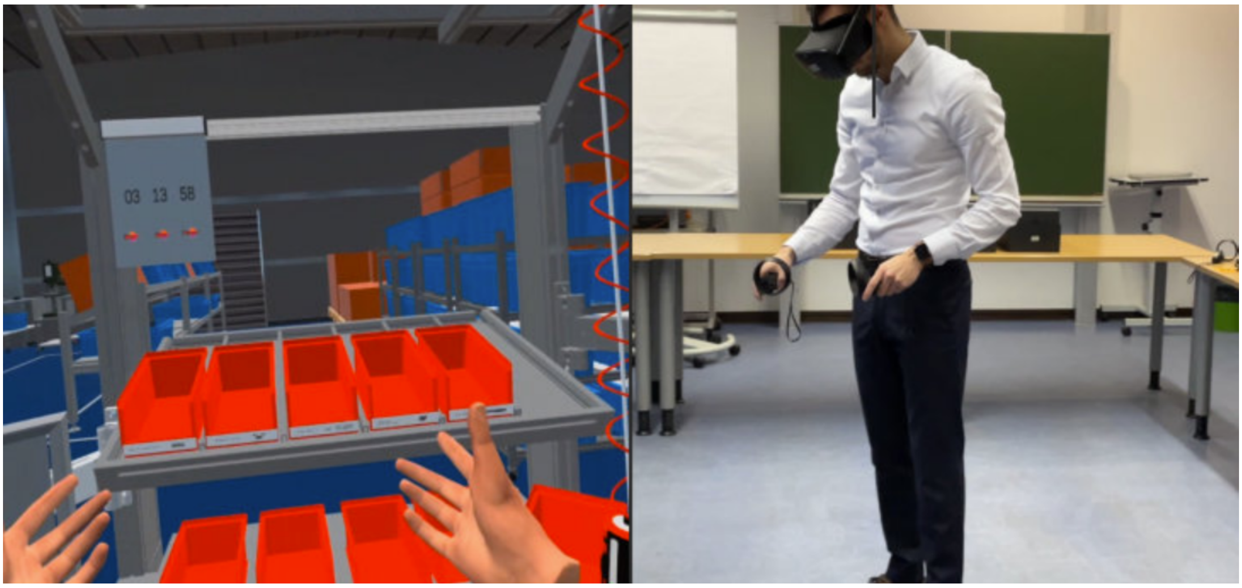

figure 2.4: Using HMD of VR [75].

Augmented reality

AR is a technology that enhances real-world scenarios by overlaying virtual elements or information onto the user's view of the physical environment. Unlike VR, which creates a fully digital environment, AR integrates digital objects into the actual place, as illustrated in figure 2.5. AR can be experienced through specialized AR glasses or by using the camera on devices like smartphones, tablets, or other devices. AR is often considered an extension of VR, as it builds upon the concept of merging digital content with the real world and require a higher level of data processing and graphics compared to VR. AR offers a more user-friendly experience because it allows users to stay connected to their physical surroundings while benefiting from additional information or virtual enhancements. The technology requires to track the user's real-world environment accurately and overlay digital objects seamlessly in real-time [34, p.182].

(a) Using HMD of AR[5]. **(b)** Using laptop of AR[47].

figure 2.5: AR

Mixed reality

MR is an immersive technology that combines elements of AR and VR to create a hybrid digital and physical environment. By overlaying digital objects onto the real world, MR enhances the user's perception of their physical surroundings, blending the virtual and real elements seamlessly. Unlike AR, MR can use physically articulated hand tracking, built-in voice commands, and virtual display in the real world, shown in figure 2.6. MR is often used in training maintenance engineers, where it can be used to create realistic and interactive simulations for training purposes in the real place. Where the projection-based MR system can connect the virtual elements directly to the environment between the project manager and task worker [56, p.5].

figure 2.6: Using HMD of MR [40].

2.2 Elements of reality training

2.2.1 Head mounted display

A HMD is a wearable device that is worn on the head, typically like a pair of goggles or a helmet, and incorporates a display screen positioned in front of the user's eyes shown in figure 2.7. HMDs can be connected to a computer, gaming console, , depending on the specific model and purpose. They may also include additional features like built-in speakers or headphones for audio output, integrated cameras for tracking and capturing the user's environment, and motion controllers for interacting with different graphic representations [55, p.1000-1001].

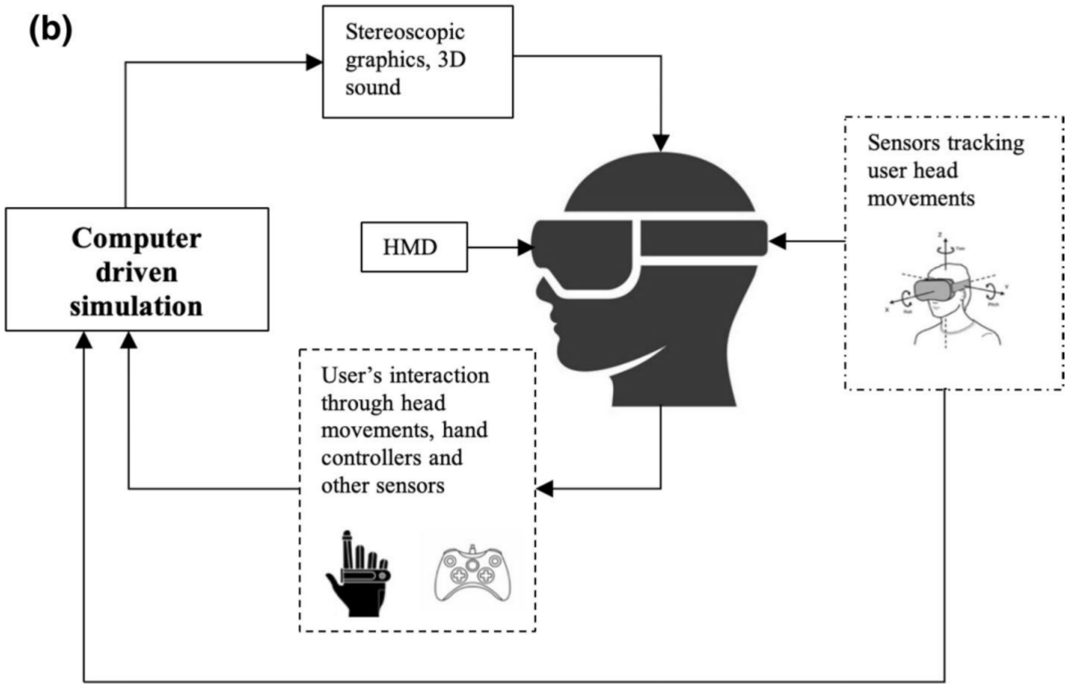

figure 2.7: Elements of HMD [55, p.1001].

2.2.2 Graphical representations

3D modeling
3D modeling refers to the process of creating a three-dimensional digital representation of a physical object or space using computer software. 3D modeling in computer graphics is a process in a three-dimensional surface, as represented in figure 2.8. In scenarios such as games and virtual screens, there are a lot of 3D representations. The technique of 3D modeling is widely used in the architecture, engineering, and construction (AEC) industry to create virtual models of buildings, infrastructure, and landscapes. 3D modeling allows architects, engineers, and contractors to visualize the project in a detailed and accurate way, identify potential issues, and improve the overall design and construction process [25]. In the manufacturing industry, 3D modeling and BIM are also relevant, but they are often referred to as 3D CAD [4].

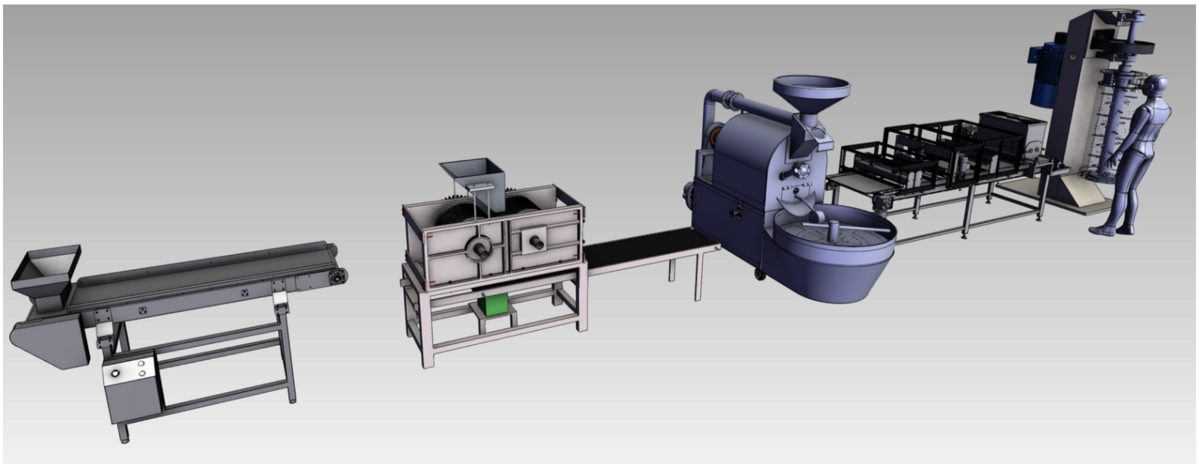

figure 2.8: 3D modeling [26].

BIM

On the other hand, BIM is a digital process that involves creating and managing a detailed information model of a building or infrastructure project to create a virtual model of the building. BIM goes beyond 3D modeling to incorporate additional information about the project, such as cost estimates, energy performance data, material specifications, and construction schedules shown in figure 2.9. BIM allows all stakeholders involved in a project to collaborate more efficiently and effectively, as the model serves as a centralized source of information and can be updated in real-time as changes are made [4].

figure 2.9: BIM [28].

3D CAD

3D CAD involves using software to create 3D models of a product or component shown in figure 2.10, which can then be used to simulate and test its performance before it is actually manufactured. This allows manufacturers to identify and resolve potential design issues and improve the product's quality and efficiency before production. The 3D CAD models can also be used to create tool paths for machines to manufacture the product [4]

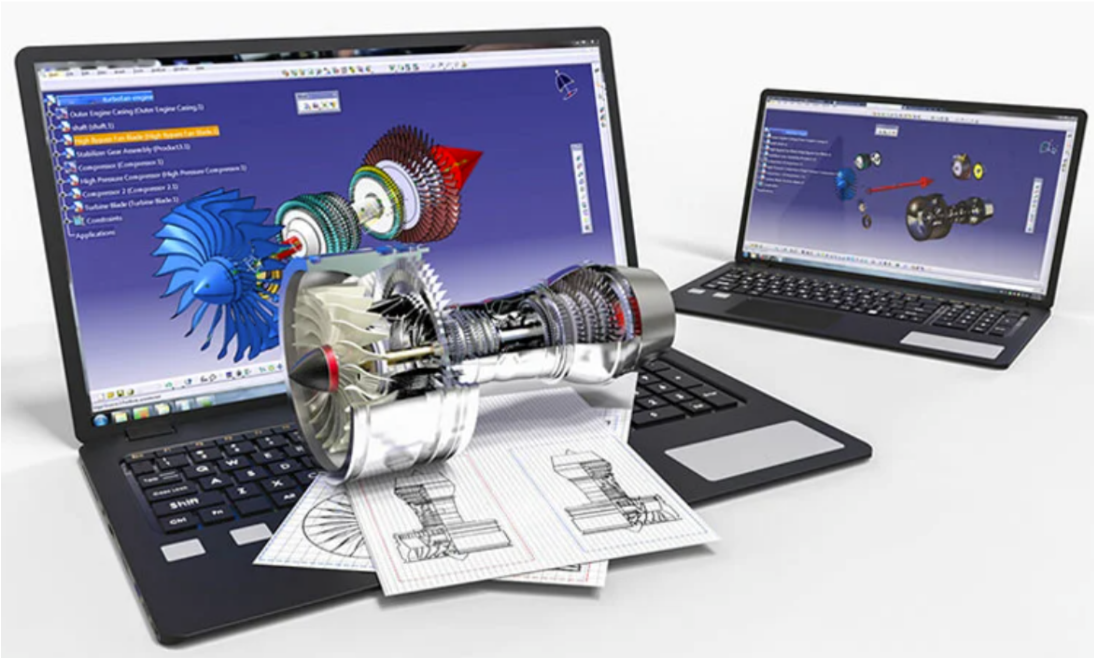

figure 2.10: 3D CAD [70].

2.2.3 Simulation software platforms

Simulation software platforms are specifically designed for training purposes and seamlessly integrate such as with HMDs and graphical representations, enhancing the overall experience. Simulation involves the development and programming of virtual models and objects that emulate specific tasks, concepts, or real-world processes [61, p.16]. Software platforms enable trainers to model and simulate complex systems or processes, facilitating interactive and hands-on learning experiences within BIM and CAD models [8].

Matterport

Matterport is a technology company that specializes in creating and distributing software, hardware, and cloud services for 3D mapping and spatial data visualization, shown in figure 2.11. The company's flagship product is the Matterport camera, which is a 3D camera that can create high-resolution, immersive 3D models of indoor spaces. The resulting models can be viewed on the web, enabling users to explore and interact with the space as if they were physically present [35].

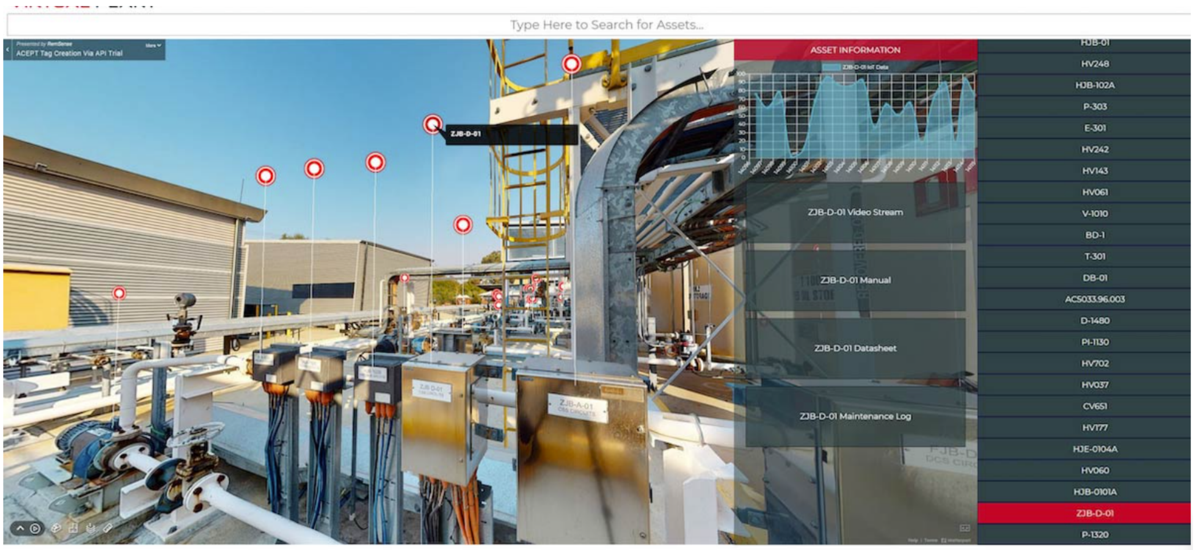

figure 2.11: 3D model from Matterport [38].

Unity

Unity provide VR tools used in game engines that offers extensive VR development capabilities shown in figure 2.12. It provides a range of tools and resources for creating immersive VR experiences, including 3D modeling, physics simulation, scripting, and VR-specific development features [71, p.1].

figure 2.12: VR software platform from Unity [24].

Vuforia

Vuforia is a AR platform that empowers marker-based AR experiences by providing advanced computer vision capabilities, as depicted in figure 2.12. This platform offers a range of features such as image recognition, object tracking, and AR content management tools. Integration of Vuforia is seamless and can be achieved in different development environments, including Unity [58, p.1-2].

figure 2.13: AR software platform app from Vuforia [66].

Microsoft

Microsoft Corporation, an American multinational technology company, is at the forefront of developing MR technologies, utilizing the Microsoft HoloLens 2 as its HMD, as depicted in figure 2.14. The HoloLens 2 was initially announced in February 2019 and released later in the same year. This cutting-edge device boasts a second-generation custom-built Holographic Processing Unit (HPU), which enables real-time computer vision with low power consumption. The HPU is responsible for executing various computer vision algorithms directly on the device, including head tracking, hand tracking, eye gaze tracking, and spatial mapping. As a fusion of VR and AR, the HoloLens 2 seamlessly overlays virtual objects onto the real world [69, p.1-2].

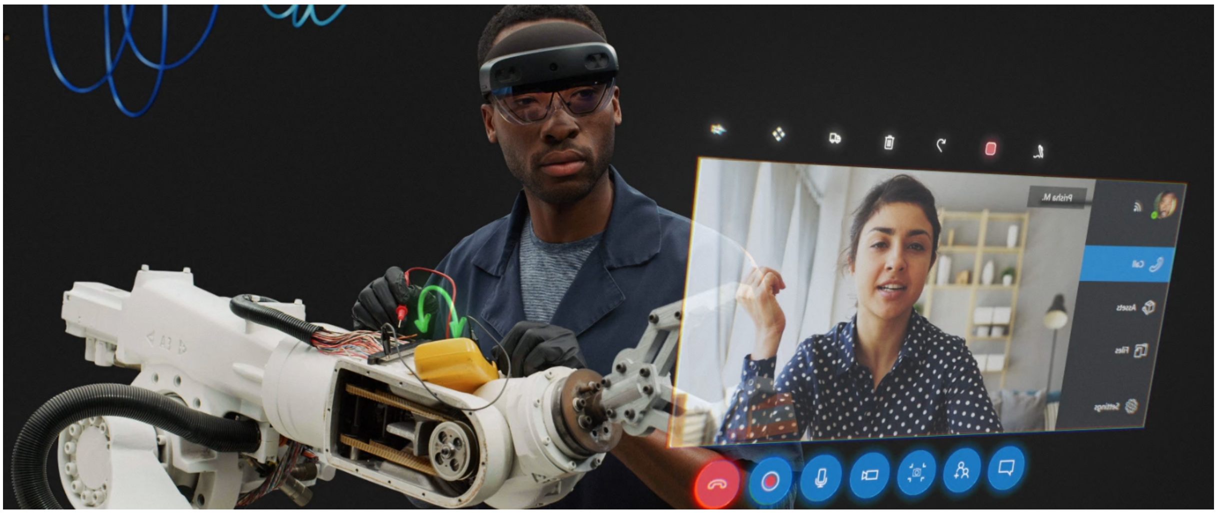

figure 2.14: Microsoft HoloLens2 [39].

Microsoft has developed Dynamics 365 Guides shown in figure 2.15, an MR application specifically designed for the HoloLens 2. This application works to to create and deploy interactive guides to assist their employees. These guides serve as step-by-step instructions and training modules for complex tasks and procedures, allowing employees to enhance their learning and perform their jobs [44].

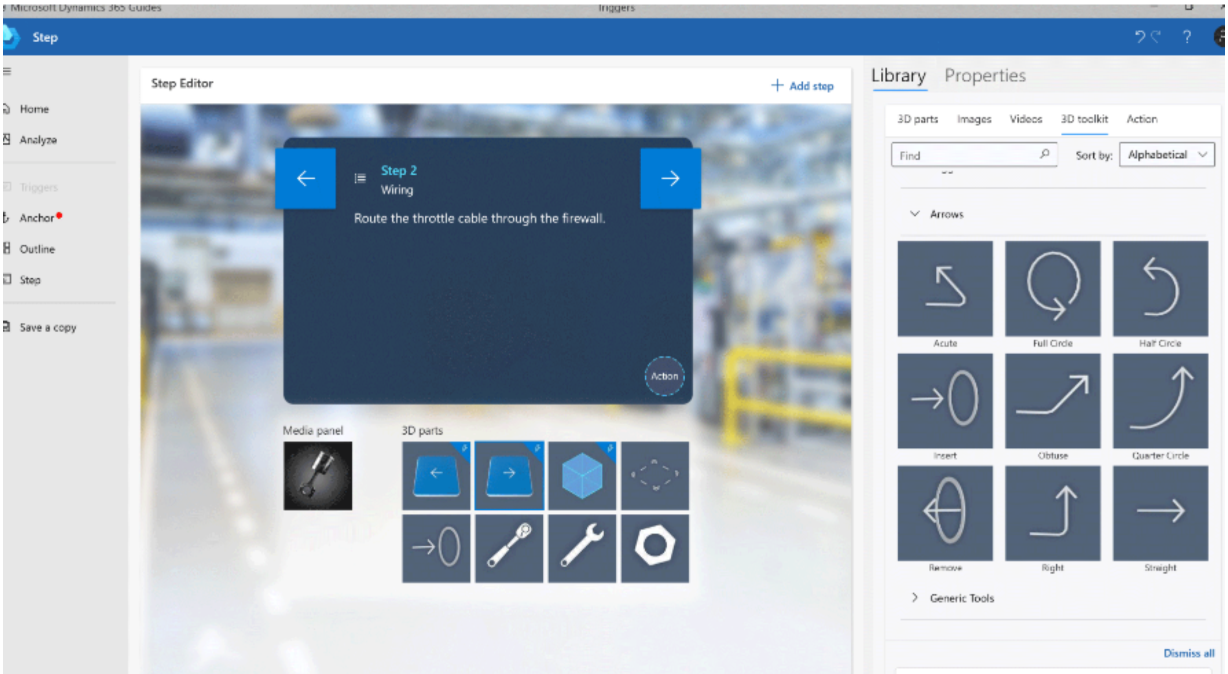

figure 2.15: Microsoft Dynamics 365 Guides [42].

2.3 Digital transformation

Digital transformation refers to the use of digital technologies to fundamentally change the way businesses operate and deliver value to customers. In the context of the manufacturing industry, digital transformation involves the integration of digital technologies of the manufacturing process [29, p.938].

Industry 4.0, also known as the fourth industrial revolution, refers to the integration of digital technologies into manufacturing processes. The term gained widespread recognition in 2011 when the "Industrie 4.0" consortium in Germany proposed strategies to enhance the efficiency of the country's manufacturing sector. Industry 4.0 represents a significant shift in traditional manufacturing approaches by embracing technological advancements [74, p.530-531].

The core idea behind Industry 4.0 as depicted in figure 2.16, is to leverage digital technologies to connect machines and operators through network connections and manage information in a systematic manner. This technological transformation brings about various methods and approaches [74, p.532].

figure 2.16: Concept of industry 4.0 [59].

2.3.1 Requirements

Looking towards 2030, the vision for Industry 4.0 encompasses a highly automated and intelligent manufacturing ecosystem that is fully integrated and connected. The goal is to achieve seamless inter connectivity in every aspect of the manufacturing process, enabling real-time data exchange between machines, systems, and people. To successfully implement new technologies and realize this vision, three strategic fields of action are essential shown in figure 2.17 as interoperability, autonomy, and sustainability [20].

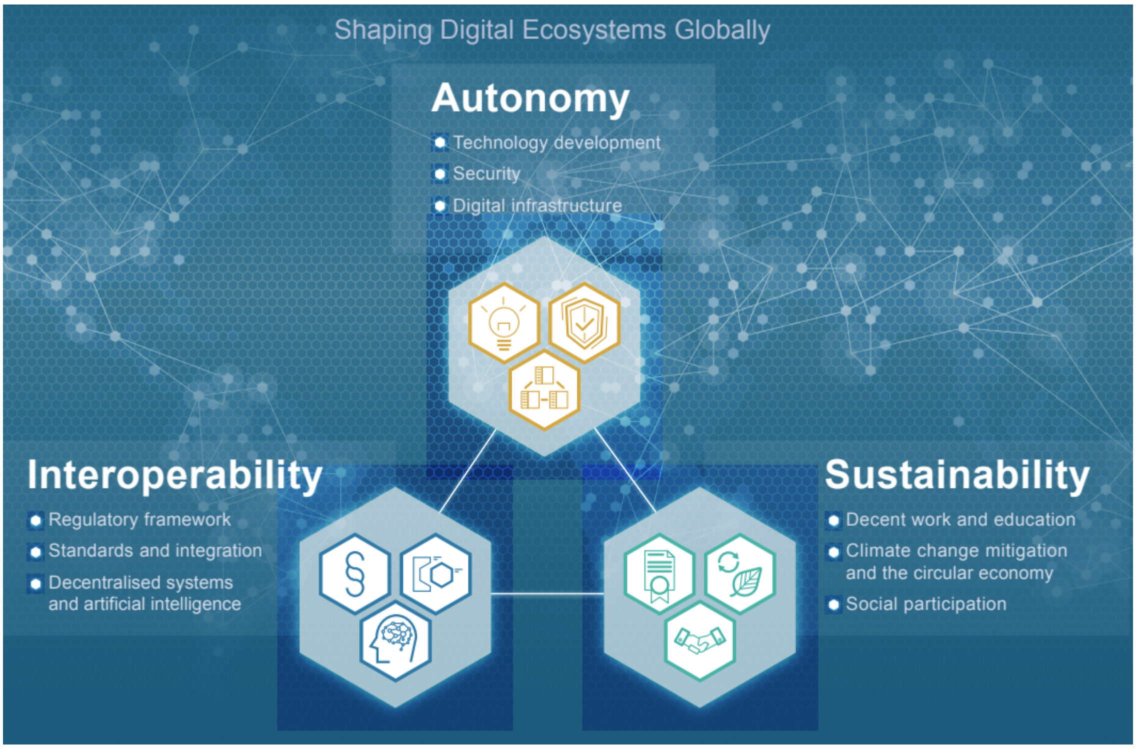

figure 2.17: Requirements for a successfully 2030 vision for reality training [20, p.4].

Interoperability

Interoperability refers to the ability of different systems, devices, or software to work together and exchange information seamlessly without encountering compatibility issues or requiring significant modifications. In other words, different systems can communicate with each other and efficiently share data [30]. Interoperability is divided into three terms:

- A regulatory framework refers to laws and regulations at the local, national, and international levels that are designed to ensure the safety and quality of products, protect the environment and promote fair competition [7].
- Standards and integration refer to creating interoperable systems by providing a common framework that can be shared across different systems and technologies [7].
- Decentralized systems and artificial intelligence (AI) are two emerging technologies that have the potential to transform the way that products are designed, produced, and distributed [62].

Autonomy
Autonomy refers to the self-determination of systems and processes to operate independently, with little or no human intervention. This can include the use of autonomous platforms and digital business models that can perform tasks without the need for human input [15]. Autonomy is divided into three terms:

- Technology development refers to the process of creating, improving, and implementing new technologies [21].
- Security is important due to the increasing adoption of digital technologies and connected systems. Systems are often connected to the internet and require data protection, IT and information security [17].
- Digital infrastructure refers to the underlying technology systems that enable digital communication, data storage, and data processing [16].

Sustainability
Sustainability refers to the modern industrial value creation to become responsible for social inclusion and minimizing waste and pollution. The suppose is to ensure a high standard of living [19]. Sustainability is divided into three terms:

- Decent work refers to productive, secure employment and offers fair wages and benefits. In contrast, education refers to acquiring knowledge, skills, and competencies necessary for workers to succeed [11].
- Climate change mitigation refers to efforts to reduce greenhouse gas emissions and limit the impact of human activities on the environment [73]. The circular economy is an economic model that seeks to minimize waste and maximize the use of resources by keeping products, components, and materials in use for as long as possible [54].
- Social participation involves social inclusion with and involving stakeholders, including employees, customers, suppliers, and the broader community [18].

2.4 Investment support funds

Investment support funds are organizations or initiatives that provide funding or financial resources to support various investments. The purpose of investment support funds is to help finance new or growing businesses or to provide capital for specific types of projects. They can also help promote economic development and job creation in certain areas or industries [12].

2.4.1 Research Council of Norway

The Research Council of Norway shown in figure 2.18 is a Norwegian government agency responsible for funding and promoting research in Norway, where it manages research funding from all of the Norwegian ministries. It was established in 1993 and operates under the Norwegian Ministry of Education and Research [31].

figure 2.18: Research Council of Norway [27].

2.4.2 Digital Europe Programme

The Digital Europe Programme shown in figure 2.19 is a funding program launched by the European Union (EU) to strengthen the EU's digital capabilities and competitiveness in the global market. Digital Europe refers to the European Union's strategy and efforts to promote digital transformation and innovation in the region. The plan aims to enable Europe to reap the benefits of the digital revolution, such as increased productivity, innovation, and economic growth [10].

figure 2.19: Digital Europe Programme [22].

3 Method

This chapter outlines the approach employed to ensure a robust and credible outcome. It begins by detailing the research methodology and data collection process. Subsequently, it delves into the methods used for Technology & Investment analysis, risk analysis, and Financial Statement analysis, all aimed at addressing the research questions.

3.1 Research method

This thesis incorporates a combination of qualitative and quantitative research methods to gather data and information. The qualitative section of the research focuses on acquiring a comprehensive understanding of the topic by presenting information that cannot be solely quantified through statistical analysis. On the other hand, the quantitative method is employed to quantify data, enabling numerical analysis through statistical procedures.

To ensure a factual basis for the research, sources with high reliability and validity have been extensively utilized. This approach ensures that the research maintains a high level of quality and credibility.

3.1.1 Qualitative method

Qualitative research entails exploring objective theories and utilizing word-based approaches rather than relying solely on quantitative measures. The qualitative method determines parts of the most critical drivers and barriers in developing reality training for the Technology & Investment analysis. This approach enables a comprehensive exploration of the topic, acknowledging that certain aspects cannot be definitively quantified alone.

3.1.2 Quantitative method

Quantitative research was employed to collect and analyze data for the thesis question. The quantitative method utilized a deductive approach, seeking to address research questions through numerical data. This quantitative approach aimed to answer a portion of the Technology & Investment analysis and fully the risk and Financial Statement analysis. The decision to employ a quantitative methodology was based on selecting the approach best suited for answering the research questions effectively.

3.1.3 Research quality

Throughout the project, significant efforts were made to ensure the use of reliable and credible sources, accompanied by critical evaluations of both authors and the content of the articles. This critical evaluation of references was undertaken to avoid any misinformation in the report and to mitigate the potential influence of vested interests that may bias information obtained solely from suppliers.

To establish a solid factual basis, priority was given to sources with high reliability and validity. Research institutions such as Springer Link, Science Direct, Forrester Consulting, the Research Council of Norway, and the European Commission were primarily relied upon. These institutions provide reputable platforms for accessing scientific articles and existing research related to the relevant topics.

3.2 Data collection

Data collection supposed to deliver a thesis of the most significant possible interest for further development to provide good references that strengthen the credibility of the writing. The data collection method is shown in figure 3.1, where the collection has been done to find current research and data from case studies to find the necessary information and guidance to clarify the possibilities and needs in the report. The technology and investment aspects of the Technology & Investment analysis are collected from current research, where research of investment is collected in the investment part and research of companies and literate in technology aspect. The risk- and Financial Statement analysis is collected from research of literature in the technology aspect and data from each case study.

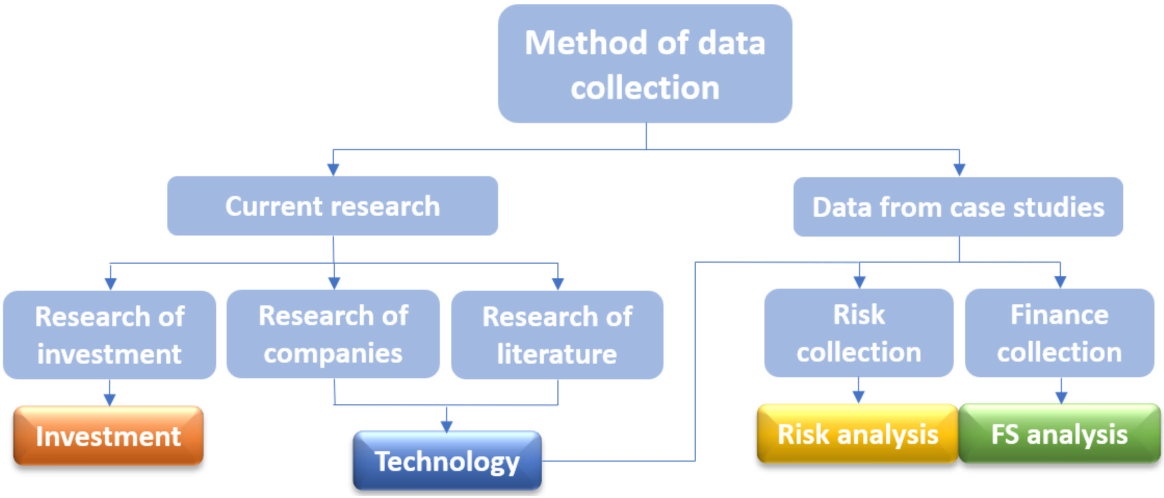

figure 3.1: Method of data collection [60].

3.2.1 Research of literature

Early in the project, a thorough analysis was done for findings of using training models of reality on the market. The investigation aimed to focus on finding research literature and the level of knowledge in relevant industries about the various solutions for training appropriate in manufacturing. The findings were done using Google Scholar as a search engine to find previous research from Springer Link and Science Direct, given that considerations were made in light of the technology aspect of reality training. It was therefore decided to find literature research in the technology context relevant to reality training in manufacturing. The research of literature aimed to collect data from the literature studies to find the drivers and barriers in the technology aspect of reality training.

3.2.2 Research of companies

The research of companies in the new technology of using reality training in reference projects has been done to get valid references from manufacturing-related projects. The findings of the references are based on new articles and recent reports from companies rather than literary studies since literature research from company references were unavailable. Obtaining data references from companies and comparing information from several sources have been used to ensure consensus and trustworthiness. The reason for comparing information is to provide quality of collected data since research from companies often has less critical evaluations than research reports. Since often the company will try to sell itself rather than having good enough quality for the references. The research of companies aimed to collect data from company references of the drivers and barriers in the technology aspect of reality training.

3.2.3 Research of investment

Finding enough data on the research of investment relevant to reality training was challenging because of such new technology. The findings were obtained from Forrester Consulting, the Research Council of Norway, and the European Commission. The data collection in research of investment aimed to find a result of the drivers and barriers in the investment aspect of reality training.

3.2.4 Risk collection

The risk collection process involved multiple steps to gather data and analyze the risk profiles of Beyonder's current operations in traditional training to create a risk analysis of reality training. These steps are outlined as follows:

- The first step was to retrieve data from Appendix 3, which provided insights into Beyonder's current operations and their utilization of traditional training methods. This information served as a baseline to understand the existing risk landscape associated with their training practices.
- The second step involved data collection from Appendix 4, specifically from Beyonder's business impact analysis. This analysis helped identify the current risk impact on QHSE levels within Beyonder's operations.
- The data from Appendix 4 also included a probability scale for each incident, which was further explored.
- To assess the Beyonder‘s risk matrix of traditional training, data from Appendix 4 was collected again. The risk matrix provided a visual representation of the risk impact and the probability scales associated with different current critical operations.

In summary, the risk collection process involved retrieving data from Appendix 3 to understand the current operations and traditional training practices at Beyonder. Data from Appendix 4 was then utilized to assess the current risk impact, probability scenarios, and risk matrix for creating a risk analysis of reality training.

3.2.5 Finance collection

The finance collection process involved retrieving data from multiple sources, including the current Norske Skog Skogn annual reports in Appendix 5, informal interviews in Appendix 6, and the total impact analysis of MR in Appendix 7. These data sources were utilized to gather relevant financial inputs for Case 1 and Case 2, compare the differences between traditional and reality training, and conduct a feasibility study Financial Statement analysis.

- Data collection from Appendix 5 focused on extracting the necessary financial inputs for Case 1 and Case 2. This involved analyzing the relevant sections of the Norske Skog Skogn annual reports to identify financial data relevant to the comparison between traditional and reality training. By examining this information, the project aimed to highlight the financial disparities between the two training approaches.
- The informal interviews documented in Appendix 6 played a crucial role in gathering information on various factors relevant to Case 1. These interviews aimed to capture insights from relevant stakeholders or experts who could provide valuable perspectives on the financial aspects associated with reality training. The data collected through these interviews helped inform the analysis and result generation for Case 1.
- Appendix 7 contained the total impact analysis of MR conducted by Forrester Consulting. This analysis provided data and insights on the overall impact of MR, including financial implications, in the context of Case 2. The findings from this analysis were used to generate a result for Case 2 and compare it to traditional training in terms of financial considerations.

By combining the inputs gathered from the finance collection process, the project aimed to conduct a comprehensive Financial Statement analysis. This analysis aimed to assess the financial feasibility of adopting reality training compared to traditional training. The collected data from various sources played a critical role in evaluating the financial viability of both approaches and informing the final Financial Statement analysis result.

In summary, the finance collection process involved extracting relevant financial inputs from Norske Skog Skogn annual reports, conducting informal interviews, and utilizing the total impact analysis of MR. These data sources were instrumental in generating results for Case 1 and Case 2, comparing traditional and reality training, and conducting a comprehensive Financial Statement analysis.

3.3 Technology & Investment analysis

A Technology & Investment analysis worked to answer the first research sub-question, *What are the most critical drivers and barriers in the development of reality training?* The whole method of the Technology & Investment analysis is represented in figure 3.2, which is the method to answer the technology and investment aspects. The data collected from the literature research became an implementation-, assessment-, and questionnaire results to answer the technology aspect. Also, research of companies became used to provide companies results to answer the technology aspect. The data collected from the research of investment became an investment results to respond to the investment aspects. Finally, the Technology & Investment analysis results became estimated from the analysed data.

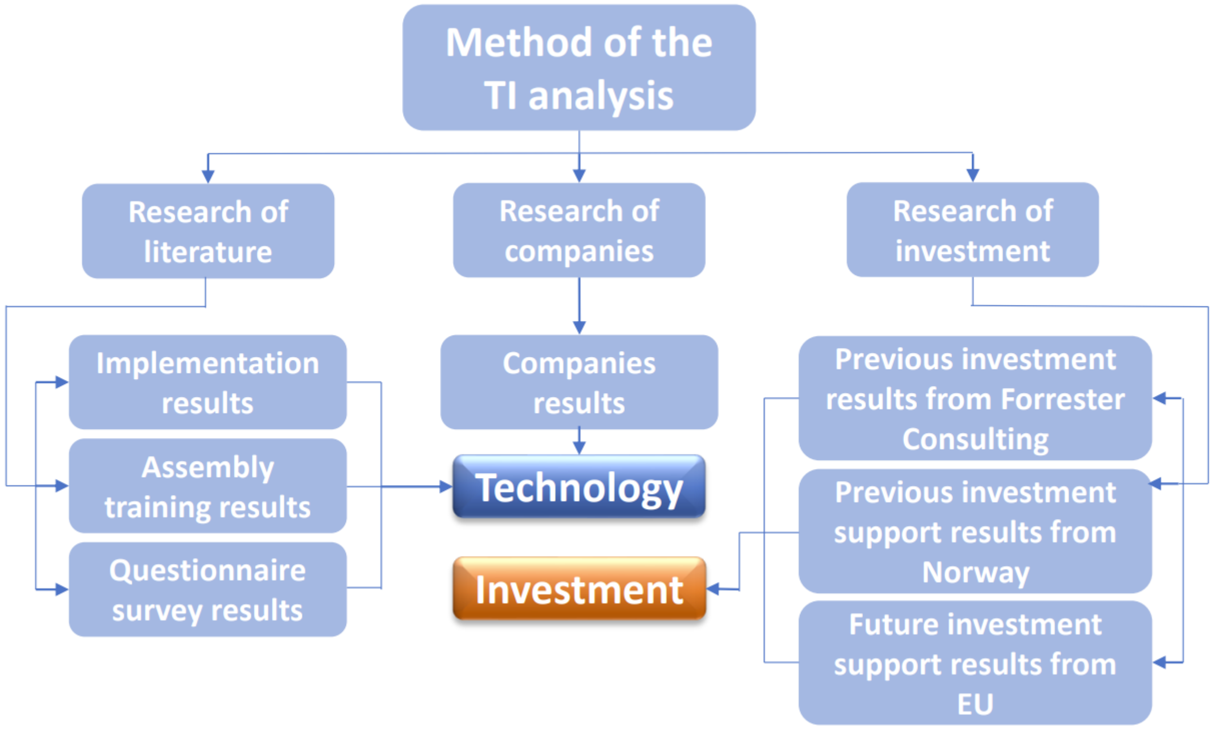

figure 3.2: Method of the Technology & Investment analysis [60].

3.3.1 Technology

Implementation results

The result created an architectural structure of a reality training system of the requirements in research of implementation and the theoretical framework. The implementation results in chapter 5.1.1 were made by research of implementation in chapter 4.1.1. The relevant sources from the report were extracted from the theory elements in chapter 2.2 and requirements of creating a training system, which is described in chapter 2.3.1. The purpose of creating a result of the architecture structure was to find the drivers of creating a successfully reality training system.

Referencing from Linde Virtual Academy was used to identify and analyze barriers associated with implementing the reality training system. The relevant sources were extracted and organized in a table from Linde. These references proved highly valuable in gaining insights into the diverse challenges faced while implementing a reality training system.

Assembly training results
The assembly training results in chapter 5.1.2 analyzed the average training time and errors between traditional - and reality training. The data was extracted from research of assembly training in chapter 4.1.2. The purpose was to find possible drivers and barriers in reality training of assembly training.

Questionnaire survey results
The questionnaire survey results created in chapter 5.1.3 analyzed mean scores from highest to lowest from the questionnaire survey research in chapter 4.1.3. The results determined the research's highest driver and barrier of response and aimed to find results in adopting of reality training.

Companies results
The companies results in chapter 5.1.4 created familiar drivers and barriers using reality training. The results were extracted from current research in chapter 4.2. The suppose results were interpreted jointly to find drivers and barriers to using reality training from company references.

3.3.2 Investment

Previous investment results from Forrester Consulting
The previous investment results from Forrester Consulting in chapter 5.2.1 were extracted from previous research of investment from Forrester Consulting in chapter 4.3.1. The results were presented from their report in total economic impact of investments. The purpose was to create a result of possible drivers and barriers in previous investment results from Forrester consulting.

Previous investment support results from Norway
The previous investment results from Norway in chapter 5.2.2 were extracted from research of previous investment from Norway in chapter 4.3.2. The results were calculated as the average amount of support from the companies in the research and the type of reality in training that has gotten investment support. The purpose was to create a result of possible drivers and barriers in previous investment results from Norway.

Future investment support results from EU
The future investment results from EU in chapter 5.2.3 were extracted from research of future investment from EU in chapter 4.14. The purpose of results was chosen as drivers and barriers of the prospective investment funds from the EU that can provide future investment support

in R&D of reality training.

Technology & Investment analysis results

Chapter 9.1 presented the final results of the Technology & Investment analysis, which aimed to determine the primary drivers and barriers influencing the development of reality training. These results were obtained by analyzing the technology and investment aspects, with drivers represented by the color green and barriers represented by the color red. The conclusion of the analysis highlighted the key factors shaping the advancement of reality training. The purpose of the result was to find an answer of the research question as *What are the most critical drivers and barriers in the development of reality training?*

3.4 Risk analysis

A risk analysis worked to answer the second research sub-question, *Does reality training affect the risk impact level upon production from traditional training?* The method of the risk analysis is shown in figure 3.3. The likelihood of errors were extracted from assembly training results in chapter 5.1.2, and the risk collection was extracted from Beyonder‘s risk case in chapter 6.1. The method further estimated the change in probability and risk matrix from the collection. Finally, the risk analysis results became estimated from the analysed data.

figure 3.3: Method of the risk analysis [60].

Change in probability

Chapter 6.10 focused on presenting and calculating the change in probability for Beyonder’s critical operations by comparing their current probability scales. The difference in probability scales between traditional training and reality training scenarios was multiplied by the likelihood of errors, taking into account the current probability scale of their critical operations. The objective was to assess and quantify the shift in the probability scale resulting from the transition from traditional training methods to reality training scenarios.

Change in risk matrix

Chapter 6.2.2 introduced a revised risk matrix specifically focused on the utilization of reality training in Beyonder's critical operations. This revised matrix was developed by considering the existing risk matrix of Beyonder and incorporating the changes in probability associated with the adoption of reality training. The objective was to assess the extent to which the use of reality training impacted Beyonder's critical operations compared to the traditional training methods.

Risk analysis results

Chapter 9.1 presented the final results of the risk analysis, which aimed to draw conclusions regarding the impact of probability variations on different scales of Beyonder's critical operations when comparing traditional training methods to reality training. The different impact scales were derived from the changes observed in the risk matrix and probability assessments. The purpose of the result was to find a answer of the research question as *Does reality training affect the risk impact level upon production from traditional training?*

3.5 Financial Statement analysis

An Financial Statement analysis worked to answer the third research sub-question, *How does reality training affect EBITDA during six years compared to traditional training?* The method for conducting the Financial Statement analysis is illustrated in Figure 3.4. In both Case 1 and Case 2, the financial data was collected from the annual report of Norske Skog Skogn. The impact of training time, both through informal interviews and the utilization of VR, was explored in Chapter 5.1.2 of Case 1. Additionally, Case 2 incorporated the total impact analysis conducted by Forrester Consulting, employing MR in the manufacturing sector. The method further presents case 1 and case 2 to determine the framework of the case results. Finally, the Financial Statement analysis results became estimated from the analysed data from results in Case 1 and Case 2.

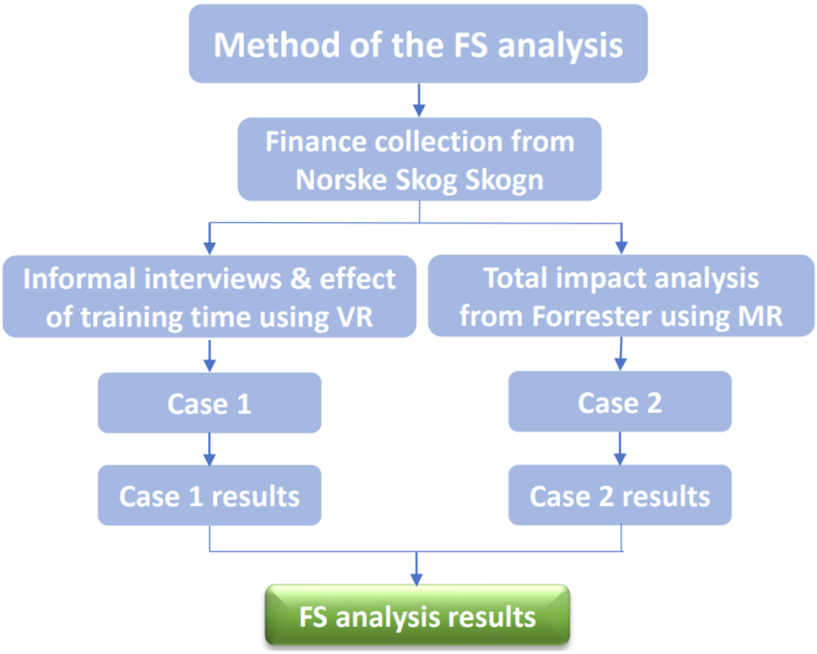

figure 3.4: Method of the Financial Statement analysis [60].

Case 1
The description in Chapter 7.1.1 was derived from the calculations conducted in Appendix 8, utilizing the financial data collected from Appendices 5 and 6. By analyzing and synthesizing the information presented in these appendices, a detailed overview of Case 1 was constructed, enabling the formulation of an accurate and well-supported result for this case.

Case 2
The description in Chapter 7.1.2 was derived from the calculations conducted in Appendix 9, utilizing the financial data collected from Appendices 5 and 7. By analyzing and synthesizing the information presented in these appendices, a detailed overview of Case 2 was constructed, enabling the formulation of an accurate and well-supported result for this case.

Case 1 results
Chapter 7.1.3 provided a comprehensive overview of the outcomes derived from Case 1. The primary focus was on evaluating the average change in EBITDA in KNOK between traditional training methods and reality training utilizing VR. These results were obtained on a monthly basis and were extracted from Appendix 8, which housed the necessary data and calculations.

The key objective of these results was to determine the average overall change in EBITDA over the span of one year. This evaluation was crucial in comparing the effectiveness of traditional training methods with the application of VR-based reality training, specifically in the context of establishing a new factory. By analyzing the impact on EBITDA, valuable insights were gained regarding the potential benefits and performance improvements offered by VR training.

Case 2 results

In Chapter 7.1.4, the outcomes of Case 2 were presented, focusing on various aspects related to the utilization of MR training in an existing factory. The results included graphical representations of the total investment savings in OPEX and the total investment costs over a span of five years, all measured in present value KNOK.

Additionally, the chapter determined the cumulative NPV by comparing the investment benefits and costs associated with the adoption of MR training. Furthermore, the final result highlighted the change in EBITDA over a five-year period, comparing traditional training methods with MR training.

The calculations performed in Appendix 9 yielded the following outcomes. The advantages of investing in MR technology were consolidated by quantifying the savings in training expenses, travel, and operational training costs. Conversely, the costs associated with implementing MR technology encompassed the procurement of devices, subscription fees, operating expenditures, maintenance charges, and training costs.

The primary objective of these results was to ascertain the average overall change in EBITDA over the course of five years when comparing traditional training methods with MR training in an existing factory.

Financial Statement analysis results

Chapter 7.1.4 presented the final outcomes of the Financial Statement analysis, incorporating the results from Case 1 and Case 2. The primary objective was to determine the change in EBITDA over a period of six years, resulting from the implementation of reality training compared to traditional training methods.

These results played a significant role in addressing the research question, which focused on understanding the impact of reality training on EBITDA over a six-year time frame. The aim was to provide a conclusive answer to this research question as *How does reality training affect EBITDA during six years compared to traditional training?*, thereby enabling the formulation of a comprehensive conclusion in Chapter 9.1.

By integrating the findings from both Case 1 and Case 2, the Financial Statement analysis results shed light on the potential influence of reality training on EBITDA, offering insights into the long-term effects and benefits derived from adopting this innovative training approach.

4 Current research

In this chapter, the current research will involve research of literature, companies and investment relevant to reality training. The chapter reviews the results using the methods of data collection to answering the Technology & Investment analysis described in chapter 3.2.

4.1 Research of literature

4.1.1 Research of implementation

The technology challenge in adopting reality training in new and existing manufacturing requires several requirements mentioned in chapter 2.3.1. The implementation research report *"Implementation challenges and success factors"* found that implementing reality training requires the three terms of technological context, environmental context, and organizational context to create a successful reality training system, as shown in figure 4.1 [34, p.186].

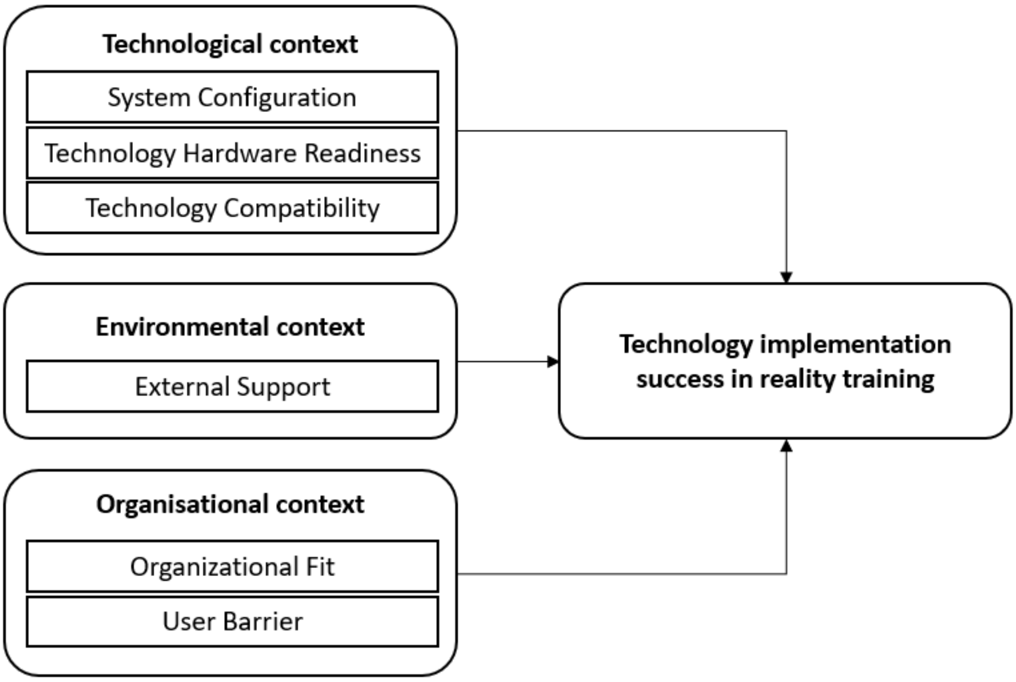

figure 4.1: Implementation requirements of reality training [34, p.186].

Technological context
Technological context is based on system configuration, technology hardware readiness, and technology compatibility:

- **System configuration** searching for bugs and finding the correct HMD that best suits the existing system and the software platform. Essential aspects in autonomy as technology development and digital infrastructure in the start create a successful system configuration [34, p.184].

- **Technology hardware readiness** requires that the readiness from the HMD is optimal so that capabilities support a specific task of industrial work since the worker uses the system for a whole day, which impacts the readiness. Then, hardware readiness must be designed, produced, and distributed successfully according to the decentralized interoperability system [34, p.185].
- **Technology compatibility** requires that the connection between the existing system connect with the software platform without connecting issues. If the existing IT system or current process within the firm lacks interoperability of security with the new software platform, it improves failure in compatibility [34, p.185].

Environmental context
Environmental context is based on external support:

- **External support** requires using industry standards to avoid uncertainty for individual firms, as the industry operates under those standards. According to the interoperability, it requires that the external support have the requirements of regulatory framework and standards. Using external support, the system vendor can provide information and know-how concerning reality training before the adoption decision during the implementation phase and provide better security as a standard in autonomy [34, p.185].

Organisational context
Organisational context is based on organisational fit and user barrier:

- **Organisational fit** requires the organization to adapt the process and involve the users before and during the organization's implementation. It will require decent work and social participation since the users must be affected by the new technology they use daily. Changing traditional training to reality training will change the users' routines [34, p.186].
- **User barrier** requires user acceptance to be successfully implemented. In that case, it affects the implementation as ergonomic problems or the perceived trust of users in the technology [34, p.186].

4.1.2 Research of assembly training

The research of assembly training report *"Assessment of virtual reality-based manufacturing assembly training system"* was to find the training completion time in different scenarios and the number of errors in actual assembly cases. The assessment of case studies was to assemble a street scooter, adjustable mid-bearing, and multi-function cart, represented in figure 4.2. Street scooter consists of 16 unique components and 25 parts in total. Bearings represent mechanical components as a manufacturing assembly case study, consisting of 8 unique components and 13 parts. A multi-function consists of 14 unique components and a total number of 35 parts [2, p.3746]

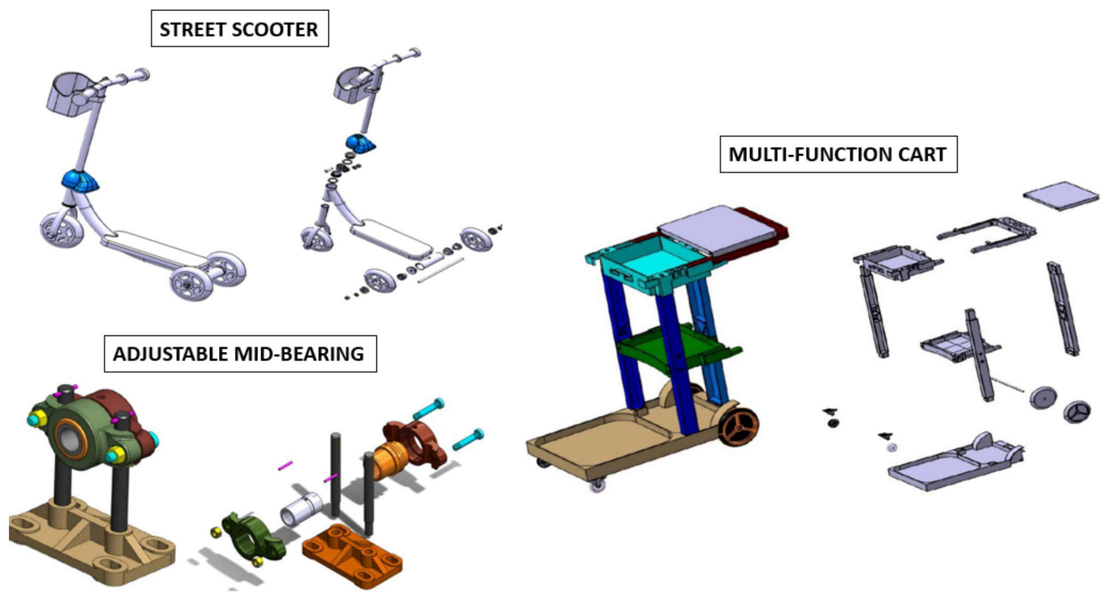

figure 4.2: Case studies [2, p.3750-3751].

In each case study shown in table 4.1, there was one assessment of traditional training and four different types of feedback using reality training by VR [2, p.3747]. Five participants were in each case study using different types of training and feedback, where the total number of participants of all the five different training approaches was a total of 25 participants. Therefore, for three case studies as participant groups, a total of 75 candidates were selected. The participants were students and employees at King Saud University, randomly assigned to different training condition groups [2, p.3748].

Type of training	**Type of feedback**	**Participants in each case**	**Participant groups**
Traditional training (TT)	Paper-based drawings & PPTs.	5	15
Reality training (VR1)	No feedback	5	15
Reality training (VR2)	Visual feedback	5	15
Reality training (VR3)	Audio feedback	5	15
Reality training (VR4)	Audio-visual feedback	5	15
Total		25	75

Table 4.1: Type of training in various feedback of participants [60].

The research shows in table 4.2 that the complete training of all four reality training scenarios has a lower complete time than traditional training. The participant groups completed the training procedure and the actual assembly task, where the participants needed to gain experience in assembling the case study product that had been assigned to them. From the case studies, the results of training completion time in minutes show that the actual assembly completion time for different VR feedback groups is not significantly different [2, p.3752].

Participant groups	TT (Min)	VR1 (Min)	VR2 (Min)	VR3 (Min)	VR4 (Min)
1	16.05	5.10	4.42	5.39	9.40
2	15.21	7.08	3.06	3.36	3.14
3	14.27	3.50	2.42	9.27	5.47
4	10.55	6.54	1.48	5.00	2.25
5	16.00	4.00	9.00	5.43	4.33

Table 4.2: Training completion in minutes of actual assembly with various training conditions [2, p.3752].

Interval plot also depicts that the errors done while doing the actual assembly for traditional training are significantly higher than those of all VR groups, shown in table 4.3 [2, p.3756].

Participant groups	TT (Min)	VR1 (Min)	VR2 (Min)	VR3 (Min)	VR4 (Min)
1	1	1	0	0	1
2	3	0	1	1	0
3	1	0	0	1	0
4	5	1	0	0	0
5	1	0	2	0	0

Table 4.3: Number of errors done in actual assembly by five different participant groups from various training conditions [2, p.3753].

4.1.3 Research of questionnaire survey

The research findings from the report ”Drivers and barriers of virtual reality adoption in UK AEC industry” questionnaires 123 UK construction professionals adopting VR as reality training , shown in table 4.4. The results of the respondent’s professional backgrounds reveal that there were most project managers of 39%, architects of 26%, engineers of 14,6%, quantity surveyors of 8,9% and building surveyors of 11,5% [6, p.1311]. The research also determined that the professionals had highest years of VR training experience between zero and five years of 68 % and lowest above 20 years of 1,6 % [6, p.1313].

Professional backgrounds	**Frequency**	**Percentage**
Project Managers	48	39
Architects	32	26
Engineers	18	14.6
Quantity surveyors	11	8.9
Building surveyors	14	11.5
Total	123	100
Years of VR training experience		
0-4 years	90	68
5-10 years	32	26
11-20 years	6	5
Above 20 years	2	1.6
Total	123	100

Table 4.4: Respondents' demographics by professional backgrounds and years of VR training experience [6, p.1311].

Responds of drivers

From 123 UK construction professionals with different years of VR training experience. The reaction rate was divided into five polls between Strongly Disagree and Strongly Agree. Drivers were chosen into five additional terms: improved safety, quality, productivity, cost reduction, and boost of R&D [6, p.1312-1313].

Drivers	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**	**Total**
Improved safety	88	33	2	0	0	123
Improved quality	74	37	11	1	0	123
Improved productivity	63	43	16	1	0	123
Cost reduction	32	47	40	4	0	123
Boost R&D	27	43	43	10	0	123

Table 4.5: Responds of drivers in reality training [6, p.1313].

Responds of barriers

The reaction rate from barriers was divided into same procedure in five polls between Strongly Disagree and Strongly Agree. Barriers were chosen into five additional terms: Lack of expertise, cultural change, cost of VR, complexity in development, and technological immaturity [6, p.1313].

Bariiers	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Lack of expertise	84	31	8	0	0	123
Cultural change	56	52	14	1	0	123
Cost of VR	58	42	21	2	0	123
Complexity in development	42	45	30	6	0	123
Technological immaturity	35	47	36	5	0	123

Table 4.6: Responds of barriers in reality training [6, p.1314].

4.2 Research of companies

4.2.1 KLM Royal Dutch Airlines

KLM Royal Dutch Airlines is the flag carrier airline of the Netherlands. The company uses scheduled training from Matterport as online reality training of instructional technologies to train pilots and other crew members, as shown in 4.3. Crew members in training can enhance their classroom work with virtual visits to aircraft at any time of day and walk around as many times as they would like [37]. KLM has also experimented with AR, using Microsoft Hololens for training maintenance engineers of the various components of an engine [53].

figure 4.3: KLM using matterport as reality training [36].

KLM is the first airline to create a training program in VR for pilots, shown in figure 4.4. The reality training program is intended to provide pilots with a more immersive and realistic training experience. The program also allows pilots to practice emergency procedures without an actual aircraft, using a virtual cockpit and VR walk-around. Virtual cockpit works how the pilot can watch a flight in a 360-degree film in the cockpit. The VR walk around using an HMD shown in figure 4.4b works how the pilot can fly the plane in a game [68].

(a) Software [68].

(b) VR HMD [68].

figure 4.4: KLM using pilot VR as reality training

The research of the references from KLM using reality training is shown in table 4.7. It shows the connections of barriers and drivers using the 3D Matterport, VR pilot, and AR technology from Microsoft. The typical driver of each technology is that reality training for KLM provides time reduction and safety and can repeat the exercise as often as possible. The most common barrier is that data management, security, and HMD often need more expertise.

Technology	Drivers	Barriers
3D Matterport	Able to train up in front before aircraft arrives [53]. Reduce carbon footprint and costs to fewer travel movements of crew [37]. Cleaning reduction time by 30% for cleaning crews [37].	Require to take picture in the environment to create a model and cant implement BIM models [53].
Pilot VR	Spare from renting an airplane and risk damaging either piece of equipment [53]. Training pilots reduce 45 minutes of training [72]. Using crew training with instructor and trainees in cabin fire situations [72].	Uncomfortable to wear after more than an hour [53]. Unwanted scenarios in data management and headset security [72].
AR Microsoft	Training maintenance engineers, where it makes the training cheaper cause no need to dismantle an original motor engine [53].	Expensive equipment [53].

Table 4.7: KLM references in drivers and barriers using reality training [60].

4.2.2 Toyota Motor North America

Toyota Motor North America (TMNA) is the North American subsidiary of the Toyota Motor Corporation, a Japanese multinational automotive manufacturer. Shown in figure 4.5, TMNA uses Microsoft Dynamics 365 integrated with an HMD of Microsoft HoloLens 2 as MR in maintenance and production operations, shown in figure. [43].

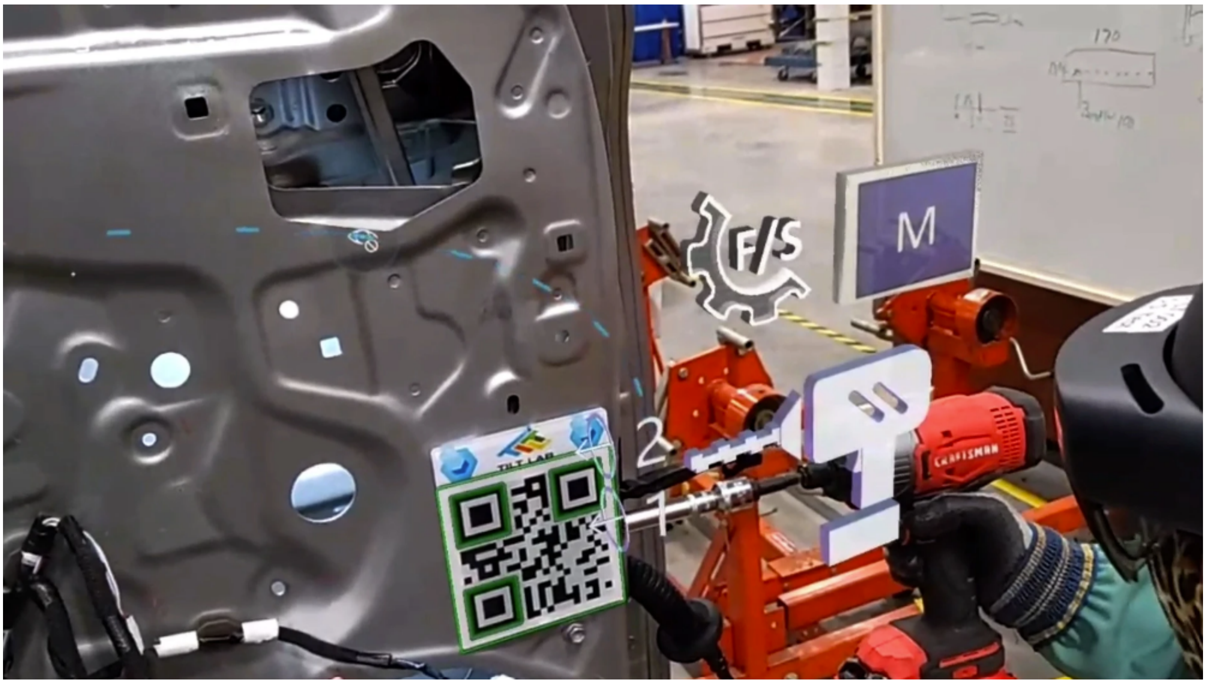

figure 4.5: Toyota motor using MR as reality training [41].

The research references of TMNA using MR in reality training as drivers and barriers are shown in table 4.8. The typical driver is that workers can work independently and repeat the exercise as often as necessary. The barrier is that it has unwanted data management scenarios, and the HMD of MR is costly initial.

Technology	Drivers	Barriers
MR Microsoft	Avoid bottlenecks where trainers can create training procedures and let trainees work independently in live production situations [43]. Can repeat a training as often as necessary [43].	Unwanted scenarios in data management and costly initial equipment [43].

Table 4.8: TMNA references in drivers and barriers using reality training [60].

4.3 Research of investment

4.3.1 Previous research of investment from Forrester Consulting

Research conducted by Forrester Consulting has examined the investment in reality training using Microsoft Hololens 2 MR technology. The data demographics for this research are summarized in table 4.9. The study involved interviews with 21 organizations spanning four diverse industries: manufacturing, AEC, healthcare, and education. These organizations varied in size, with annual revenue ranging from $500 million to $100 billion. The research encompassed organizations from North America, Europe, and Asia.In terms of deployment, the HMD size ranged from five to 400 devices, catering to user bases ranging from 10 to 3000 individuals. The data collected from these interviews provide valuable insights into the practical implementation and impact of reality training using MR technology with Hololens 2 [Appendix 7, p.6].

Data demographics	**MR Microsoft**
Interviews conducted	23 decision-makers from 21 different organizations, where 13 were specified in a robust partner ecosystem of independent software vendors & eight were systems integrators in expertise and offerings.
Type of industries	Manufacturing, AEC, Healthcare & Education.
Organization sizes	Between $500 million & $100 billion in annual revenue.
Regions	Organizations from North America, Europe & Asia.
Deployment size of HMD	Range from five - 400 HMD with between 10 - 3000 users.

Table 4.9: Data demographics from Forrester Consulting [Appendix 7, p.6].

The composite organization

Forrester Consulting has constructed a composite organization as a representative model based on the data demographics. This composite organization is a North American company engaged in selling services and providing customer support. It boasts a global workforce of 5000 employees and generates annual revenue exceeding $1 billion. The composite organization is a foundation for evaluating the MR deployment, with information regarding MR users and technologists outlined in table 4.10. This composite organization is an investment project to facilitate an overview of the investment benefits and costs associated with reality training using MR technology [Appendix 7, p.14].

User role	Employee location	Number of users
Field task workers	Any location	50
Onsite task workers	Major company sites	120
Project & site leaders	Major company sites	15
Specialized experts	Any location	15
General business users	Any location	500 to 1000 per year
Implementing & manage the MR deployment	Any location	9

Table 4.10: MR users & technologists in MR deployment at the composite organization [Appendix 7, p.14].

Investment benefits

Forrester Consulting's comprehensive research on investment benefits using MR technology across the four different industries is summarized in Figure 4.11. The study identifies various types of benefits, including training efficiency, productivity enhancements for field task workers, task workers, leaders, and specialized experts, as well as cost savings related to travel and operations. These benefits have been estimated and evaluated over a three-year period, providing valuable insights into the potential advantages of adopting MR technology in terms of improving training effectiveness, boosting productivity across different roles, and reducing costs associated with travel and operations.

Type of benefit	**Advantages from data demographics using MR over three years**	**Source**
Training efficiency	Reduced training time by 60%.	Appendix 7, p.16
Field task worker productivity	-Improved fully efficiency by 40% of field work for 30 % of field tasks. -Reduced follow-up visits by 75% with a 10 % of follow-up visits.	Appendix 7, p.18
Task worker productivity	-Improved efficiency by 60% for 15% of onsite tasks. -Reduced rework by 50% for 10% of rework tasks.	Appendix 7, p.20
Leader productivity	-Improved leader productivity by 30% for 50 % of leaders' workloads in training, design workloads and project planning.	Appendix 7, p.22
Specialized expert productivity	- Reduced task work per expert by 30% -Prevented 75% of monthly trips with 90 % of labor per trip.	Appendix 7, p.24
Travel savings	-Saved avoided field worker & expert trips	Appendix 7, p.26
Operational cost savings	-Avoided consumables usage for instruction & training by 80%. -Avoided consumables per leader/expert by 10%. -Reduced personal protective equipment (PPE) by 60%. -Reduction in total operation costs of revenue from avoided rework by 0,2%.	Appendix 7, p.29

Table 4.11: Each benefits of advantages from data demographics using MR over three years [60].

Investment costs

Forrester Consulting's research on investment costs associated with using MR technology is summarized in figure 4.11. The study provides estimates for various cost drivers, including the costs of Hololens 2 devices, subscriptions, operations, maintenance, and training. These cost factors have been evaluated to provide insights into the financial considerations and costs that associated with implementing MR technology, offering a comprehensive understanding of the investment costs involved.

Type of cost	**Disadvantages from data demographics using MR over three years**	**Source**
Hololens 2 devices	-Initial device purchase costs of total 105 devices is highest of $367 500.	Appendix 7, p.37
Subscription	-Each year, the highest maintenance costs are attributed to application subscriptions, amounting to $328 000.	Appendix 7, p.38
Operation & maintenance	-The highest cost in project management, starting from the initial phase of the startup, is $312,000.	Appendix 7, p.40
Training	-During the first year of training, the highest cost amounts to $184 800, with 100% of the users being new to MR	Appendix 7, p.41

Table 4.12: Each costs of disadvantages from data demographics using MR over three years [60].

4.3.2 Previous investment support from Norway

The research findings from the previous investment support provided by the Research Council of Norway are presented in Figure 4.13. These investments were geared towards supporting R&D projects focused on innovating of reality training. The amount of support allocated to each project was contingent upon the project's description and the duration of the project period. It's important to note that the investment support was open to both public and private companies, reflecting a commitment to fostering advancements in reality training across various sectors in Norway.

Company	**Amount of support**	**Project period**	**Project description**
CTD AS	0,25 million NOK	2023-2023	Use of VR for increased competence between service levels for a more robust health sector[49].
Wilhelmsen ships service AS	5,2 million NOK	2021-2026	Behavioral change & learning powered by virtual gaming technology & artificial intelligence[48].
Kongsberg Digital AS	6,5 million NOK	2017-2022	Innovating maritime training simulators using VR & AR [50].
University of Bergen	4,1 million NOK	2014-2017	VR training of a motivating & effective way of regaining arm motor function after stroke [51].

Table 4.13: Previous investment support from the Research Council Of Norway in reality training [60].

4.3.3 Future investment support from EU

According to research conducted by the Digital Europe Programme, the program has an estimated value of approximately 7.6 billion euros and spans a long-term budget period from 2021 to 2027. Table 4.14 outlines the areas in which the fund will allocate funding, including supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and the promotion of widespread utilization of digital technologies across the economy and society.

Priorities	Amount of support	Description of requirements
Supercomputing	€2.2 BILLION	Supporting build up in supercomputing & strengthen the data processing capacities [13].
Artificial intelligence	€2.1 BILLION	Supporting artificial intelligence of an energy-efficient cloud infrastructure [13].
Cybersecurity	€1.6 BILLION	Supporting cybersecurity between the data infrastructures & the wide deployment of the capacities across the economy [13].
Digital technologies across the economy and society	€1.1 BILLION	Supporting R&D of the digital transformation & advanced digital technologies in small and medium-sized enterprises of the industry [13].
Advanced digital	€580 MILLION	Supporting training & upskilling of the existing workforce in areas like AI, cybersecurity, quantum, & computing [13].

Table 4.14: The long term budget of the Digital Europe Programme 2021 - 2027 [60].

5 Technology & Investment analysis

This chapter highlights the results of the Technology & Investment analysis to answer critical drivers and barriers aspects of reality training in manufacturing. The chapter reviews the results using the methods described in chapter 3.3. The analysis is presented as drivers and barriers according to the questions, shown in figure 5.1 below.

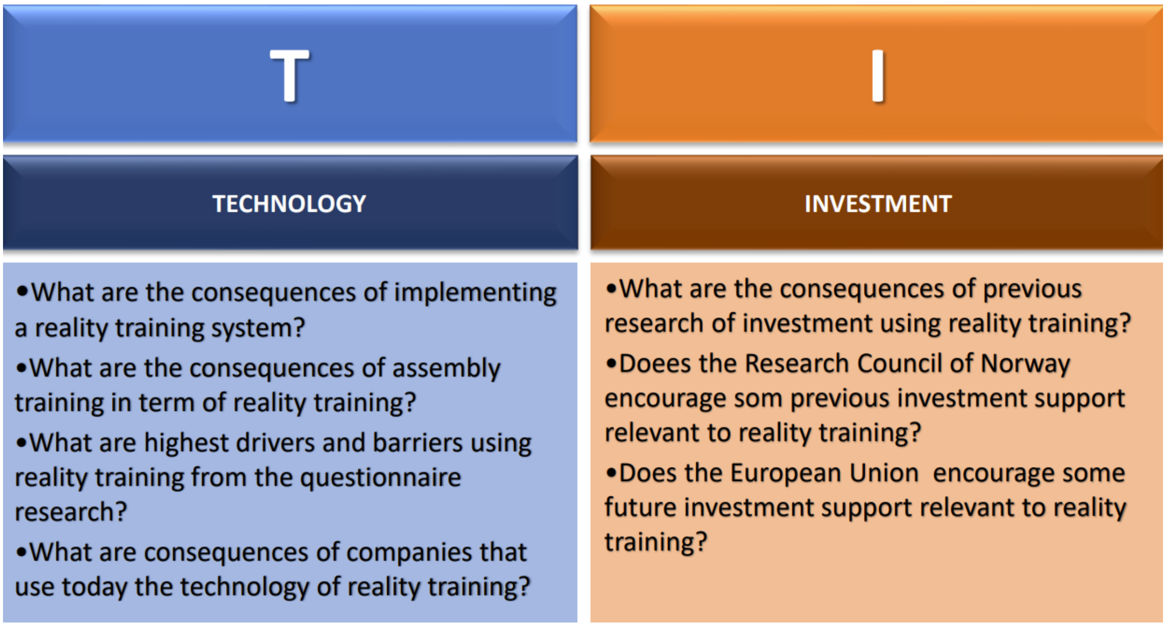

figure 5.1: Technology & Investment analysis [60].

5.1 Technology

5.1.1 Implementation results

The architectural structure of the reality training system, depicted in Figure 5.2, is built upon the findings of the research conducted in chapter 4.1.1. The system has been designed to meet the requirements of interoperability, autonomy, and sustainability outlined in Chapter 2.3.1.

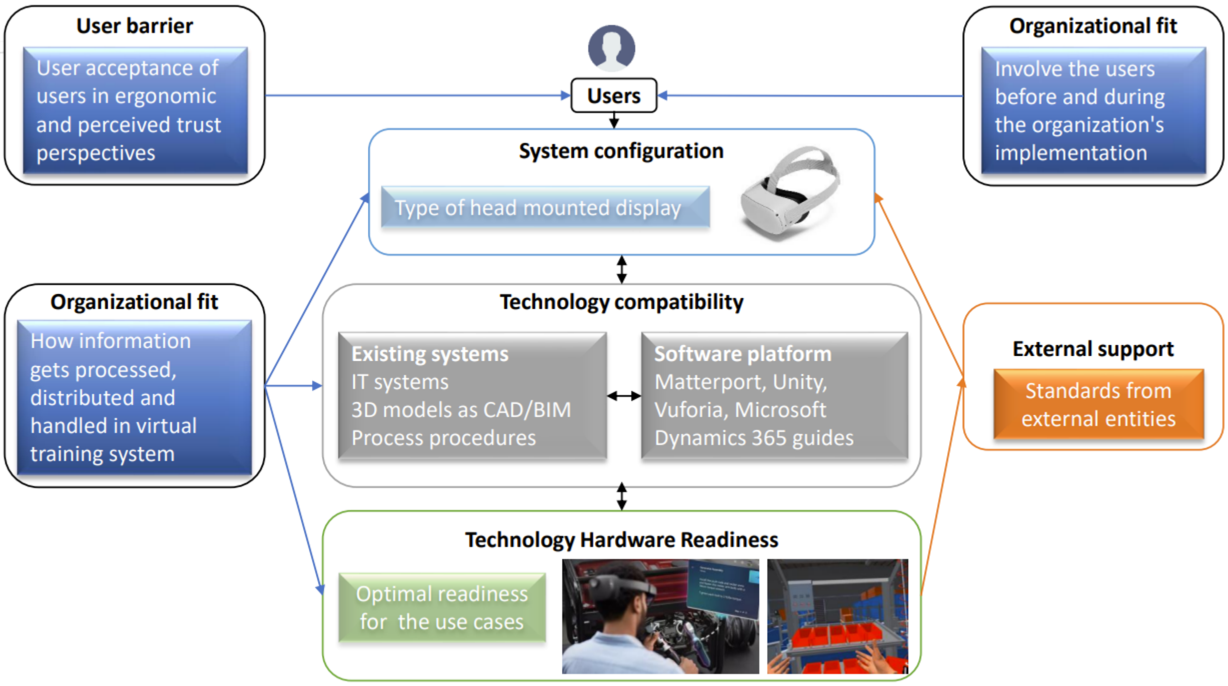

figure 5.2: An architectural structure of the reality training system [60].

In the technological context, the system emphasizes autonomy by allowing for flexible system configuration. It also focuses on interoperability by ensuring compatibility with various technologies and considering hardware readiness.

The environmental context considers the importance of interoperability standards provided by external support. These standards facilitate seamless integration with other systems and foster independence.

The organizational context addresses sustainability by identifying and addressing user barriers. Additionally, the system is designed to fit seamlessly within existing organizational structures and processes.

Overall, the architectural structure of the reality training system is the result of careful consideration of the technological, environmental, and organizational factors to ensure the system's effectiveness and long-term viability.

Table 5.1 illustrates the results of challenges associated with the implementation of the reality training system. These challenges include low-resolution graphics, insufficient haptic feedback, high costs of creation and maintenance, and inadequate data collection. Addressing these barriers is crucial for the successful development and deployment of an effective reality training system.

Type of barrier	Description
Low-resolution graphics	Challenge that need achieving a truly realistic hardware readiness environment of intricate details and textures in the reality world [3].
Insufficiency of haptic feedback	Challenges for precise and responsive haptic feedback need to achieve true realism within a reality training environment, users must be able to physically interact with objects [3].
High costs of creating and maintaining	Challenge of the substantial cost involved in hardware and software of expertise as designers and engineers in creating and maintaining highly detailed and accurate reality environments [3].
Inadequate collection of data	Challenge of data collection when creating reality environments of the gathering and processing of an extensive amount of data, which can be both time-consuming and costly [3].

Table 5.1: The result of barriers outlined in the implementation results correspond to challenges faced in the reality training system [60].

5.1.2 Assembly training results

The assembly training results shown in figure 5.2 are based on the research of assembly training in chapter 4.1.2. The total average assembly completion time for traditional training was 14 minutes and 34 seconds. The average assembly completion time for all four reality training scenarios was 5 minutes and 10 seconds. The entire time reduction of reality training is 9 minutes and 24 seconds, a 64,49 % reduction from traditional training. The total average errors from traditional were 2,2 and 0.4 for reality training , with an error reduction of 81,82 %.

Assembly results	TT (Min)	VR1 (Min)	VR2 (Min)	VR3 (Min)	VR4 (min)	Average estimations of using VR
Total average time	14:34	05:24	04:16	05:53	05:08	05:10 Min
Time reduction of TT	0%	62,87%	70,74%	59,59%	64,77%	**64,50%**
Total average errors	2,20	0,40	0,60	0,40	0,20	0,40
Error reduction of TT	0%	81,82%	72,73%	81,82%	90,91%	**81,82%**

Table 5.2: Assembly training results of training complete time and errors [60].

5.1.3 Questionnaire survey results

The questionnaire survey results shown in table 5.3 of adopting reality training in the UK are based on the research of questionnaire survey in chapter 4.1.3. The highest mean score of drivers' responds was 4,7 in improved safety, with 71.5% strongly agree. The highest mean score of the respondents of barriers was 4,62 in lack of expertise, with 68,3% strongly agree.

Drivers	**Strongly Agree (5)**	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly Disagree (1)**	**Mean Score**
Improved safety	71,5%	26,8%	1,6%	0%	0%	**4,70**
Improved quality	60,2%	30,1%	8,9%	0,8%	0%	4,50
Improved productivity	51.2%	35,0%	13,0%	0,8%	0%	4,37
Cost reduction	26,0%	38,2%	32,5%	3,3%	0%	3,87
Boost R&D	22,0%	35,0%	35,0%	8,1%	0%	3,71
Barriers						
Lack of expertise	68,3%	25,2%	6,5%	0%	0%	**4,62**
Cultural change	45,5%	42,3%	11,4%	0,8%	0%	4,33
Cost of VR	47,2%	34,1%	17,1%	1,6%	0%	4,27
Complexity in development	34,1%	36,6%	24,4%	4,9%	0%	4,00
Technological immaturity	28,5%	38,2%	29,3%	4,1%	0%	3,91

Table 5.3: Questionnaire survey results [60].

5.1.4 Companies results

The common results shown in table 5.4 are based on all three company results of implementing reality training , which is based on the research of companies in chapter 4.2. The results showed that familiar drivers reduce training time and the possibility of repeating the activity as often as necessary. The common barriers are the lack of unwanted data management scenarios and expensive equipment.

Technology	Drivers	Barriers
Reality training	Reduce training time. Can repeat a training as often as necessary.	Unwanted scenarios in data management. Expensive equipment.

Table 5.4: Common results from companies using reality training [60].

5.2 Investment

5.2.1 Previous investment results from Forrester Consulting

Based on Forester's previous research on investment, the financial analysis of the composite organization demonstrated a remarkable three-year return on investment of 177 % shown in figure 5.3. The analysis further unveiled a NPV of $7.6 million and a payback period of 13 months. The total benefits accrued to $11.9 million, exceeding the total costs of $4.3 million.

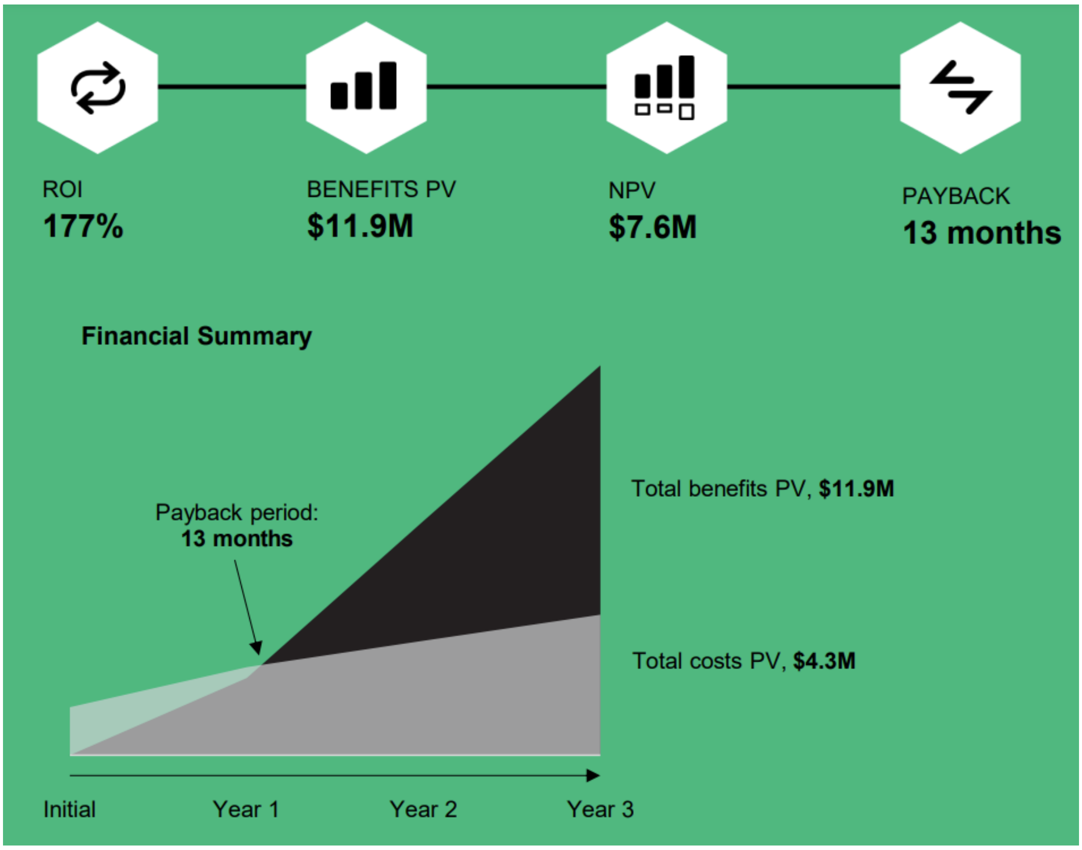

figure 5.3: Total economic impact of investments [23, p.4].

5.2.2 Previous investment support results from Norway

The results of the previous amount of support from Norway in R&D of reality training are shown in table 5.5. The average amount of support became 4,01 million NOK based on the companies in chapter 4.3.2. The results show that VR and AR are the common drivers of reality training that has gotten previous support from the Research Council of Norway.

R&D	Type of fund	Average amount of support	Type of reality
Reality training	Research Council of Norway	4,01 million NOK	VR & AR

Table 5.5: Previous investment results from the Research Council of Norway [60].

5.2.3 Future investment support results from EU

The research conducted in chapter 4.14 presents the outcomes of future investment through the Digital Europe Programme, as depicted in table 5.6. In the context of RD support for reality training, the drivers behind the funds are digital technologies across the economy and society and the advanced digital fund. However, the funds for supercomputing, artificial intelligence, and cybersecurity pose barriers and do not provide support in this specific area.

R&D	Drivers	Barriers
Reality training	Digital technologies across the economy and society fund support in digital transformation in small and medium-sized enterprises, where R&D in reality training is a form of digital transformation. Advanced digital fund can provide support in integration of AI and cybersecurity in R&D of reality training, where the purpose is to support the training and upskilling of the advanced digitization.	The Supercomputing, artificial-intelligence and cybersecurity funds is to specific that it cant be use in R&D of reality training. It means that the specific funds are the focus of their particular business, and reality training cant integrates into it.

Table 5.6: Results in drivers and barriers of future investment support from Digitale Europe in R&D of reality training [60].

6 Risk analysis

This chapter focuses on the outcomes of the risk analysis conducted to determine the impact of reality training on the risk level in manufacturing production. The analysis results are evaluated based on the methods outlined in Chapter 3.4. By employing these methodologies, the chapter provides an in-depth review of the findings, shedding light on how reality training influences the overall risk profile in manufacturing operations for Beyonder.

6.1 Presentation of the risk case

Beyonder AS is a Norwegian battery manufacturer located in Sandnes, which develops and manufactures highly sustainable battery cells for industrial applications such as renewable energy sources, frequency regulation, and charging infrastructure for heavy transport. Today, they have a battery center in R&D for battery production shown in figure 6.1a. The battery company will build a new full-scale manufacturing of batteries shown in figure 6.1b, which was estimated to be ready to produce battery cells by the end of 2024. This has been postponed due to insufficient expertise in battery production and needs more R&D [Appendix 1, p.8-10]. The current operations in the battery center today have a production of 120 operators. They have estimated a production capacity of five production lines with 900 operators for full-scale manufacturing. From establishing a new factory, they have estimated approximately 6-month training of different machines [Appendix 2].

(a) Battery center [Appendix 1, p.10]

(b) Full-scale manufacturing [Appendix 1, p.10]

figure 6.1: Beyonder AS

Beyonder uses traditional training today as technical manuals shown in Appendix 3 to train workers in production for maintenance procedures, operations, and emergency response scenarios. The company uses technical manuals in Microsoft Word and presents the techniques for the workers from individual pictures, shown in figure 6.2. They use the manuals to sign where the emergency buttons are in each machine and how it works. Also, they mark where the air pressure is and describe in words how much pressure is needed. The manuals also describe equipment maintenance and setting the machine parameters manually. All the machines are also bought from China and need to be translated from Chinese to English, shown in Appendix 3.

figure 6.2: Current technical manuals Beyonder use of training operators upon production [Appendix 3].

6.1.1 Business impact analysis

Beyonder has developed a framework of a business impact analysis for maintenance procedures and their operation, shown in Appendix 4, page 1. The framework demonstrates the impact of catastrophic, major, moderate, minor, and negligible. Each significance arises regarding health safety, environment, commercial, compliance, assets, and costs. The consequences of commercial, compliance, and assets define the quality aspects.

Catastrophic

Table 6.1 shows the highest scenario of the catastrophic impact, which causes death, and the damage will not be repaired within the foreseeable future. As the quality, it will lead to loss of contract, global reputation, assets, and significant legal consequences.

Impact	Health & safety	Environment	Commercial	Compliance	Assets	Cost (NOK)
Catastrophic	Death	Damage that cannot be repaired within the foreseeable future	Loss of contract & global reputation	Serious breach of compliance leading to significant legal consequences	Loss of assets	1M+

Table 6.1: Catastrophic impact analysis [Appendix 4, p.1].

Major

Table 6.2 shows the second highest scenario of the major impact, which causes sickness absence over 90 days, and damage that cannot be repaired within ten years. As the quality, it will lead to loss of job, national reputation, major assets, and legal consequences.

Impact	Health & safety	Environment	Commercial	Compliance	Assets	Cost (NOK)
Major	Sickness absence over 90 days	Damage that cannot be repaired within 10 years	Loss of job & national reputation	Breach of compliance leading to legal consequences	Loss of major assets	500K > 1M

Table 6.2: Major impact analysis [Appendix 4, p.1].

Moderate

Table 6.3 shows the middle scenario of the moderate impact, which causes sickness for about 30-90 days, and damage that cannot be repaired within one year. As the quality, it will lead to serious customer complaints, national media attention, critical assets, and moderate breach compliance leading to warnings.

Impact	Health & safety	Environment	Commercial	Compliance	Assets	Cost (NOK)
Moderate	Sickness about 30-90 days	Damage that cannot be repaired within 1 year	Serious customer complaints & national media attention	Minor to moderate breach compliance leading to warning	Critical assets affected	250K > 500K

Table 6.3: Moderate impact analysis [Appendix 4, p.1].

Minor

Table 6.4 shows the second lowest scenario of the minor impact, which causes sickness for about 1-30 days, and damage that can easily be repaired. As the quality, it will lead to customer complaints, local media attention, assets affected with little margin, and breach of instruction, which do not represent a breach of legal requirements.

Impact	Health & safety	Environment	Commercial	Compliance	Assets	Cost (NOK)
Minor	Sickness about 1-30 days	Damage that can easily be repaired	Customer complaint & local media attention	Breach of instruction which do not represent breach of legal requirements	Assets affected with little margin	100K > 250K

Table 6.4: Minor impact analysis [Appendix 4, p.1].

Negligible

Table 6.5 shows the lowest scenario of the negligible impact, which causes sickness for about one day, and has no consequence. The quality will lead to an insignificant effect, local media attention, a little threat to assets, and a minor impact.

Impact	Health & safety	Environment	Commercial	Compliance	Assets	Cost (NOK)
Negligible	Sickness about 1 day	No consequence	Negligible impact	Minor impact	Little threat to assets	100K > 250K

Table 6.5: Negligible impact analysis [Appendix 4, p.1].

6.1.2 Definition of probability scenario

Beyonder has defined five scenarios in each probability scale shown in table 6.6. The highest scenario is almost certain, which is above 90 % chance of happening. The lowest one is rare, which is less than five percent.

Type of scenario	Type of probability scale
Almost certain	Above 90% chance of happening
Likely	Between 60% - 90% chance of happening
Possible	Between 20% - 60% chance of happening
Unlikely	Between 5% - 20% chance of happening
Rare	Less than 5% chance of happening

Table 6.6: Definition of scenarios in different probability scales [Appendix 4, p.2].

6.1.3 Risk matrix by current operations

Beyonder has created a risk matrix shown in table 6.7 regarding the business impact analysis and different scenarios of the probability scales. According to their operations in maintenance procedures, production, and emergency response scenarios, they have plotted different actions from their operations in the risk matrix. The definition of each color refers to the weight of risk action, shown in table 6.8. The weight of risk action refers to the probability of an event occurring with the event's impact.

Probability/ Impact	Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic					
Major					
Moderate	-Electric shock of the electrical components. -Insufficient air pressure causes mechanical failure.	-Skin corrosion in contact with electrolyte. -Machines is operated with non functional safety equipment.	-DSF machines have a flattening process that can damage hands.		
Minor	-Physical injury when removing the battery. -Physical injury by equipment maintenance.				
Negligible					

Table 6.7: Risk matrix by current operations of using trational training[Appendix 4, p.2].

Definition of colors	Weight of risk action
	Stop/Emergency
	Urgent action
	Action
	Monitor
	No action

Table 6.8: Definition of colors by the weight of risk actions [Appendix 4, p.2].

6.2 Risk analysis of using reality training

As described in the method in chapter 3.4, the risk analysis results are based on Beyonder‘s risk case and the assembly training results in chapter 5.1.2. The results present the change in probability and the risk matrix from traditional training to reality training. The critical operations from the current probability scale in possible, unlikely- and rare scenarios are repeated in table 6.9 to get a decent overview of what the result will find.

Type of scenario	Type of critical operation	Current probability scale
Possible	DSF machines have a flattening process that can damage hands	20% - 60%
Unlikely	Skin corrosion in contact with electrolyte	5% - 20%
Unlikely	Machines is operated with non functional safety equipment	5% - 20%
Rare	Electric shock of the electrical components	>5%
Rare	Insufficient air pressure causes mechanical failure	>5%
Rare	Physical injury when removing the battery	>5%
Rare	Physical injury by equipment maintenance	>5%

Table 6.9: Current chance of happening by using traditional training in critical operations [60].

6.2.1 Change in probability

The change in probability is based on the assembly training results in chapter 5.1.2 with a likelihood of errors of 81,82%. In table 6.10 the difference in probability scale in possible scenarios became between 4% - 10,9% in a chance of happening with a decrease in probability scale between 16% - 49,1%. In an unlikely scenario, the change in probability scale became between 0,9% - 4% in a chance of happening with a reduction in probability scale between 4,1% - 16%. The lowest probability scenario got a change of less than 0,9% in a chance of happening with a reduction less than 4,1%.

Type of scenario	**Current probability scale**	**Likelihood of errors**	**Change in probability scale**	**Reduction in probability scale**
Possible	Between 20% - 60% chance of happening	81,82%	Between 4% - 10,9% chance of happening	16% - 49,1%
Unlikely	Between 5% - 20% chance of happening	81,82%	Between 0,9% - 4% chance of happening	4,1% - 16%
Rare	Less than 5% chance of happening	81,82%	Less than 0,9% chance of happening	>4,1%

Table 6.10: Change in probability scales from traditional training to reality training in different scenarios [60].

6.2.2 Change in the risk matrix

The change in probability gave the critical operations in possible and unlikely scenarios a difference in the risk matrix of using reality training, shown in figure 6.11. The change of the critical operation *"DSF machines have a flattening process that can damage hands"* changed from possible to unlikely. The essential operations that became changed from unlikely to rare were *"Skin corrosion in contact with electrolyte"* and *"Machines is operated with nonfunctional safety equipment"*. The remaining operations were in the same scenario as rare since this is the lowest scenario in the matrix.

Probability/ Impact	Rare	Unlikely	Possible	Likely	Almost certain
Catastrophic					
Major					
Moderate	-Electric shock of the electrical components. -Insufficient air pressure causes mechanical failure. -Skin corrosion in contact with electrolyte. -Machines is operated with non functional safety equipment.	DSF machines have a flattening process that can damage hands.			
Minor	-Physical injury when removing the battery. -Physical injury by equipment maintenance.				
Negligible					

Table 6.11: Risk matrix of reality training [60].

7 Financial Statement analysis

7.1 Presentation of the financial statement case

Norske Skog Skogn AS is a Norwegian paper mill manufacturer located in the municipality of Levanger, shown in figure 7.1. The company was founded in 1962 which produces newsprint and magazine paper from wood pulp [64]. The manufacture have about 419 employees according to the annual report 2021 [Appendix 5, p.5]. Norske Skog Skogn AS is part of the Norske Skog ASA, one of the world's largest newsprint and magazine paper producers. The company uses traditional training today as technical manuals and courses to train workers for maintenance procedures and operations [63].

figure 7.1: Norske Skog Skogn [1].

7.1.1 Case 1

In figure 7.2, it illustrates the case 1 to find the average change in EBITDA between traditional training and reality training of one year. The analysis includes four different training duration's before generating revenue: three months, six months, nine months, and one year. The comparison is made between the training approaches for each duration and the whole description is illustrated in Appendix 8.

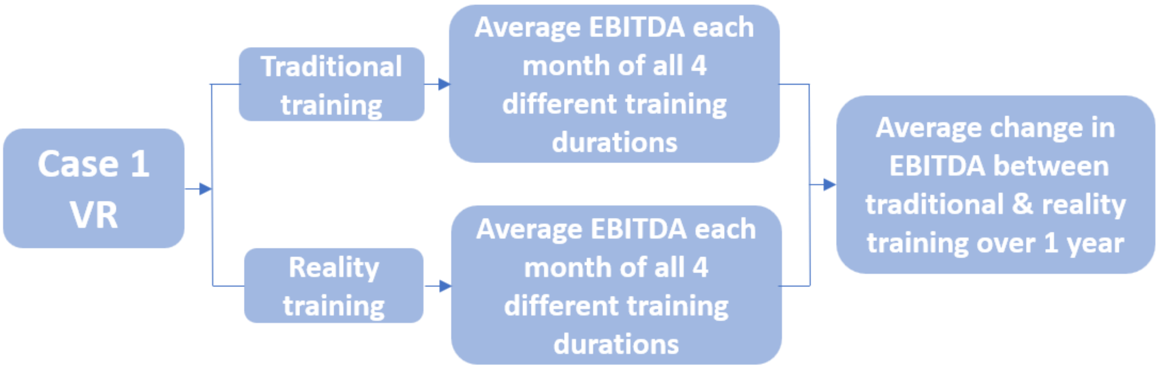

figure 7.2: Case 1 description [60].

7.1.2 Case 2

The second case depicted in figure 7.3 of the Financial Statement analysis focused on examining the present value of investment benefits and costs associated with utilizing MR as a form of reality training over a span of five years. The aim was to assess the profitability of MR technology by investigating the NPV between investment benefits and costs. Furthermore, in evaluating the transition to reality training, the change in EBITDA was viewed as an increase due to the reduction in OPEX compared to the average EBITDA observed in Norske Skog Skogn's annual report for traditional training methods. A comprehensive depiction of case 2 can be found in Appendix 9.

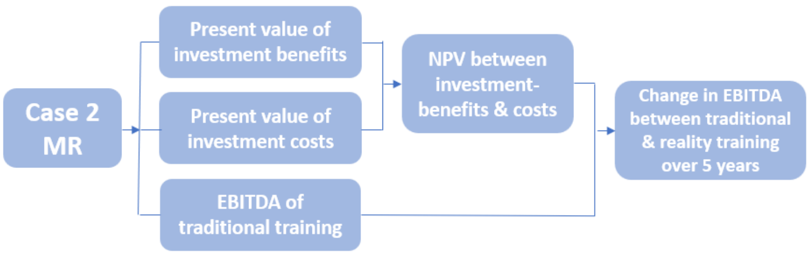

figure 7.3: Case 2 description [60].

7.1.3 Case 1 results

The findings of the average monthly EBITDA for both traditional and reality training using VR in a new factory over a year are presented in figure 7.4. The results indicate that the costs associated with reality training are highest in the first month of -52 556 KNOK. This is because the average training costs for duration's ranging from 3 months to 1 year are incurred before the factory becomes operational and starts generating revenue. In contrast, traditional training requires directly training workers in the actual factory, leading to an average positive EBITDA from October on wards.

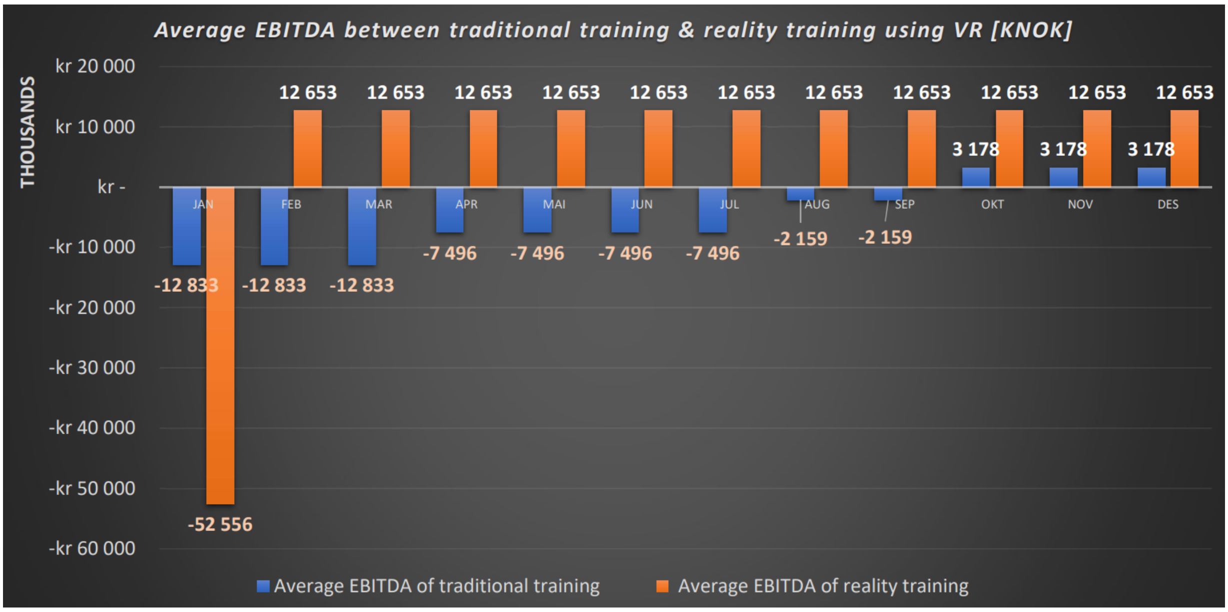

figure 7.4: The average EBITDA between traditional and reality training each month using VR, measured in KNOK [Appendix 8, p.3].

The results of the average change in EBITDA between traditional and reality training are illustrated in figure 7.5. The findings indicate that the most significant negative change occurs in the first month, with a value of -39 722 KNOK. Conversely, the most significant positive change was observed in February, with a value of 25 487 KNOK. This pattern can be attributed to the fact that the costs associated with reality training are highest in the first month, negatively impacting EBITDA. For a more detailed analysis and a comprehensive summary of the findings, please consult Appendix 8, from pages 1 to 3.

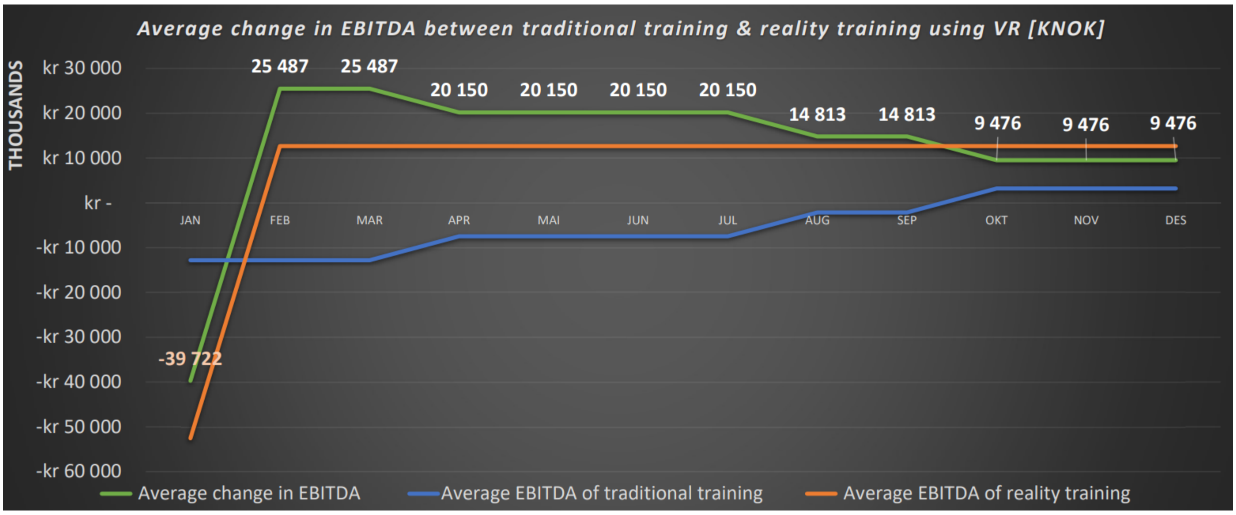

figure 7.5: The average change in EBITDA between traditional and reality training each month, measured in KNOK [Appendix 8, p.3].

7.1.4 Case 2 results

Investment benefits results

In figure 7.6, it demonstrates the various investment benefits in reduction of OPEX by using MR as reality training. The most significant benefit observed annually is the savings in training costs. On the other hand, the lowest benefit recorded pertains to savings in travel costs, which exhibits a declining trend between years 3 and 5. This decline can be attributed to the discount rate, as the benefits does not increase significantly during this period. Despite this temporary decrease, it is important to note that all the investments yield positive benefits each year. For detailed information and a comprehensive summary of the findings regarding each saving benefit over five years, please refer to Appendix 9, from pages 1 to 4.

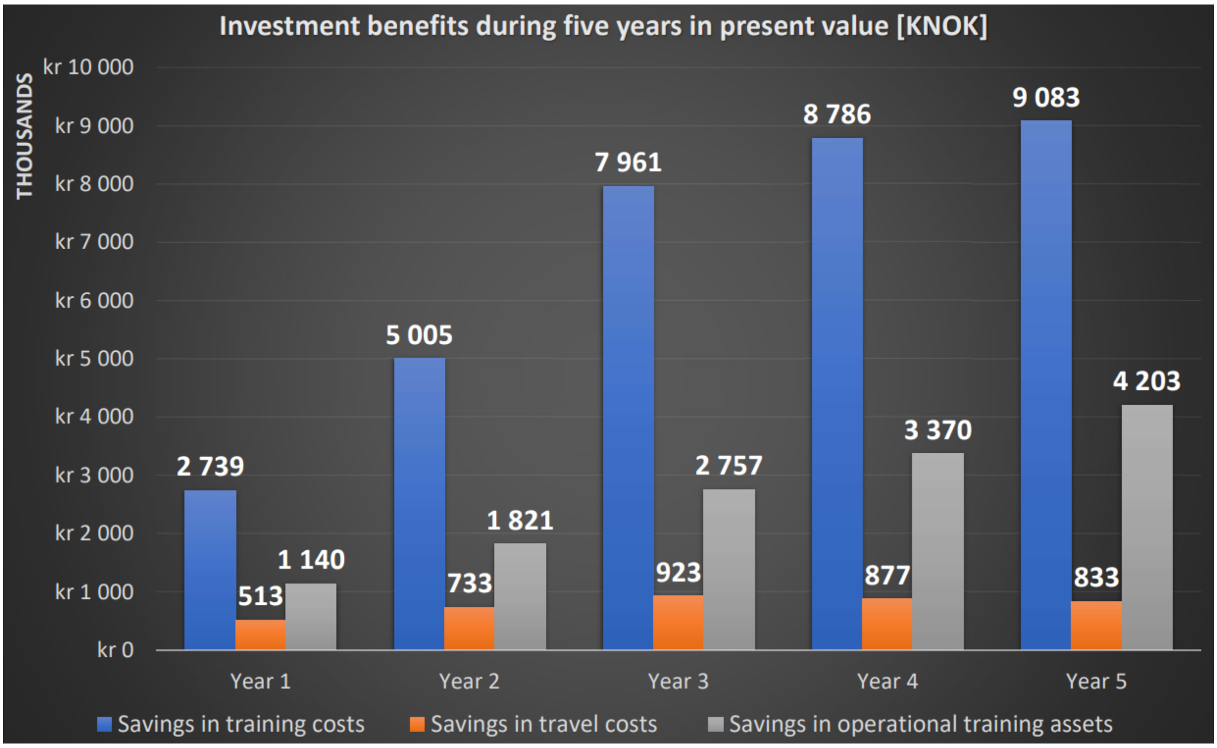

figure 7.6: Investment benefits during five years in present value of KNOK [Appendix 9, p.5].

The implementation of MR for training purposes in Norske Skog Skogn's operations has proven to be effective, resulting in a yearly increase in investment benefits, as illustrated in Figure 7.7. It is worth noting that the benefits exhibit a significant surge between year one and year three. This can be attributed to the highest increase in productivity and efficiency during the initial three-year period. For a detailed analysis and a comprehensive summary of the findings regarding the total savings benefits over the span of five years, please refer to Appendix 9, specifically pages 4 and 5.

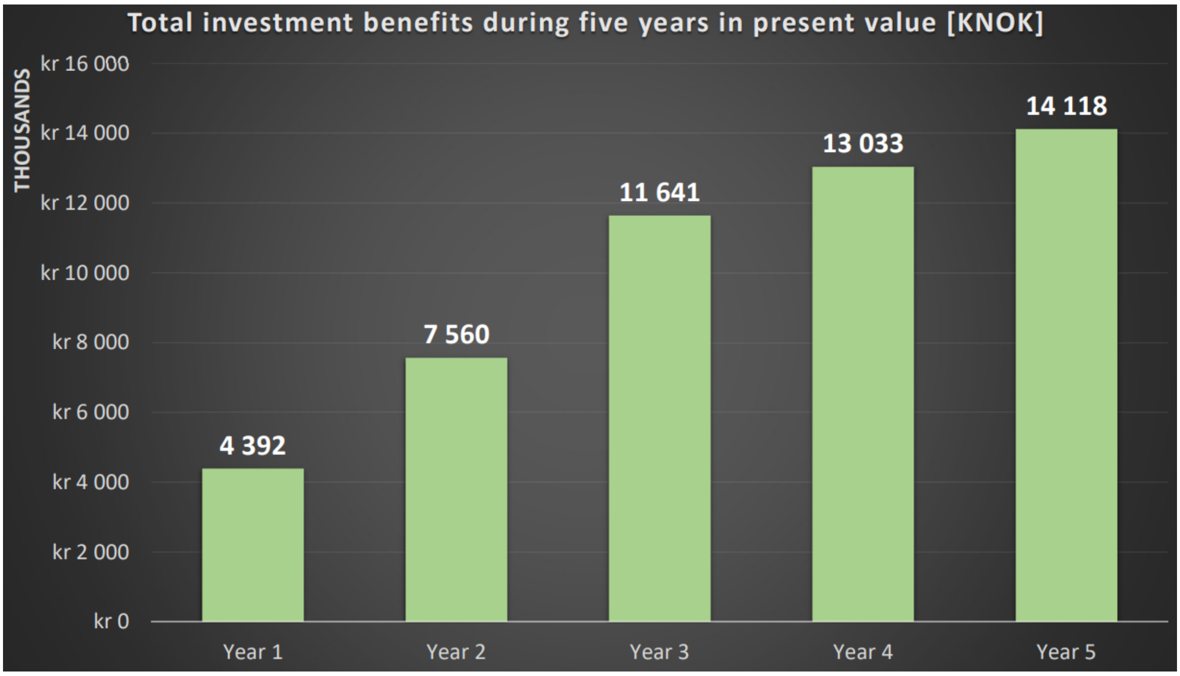

figure 7.7: Total investment benefits during five years in present value of KNOK [Appendix 9, p.5].

Investment costs results

Figure 7.8 illustrates the investment costs associated with implementing and utilizing MR technology in Norske Skog Skogn's operations. The highest price is attributed to the operation and maintenance expenses during the initial startup phase and in year 1. On the other hand, the lowest costs incurred over the years about the HMD of Hololens 2 and the general training costs associated with its usage. For a more detailed understanding of the findings related to the investment costs over the five years, refer to Appendix 9, specifically pages 6 to 8.

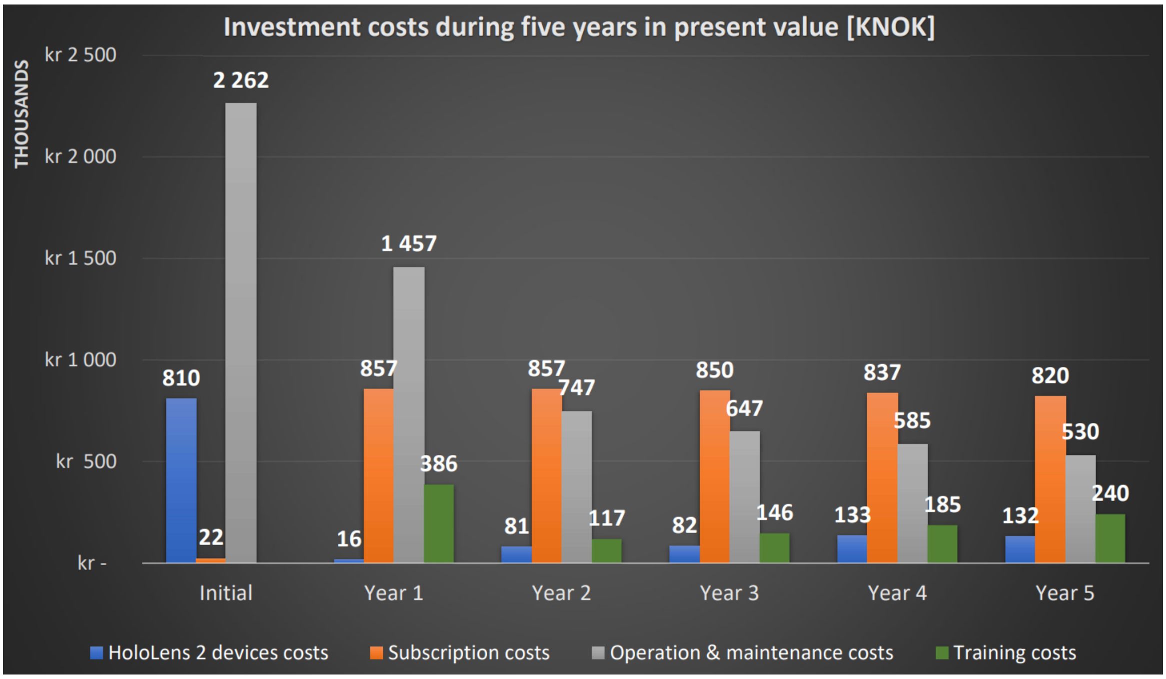

figure 7.8: Investment costs during five years in present value of KNOK [Appendix 9, p.8].

Figure 7.9 presents the total investment costs in present value over five years. The highest costs are incurred during the initial phase and in year 1, with the approximate cost double compared to years 2 to 5. For a more comprehensive understanding and detailed summary of the findings regarding the total investment costs over the five years, all the calculations are referred to Appendix 9, from pages 8 and 9.

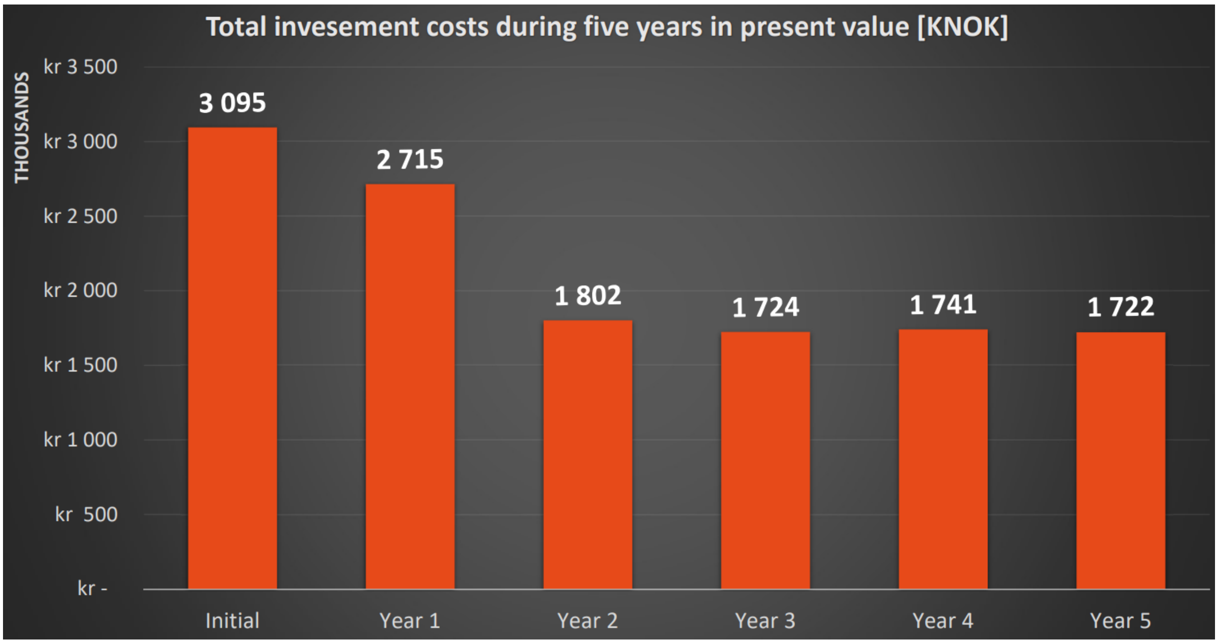

figure 7.9: Total investment costs during five years in present value of KNOK [Appendix 9, p.9].

Figure 7.10 displays the cumulative NPV over five years, considering the investment benefits and costs. The results reveal a payback period of approximately 15 months and a total NPV of 37 946 KNOK over five years. For a comprehensive breakdown and detailed analysis of the cumulative NPV, its referred to Appendix 9 on page 10, where the detailed results are presented.

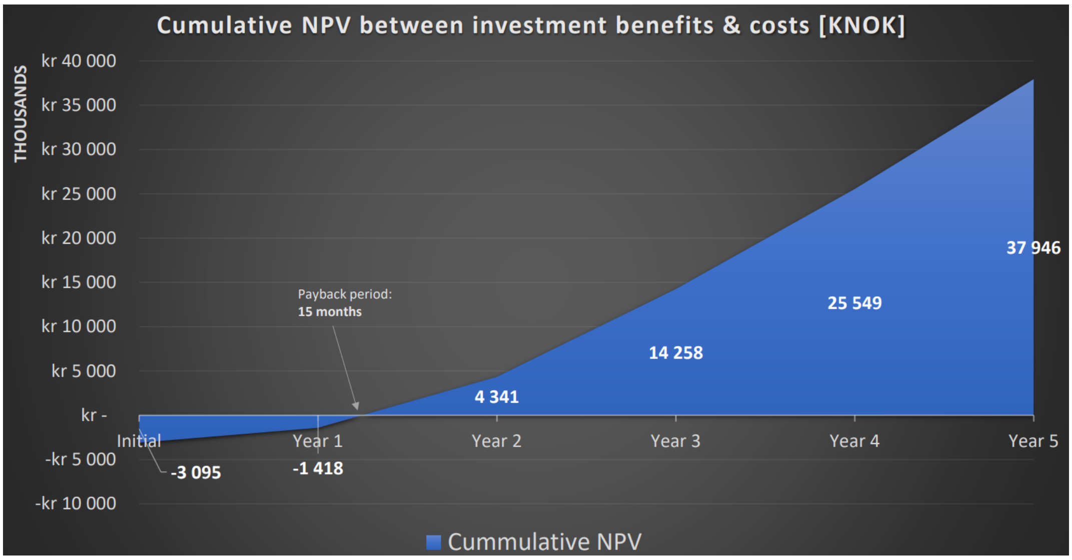

figure 7.10: Cumulative NPV between investment benefits & costs of KNOK [Appendix 9, p.10].

Figure 7.11 depicts the EBITDA comparison between traditional and reality training using MR. The results highlight that the EBITDA derived from reality training consistently increases, surpassing the results obtained from traditional training. This indicates that MR training consistently generates higher EBITDA each year than traditional training. For the full description of the results, refer to Appendix 9 on page 11.

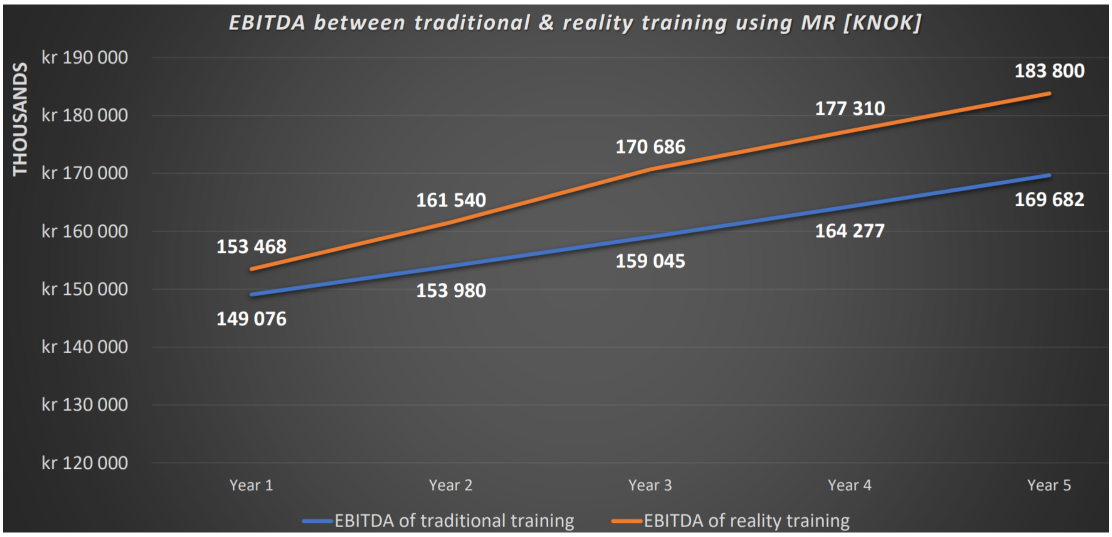

figure 7.11: EBITDA between traditional & reality training using MR of KNOK [Appendix 9, p.11].

Financial Statement analysis results

Figure 7.12 presents the EBITDA comparison between traditional and reality training using VR in the first year of a new factory and the subsequent five years of utilizing MR. Notably, the highest increase in EBITDA occurs between year one and year 2. This can be attributed to the additional costs incurred in training, which precedes revenue generation. The results demonstrate that the initial year is crucial for revenue generation in both training scenarios. However, VR training exhibits a higher increase in EBITDA during the first year, albeit with a lower increase in year 2. In contrast, the increase in EBITDA when using MR from year 2 to year 6 in an existing factory shows a diminishing upward trend. For a comprehensive description of the results, please refer to Appendix 9, in page 12, where a detailed analysis is provided.

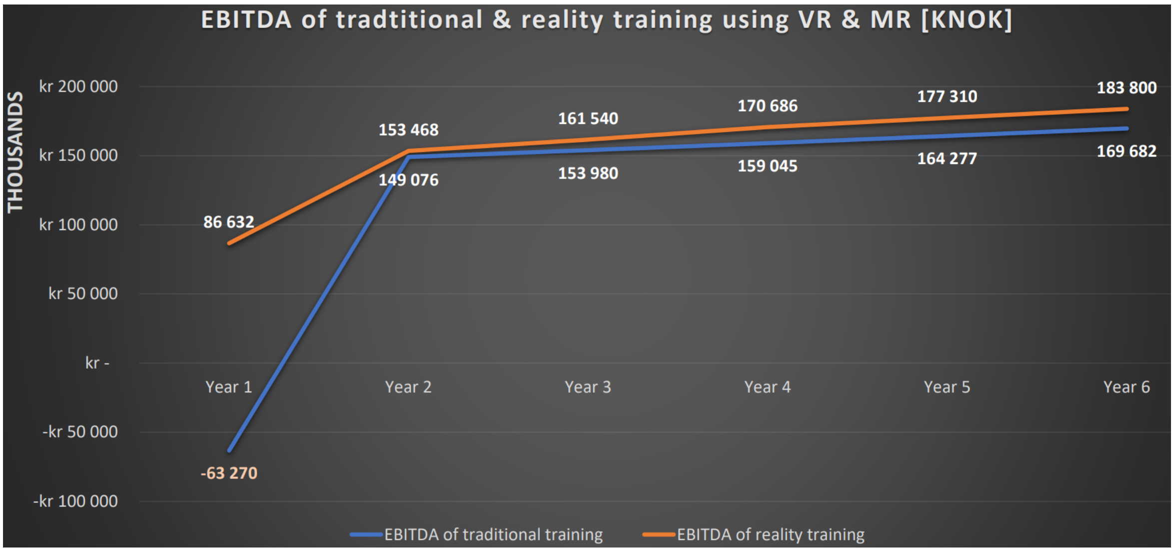

figure 7.12: EBITDA of traditional training & reality training using VR & MR of KNOK [Appendix 9, p.12].

8 Discussion

This chapter discusses the results of establishing reality training in manufacturing. The discussion is about the consequences that emerge regarding Technology & Investment analysis, risk analysis, and Financial Statement analysis. It will also shed light on potential weaknesses in the applied method.

8.1 Method criticism

In all data collection methods, it is essential to be critical. Critical choices of literature and interviewees are crucial for delivering a report with professional weight without becoming subjective. Collecting data from suppliers who try to convince the buyer/audience that their product is the best on the market may color/impact the data. This predetermined attitude to an issue can lead to subjectivity and hinder critical thinking, where hypotheses are essential with an objective approach. It cannot rule out that actions in the report are influenced by the opinions and attitudes of the various software- and references from companies. Therefore, it has tried to be objective in all phases of the report.

Supervisors and employees of Beyonder and Norske Skog Skogn have been used in the report to confirm that the adjustments to risk and accounts are satisfactory. Using them as controllers creates a more secure and satisfactory source in addition to the knowledge acquired from engineering education. There has been no interest in any of the solutions beyond the norm, potentially affecting objectivity and the critical thinking the project requires.

8.2 Technology & Investment analysis

The analysis conducted by Technology & Investment provided results to address each question from both technology and investment perspectives. However, it was observed that there needed to be more specificity in defining the technology questions. Technology encompasses many definitions, making it difficult to provide precise answers. Additionally, due to the novelty of reality training technology, gathering sufficient data and information has been challenging. Consequently, a broader definition was adopted based on the available information to compensate for this lack of data.

Implementation results

Based on the implementation results of the architecture structure, it is necessary to provide more specific specifications regarding the type of standard, organizational fit, and use barriers that should be considered for the reality training system in different practical scenarios within a specific company. The framework of the reality training system should offer concrete guidance on selecting the appropriate standards or views for projects like Beyonder or Norske Skog Skogn. While the research question aims to provide a general framework for manufacturing, it is essential to incorporate more detailed considerations during the system development for a specific company.

Assessment results

The claim that reality training reduces training time by 64.49% and error reduction by 81.82% compared to traditional training is a matter of debate. Due to the relatively new nature of the technology, finding additional research studies on this topic has been challenging. If the assessment results were based on multiple research articles rather than just one, it could have provided a more concrete and reliable outcome regarding the extent of time reduction and error reduction achieved through reality training.

Questionnaire survey results

The relevance of using a survey for reality training in the AEC industry can be debated, considering that the research question specifically pertained to manufacturing. However, it is worth noting that the construction industry shares similarities with manufacturing regarding reality training. The survey results demonstrated similar effects on other drivers and barriers compared to existing research. Therefore, despite the industry difference, the survey findings can still provide valuable insights for reality training in the AEC industry.

Companies results

KLM is a relevant case study for a thesis focused on manufacturing due to its expertise in reality training and its application in training individuals on how machines and vehicles operate. While the operations in a flight company may differ from manufacturing production, the procedure for using applications in reality training exhibits similarities. KLM's extensive experience and numerous references from previous projects make it an ideal choice for research. Notably, only a few companies with significant expertise in reality training, particularly in VR, have publicly made their references available. Therefore, it is justified to select KLM as a subject of investigation, given its substantial contributions to reality training.

Investment results

When examining the NPV between investment benefits and costs of using MR technology, it is essential to consider a range of studies rather than relying solely on one research source, such as Forrester Consulting from the previous investment results. Since MR is a relatively new technology that was initially adopted by Microsoft in 2019, it can be challenging to find comparable sources for comparison. However, it is still valuable to include multiple studies to obtain a comprehensive understanding of the investment landscape. In this case, due to the limited availability of sources on MR, the decision was made to utilize the research from Forrester Consulting as the primary source.

8.3 Risk analysis

The results of the risk analysis can be discussed in terms of whether researching the likelihood of errors in assembling machines in battery technology would have improved the outcome. It is essential to consider that error reduction primarily focuses on assembling parts and may not directly address specific issues in battery production, making it a potentially irrelevant factor. Additionally, considering Beyonder's current development phase, they require more experience in battery production to form a solid foundation for risk assessment. Although useful for their research purposes, the current calculation needs improvement before it can be applied to full-scale production and development. With 900 industrial workers, this risk analysis results could be more robust, as the scope of risk is much larger and necessitates further research.

A more precise answer regarding the QHSE levels and their different impacts would be beneficial to divide the risk matrix according to the quality, health, safety, and environmental probabilities. For instance, health and safety effects, such as skin corrosion from contact with electrolytes, may have a higher impact than environmental effects, which could be relatively lower. Unfortunately, due to the time constraints of the master's thesis, this specific division was not investigated. However, incorporating this approach likely resulted in a more precise evaluation of the QHSE-level impact.

8.4 Financial Statement analysis

The Financial Statement analysis explored the relevance of the results in current practices by integrating Case 1, which involves using VR, and Case 2, which consists in using MR. Introducing a switch between VR and MR in practice can complicate the training of each reality training system. Investigating more companies in each case would be more precise results. Furthermore, keeping the cases separate without integrating VR and MR is advisable, as this would allow for a clearer examination of each approach's effectiveness.

The discussion on the results of case 2 can address the satisfaction of investment benefits by considering all the factors contributing to increased productivity and efficiency. However, it is important to note that the findings are based on research conducted by Forrester Consulting, which may be biased toward Microsoft's goal of selling MR to customers. As a result, there is a possibility of an exaggerated increase in productivity being presented.

To account for this potential bias, it has adjusted the factors by decreasing them by half during the first year and gradually increasing them in the subsequent years. This adjustment is based on the understanding that productivity and efficiency are typically at their lower levels during the initial year of using MR technology. These assumptions have been made by estimating the factors, but it can discuss whether this is the right way to estimate them.

9 Conclusion

9.1 Part 1 – Sub-questions

What are the most critical drivers and barriers in the development of reality training?

In the development of reality training, technology serves as both the most potent driver and barrier, shown in figure 9.1. The adoption of new technology, such as a reality training system, necessitates a substantial amount of expertise and specific requirements to mitigate implementation challenges effectively. The utilization of reality training has demonstrated several significant drivers, including reduced training time, improved safety, and the ability to repeat training as needed to minimize errors. However, reality training being a new technology also entails certain barriers, such as a lack of expertise, challenges in data management, and high associated costs. These barriers need to be addressed to fully leverage the potential of reality training.

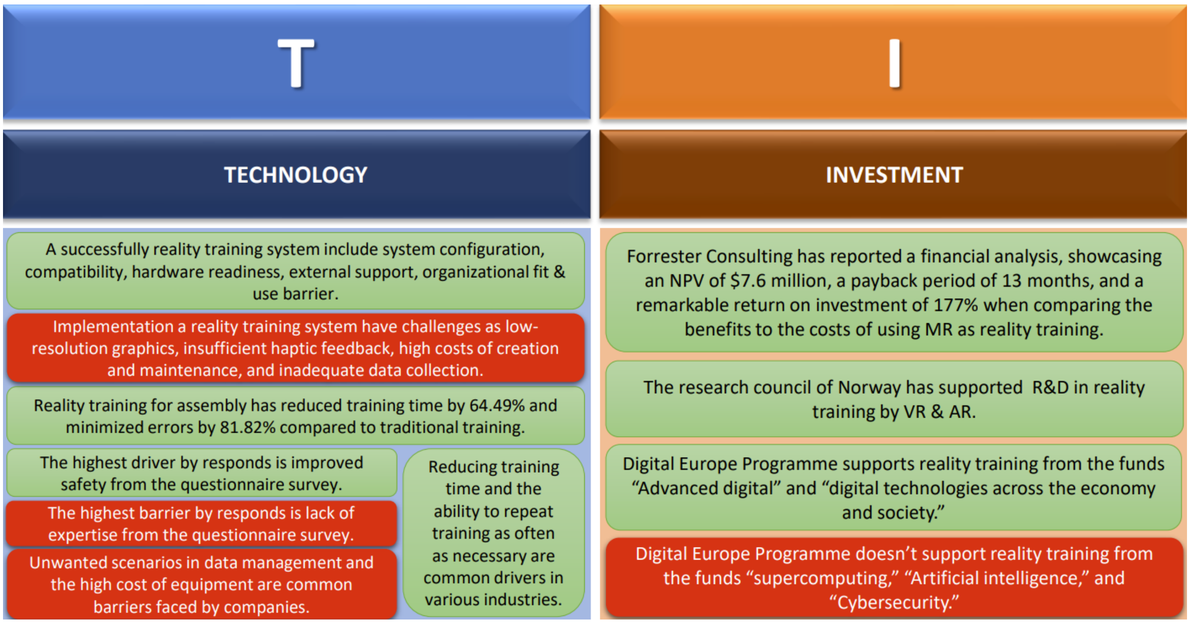

figure 9.1: Technology & Investment analysis conclusion [60].

Does reality training affect the risk impact level of the probability upon production from traditional training?

Figure 9.2 demonstrates that reality training affect the risk impact on the probability of production-related risks compared to traditional training. When considering a moderate impact level in a possible chance scenario, reality training reduces the probability by 49.1% compared to traditional training. Specifically, the probability decreases from 60% to 10.9% in this scenario. In the case of a moderate impact level in an unlikely chance scenario, reality training decreases the probability by 16%, with the probability shifting from 20% to 4%. Lastly, in the case of a minor impact level in a rare chance scenario, reality training reduces the probability by 4.1%, resulting in a decrease from 5% to 0.9%. These findings highlight the risk mitigation potential of reality training in reducing the likelihood in impacts with an average of 23,1 % of production-related incidents when compared to traditional training methods.

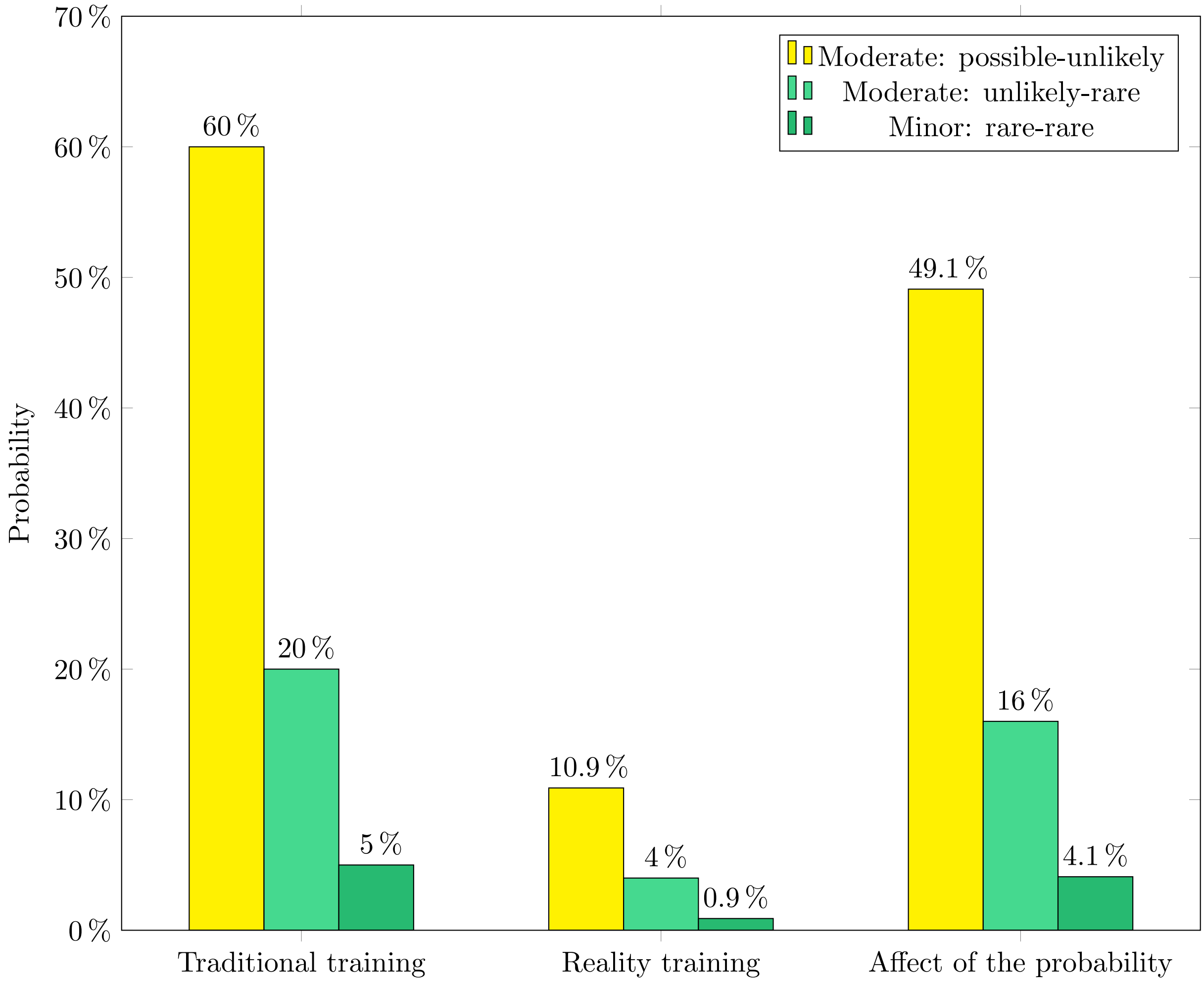

figure 9.2: Risk analysis conclusion [60].

How does reality training affect EBITDA during six years compared to traditional training?

As illustrated in figure 9.3, reality training has a noticeable effect on EBITDA over a six-year period compared to traditional training. The analysis concludes that reality training increase EBITDA by 200 646 KNOK, increasing it from 732 790 KNOK in traditional training to 933 436 KNOK in reality training. This indicates that the implementation of reality training has a tangible effect on the financial performance of the organization, resulting in a higher EBITDA compared to traditional training methods.

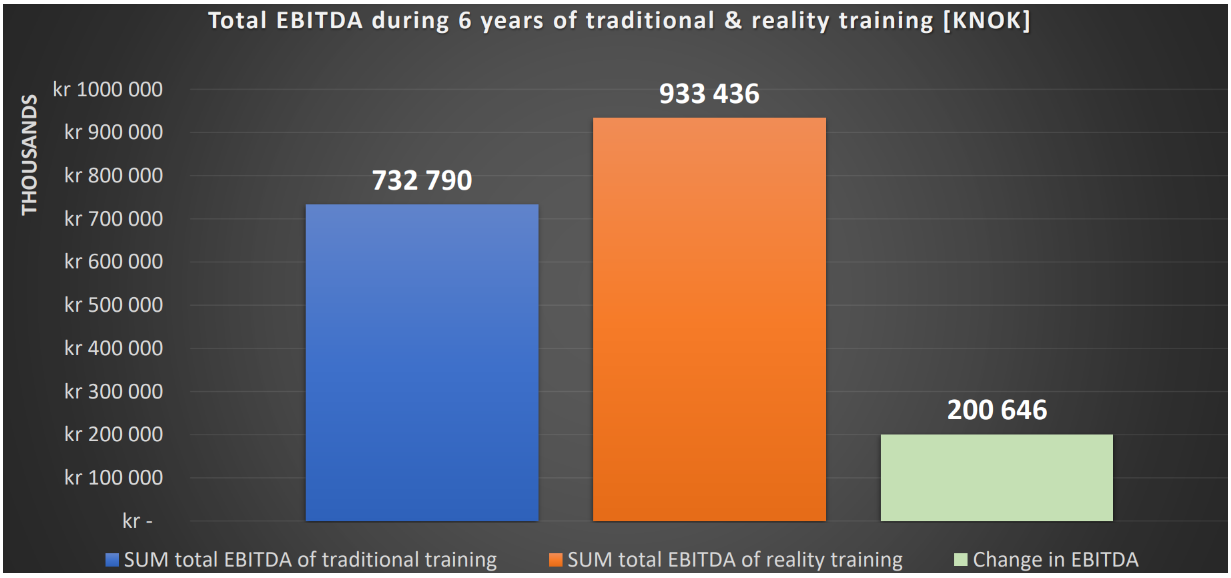

figure 9.3: Financial Statement analysis conclusion [Appendix 9, p.12].

9.2 Part 2 – Main question

What are the consequences using reality training in manufacturing?
The utilization of reality training in manufacturing entails both drivers and barriers in its implementation, leading to various consequences. One of the notable challenges is the high startup costs associated with implementing reality training in existing manufacturing processes. However, the benefits of adopting reality training in manufacturing operations includes reduced training time, improved safety measures, and the ability to repeat the training as necessary to minimize errors and costs.

Moreover, reality training demonstrates its risk mitigation potential by reducing the likelihood of production-related incidents by 23.1% across different impact levels. This provides a significant advantage for manufacturing companies like Beyonder compared to traditional training methods.

Furthermore, the implementation of reality training in manufacturing has a tangible impact on the organization's financial performance. For instance, Norske Skog Skogn experienced a higher EBITDA over six years in reality training, with a increase of 200 646 KNOK when compared to traditional training methods. These findings highlight the comprehensive effects of reality training on various aspects of manufacturing operations, including risk reduction, operational efficiency, and financial outcomes.

10 Recommendations

This master's thesis aims to explore the concept of reality training in the context of manufacturing by utilizing existing literature and the expertise gained through the education. The acquired knowledge serves as a foundation for providing recommendations for further work that can address various aspects of reality training and may be of interest to the client.

Based on the study's experience, limited research is available on the specific research question related to reality training. Therefore, I recommend that the client conducts further investigation into the consequences of reality training. This can provide valuable insights and potentially create a competitive advantage for the client, both financially and in terms of running a more environmentally conscious business.

Considering the constraints of the task time frame, the report's content has been restricted. As a result, it is advisable to closely examine the limitations and assumptions presented in the report for further work. To guide this examination, the following issues are considered interesting for further exploration::

- Environmental Impact: Investigate the environmental benefits and impact of reality training
- User Experience and Acceptance: Explore the user experience of reality training and assess user acceptance.
- Organizational Readiness: Evaluate the readiness of the organization to adopt reality training.
- Industry-specific Applications: Investigate industry-specific applications of reality training beyond the manufacturing sector.

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Appendix

Appendix 1: ENOVA application from Beyonder

Appendix 2: Informal interviews Beyonder

Appendix 3: Beyonder training operating procedure

Appendix 4 - Risk assessment Beyonder

Appendix 5 - Annual report Norske Skog Skogn 2017 - 2021

Appendix 6 - Informal interviews Norske Skog Skogn

Appendix 7 - The Total Economic Impact Of Mixed Reality

Appendix 8 - Case 1

Appendix 9 - Case 2