

**Defining Factory Layout Design Processes in Virtual Reality**  
**Modeling Environment**

Neles Finland Oy



Bachelor's thesis

Degree Programme in ICT, Bio and Circular Economy, Engineering, Forssa

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## TIIVISTELMÄ

Opinnäytetyön aiheena oli määrittää prosessit sekä ohjeistukset tehdasympäristössä tapahtuvan tehdassuunnittelun virtuaaliympäristön käyttöön hyödyntämällä virtuaalitodellisuutta. Opinnäytetyön toimeksiantajana toimi Neles Finland Oy, jolle opinnäytetyöhön liittyvät prosessit määriteltiin ja ohjeistukset toteutettiin. Virtuaalisen tehdasympäristön pohjana toimii Neleksen tuotantolaitos Hakkilassa Vantaalla.

Opinnäytetyö toteutettiin osallistumalla virtuaalitodellisuuden projektiin, missä luotiin digitaalinen tehdaskaksonen virtuaaliympäristöön yhdessä Geo Exact Oy:n sekä 3D Talo Finland Oy:n kanssa. Projektin aikana käsiteltiin virtuaaliympäristön toiminnallisuuksia, tehtiin parannuksia, korjauksia ja muokausehdotuksia. Opinnäytetyötä täydennettiin tutkimalla ja perehtymällä virtuaalitodellisuuden ja layout-suunnittelun teoriaan, määriteltiin systemaattinen projektitapaamisten kulkukaavio, käsiteltiin ympäristöjen eroja ja ongelmia, huomioitiin kestävän kehityksen näkökulmaa liittyen kokonaisprosessiin, sekä toteutettiin yrityksen sisäinen kysely aiheeseen liittyen.

Opinnäytetyön tuloksena saavutettiin varmuus hyödyntää virtuaalitodellisuutta tehdassuunnittelun operatiivisessa toiminnassa lähitulevaisuudessa. Neleksellä on tulossa useita tehdassuunnittelua vaativia muutoksia, joissa on tarkoitus hyödyntää opinnäytetyössä tuotettua materiaalia uutena tehdassuunnittelun metodina.

Avainsanat Virtuaalitodellisuus, tehdassuunnittelu, prosessi, käyttöohje

Sivut 49 sivua ja liitteitä 8 sivua

Degree Programme in ICT, Bio and Circular Economy, Engineering **Abstract**

Forssa

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Subject	Defining Factory Layout Design Processes in Virtual Reality Modeling Environment	
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#### ABSTRACT

The aim of the bachelor thesis was to describe processes and define instructions in factory operations for a layout design with the support of virtual reality. Neles Finland Oy was the commissioner of the thesis, for whom the processes were defined and instructions created. Neles factory in Hakkila Vantaa was used as a basis for the virtual factory environment.

The thesis was executed by participating in the virtual reality project, where a digital twin of the factory was implemented into the virtual reality environment. Neles partnered with Geo Exact Oy and 3D Talo Finland Oy to complete this project. The functionalities of the virtual environment were addressed throughout the project. Recommendations for updates, improvements, and modifications were addressed and adapted. The thesis was supplemented by studying the theory of virtual reality and layout planning. Furthermore, a systematic flow for project meetings was established, environment differences and problematic issues were addressed, sustainable development perspectives were presented, and an internal survey was conducted.

As a result of the thesis, certainty was achieved to utilize virtual reality for factory layout planning in operational functions in the near future. Neles is coming up with several changes that require factory layout planning, in which the material produced in the thesis will be utilized as the new factory planning method.

Keywords Virtual reality, factory layout planning, process, instructions

Pages 49 pages and appendices 8 pages

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## **APPENDICES**

Appendix 1: Questionnaire questions and results in Finnish

Appendix 2: Feedback on the thesis by Neles in Finnish

## **LIST OF ABBREVIATIONS**

.ifc – A file format used by Building Information Modeling programs

2D – Two-dimensional

3D – Three-dimensional

AR – Augmented reality

AutoCAD – Computer-aided design software application

CAD – Computer-aided design

CPU – Central processing unit

FLP – Factory layout planning

FOV – Field of view

FPS – Frames per second

GPU – Graphics processing unit

HMD – Head-mounted display

IoT – Internet of Things

MR – Mixed reality

PwC - PricewaterhouseCoopers

RAM – Random access memory

RFID – Radio-frequency identification

VAT – Value added tax

VLP – Virtual (reality) layout planning

VR – Virtual reality

XR – Extended reality

# 1 INTRODUCTION

## 1.1 Background

Manufacturing companies use layout planning when in need of design improvements or adjustments. Factory layout planning (FLP) is necessary to ensure an effective manufacturing cycle. With a well-thought pre-planned factory layout design, manufacturers are able to improve productivity and reduce the costs of operations remarkably. (Gong, 2018, p. 1) Within a virtual reality (VR) environment, a visual depth perspective and immersion can be achieved, which is not possible in a two-dimensional (2D) layout (Iqbal & Mohammed Saleem J, 2001, p. 403).

The commissioner of this thesis is Neles Finland Oy. Neles is looking to implement virtual reality into Vantaa, Finland factory layout planning entirely during the spring of 2021. This thesis is expected to be completed by the end of March 2021. Approximately one-fourth of the Vantaa factory was modeled into Design Space software by the end of April 2020. The Design Space software is developed by 3D Talo Finland Oy. A new project was initiated in early October of 2020 to model the rest of the factory. Neles partners with 3D Talo Finland Oy and Geo Exact Oy to complete this VR project. In the project, Geo Exact is responsible for laser scanning the on-site facilities as well as optimizing the point cloud and modeling data, whereas 3D Talo is responsible for implementing and adjusting the received data into Design Space.

Searching for and acquiring new technologies is necessary at present. Virtual reality layout planning (VLP) can help users envision the environment before making any adjustments physically in the real environment. From an economic sustainable development perspective, Neles is capable of reducing the risk for money or time wasted during a layout planning process with virtual reality layout planning. As a technology, virtual reality is also proven to give a productivity boost of 25% by surveyed companies (Vigliarolo, 2020). With VLP, Neles can observe any recycling-related issues before conducting adjustments to the real physical environment.



## **1.2 Aims and the objectives**

Guidance will be required for the users operating with FLP in the VR environment. Thus, this thesis aims to define systematic instructions for virtual layout planning (VLP). The instructions are designed to assist users during specific decision-making processes related to upcoming layout planning projects or adjustments in the layout design of the factory.

The main objective of this thesis is to provide consistency and clarity during virtual reality layout designing processes. The main objective includes activities such as verifying the space needed for machines during change, ensuring a safe environment, being able to visualize the space required for machine operators, and enhancing the possibility for maintenance operations. The secondary objective is to reduce the disagreements of stakeholders during any layout adjustments. Stakeholders, such as machine operators, designers, project leaders, supervisors, and similar personnel, can properly visualize the pre-planned virtual environment together instead of only discussing the considered layout adjustments based on a two-dimensional (2D) blueprint. (Gong, 2018, p. 2) With VLP, Neles is going to be able to improve the communication coordination and co-operation between stakeholders.

## **1.3 Introduction of Neles Finland Oy**

Neles Finland Oy is a manufacturer of flow control solutions and services such as control-, on-off-, emergency shutdown-, butterfly-, segment-, ball-, and numerous other kinds of valves. Neles also produces other valve-related products like actuators, limit switches and valve controllers. The customers of Neles operate in oil and gas refining, pulp, paper and bioproducts, chemicals and other similar process industries.

Neles Finland Oy was founded in 1956 by Antti Nelimarkka and Eino Santasalo. In 2021, Neles has approximately 2900 employees in 40 different locations, of which around 800 is located at the headquarters in Vantaa, Finland. Neles was earlier known as Metso Flow Control, but Neles demerged from Metso Oyj on July 1, 2020. Neles factory was relocated to Vantaa, Hakkila, in 2011. The size of the Vantaa factory layout is approximately 25000 m<sup>2</sup>. The free available height inside the open-area of the factory is eight meters at its lowest and 12 meters at its highest.

## 2 THEORY OF FACTORY LAYOUT PLANNING

This chapter addresses the fundamentals of the factory layout planning (FLP) and describes the present and previous FLP procedures of Neles.

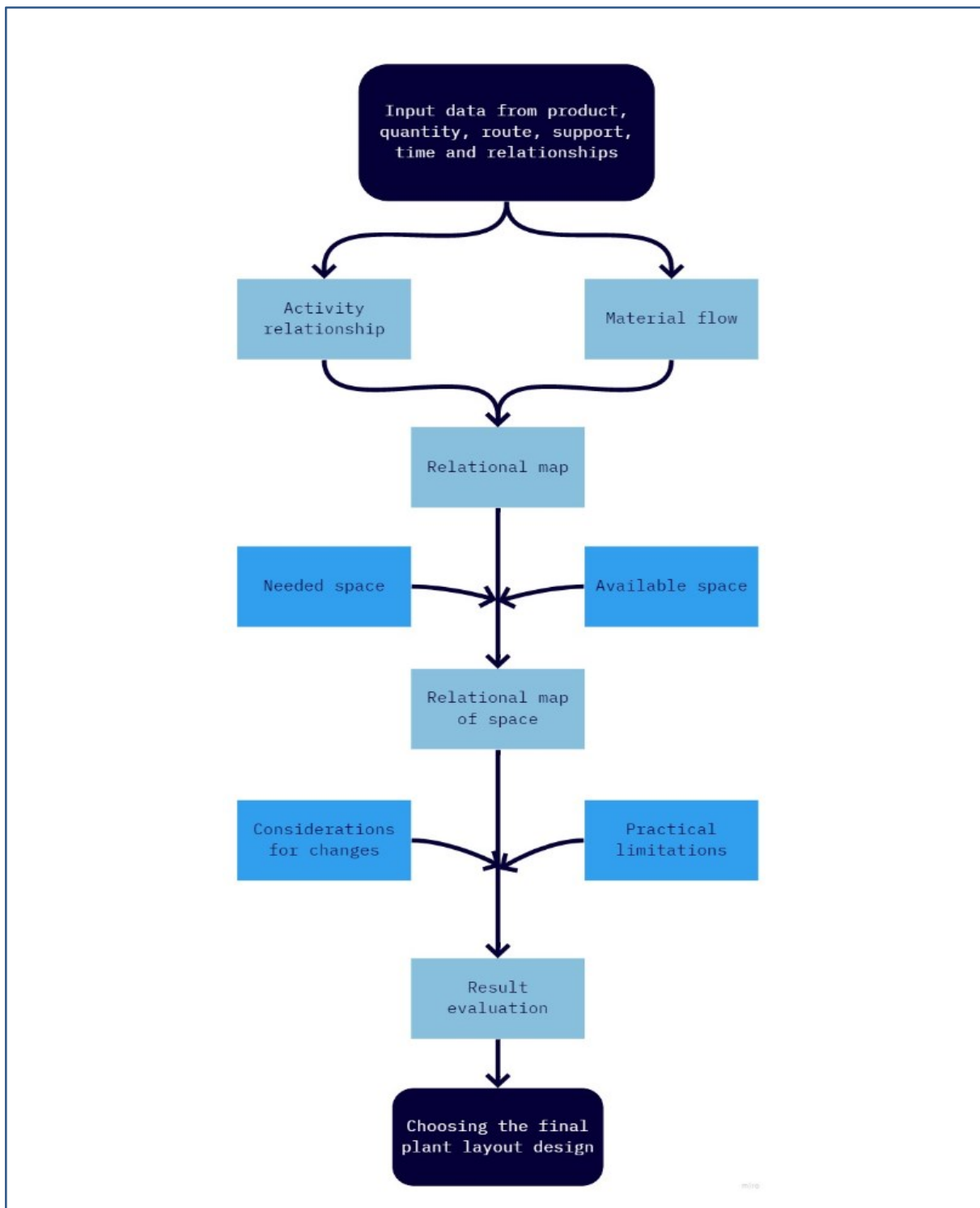
### 2.1 Factory layout planning

The productivity of a manufacturer depends on several things, including factory layout planning. The two considerable groups in factory layout planning can be determined as design and optimizations. Optimizations rely on mathematical calculations and formulas to provide an optimal resource flow between the departments in factory premises. (Nåfors, 2019, p. 11) In contrast, the design is based more on previous experience (Nåfors, 2019, p. 11) as well as production quality and control (Naqvi et al., 2016, p. 3).

FLP allows manufacturers to evaluate the most optimal physical configuration of resource-flows within a facility. Layouts determine specific locations such as physical positions of departments, machines, offices, and workgroups. Layouts are often initially planned for the most optimal way when building or relocating to a factory facility. However, a re-design of the layout is presumably inevitable as the companies grow and changes occur in production volumes, processes, products, and as technologies develop further. (Abraham & Sasikumar, 2013, p. 656) Manufacturers in factory environments can ensure an essential and effective manufacturing cycle by properly performing factory layout planning. With a pre-planned factory layout, manufacturing companies can improve productivity and reduce the costs of operations. (Gong, 2018, p. 1)

Multiple methods can be used to design the layout of the factory. Virtual reality layout planning (VLP) and systematic layout planning (SLP) are both FLP modeling approaches and methods particularly (Naqvi et al., 2016, p. 3). The SLP approach demonstrates the process design of the factory from input data and other practices to determine its configuration. SLP is believed to enhance the production flow inside the factory and to gain additional usable floor space. (Wiyaratn & Watanapa, 2010, p. 1382) The SLP framework conducted by (Wiyaratn & Watanapa, 2010, p. 1383) is visualized in a flow-chart in Figure 1.

Figure 1. Systematic layout planning framework visualization in a flow-chart

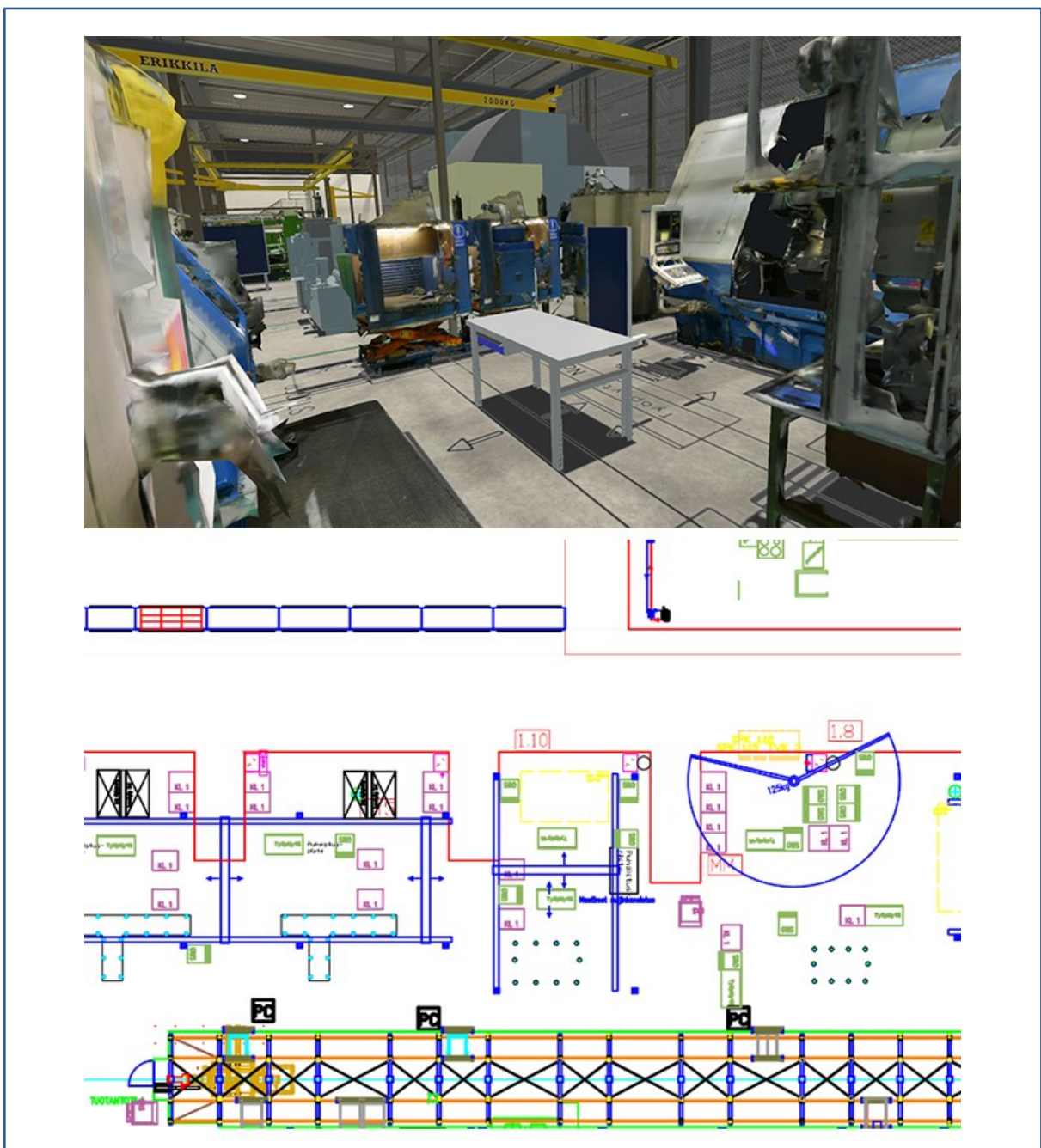


SLP is a well-known method and tool for delivering functional guidance and a practice-oriented systematic procedure. However, SLP is commonly regarded as a relatively slow and time-consuming practice, despite the fact that SLP is recognized as one of the primary methods for conducting FLP (Naqvi et al., 2016, p. 13). Virtual reality layout planning is discussed in Chapter 4 below.

## 2.2 2D and 3D layout planning

3D layout planning, such as virtual layout planning (VLP), makes a considerable difference in layout planning compared to 2D layout planning. 2D layout planning is problematic when attempting to observe the environment in a horizontal manner, such as the location of any piping or rails in the ceiling. In 3D layout planning, the designers can observe the distances and positionings horizontally and get a better view of depth aspects. The differences between a 2D AutoCAD layout and a 3D virtual environment layout can be seen in Figure 2.

Figure 2. 3D virtual environment layout and a traditional AutoCAD 2D layout



### 2.3 Current layout planning procedures

Neles relocated to the Vantaa factory during 2010-2011. To date, the relocating and move-in of the factory to Vantaa has been the most noticeable layout procedure. The entire layout of the factory manufacturing process-flow was designed in 2D in AutoCAD software developed by Autodesk. Back in 2010, no program other than AutoCAD was used for layout planning. Within AutoCAD, users can design a layer and a grouping framework in 2D and 3D. One layer could be set for pipes within a building, as another layer could be set for building foundations. The layers can be displayed on the software simultaneously or separately. The software is primarily designed and used by designers and drafters. (Study, 2019)

The layout planning flow at Neles starts primarily with the initiative reasoning and the need for change or improvement. Since the reallocation of the factory in 2011, only slight layout changes have been made, such as moving individual machines or re-planning individual work-cell environments. Piping and monitoring have to be done for power, water, electricals, and pressure-air. The scheduling of the layout projects is critical. Therefore, planning a timeframe for a project should be done as early in the process as possible. Neles is partnering with subcontractors on the actual physical moving of machines and machine peripherals.

Once the reason for the wanted layout changes is known, the intended configuration of the changes, such as the expected position of the machine, the area of the machine, the space available for machine operators, the location of the peripherals, and many more, were drawn into AutoCAD. However, the Vantaa factory AutoCAD 2D layout file is currently outdated and therefore not used. Previously individual designers were responsible for the layout of individual departments. Additionally, Neles had a main-user responsible for retaining the layout file. Due to personnel leaving the layout responsibility roles, the 2D AutoCAD layout file became outdated. The 2D layout in AutoCAD should be revised and retained until modern innovations are adequate and trustworthy enough for a complete replacement.

Involving machine operators and other employees working in the areas where layout adjustments are planned is essential since the designers may not be able to consider every aspect of the environment. More feedback and additional non-thought-out ideas emerge when designing and planning with employees working in the fields of planned layout

adjustments. One of the previous practices of how planning was carried out with machine operators was by printing the main factory floor layout onto paper and the machine layout onto a separate paper. The printed documents were placed on the work-unit desks of the employees and the machine layout papers were requested to be placed on top of the main factory floor layout paper. The paper-on-paper approach brought forth new design suggestions and therefore the designers were able to alter the initially planned layout.

### 3 THEORY OF VIRTUAL REALITY

Virtual reality is a programmed three-dimensional (3D) artificial environment that simulates a real or an imaginary world. Users can experience virtual environments with virtual reality equipment, such as VR glasses and a computer. (Rouse, 2015) Virtual reality makes users experience immersion, the feeling of being a part of the surrounding virtual environment (Strickland, 2007).

Multiple manufacturers efforts to get high-quality consumer-level virtual reality products into the market during the previous decades without significant success until the 2010s. (Linowes, 2015, p. 3) Most virtual reality configurations are positioned into three different categories, as seen in Table 1. These categories are ranked by the immersiveness of the virtual reality that is experienced by the used devices. (Mujber, Szecsi, & Hashmi, 2004, p. 1835)

Table 1. Categorization of virtual reality configurations

<b>VR configurations</b>	<b>Non-immersive</b>	<b>Semi-immersive</b>	<b>Fully-immersive</b>
<b>Devices (e.g.)</b>	Mouse, keyboard, monitor	Driving wheel and joystick, large projector screen	VR headset/HMD set-up, CAVE system
<b>Degree of immersion</b>	Non to low	Medium to high	High to very immersive
<b>Interaction</b>	Low	Medium	High
<b>Price</b>	Low to medium	Medium to high	High to very high

### 3.1 History and the direction of virtual reality

During the previous years, technologies have been developing at an unforeseen pace on a massive scale. Kurzweil stated in his article *The Law of Accelerating Returns*, “We won’t experience 100 years of progress in the 21<sup>st</sup> century – it will be more like 20,000 years of progress (at today’s rate)” (Kurzweil, 2001). The most significant driving factor in the VR consumer market is pricing. The modern-day prices are still too high for virtual reality devices to be used in every household. (Poetker, 2019) Many companies in sectors such as training, education, healthcare, manufacturing, videogames and marketing use virtual reality to their advantage (Mitchell, 2020). Accessing websites through a virtual reality headset is likely to be as frequent as visiting websites on a computer in the future. (Linowes, 2015, p. 4)

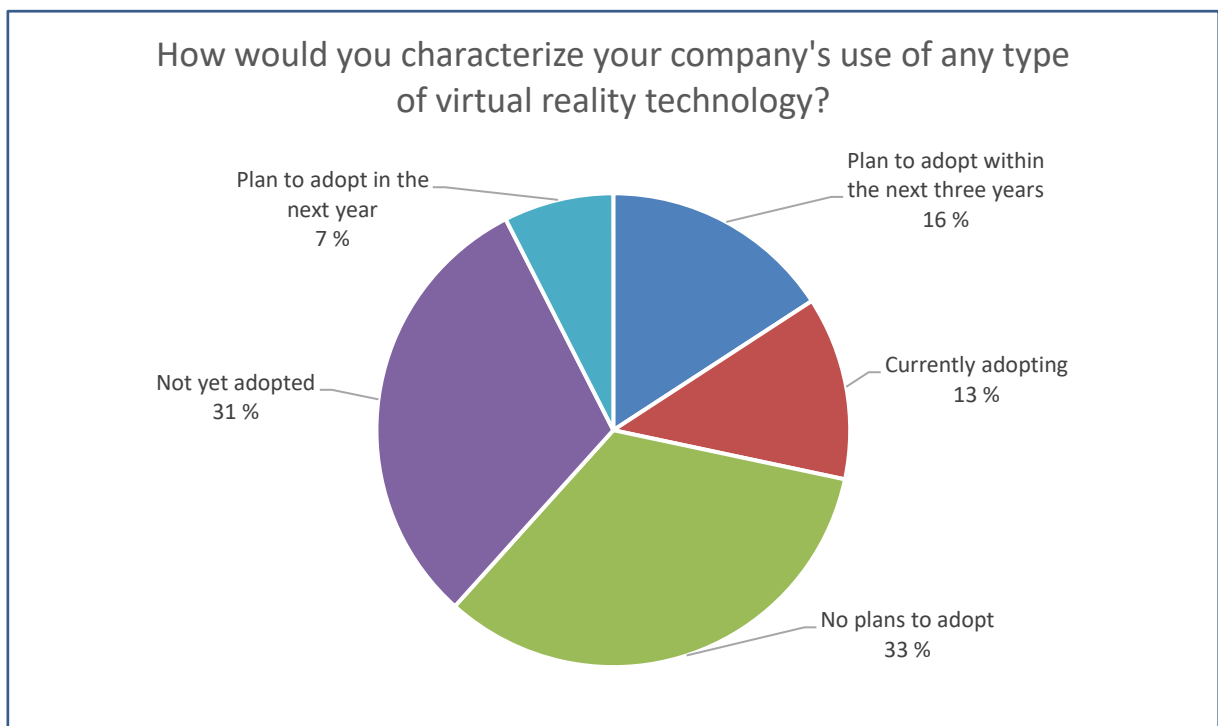
Virtual reality was heard as a term for the first time in 1938. French theater director named Antonin Artaud referred in his book “*The Theatre and its Double*” to fictitious theater as “*la réalité virtuelle*”. The phrase translates to virtual reality in English. (Ganesh, 2019) In 1962, Morton Heilig built the first actual concept of a VR device called Sensorama. Sensorama presented brief 3D-based television shows with speakers mimicking sound, fans replicating the wind and an odor emitter simulating the smell of the environment shown on the screen. Sensorama never turned out to be a global success. The public did not realize the actual commercial use of virtual reality until the 1990s. (Arvanaghi & Skytt, 2016) In 1991, Sega had its first attempt in virtual reality. However, the product was never released. Developers were worried that consumers using the VR headset might accidentally injure themselves due to the degree of realism. In 1995, Nintendo launched the first portable console that could display 3D graphics. The portable console named Virtual Boy never turned out into a success story. The Virtual Boy sold for \$180 at launch, but the price plummeted to less than \$100 in a year. The lifespan of the console was no more than slightly over a year. Software support was terrible, and there were only 22 playable games at the time of discontinuation. (Poetker, 2019)

After the 1990s, there were no exceptional innovations in the industry of virtual reality until Palmer Luckey developed the first prototype (PR1) of the Oculus Rift headset in 2010. The first prototype displayed an image onto the screen in 2D, but because of the massive scale, the headset was able to fit in a 6-inch display with a 90° field-of-view (FOV). In 2012, Palmer Luckey built a sixth version of the prototype, which was named the Rift. The Rift recognized

movement with a motion sensor, pre-render presented 3D images, and predicted movement with advanced algorithms. Palmer Luckey and the rest of the Oculus team launched a campaign on Kickstarter with a target of raising \$250,000, which exceeded in 24 hours. The Kickstarter campaign resulted in raising over \$2.4 million during the whole period. (Rubin, 2014) Facebook signed a deal in 2014 to purchase Oculus Vr, Inc. for a value of approximately \$2 billion (Kovach, 2014).

In 2015, PwC US surveyed 121 manufacturing businesses inside the United States about the possible adaptation of virtual reality into manufacturing companies. One of the survey questions seen in Chart 1, “How would you characterize your company’s use of any type of virtual reality technology?” had five answer options for the surveyed businesses.

Chart 1. Survey question for manufacturing companies about a virtual reality utilization possibility in their own companies (PwC US, n.d.)

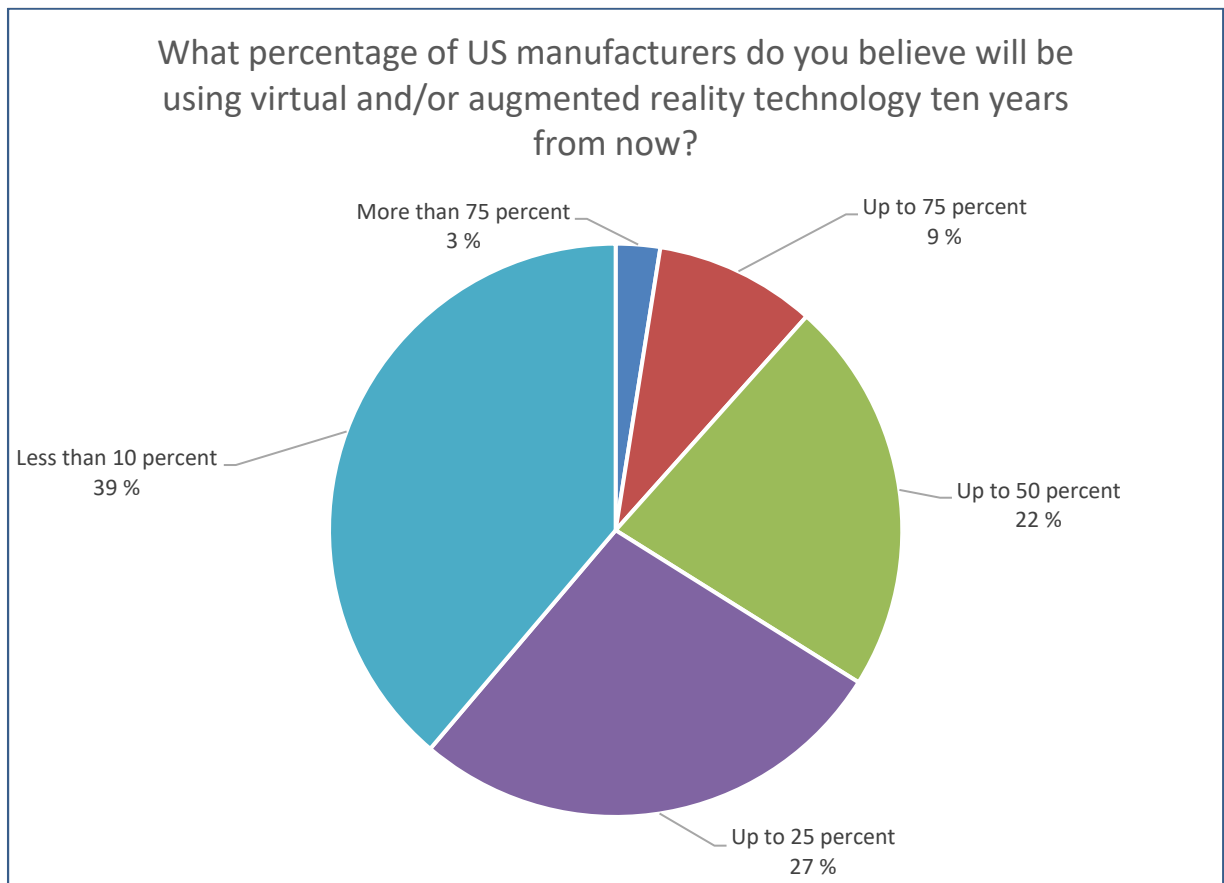


According to the survey responses, the received results were as follows: no plans to adopt by 33% of the received survey answers, not yet adopted by 31%, planning to adopt within the next three years by 16%, currently adopting by 13% and planning to adopt in the next year by 7%. The survey results implicate that more than one in three manufacturers are planning to adopt VR and AR technologies from 2015 to 2018.



The second survey question, “What percentage of US manufacturers do you believe will be using virtual and/or augmented reality technology ten years from now?” as seen in Chart 2, also had five answer options for the surveyed businesses.

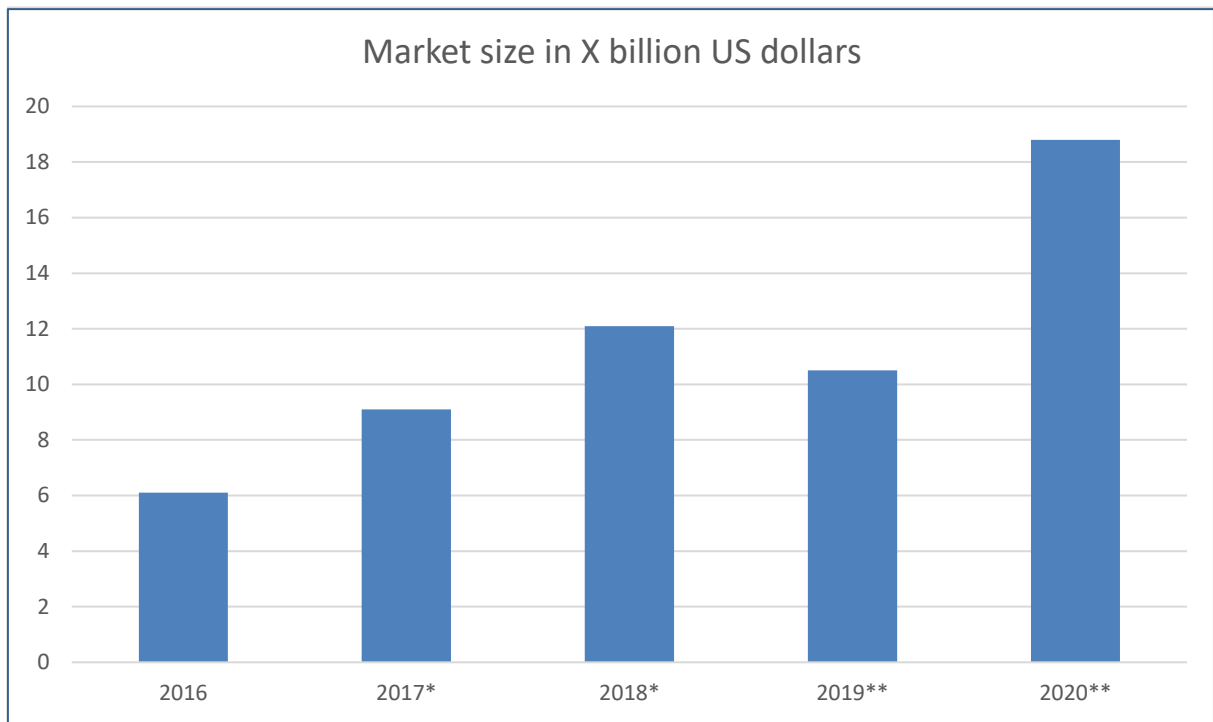
Chart 2. Survey question for manufacturing companies about virtual reality and augmented reality utilization possibilities in the entire US (PwC US, n.d.)



The outcomes of the results as seen in Chart 2 were as follows: 39% of the surveyed businesses answered less than 10 percent, 27% answered up to 25 percent, 22% answered up to 50 percent, 9% answered up to 75 percent whereas the rest 3% answered more than 75 percent.

Virtual reality and augmented reality (AR) have had a massive industry growth in the previous five years. Thus, the surveyed statistics in 2015 differ from the actual statistics in 2020. In contrast, the forecast for the market size worldwide from 2016 to 2020 in VR and AR can be identified in Chart 3. The market size has more than doubled from 2016 to 2020.

Chart 3. Forecasted virtual reality and augmented reality market size worldwide from 2016 to 2020 in X billion US dollars (Tankovska, 2020)



In addition, the market size and value of the virtual reality industry are expected to escalate at a compound annual growth rate (CAGR) of 21.6%, ranging from 2020 to 2027. The revenue forecast for 2027 is expected to be \$62.1 billion. Virtual reality has found its many application use cases during the previous years and will be used increasingly in the future as well. (Grand View Research, 2020)

The present pandemic situation could accelerate the implementation of VR and AR applications into business use since businesses are currently looking into finding ways to minimize human interactions. (Vigliarolo, 2020) Foreseeing the upcoming is challenging, but virtual reality developing rapidly in the future should be expected. Virtual reality is going to allow the possibility to solve unique challenges and present innovative opportunities that would not be possible in real life. (Lindner, 2020, p. 1)

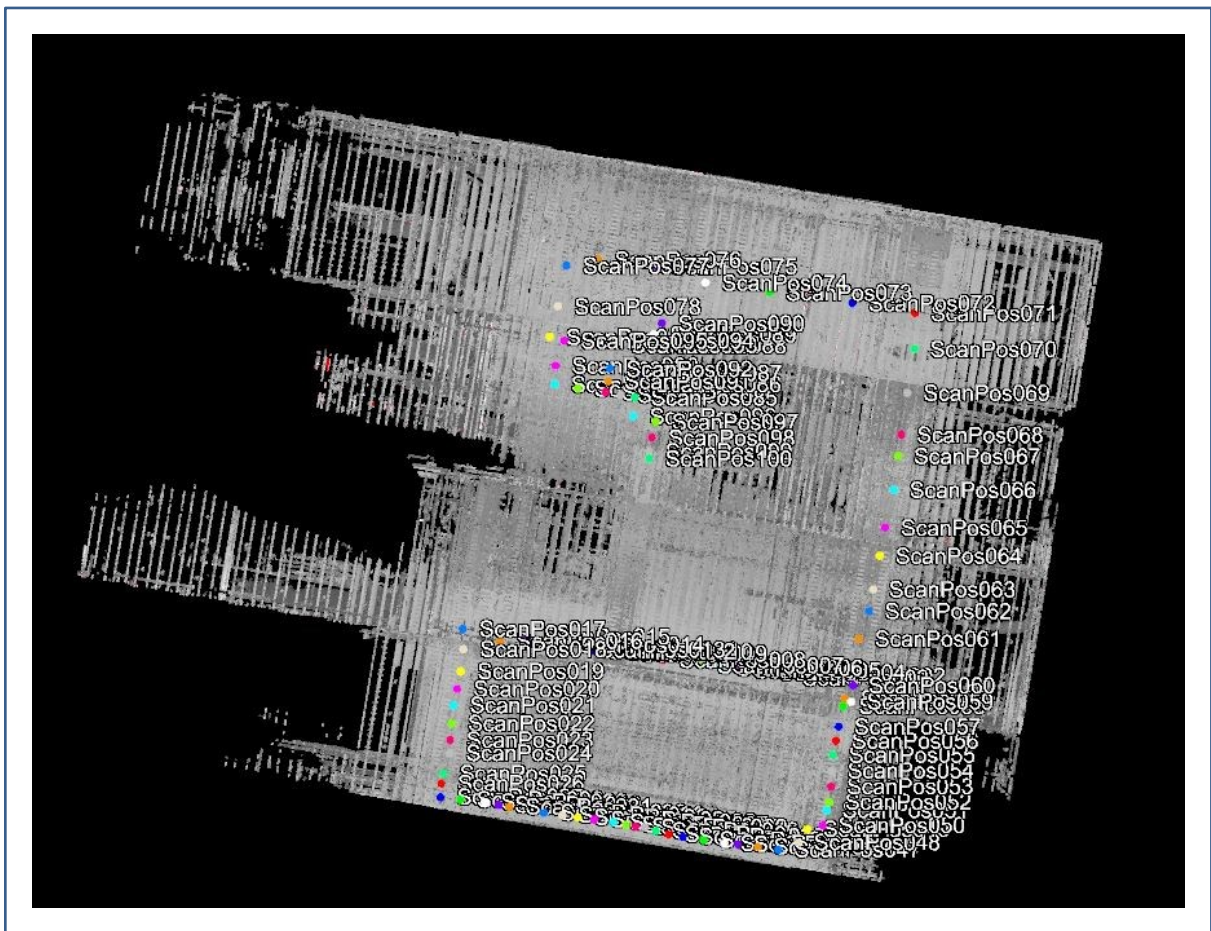
A Finnish company called Varjo is one of the best virtual reality and mixed reality system manufacturers. Varjo is currently providing the most competitive and high-end devices in the consumer markets. As the quality goes up, so does the price. Varjo is currently selling a VR-3 headset with a total price-tag of 3990 €. (Varjo Technologies, n.d.)

### 3.2 Modeling technology

Neles cooperates with Geo Exact Oy and 3D Talo Finland Oy to build the virtual environment. The involvements of both companies in the project are explained in this chapter.

The laser scanner of Geo Exact Oy produces a digital point cloud data block of the real environment. When scanning the factory, close to 800 scanning positions were used, reaching a total of over nine billion points. A portion of the scanning positions is shown in Figure 3. The area scanned was approximately 19000 m<sup>2</sup>. Geo Exact processes, cleans, filters, cuts excess or non-visible points, exports, and performs several more adjustments to the point cloud data before the data can be sent to 3D Talo. Pipes, floors, walls, supporting beams, and many similar objects are separately 3D-modeled. The data sent to 3D Talo is in the form of .ifc and point cloud for precise object separations.

Figure 3. The first 100 scanning positions visualized as a point cloud data

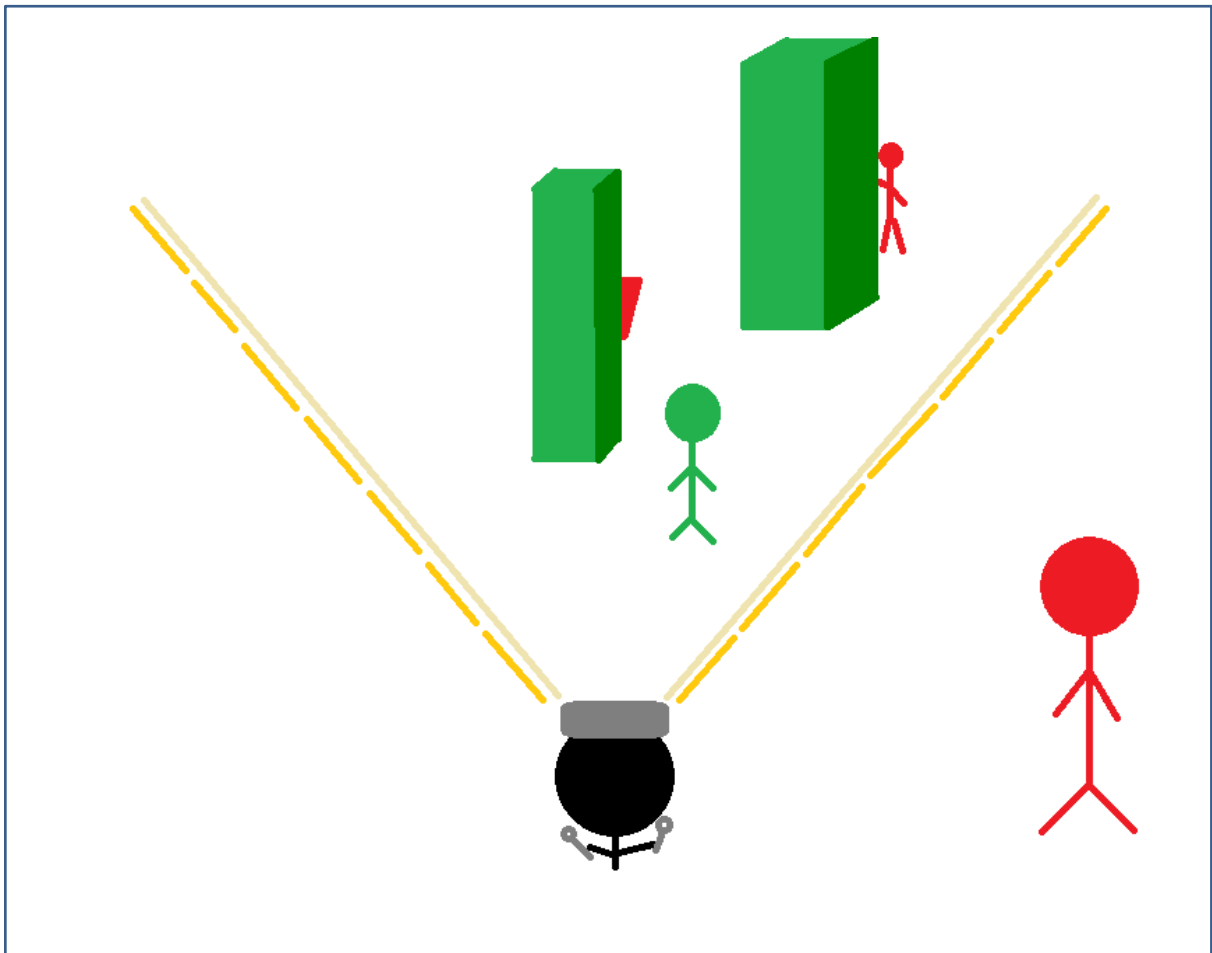


Geo Exact asserted the value of using proper and professional equipment in the interview. Suppose the initial details and accuracy of the laser scanner are not reasonably reliable. In that case, the whole process will most likely suffer as all the post-processed quality depends on the laser-scanned data in each step of the process.

3D Talo Finland Oy processes the received data and integrates the 3D-data into Design Space, whether the data is a point cloud, a CAD model, .ifc, or similar. 3D Talo combines these 3D data components to Design Space to create a virtual environment layout for the factory. 3D Talo cuts objects out of the point cloud to create separate movable objects. As the rest of the factory is modeled into Design Space, the virtual environment is also getting larger by size. The handling of the layout model is more complicated when the virtual environment expands. Technically, using a virtual reality headset is not comfortable if the frames per second (FPS) decrease significantly since low FPS could cause nausea. Thus, it is necessary to utilize certain game engine features such as level of detail (LOD) and occlusion culling.

LOD is a feature where the geometry of an object changes depending on the distance from the point of view. The further the distance, the less detail is shown and vice versa. (Seo, Kim, & Kang, 1999, p. 104) The occlusion culling feature disables the rendering of non-displaying objects. The objects could be obscured behind other objects or simply not seen in the view field of the camera as visualized in Figure 4. (Unity, n.d.) The green objects can be seen from the point-of-view and the red objects cannot be seen from the point-of-view. If there are objects behind green objects, red objects in this case, occlusion culling will disable the rendering of the obscured objects.

Figure 4. Occlusion culling feature visualized from a user point of view



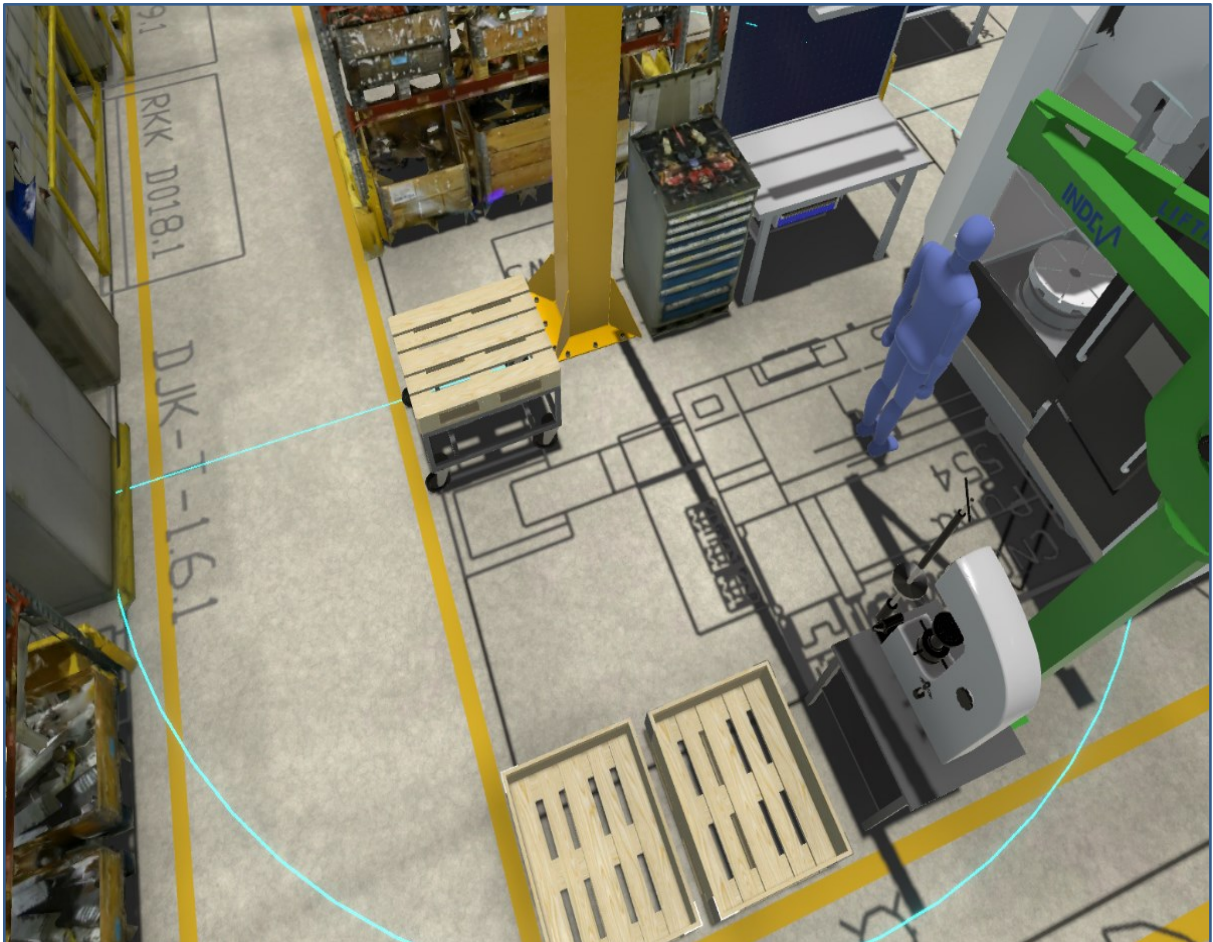
### 3.3 Modeling environment

Design Space is a virtual reality software developed by 3D Talo Finland Oy. In Design Space, the users can immersively visualize the surrounding of an environment **Error! Reference source not found.** Neles is currently using Design Space in offline mode. However, Design Space can also be used in an online mode where multiple users can simultaneously interact and experience the virtual environment. (3D Talo Finland Oy, n.d.)

Design Space is based on Unity. Unity is a game engine mainly used when creating video games or other immersive media. The original goal for Unity was to be an inexpensive game engine with professional tools primarily for amateurs. (Haas, 2014, p. 1) Unity natively supports many virtual reality devices by different manufacturers such as Oculus or Sony. The primary scripting language is C#. (Ahola, 2019, p. 9) 3D Talo indicated that they seek to develop Design Space in a direction where fewer specific customizations are required in new virtual environment

creation cases. However, specific customizations could be required depending on the use-case of the software. 3D Talo has made multiple specific customizations for Neles, as seen in Figure 5. Users can see the factory layout grid on the virtual environment factory floor by pressing a keyboard button. The blue lines visualize the maximum turning range of the cranes.

Figure 5. Design space Neles factory virtual environment

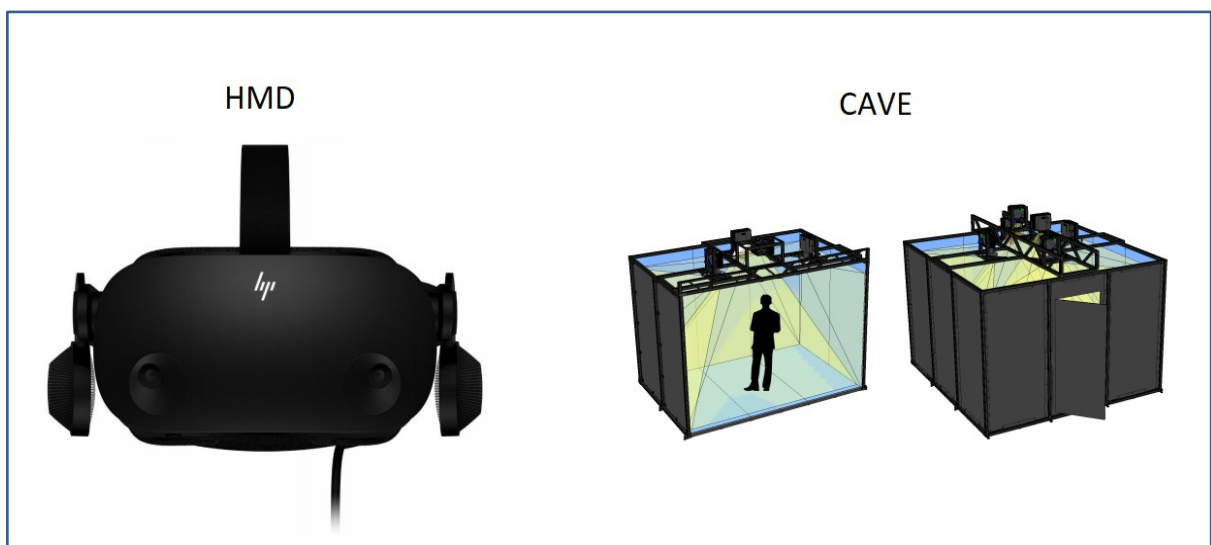


As the virtual environment can be accessed from any physical location, the virtual environment could be used in cases where a person needs to visit the factory and observe the environment for any reason. By accessing the virtual environment instead of physically having to visit the factory premises, any excess emission by traveling is minimized and an essential part of sustainability is achieved.

### 3.4 Virtual reality equipment

Modern-day virtual reality technology is primarily used through an HMD (head-mounted display) or a separate VR system, such as CAVE Automatic Virtual Environment (Figure 6). The CAVE system overcomes the disadvantages and limitations of a typical HMD. The CAVE represents a room-sized 3D system that allows multiple individuals to interact and experience the environment simultaneously. However, because of the scale and cost of a CAVE system, it is primarily used in particular cases of engineering. (Visbox, n.d.)

Figure 6. Visual representation of an HMD and a CAVE system



Head-mounted display, often called VR headsets, allows their users to interact in virtual environments by moving their hands, eyes, body, and head. Virtual reality devices will use other human sense-stimulating elements in the future, such as taste, smell, and touch, to feel actual force feedback. (Strickland, 2007) Modern-day manufacturers mainly produce VR devices based on visual and auditory elements as well as basic touch features, such as controllers.

A typical example of a low-cost HMD is Google Cardboard, where users insert their smartphones into a cardboard box. Cardboard virtual reality set-ups are inexpensive when assuming that the user already owns a smartphone, varying from a few euro to a maximum of 20 €. Because of the low price, the cardboard HMD does not support much more interaction

than the head movement of the user. For scenarios that are passive and do not need much interaction, the cardboard box is relatively good, given its price-to-value ratio. (Poetker, 2019)

In the virtual reality industry, several major league companies such as Apple, Google, HTC, Microsoft, Samsung, Sony, and Valve have developed virtual reality products since 2015. The prices of standard modern-day consumer VR headsets vary mostly from approximately 300 € to 1200 €. Professional and the most top-end headsets cost up to thousands of euro. Oculus Quest 2 is an entirely standalone VR headset and does not require a PC when in use but can also be connected to a PC if needed. When using a VR headset that is not entirely standalone, it is essential to note that a PC with suitable hardware is required for the headset to work correctly. (Brewster, 2020) Most of the consumer VR headsets require a computer to work.

Neles has been using an HTC Vive Pro -VR headset since the spring of 2019. The headset is excellent for virtual reality layout planning when considering the specifications, such as resolution per eye or field-of-view. However, the biggest problem with HTC Vive Pro is that the entire set-up is not mobile and user-friendly due to the required use of base stations. The base stations define the available space of a room and they recognize the movement of the headset or controllers. The base stations are ideally supposed to be mounted on opposite ceiling corners of a room and no more than a maximum distance of 5 meters apart at an angle of 30 to 45 degrees downwards. (Vive, n.d.) When the base stations need to be correctly set up, particularly when relocating to various meetings and demonstrating virtual layout planning processes, the set-up process seems like a significant waste of time. The odds of the headset not functioning correctly are high due to not being able to mount the base stations correctly.

Therefore, Neles is acquiring a new user-friendly and base-free headset to ease the process of relocating and presenting. The new headset should be mobile and easy to use, with good enough specifications for VLP. As shown in Table 2, research for the new headset has been done with two considered options. The first option is HP Reverb G2 and the second option is Oculus Rift S.



Table 2. Virtual reality headset comparison table (HP, n.d.; Oculus, n.d.)

VR headset comparison table	HP Reverb G2	Oculus Rift S
<b>Display</b>	2x 2.89" LCD	1x LCD
<b>Resolution</b>	2160x2160 per eye, dual panel	2560x1440 single panel
<b>Frequency</b>	90Hz	80Hz
<b>Weight</b>	550 (g)	500 (g)
<b>IPD</b>	Yes	No
<b>Tracking</b>	4 cameras for tracking, base-free	5 cameras, insight tracking, base-free
<b>Price</b>	645,08 € (0% VAT)	362,82 € (0% VAT)
<b>Availability</b>	Orderable	Orderable
<b>Launch date</b>	Shipping starts for the first pre-orders in late November 2020	March 2019

The specifications are retrieved from the websites of the manufacturers and gathered into a comparison table. The prices are based on a VAT-free price from a Finnish retailer. Referring to Table 2Table 2**Error! Reference source not found.**, HP Reverb G2 has higher resolution and frequency rate, and a possibility for manual interpupillary distance (IPD) adjustment. Oculus Rift S does not have an option for IPD adjustment, which could decrease comfort and optimal quality. IPD manual adjustment allows users to change the distance between the lenses horizontally. IPD defines as the distance between the center of pupils. (Lang, 2020). Reverb G2 is more expensive and was only pre-orderable when the headset was placed for order. Rift S has one additional camera on top of the headset.

Although the Rift S headset is decent enough for VLP, virtual reality technology is continuously developing. Due to the increasing growth of the industry, virtual reality applications will require more advanced equipment in the future. Thus, it would be an excellent reason to acquire a headset with good enough specifications to be able to work for a more extended period. The Rift S headset lacks image quality compared with the Reverb G2 because of a substantial resolution difference as shown in Figure 7Figure 7.

Figure 7. Screen capture of a virtual reality headset comparison video (Ang, 2020)



The gauges, buttons, screens, texts and numbers have a clear visual difference. The gauge values can hardly be seen on the Rift S headset, whereas the Reverb G2 is close to having a photo-realistic quality. The color-depth in Reverb G2 is very good since the colors are vibrant and have a rich contrast. (Ang, 2020) Based on all the previously mentioned factors, Neles is going to acquire the HP Reverb G2 for virtual layout planning. The headset can also be used in other areas of expertise in the future, not just in VLP. Therefore, it is also essential to invest in a high-quality headset.

Neles also acquired a Lenovo P15 VR laptop for virtual layout planning. The P15 VR laptop is equipped with a Nvidia RTX5000 graphics processing unit (GPU), an Intel Core i7-10850H central processing unit (CPU), and 64 GB of random-access memory (RAM). The minimum requirements to run the HP Reverb G2 headset at a maximum resolution are high. Therefore, the P15 VR laptop is a suitable fit for Neles to operate the virtual environment properly.

## 4 UTILIZING VIRTUAL REALITY IN LAYOUT PLANNING

Technologies develop quickly in modern-day applications and customer expectations are becoming more difficult to fulfill as competition in the industry increases. Therefore, the implementation and utilization of new technologies are now more critical than ever. Virtual reality provides a unique opportunity to interact with objects to strengthen qualitative and quantitative decision-making by visualizing the elements, especially in layout planning. (Iqbal & Mohammed Saleem J, 2001, p. 1834) During any layout projects, the prioritization of VLP is essential. As discussed internally, prioritizing VLP over traditional 2D layout planning should be done, but considering that actual millimeter-specific layout planning is currently mostly undoable. Therefore, the original 2D layout blueprint should also be actively revised and retained in the future until VLP is an entirely reliable method to perform FLP.

Neles can effectively interact with stakeholders and visualize the proposed project changes by using virtual reality in layout planning. Neles can produce a better environment, including an ergonomic viewpoint, and quickly experiment with different variations. Virtual reality allows the cooperative visualization of the surrounding environment in a manner where a depth perspective and immersion can be achieved when presenting upcoming layout changes to machine operators and other stakeholders. The visualization is not correspondingly possible on a 2D layout. (Iqbal & Mohammed Saleem J, 2001, p. 403)

Virtual reality layout planning has already brought up good results during previous meetings. In a work-cell layout adjustment meeting with an operator, a smaller lift-assist crane was placed on the left side of the work-cell in the virtual environment. The machine operator discovered that since he is right-handed, the crane should be on the right side instead, making the crane more comfortable and natural to use. However, VLP has also shown some negative aspects during another layout planning meeting. An object was placed into a particular position in the virtual environment, where operators thought the object was way too close. In reality, after the physical installations, the object was not as close to the operators as they thought in the real environment. Therefore, measuring the real environment distances and then implementing the suitable measures for the virtual environment is essential to avoid any possible misunderstandings.

#### 4.1 Accuracy between environments

Differences can be found when comparing the accuracy between the real-world environment and the virtual environment. The key was to check whether the peripherals could fit between the new pre-planned location of a machine and the yellow aisle line. As a result, the peripherals did fit behind the machine, as seen in Figure 8. However, additional piping and other miscellaneous objects do not appear correctly in the virtual environment since the machine has been individually cut from a point cloud into an object. Therefore, before making any decisions based on the pre-planned design, the on-site real-world premises should always be double-checked for possible divergencies. The locations of the peripherals in the real environment might often vary.

Figure 8. Comparison of virtual reality environment and real environment



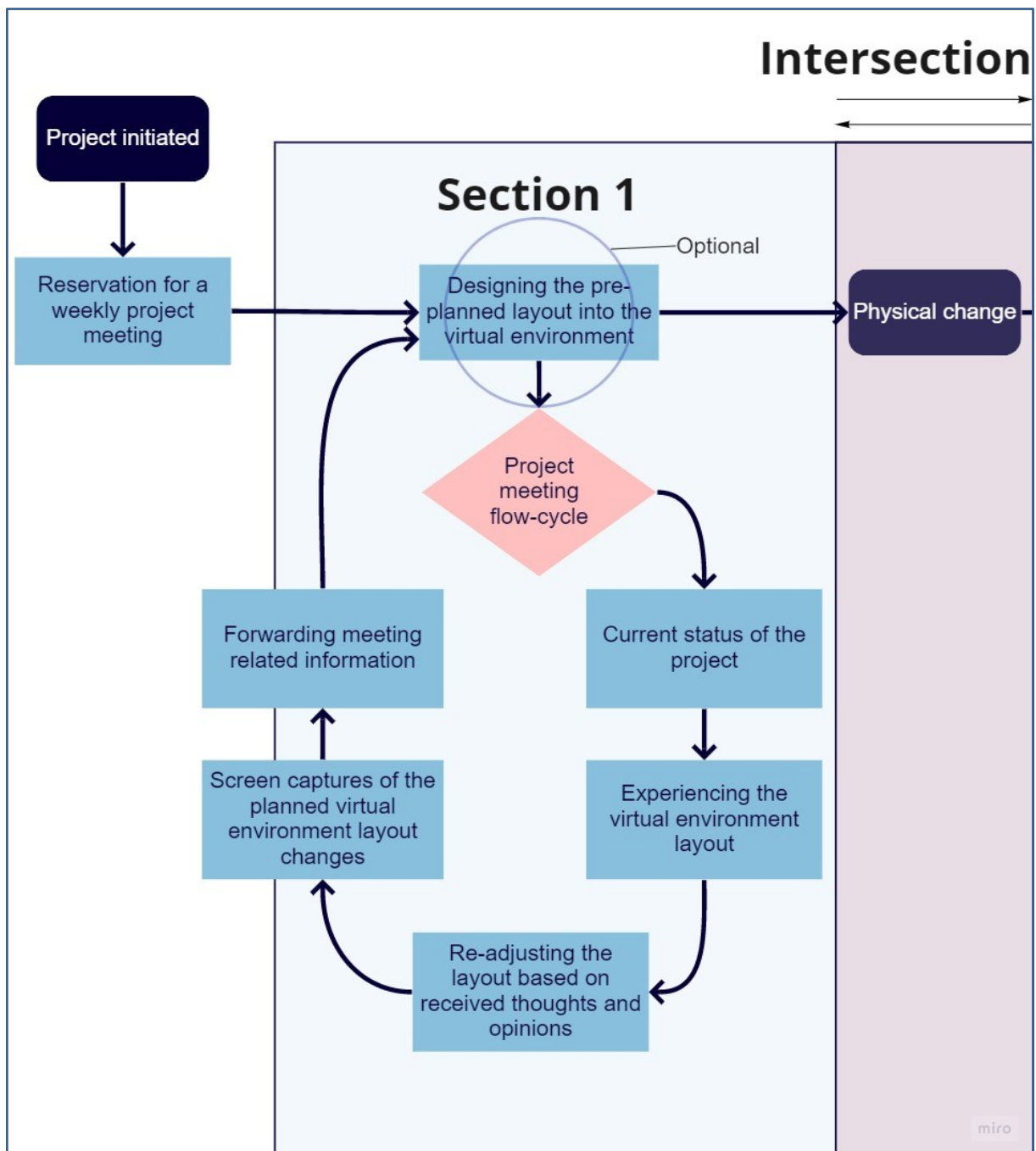
Maintaining the virtual environment as close to 1:1 ratio to the real environment is necessary not just before the pre-planned adjustments but also after. The real environment might have peripherals such as pipes, wiring, pallets, chairs, tables, and other miscellaneous items, in various locations separate from the virtual environment.

## 4.2 Systematic project meeting flow

Meetings are typically a pre-planned set of events with specific goals and results. Meetings offer an opportunity for all members to focus on the subject of the meeting. Meetings are essential in the implementation of corporate strategies or structural improvements. Meetings may be open meetings with no specific participant group or closed meetings with a defined and limited participant group. (Jarzabkowski & Seidl, 2007, pp. 5-8) Projects must have a continuous and systematic flow to prevent problematic situations such as lack of communication or potential misunderstandings between the stakeholders. Therefore, the utilization of meetings during a project is critical. Microsoft Teams sessions provide broader significance for becoming more collaborative since the virtual environments can be simultaneously and intuitively experienced during the project meetings through a shared screen.

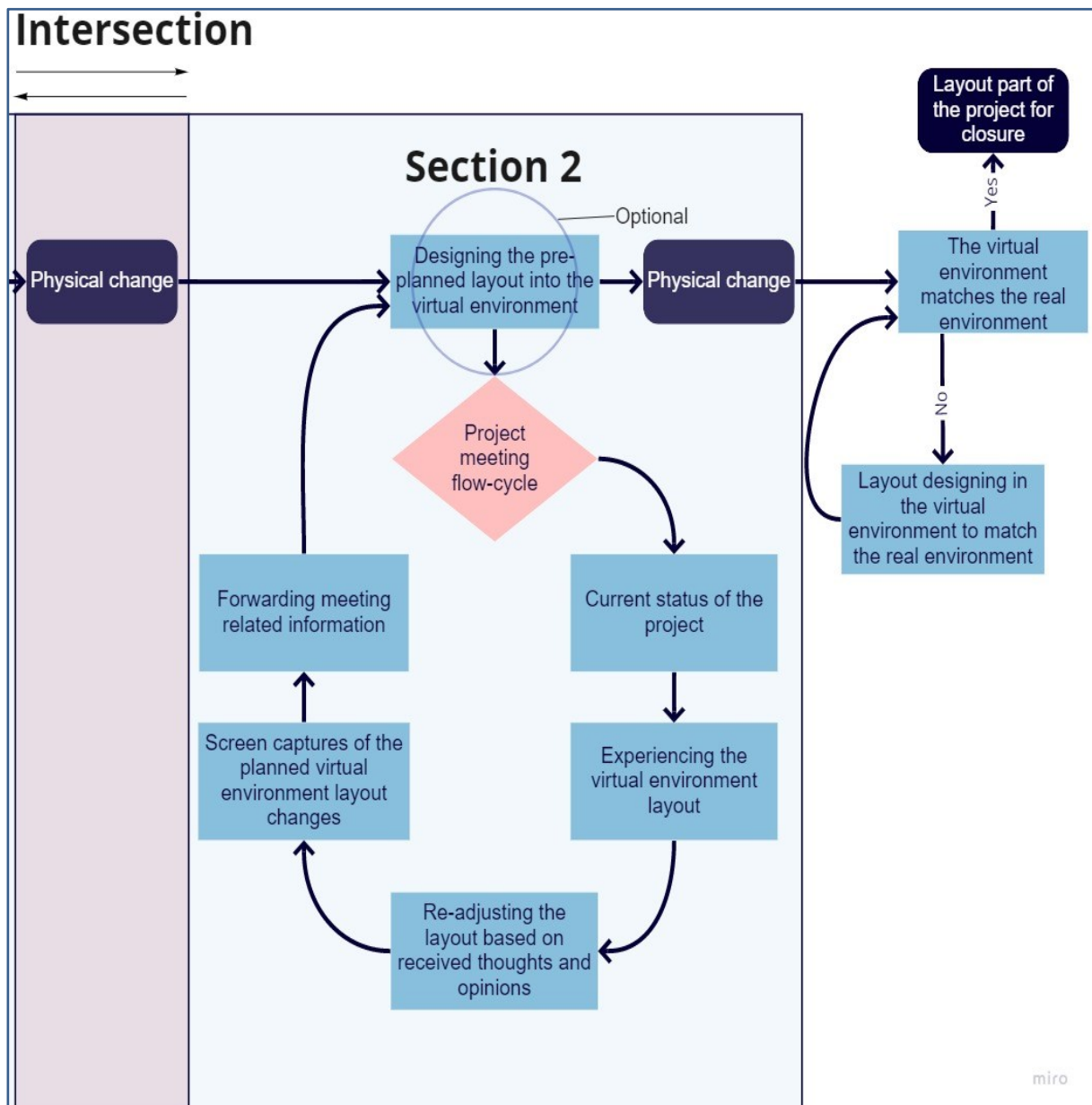
As experienced in previous meetings during an ongoing layout project, having a systematic flow for each meeting is essential, visualized in Figure 9 **Error! Reference source not found.** Weekly meetings should be held with as many stakeholders as possible to visualize the virtual environment together and to be able to secure any adjustment-related issues or possibilities. Layout projects vary; thus, following the flow-chart in every case might not be the ideal option. However, using it as a base should ease the process of virtual reality layout planning-related meetings. Stakeholders that should be involved in the layout project meetings are project managers, supervisors, machine operators, designers, and other head personnel related to the project.

Figure 9. Section 1 of the systematic layout project meeting flow-cycle



Section 1 would focus on the virtual layout planning of the main part of any project, such as moving a machine. The Section 1 project meeting flow-cycle would repeat itself in weekly meetings until the first section of the physical change in the real environment has been completed. Section 2, as visualized in Figure 10, has the same flow-cycle as Section 1. However, Section 2 has an intersection with section 1 in a sense, where Section 2 should be initiated before the first physical change to minimize any risk for possible time waste.

Figure 10. Section 2 of the systematic layout project meeting flow-cycle



Section 2 reflects improvements in the work environment, such as the procurement of essential hardware or peripherals for machine operators to ease working and ensure that the work environment is appropriately spaced, ergonomic, safe, and as practical as possible. The essential hardware or peripherals could be tables, chairs, computers, monitors, tool drawers, and other similar items. The flow-cycle for both of the previously mentioned sections is more thoroughly described in Table 3.

Table 3. project meeting flow-cycle for virtual reality layout planning

Project meeting flow	Definitions	Responsibility roles
<b>Current status of the project</b>	Discussion of the current status of the project. Mainly focusing on the following questions: What is the current status of the project? What is the next step? What are we going to focus on in this meeting?	Project person, ideally project manager
<b>Experiencing the virtual environment layout</b>	The designer(s) could design the pre-planned layout adjustments ideas before each of the meetings. Designing before the meeting is optional if new ideas and brainstorming are wanted for the layout adjustments. In this part, the designer(s) would be presenting the ideas to other stakeholders of the project through a projected screen and a Teams call.	Designer(s)
<b>Re-adjusting the layout based on received thoughts and opinions</b>	The designer(s) would, altogether with other stakeholders, design the virtual environment based on received opinions and thoughts. The designing process would be ideal if the machine operators would also use VR equipment.	All meeting stakeholders
<b>Screen captures of the planned virtual environment</b>	Screen captures of the planned layout changes are essential. Screen capturing could be done using a screen capture tool in the Design Space software or by a print screen button in the Windows environment.	Designer(s)
<b>Forwarding meeting related information</b>	This part focuses on documentation and forwarding meeting related information. The forwarded information could be, e.g., current status of the project, the next phase of the project, and the screen captures of the modified virtual environment.	Project manager



Determining roles for a project meeting is necessary to maximize the potential and flow of each meeting.

Designer(s) could be any project stakeholder capable of using the virtual reality equipment intuitively in a meeting and modifying the virtual environment by received opinions and discussed adjustments. The designer would ideally be the project manager or a person dedicated to the role. The designer would also need to take screen captures from the virtual environment of the planned adjustments and forward them to the project manager.

The project manager would need to ensure that the project meeting flow is on time. The project manager must know the project thoroughly to clarify the status and progress of the project to guide other stakeholders in the meeting. The project manager must be knowledgeable of the capabilities of the virtual environment as well as VLP in general. The project manager will also need to forward the screen captures to non-participated stakeholders to show the thought design of the planned adjustments. Screen captures additionally allow the possibility for documentation in the future.

The meeting stakeholders should include everyone related to the layout planning project. Machine operators or supervisors are not necessarily required to know more than the basic concept of the project. However, it is essential to provide opinions by basing on the previous working environment for the planned adjustments to allow the possibility to minimize risks and any possible time or money wasted before-hand. Thus, machine operators involved in the meeting should have experience working in the area where the layout changes are planned.

### 4.3 Sustainable development

Sustainable development is a continuous and directed method of development that is intended to ensure that current and future generations have the ability to live well. A part of sustainable development is economic sustainability. Economic sustainability is based on well-balanced growth, therefore preventing debt or wasting resources, such as money. Investments in training or research- and development work are gradually becoming the foundation of sustainable economic development. (Kniivilä, 2011, pp. 9-10)

Focusing on sustainable development from an economic perspective is necessary. With VLP, Neles is in a position to strengthen the planning system for any potential risk of money or time wasted. Studies have shown that a well-planned production layout design has a chance of minimizing overall operational costs by 50% (Gong, 2018, p. 1). Poor layout design may contribute to a large amount of work in progress and inventory, higher costs, dissatisfied customers, inflexibility, and inefficiency (Abraham & Sasikumar, 2013, p. 655). The virtual reality and augmented reality cloud provider company called Grid Raster surveyed 215 businesses, of which 61% responded that implementing AR or VR technologies resulted in a cost-saving of 20%. In addition, 29% of the surveyed respondents registered a value of 25% improvement in productivity. (Vigliarolo, 2020)

Neles can visualize and plan the layout of the factory in a way where distances and positioning of sectors or particular objects are logical and fluent. Layout planning eases the possibility to secure the safety of workers in the present and the future. To sustainably develop the entire VLP method itself and minimize any possible risks of delays or economic damage, the upkeep of designing instructions and the virtual environment layout is necessary. The intention is to use existing furniture and other peripherals without being forced to rebuild unless necessary. Fundamentally, current resources are used to avoid unnecessary waste or additional recycling. However, before any real layout adjustments are performed, Neles can better consider any questions related to recycling before-hand when observing the virtual environment.

#### 4.4 Problematic issues

Problematic issues with virtual reality layout planning in the case of Neles are going to be further looked into in this chapter. During the writing of this thesis, problems have arisen in attempts to find permanent solutions to each problem, but with a minimum of a partial solution. The majority of the issues addressed in this chapter are common virtual reality complications or stumbling blocks that can be encountered in a variety of other VR-related use cases. Virtual reality is still underdeveloped in several ways, which poses potential challenges and difficulties for its users. However, as a fast developing and growing technology, most of the challenges listed in this chapter will have reasonable solutions, most likely in the near future.

**Problem 1:** Challenges in performing dimensionally accurate and millimeter-specific modeling in the virtual reality environment due to the natural movement of the hands.

Solution 1: There is currently not a definitive solution to this problem. However, Neles should continue layout planning and modeling in AutoCAD when making geometrically minor adjustments, such as moving an object only by a few millimeters. Virtual reality layout planning should, however, be performed if the user is layout planning in the range of five to ten millimeters. Precise millimeter-specific VLP will most likely be possible in the future, e.g., by inserting fixed-position coordinates and without having to rely on hand movement.

**Problem 2:** In the case of Neles, the objects are implemented 3D data models or individually separated objects from the point cloud. It is currently not possible to visually change the dimensions or certain parts of implemented objects inside the virtual reality environment, such as factory machines. The objects have to be individually cut out of the point cloud in a separate software and implemented into Design Space as a new object. At the moment, 3D Talo has been doing this per the requests of Neles.

Solution 2: Currently, conducting the mentioned adjustments in the Design Space environment is not possible. This workaround of this problem is that the objects should be modified or adjusted in a separate 3D modeling program, such as SolidWorks, and then re-implement the 3D model into Design Space as a new object.

**Problem 3:** Neles has been using an HTC Vive Pro headset that requires base stations to be able to use the headset. Use of the headset is challenging when relocating and presenting in various meetings. Suppose the headset or controllers get out of the required visual range of the base stations, the controllers might start shaking and the point-of-view position might randomly teleport to another location.

Solution 3: To solve this problem, Neles decided to acquire an HP Reverb G2 base-free headset with the support of the headset comparison table conducted in this thesis. The Reverb G2 headset does not require base stations. Instead, the headset uses the cameras to monitor the external location defined in the initial headset set-up.

**Problem 4:** Motion sickness is a significant problem with the amount varying by each individual. Studies have shown that by commercially available VR systems, motion sickness appears in 40% to 70% of users after only 15 minutes of use (Kim, 2019).

Solution 4: There is currently no definitive solution to this problem, although several factors can reduce the possibility of motion sickness. The equipment used during VLP, such as a VR headset and a computer, should be up-to-date and capable of meeting the minimal requirements and standards to reach the highest FPS and Hz possible. For the connectivity from the VR headset to the computer, Neles used a DisplayPort to USB-C adapter, which only allowed a refresh rate of 60Hz per second even though the headset could display 90Hz. Neles acquired a new adapter to overcome this problem.

**Problem 5:** New users have complications in conducting layout modeling in the virtual reality environment. For some users, navigating in the virtual environment with virtual reality equipment takes much time to learn.

Solution 5: The instructions defined in this thesis are aiming to assist in the problem. The instructions will help the users navigate in the environment, learn the basics of the environment, conduct layout changes intuitively as well as load and save the environment.

## 5 DEFINING DESIGN PROCEDURES

This chapter defines the instructions and guidelines for factory layout planning in a virtual reality environment. Additionally, a questionnaire is presented and analyzed, future recommendations based on the thesis results suggested, and consideration of possible virtual reality use cases in various areas of expertise are further examined.

The initial step for the instructions was to describe the interface so that the form of the instructions would remain logical and dynamic. Technical guidelines describe the modeling and designing process with step-by-step images and a video recording. Guidelines for design describe the general fundamentals of the design process and key points to consider, such as the ergonomics of the work unit, when the user should prioritize virtual over typical 2D AutoCAD and on-paper layout planning, specifying the minimum standard needed by the user to be able to function with VR equipment, and more.

The guidelines and instructions are intended for users who use virtual reality layout to plan and design on the Design Space software. The instructions guide and help users get acquainted with the environment by completing a fictitious work-unit configuration design process. Neles hopes that, with the help of the rules and guides, users will be able to start prioritizing virtual reality layout planning over traditional techniques. Virtual reality helps the users visualize the depth as well as certain objects and peripherals differently compared to traditional layout planning methods.

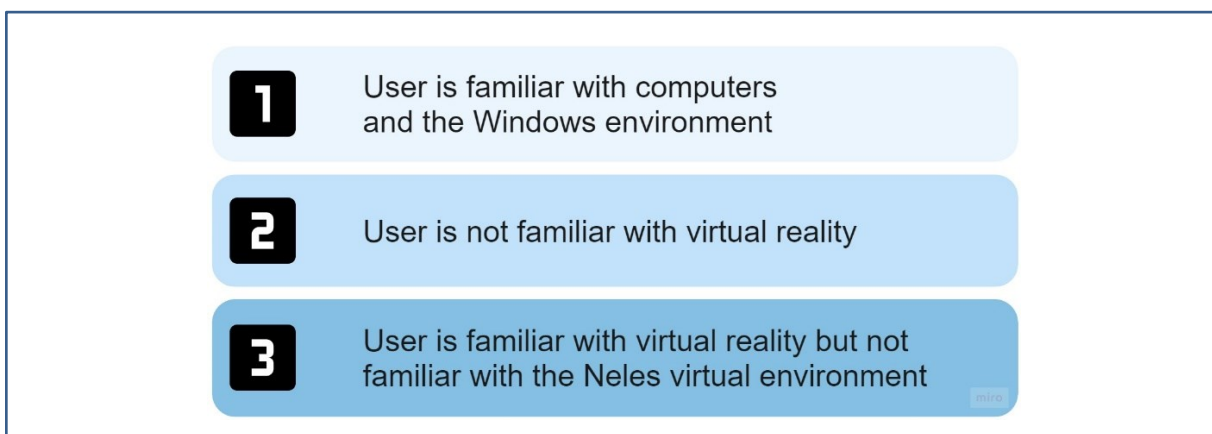
As stated in Chapter 2.3, the original blueprint layout of Hakkila, Vantaa factory master-file on AutoCAD is outdated. Personnel changes were a significant factor and the main reason for the layout Autocad file to be out-of-date. Therefore, the instructions are a critical asset for the designing processes, allowing the users to quickly catch up with the environment and layout planning in a virtual reality environment.

## 5.1 Virtual environment designing fundamentals

Adjustments in the real environment should not be conducted without before-hand planning unless the adjustment process is a simple and straightforward task. Most of the time, virtual reality layout planning should be prioritized over traditional AutoCAD layout planning, particularly where stakeholders need to visualize and observe potential variations for the position of the suggested adjustments simultaneously. Standard AutoCAD layout planning should be prioritized if the stakeholders are planning changes in a millimeter-specific way or if the stakeholders want to visualize if, for example, a machine would fit in a very specific position. AutoCAD provides a more comprehensive and official factory blueprint top-down observation. However, the best solution would be to mix both of these layout planning methods. When combining AutoCAD 2D layout planning with VLP, the stakeholders can get the 2D blueprint and overall room visual observation aspects altogether.

Personnel operating virtual reality equipment and manipulating the virtual environment may not need to have extensive expertise in information technology, design, or other related fields particularly if the users are designing in accordance with the defined technical instructions. However, for personnel unfamiliar with computers and computer equipment in general, getting started with VLP can take significantly longer than for more advanced computer users, specifically if stakeholders require quick navigation and intuitive design, such as during a meeting session. Therefore, for the designing process and more specifically for the responsibility of the designing process, a base-line for knowhows is defined. The initial step is defining the basic collection of skills that a VLP responsibility individual should have in order to get started quickly with the process. Three categories are defined in Figure 11:

Figure 11. Skill categorization base-line for virtual layout planning



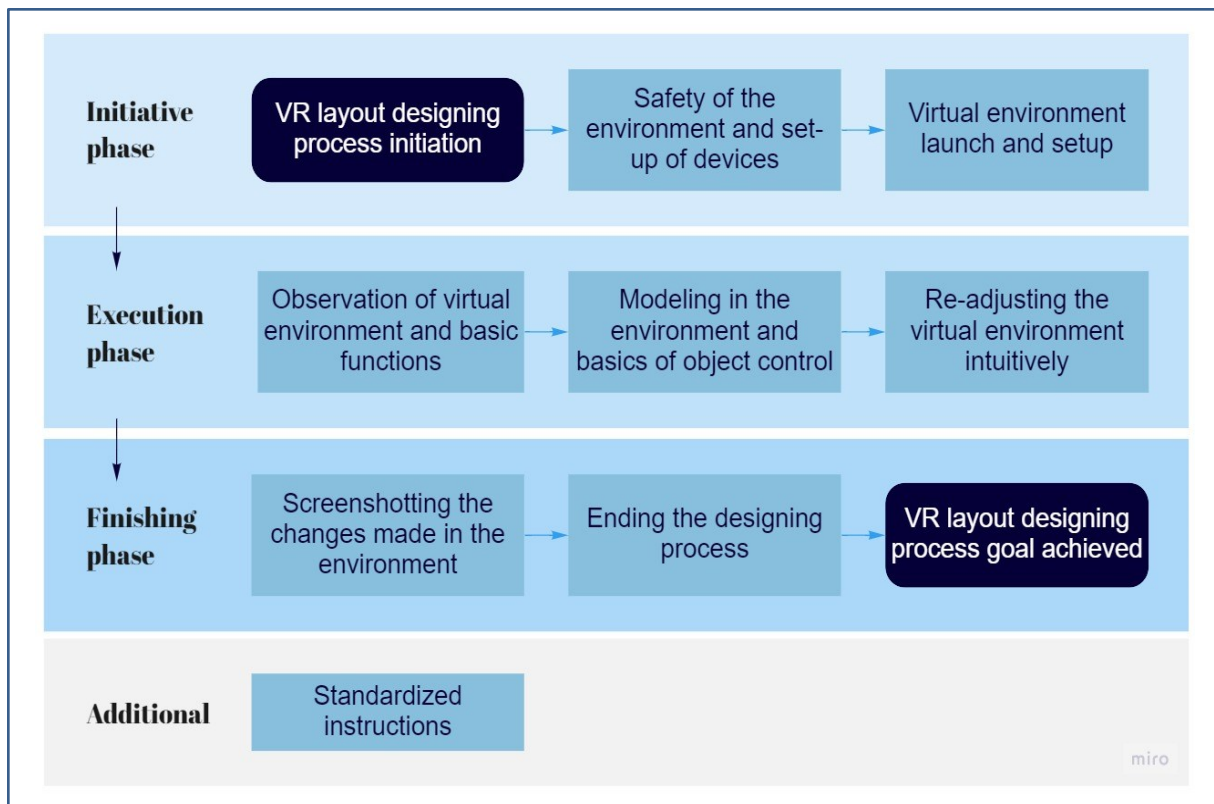
The minimum set of skills that the user should have is Category 1. To navigate and execute layout planning intuitively and adequately in the virtual environment of Neles, the person responsible for the VLP designing process should be familiar with computers and the Windows environment. Learning the virtual environment requires time and practice; thus, by fulfilling the criteria of Category 1, the users are more readily introduced to the virtual environment.

During the initiation of any layout adjustments projects or processes, all of the related stakeholders should be involved in the planning process as much as possible. The machine operators and other factory workers working in the planned area should be asked questions such as “What items are required for the worker to be able to perform their tasks properly?”, “Is the worker in need of any new items, such as tool drawers, tables, chairs, or anything else?”, “How much open space is required in the working unit and the machine operating surroundings?”, “What are the optimal placement locations for the items”, “Is anything moved through the work environment; does the aisle need to be wide enough for a forklift passage?”, “How large are the objects moved next-to and into the operating machines?”, “Are assisting cranes required in the working environment?”, “How can we make sure that the ergonomics of a work-cell environment is optimal?” and similar questions related to the planned area. These afore mentioned questions should also be thought-out and discussed during a VLP meeting also. The machine operators should be encouraged to talk openly about the matters in the work-cell environment and continuously asked for any possible improvements to avoid any possible hazards and inconveniences after the implementation of the planned layout.

Virtual reality does not contain all of the peripherals and objects found in the real world, as detailed in Chapter 4.1. As a result, not everything can be nor would make sense to be planned in the virtual environment. Before, after, and during the layout process, risk assessments should be administered in the real environment. Final layout planning choices can never be based solely on the planned layout in virtual reality to prevent possible unwanted coincidences. The real environment must be considered alongside any adjustment, no matter how large or small the planned layout adjustment is. In this scenario, double-checking both real and virtual environments for possible mismatches or deficiencies is a good practice.

## 5.2 Technical instructions

Figure 12. The main four categories for technical specific instructions

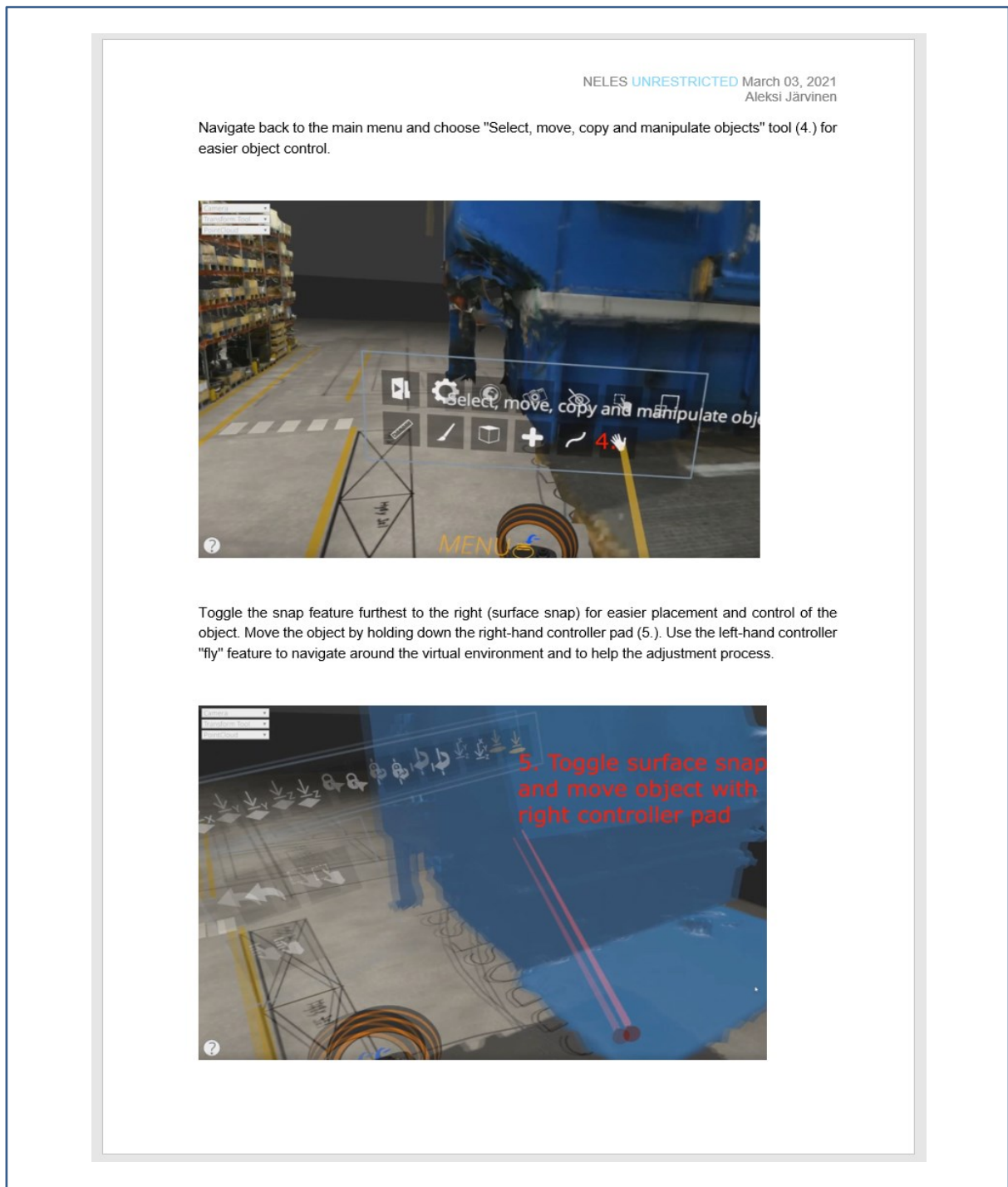


The technical-specific instructions are divided into four main categories: initiative phase, execution phase, finishing phase, and additional standardized instructions. The total amount of instructions is eight, as seen in Figure 12. The standardized instructions include the object naming ideology, Neles specific features, virtual environment save file standards, and more.

The aim was to make the technical instructions as precise as possible but not too specific in terms of technical characteristics. The instructions are designed intentionally, not to be very specific, since the technology on both the hardware and software side are updated at a fast, continuous pace. For example, defining particular buttons and push point implementations in the instructions would not be beneficial. The instructions would be outdated every few months and could cause confusion during use. The technical instructions are aimed to be the base on how-to execute virtual layout planning in the virtual environment by anyone using the equipment.



Figure 13. Example page of technical instructions



The technical instructions were purposely designed to be easy to read and easy to assimilate. An example of the technical instructions can be seen in Figure 13. The step-by-step process is more thoroughly explained above the images and the document follows a certain number-pattern ranging from 1 to 12, depending on the number of screenshots and steps. The instructions are kept in the in-company intranet, and therefore not implemented as an appendix to the thesis. The total number of instructions is eight, with each section of instructions containing at least five pages. The step-by-step images and sections were

documented by a screen recording software and then compiled with a video editing program. The uploaded videos can also be seen on the company intranet. Users learning to use the virtual environment designing tools for the first time are encouraged to begin with the more thoroughly described step-by-step process.

### **5.3 Questionnaire survey**

The questionnaire bases its purpose and questions on factory layout planning and virtual reality utilizations. The questionnaire is not a research or scientific analysis. However, the objectives of the questionnaire were to gain both quantitative and qualitative data, opinions, and preferences regarding layout planning, specifically from the utilization of virtual reality in layout planning for the internal purposes of Neles.

A structured interview was used as a method to conduct a form questionnaire for this thesis. The method is suitable for use when collecting information from a relatively large number of people. A structured interview is a pre-planned interview with the same questions and a presentation order for each person participating in the questionnaire. The information obtained by this method is comparable, and the processing of the obtained data is relatively easy and fast. (KAMK, n.d.) Questionnaires often use both open and closed questions to collect both quantitative and qualitative results. Respondents are able to provide quantitative information by asking questions with answers such as 'yes' or 'no'. (McLeod, 2018) Therefore, the questionnaire in this thesis is carried out in accordance with the principles of a structured interview.

Microsoft Forms is used as a framework for the questionnaire. The questionnaire reached close to 100 respondents, mainly chiefs and supervisors. The respondents were instructed to forward the questionnaire to their subordinates. The respondents were given a two-week deadline, resulting in a total amount of 32 participants and answers. The questionnaire questions and results can be seen in Appendix 1. The responses included many unpredictable perspectives related to virtual reality and layout planning. Additional findings from the quantitative portion of the questionnaire; on Question 5, 63% replied yes (Kyllä). The majority replied to Question 7 with a high ranking. In this scenario, most voters (73%) totaled a high rating of 4-5 to Question 7.

## 5.4 Future suggestions based on the thesis results

Neles should consider expanding the virtual environment and virtual reality use to other locations and factories worldwide. The personnel of Neles would be able to access the on-site premises and observe the environment remotely. The virtual environments would reduce the need for travel and save time as Design Space lets users interact with each other simultaneously.

The questionnaire conducted during this thesis could be re-done for external clients to market virtual reality utilizations in numerous sectors at Neles. Re-doing the questionnaire would also help Neles gain valuable information on both internal and external client needs. The questionnaire could focus on the same questions or be more precisely customized depending on the target audience.

In the Design Space software and the virtual environment of Neles, users cannot see or concretize the weights for any object. The environment could be even more functional with such a feature for specific situations. Neles has also been in discussion with 3D Talo Finland Oy, where Neles would want to see the simulation of a manufacturing process flow visually in the virtual environment of Neles. The visual aspect of a simulation manufacturing process flow could be displaying and directing arrows and lines around the factory in the virtual environment or simulating the movement of objects such as forklifts. However, the manufacturing process flow visualization will not be further studied in this thesis, although it is a considerable and recommendable feature to have in the future.

Displaying and visualizing internet-of-things (IoT) data in the virtual environment would also be an intriguing feature. IoT data from the utilization capacity, occupancy patterns, time course, time estimation, or any related data that can be used and analyzed that would be helpful. It would be more beneficial if the IoT sensors or RFID tags and readers could also track factors such as CNC-machine power, usage capacity and heat levels. In addition, the data could be used to store information in the database for documentation, for example.

## 5.5 Virtual reality use case possibilities

This chapter will concentrate on multiple potential virtual reality use cases currently in the utilization of businesses. Observing the use cases of other companies is essential. The observed companies are not necessarily rival companies in this matter, but from different use case areas of expertise to consider additional virtual reality implementations for Neles. Virtual reality has become a more significant factor in gaining a competitive advantage in the industry of manufacturing (Cooper, n.d.).

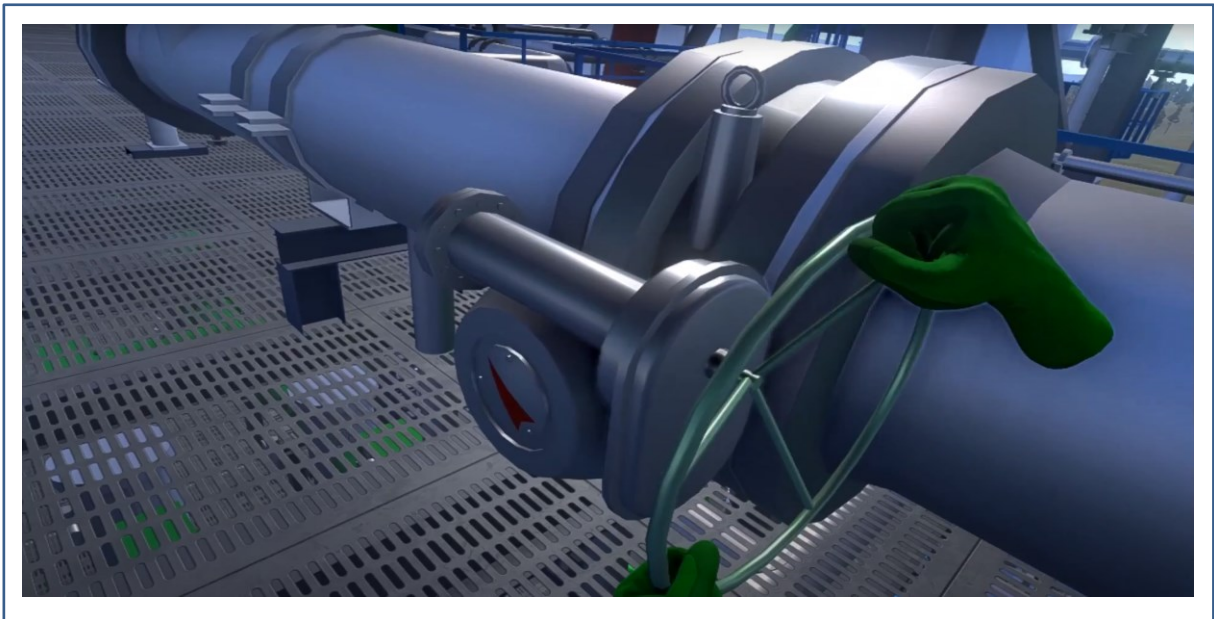
During the company virtual reality use case observation, the following three subjects are further examined:

- Company name and industry
- Virtual reality use case and category
- Implementation possibility for the use of Neles

### 5.5.1 Linde plc – virtual reality training

Linde plc is a company focusing on industrial gases and engineering. Linde provides industrial gases for applications such as oxygen for hospitals or high purity and specialty gases to manufacture electronics. (Angel, n.d.) Linde has taken a leap into the simulation possibilities of virtual reality by virtual reality training. VR training enhances the safety of workers in high-risk factory environments. In the virtual factory environment of Linde, workers can navigate and explore the on-site surroundings virtually before accessing the plant, visualize the location of any components, measure distances, and understand the use of different types of equipment (Figure 14). Linde additionally trains truck drivers by simulating the unloadings of hazardous liquid gases. (Cooper, n.d.)

Figure 14. Screen capture of VR training for operators video (Linde, 2018)

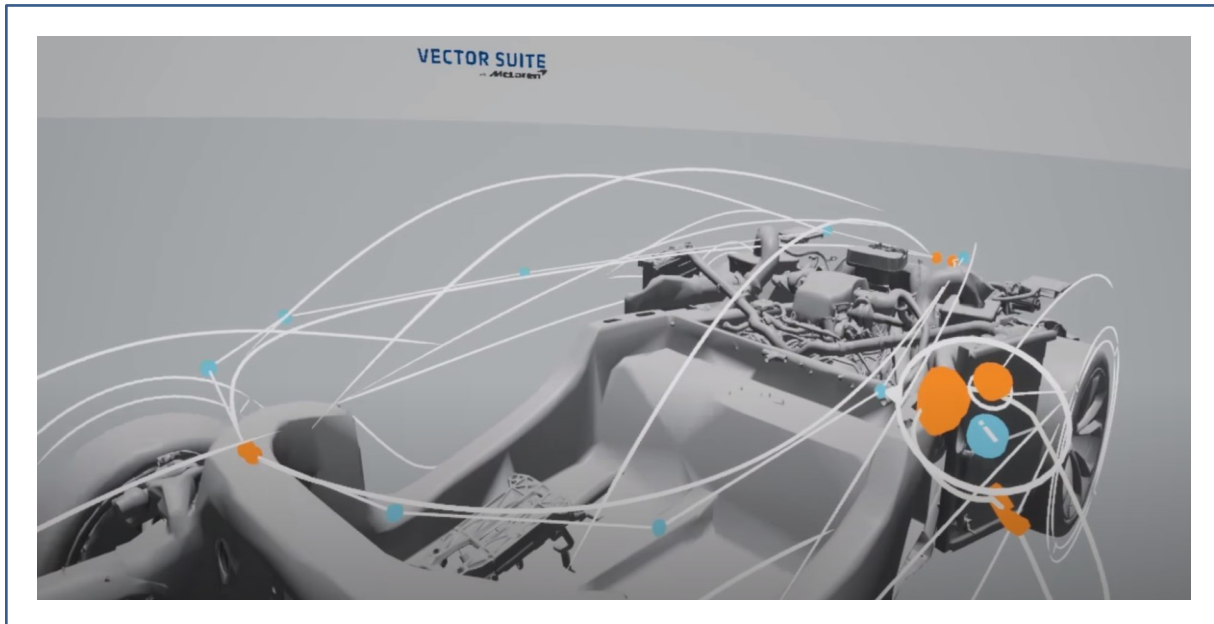


Should VR training be implemented for the use of Neles? Visiting the factory premises remotely by subcontractors could most likely be accomplished with the current virtual environment that Neles has with some modifications. VR training would be ideal for training workers or subcontractors virtually before-hand, especially in the current pandemic situation and in the future as well. Such a feature could also enhance and ease the possibility of maintenance work. Users using the Design Space software should be using a VR headset for full-immersion. However, the virtual environment does not necessarily require the user to use the VR headset since the environment can also be accessed by a mouse and a keyboard.

### 5.5.2 McLaren Automotive – virtual reality design and engineering

McLaren is an innovative manufacturing and engineering company in the industry of automotive, motorsport, transport, health, and numerous more. McLaren states that virtual reality designing is one of their innovations. McLaren had the challenge of not being able to enhance the overall designing processes. To overcome this challenge, McLaren developed a virtual reality designing system with Vector Suite software company. The software guides engineers and designers to easily convert concepts into virtual objects intuitively and with an exceptional level of realism (Figure 15). (McLaren, n.d.)

Figure 15. Screen capture of “How McLaren Automotive uses virtual reality to design its sportscars and supercars” video (Automotive, 2018)

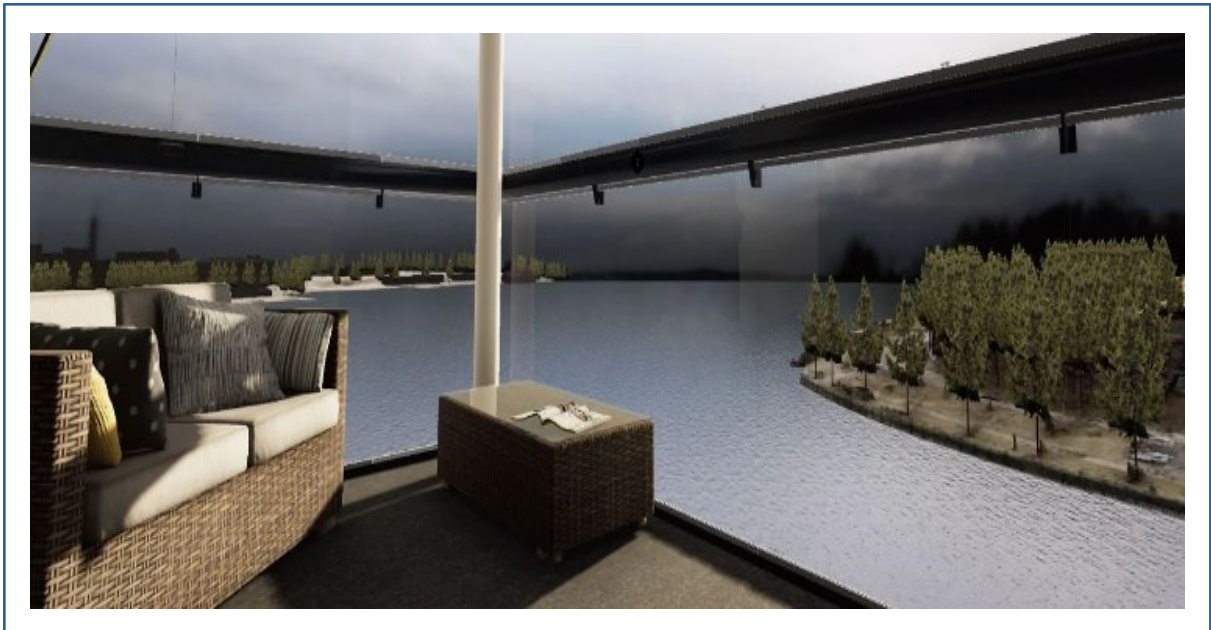


Should CAD virtual reality designing be implemented for the use of Neles? Virtual reality integrations in their applications have been developed by CAD tech firms such as SolidWorks and Autodesk. Virtual reality is expected in CAD design to minimize physical prototyping expenses, enhance internal designing sessions, and to make educated decisions in the development or production process in advance. Furthermore, CAD designing may also allow a marketing opportunity to promote products or the use of virtual reality in a manufacturing environment. (English, 2020)

### 5.5.3 SWECO – virtual reality marketing and construction planning

Sweco specializes in the built environment and industry, planning the cities of the future and a more sustainable society. Sweco offers safe buildings, efficient infrastructure, sustainable energy as well as water solutions. (SWECO, n.d.) Sweco has developed a software named VirtualSite that uses virtual reality technology. VirtualSite makes collaborative planning and communication through a shared view possible in any physical location. The most significant benefit of VirtualSite is to ease the communication between stakeholders. Involved stakeholders can visualize the virtual environment together. In marketing, virtual reality can be used to perform a supervised sightseeing round of a specific location. (Huopio & Jokinen, 2020)

Figure 16. Sweco VirtualSite visualization of balcony glazing solutions



A glazing solution provider company called Lumon was looking to present their products, specifically in trade fairs, for the customers to be able to visualize the product in a realistic-looking virtual environment, as shown in Figure 16. Thus in 2019, Lumon started cooperating with Sweco to use and customize the VirtualSite for the needs of Lumon. Many initial data, such as accurate landscape photographing with a drone, realistic weather conditions, realistic balcony environments, and detailed product models, were implemented in the personalized VirtualSite environment. Lumon received the reactions they expected after Lumon was able to validate VirtualSite at a trade fair. Lumon no longer needs to build reasonably large physical models to be able to display and showcase their products. (Kivioja, 2020)

Should VR training be implemented for the use of Neles? The software seems to have quite similar features as Design Space from the planning perspective. The solution of Sweco appears to be interesting from a marketing standpoint and should be further investigated. Virtual reality and other mixed reality applications will rapidly grow in popularity in the future; therefore, researching the use of virtual reality technology for marketing purposes should be considered.

#### 5.5.4 Additional possibilities

Neles uses SolidWorks modeling software for designing 3D models related to valves, valve parts, and other factory manufacturing related components. SolidWorks has a virtual reality feature where users could experience the 3D models within VR and AR environments. (SolidWorks, n.d.) By observing the model through a virtual reality headset, the users can reify things that they would not be able to traditionally through a monitor screen.

Neles can prepare personnel with possible complications or difficulties during presentations and meetings with virtual reality. VirtualSpeech offers soft-skill courses, where people can learn from online classes and exercise in virtual reality environments. The courses cover subjects such as interview planning, public speaking, promotional presentations, managing remote teams, and many more. (VirtualSpeech, n.d.) Neles could improve the way of doing business by utilizing and implementing new technologies and therefore gaining an edge over competitors.

Furthermore, Neles could benefit from virtual reality by enabling a possible customer inspection of valves, for example, by providing digital 3D components for its customers. Customers of Neles could be using software that allows them to simulate and visualize the 3D component by a virtual headset. The 3D component could be scanned using mobile software and then integrated into the software. This feature could also be enhanced with a 2D view and 360 camera simulation, similar to Valtra with their product showroom. (Valtra, n.d.)



## 6 CONCLUSIONS AND DISCUSSION

The initial objective of this thesis was to provide consistency and clarity during virtual reality layout designing processes and, therefore, improve communication coordination and cooperation between all layout adjustment stakeholders. The thesis was initiated by progressing forward with the virtual reality project altogether with Geo Exact Oy and 3D Talo Finland Oy. The factory premises were laser scanned and modeled as desired into a digital twin to function as the virtual environment and layout planning basis. The goal of the virtual environment is for the personnel of Neles to be able to execute planning adjustments virtually in a proactive manner to maximize the benefits of layout designing and minimizing potential risks such as wasting time or capital. The initial plan was for the virtual layout designing instructions to describe and assist in the overall layout designing process, which was accomplished by specifying step-by-step guidance as well as other design-related topics in the thesis.

The objectives were achieved using the currently available technology. Virtual reality in layout planning helps users visualize and observe the factory environment from a three-dimensional perspective. The three-dimensionality in layout planning compared to previous traditional layout planning methods assists the users observe the depths and heights of the environment in a realistic way. Additionally, virtual reality helps perceive the visual aspect of the environments in a more explanatory way when comparing with, for example, AutoCAD layout designing. In definition, designers can intuitively make adjustments to the virtual environment to produce several variations of the intended environment in collaboration with other stakeholders. According to the findings of this thesis, the virtual layout preparation approach is beneficial. There is a strong desire for VLP to be used in operational activities in the immediate future. Neles has upcoming changes requiring layout planning, and there is a strong desire to use virtual reality as a new layout designing method.

The instructions are aimed to support the users during specific processes for layout planning and aim to guide them through the process flow. The first step was to describe and simulate the hypothetical layout process in the virtual environment. Based on the hypothetical layout process, a flow-chart was formed from which the instructions were defined. The total amount of the instructions was eight, supporting in the initiative virtual

environment set-up phase, the execution phase of modifying a work-cell environment and the finishing phase to know how to end the designing process. For Neles to be able to continue to use the instructions as a basis for layout planning, the instructions must be evaluated for validity at least once per quarter. Because of the COVID-19 virus, the instructions have not been benchmarked, as benchmarking would necessarily require close communication with various employees and the use of the same equipment. However, the processes and instructions have been reviewed with Neles and approved to utilize them in the virtual reality layout designing process. The instructions are to be put into practice as quickly as possible for future projects that require layout planning. In the coming weeks, the final modifications to the virtual environment will be done. When the virtual environment is entirely functional and ready for use, Neles can begin executing the necessary operational layout changes with the assistance of VLP. The aim of the instructions is to be involved in every virtual reality layout process to support the operational activities.

The Vantaa factory virtual reality environment should be upkept as much as possible to ensure that it maintains 1:1 ratio with the real environment. Keeping the virtual environment strictly and precisely similar to the real environment is not currently possible, but making sure that the main layout flow is somewhat similar and reliable is very crucial to minimize possible risks and ensure that the virtual digital twin of the factory does not become outdated. During any interface change in either virtual or real environments, double-checking must be used in all situations to ensure that the environments are somewhat identical. Virtual reality technology is developing at a fast pace rate. For Neles to stay up-to-date in the future and keep virtual layout planning as a relevant and beneficial method, the overall process and designing flow must be revised relatively often. As the technology is developing, the equipment and software used will become better and more intuitive.

In the course of this thesis, using virtual reality intuitively can still be relatively complex. Additional complications may occur, which can significantly affect the willingness of a basic consumer to use any virtual reality equipment. Multiple problematic situations occurred during the thesis writing, causing slight frustration when dealing with the problems for an extended period of time. The equipment used for the layout planning process has some issues, such as not working well enough, the computer may have lagged and not worked correctly due to power input handling issues, the computer has not recognized the virtual reality

headset, and the computer may have recognized the headset, but the screen of the headset did not turn on. These issues have a negative influence on the intuitive and user-friendly elements of virtual reality.

During the writing of this thesis, finding focused scientific articles based on virtual reality and, more specifically, virtual reality in layout planning was quite difficult. A large number of focused, high-quality scientific articles on the subject were locked behind a fee, therefore, without access to use them. In general, the writing and overall process of the thesis advanced smoothly and at a satisfying level. The communication between thesis stakeholders from both the university and commissioner was active; get-togethers and checkups were held at least once each month to ensure that the thesis progress stayed on flow and needed points are noted. The writing of the thesis went according to the target schedule. The thesis was initiated in late September 2020 and finished in late March 2021. All of the thesis presentations; planning seminar, mid seminar, and final presentation seminar, went according to the planned schedule inside the agreed 6-month period.

According to the feedback of Neles, the processes described in this thesis provide excellent opportunities to use virtual reality in layout modification projects by reaching the objectives set in the early stages of the thesis. The ability to execute layout planning while expanding to new areas is also enhanced by the thesis results and by the virtual environment. The opportunity for functionality and operations development in the future is excellent.

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## Appendix 1: Questionnaire questions and results in Finnish

Aleksi Järvinen  
NELES

11.03.2021

### Virtuaaliodellisuuden hyödyntäminen tehtaan työympäristöjen suunnittelussa

Kyselyn kysymykset sekä vastaukset

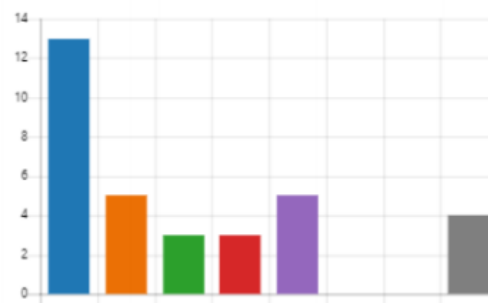
Responses

33

#### 1. Valitse työroolisi

[More Details](#)

● Päällikkö	13
● Työnjohtaja	5
● Kehityshenkilö	3
● Asiantuntija	3
● Työntekijä	5
● Kokoonpanija	0
● Koneistaja	0
● Muu	4



#### 2. Kuinka useasti olet osallistunut työympäristön kehittämiseen?

[More Details](#)

● Olen osallistunut useammin k...	13
● Olen osallistunut 1-5 kertaa	10
● En ole osallistunut	10



#### 3. Haluaisitko osallistua työympäristön kehittämiseen jatkossa?

[More Details](#)

● Kyllä	28
● Ei	5



Aleksi Järvinen  
NELES

11.03.2021

4. Kuinka useasti työympäristön kehittämisen yhteydessä esille on tullut virtuaalitodellisuus?

[More Details](#)

● Useammin kuin 5 kertaa	5
● 1-5 kertaa	10
● Ei ole	18



5. Onko sinulla kokemusta virtuaalitodellisuudesta?

[More Details](#)

[Insights](#)

● Kyllä	21
● Ei	12



6. Oletko käyttänyt virtuaalitodellisuuden laitteistoa aikaisemmin? (Esim. VR lasit)

[More Details](#)

[Insights](#)

● Olen käyttänyt useammin kuin...	7
● Olen käyttänyt 1-5 kertaa	20
● En ole käyttänyt	6



7. Kuinka mukavaksi koit virtuaalilasien käytön? Vastaa vain jos olet käyttänyt virtuaalilaseja. (1 = Epämukavaa ja pahoinvointia ilmeni, 5 = Mukavaa, eikä ilmennyt pahoinvointia)

[More Details](#)

[Insights](#)

27

Responses

4

Average Number

8. Kuinka hyödyllisenä pidät virtuaalitodellisuutta työympäristön suunnittelussa verrattuna aikaisempiin tapoihin? Vastaa vain jos olet ollut osallisena. (1 = Hyödytön, 5 = Erittäin hyödyllinen)

[More Details](#)

[Insights](#)

18

Responses

4.28

Average Number

Alexi Järvinen  
NELES

11.03.2021

## 9. Mitä hyötyjä näet virtuaaliodellisuudesta työympäristön suunnittelussa?

24 Responses

1	Antaa hyvät mahdollisuudet käydä nopeasti välitse eri vaihtoehtoja ja pystyy myös suorittamaan tarvittavat mittaukset menemättä lattialle
2	- Muunneltavuus lennosta - Mahdollistaa kokeilujen tekemisen joustavasti
3	Eri variaatioiden tekemisen helppous.
4	yksityiskohtainen suunnittelu
5	Tilan käyttö pystytään optimoimaan virtualisoimalla tila ja kalusteet / koneet helposti. Antaa myös mahdollisuuden nopeasti kokeilla monenlaisia vaihtoehtoja lay outille.
6	Tilan näkeminen 3D-maailmassa tekee etäisyyksien hahmottamisesta helpompaa. Työympäristön todellisen luonteen hahmottaa täten huomattavasti paremmin VR lasien kautta kuin esimerkiksi AutoCadin 2D mallia tuijottaen.
7	Liikeradat ja mahdolliset esteet on helpompi havaita. Malli luo huomattavasti todellisemmän tuntuksen ympäristön kuin 2D tai normaali 3D malli.
8	Kustannustehokkaampaa kuiin muutoin.
9	Saa paremman käsityksen ympäristöstä
10	Layout kokeilut virtuaaliodellisuutta hyödyntäen voisi olla enemmän mahdollisuus kun uhka. Välttyttäisiin turhilta kompastumisilta.
11	Mahdollisuus kehittää ympäristöä visuaalisesti ja havainnoida se todellisessa mittakaavassa. Mahdollisuus demota tapahtumia animaatioilla. Mahdollisuus liikuttaa toimintoja "käsin" virtuaaliympäristössä. Helppous esittää asioita henkilölle, jolla ei aiempaa kokemusta.
12	Uusien asioiden hahmottaminen on paljon helpompaa tällä menetelmällä ja se toimii hyvänä tukena muiden menetelmien rinnalla.
13	Tarkentaa suunnittelua ja helpottaa päätöksen tekoa eri vaihtoehtojen välillä, kun näkee virtuaalisesti vaihtoehdot.

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14	Voi auttaa hahmottamaan tilantuntua paremmin.
15	Nopeus, havainnollisempi, simulointi helpompaa. Helpompi sisäistää ja ymmärtää muutoksen mahdollisuudet ja uhkat.
16	Virtuaalitodellisuudessa pääsee näkemään lähes todellisen ympäristön. Pääsee muokkaamaan kalusteiden ja laitteiden järjestystä. Siellä pystyy hyvi tarkkailemaan tarvittavan työskentelytilan riittävyttä. Virtuaaliympäristössä pääsee myös lintuperspektiiviin katsomaan kokonaisuutta ylempää.
17	Näkisi paikan paremmin kuin 2D lay-outissa. Sekä jos pystyy näkemään ilma ja sähkövetojen paikat.
18	Helpottaa mallintamista ja mahdollistaa eri vaihtoehtojen kokeilua nopeasti ja edullisesti. Voidaan kokeilla etukäteen ilman todellista toteuttamista
19	Usein tietyt asiat aukeavat huomattavasti paremmin kun saa käsityksen miltä asiat todellisuudessa tulisi näyttämään. Helpottaa varmasti myös suunnittelua kun asioita pystyy mallintamaan todelliseen ympäristöön.
20	Mielestäni virtuaalitodellisuus työympäristöstä on hyötyä suunnittelussa jos kaikki tarvittava mallit koneista, kalusteista on käytettävissä. Lisäksi kalusteiden / koneiden siirrossa virtuaalitodellisuudessa pitää olla riittävä helppo, mutta hyvä tarkkuus oltava hyvä.
21	Ei kokemusta mutta varmaan joitakin asioita pystyy mallintamaan etukäteen ja ei tarvitse mennä aina raskaimman kautta...
22	Eiköhän se anna uudehkoa näkökulmaa layout suunnitteluun yms.
23	Huomaa kenkreettisemmin miltä tilanne näyttää
24	Ympäristön hahmottaminen 3Dnä huomattavasti helpompaa. Selkeämpi ymmärrys työympäristöstä ja ulottuvuuksista ja ergonomiasta.

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## 10. Mitä haittoja näet virtuaalitodellisuudesta työympäristön suunnittelussa?

19 Responses

1	en näe
2	- Kokemisen puute eli käytännössä työskentely suunnitellulla ympäristöllä voi olla vaikea hahmottaa virtuaalisesti.
3	Ei nyt tule oikein mitään mieleen
4	VR ympäristöjen rakentaminen voi olla kallista, riippuu tilanteesta. Täten pitäisi tarkkaan miettiä VR:n tarpeellisuus. Joillakin ihmisillä VR lasit aiheuttavat pahoinvointia
5	Ensimmäinen mallintaminen vie aikaa.
6	Ei kuitenkaan vastaa todellisuutta. Tuotteiden painot vaikea hahmottaa.
7	Mahdollinen panostus, tai panostamattomuus. Saattaa unohtua massaan.
8	Virtuaalisesti suunnitellut toiminnot on analysoitava kriittisesti, jotta ei synny vääristymiä todellisessa käyttötilanteessa --> asiat saadaan näyttämään helpommalta, kuin ne todellisuudessa ovat.
9	Ohjelmistoissa saattaa olla vielä jonkin verran bugeja, mutta korjaantuvat varmasti ajan saatossa.
10	Eipä tule heti mitään mieleen.
11	käyttöliittymät ovat olleet toistaiseksi hieman kankeita
12	"Punainen lanka" voi kadota techno-kikkailun alle, over engineering, kustannukset.
13	En varsinaisesti näe haittaa, mutta haasteena voi olla laitteiden ja kaluston kirjaston laajuus ja sen muokkaus. Onko siellä aina kaikki tarpeellinen.
14	Miten pystytään jakamaan tietoa? Että meneekö siten, että vain muutamilla paikoilla on mahdollista tätä testata?
15	Itse laitteistojen / ohjelmistojen opettelu / hankinta
16	Suunnittelu voi olla huomattavasti hitaampaa.

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17	En näe haittoja, mutta voiko lay-out suunnittelu olla hitaampi verrattuna pahvien avulla tehty tarkasteluun / suunnitteluun?
18	Vääristyneet kuvasuhteet
19	Mittatarkkuus ja muokattavuus ovat vielä puutteellisia, joten vielä tällä hetkellä tietyt asiat on tehtävä 2D-ympäristössä.

### 11. Minkälaisia hyödyntämismahdollisuuksia näet virtuaalitodellisuudelle yrityksessämme? Miten toimintaa tulisi virtuaalitodellisuuden näkökulmasta kehittää?

#### 19 Responses

1	- Mahdollinen virtuaalitodellisuuden käyttö koulutuksessa
2	Tilojen suunnittelun lisäksi, varmaan mahdollisuuksia käyttää apuna esim. kokoonpanotyössä, mittaamisessa, ym.
3	Mielestäni tehtaan layoutin vieminen VR maailmaan oli oikea siirto ja seuraavina steppeinä sen jatkokehitys. Yrityksellä tulisi olla tehtaan layoutista 3D VR malli, sekä mittatarkka ja PÄIVITETTY 2D AutoCad malli.
4	Piilevät epäkäytännöllisyydet tulevat ilmi kun voi testata virtuaalisesti.
5	Tehtaan muutokset helpottuvat.
6	Jo pelkästään palaverien toteuttamisessa VR:llä olisi iso rooli. Mahdollisesti myös asiakastarkastuksissa etc.
7	Tuotekokoonpano linjojen suunnittelussa hyötyä. Kottoritoiminnassa ei niinkään tarpeellinen.
8	Simulointi ja demoaminen asiakkaille ja henkilökunnalle. Tehdasvierailut messuympäristössä. Konekannan mahdollinen kartoitus (kartta!), esim tällä hetkellä ei ole työntekijöille mahdollista saada layout piirustusta missä mikäkin kone sijaitsee.
9	Layoutsuunnittelu, uusien laitteiden / tuotantomallin suunnittelu sekä työhön perehdytys --> esim. työhönopastus virtuaalisesti ennen kuin uusi työntekijä menee varsinaisesti tuotantoon oppiin --> säästetään osaajien resursseja --> mahdollistaa etäperehdytyksen tiettyyn pisteeseen saakka (yleistieto ja työvaiheet).

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10	Layout suunnittelu, uusien tuotteiden rakenteiden kouluttaminen , ihmisten (asiakkaat/työntekijät) kouluttaminen 3D ympäristössä
11	Työympäristöjen kehittämiseen, tavaravirtojen suunnitteluun.
12	Sopii hyvin esittelykäyttöön ja lopputuloksen katselmointiin. Varsinainen suunnittelutyö edistyy nopeammin näyttöpäätteellä.
13	Isot mahdollisuudet varsinkin isompien layout muutoksien simuloinnissa. Hukkien analysointi. AR:ssä ehkä isoimmat mahdollisuudet, perehdyttämiseen, työhjeisiin ym. Kun lasit, projektiot kehittyi. Asennuslaadun kasvu, tehokkuuden kasvu. Hinta varmaan suurin este, laitteistot vielä protoasteella.
14	Virtuaaliympäristöön voisi tulla useampi henkilö, jolloin siellä todellisuudessa näkee kollegan. Näin työympäristö tarkastelusta saa mielekkäämpää. Virtuaaliympäristössä voisi suunnitella laitteiden ja erityisesti koneiden siirtoreittejä layoutmuutoksia tehdessä. Virtuaaliympäristöä voisi hyödyntää laajemmin tuotekoulutuksissa ja kokoonpanoharjoittelussa, laitteiden käytössä. huoltotoiminnassa, tuotteen käyttösovellusten tarkastelussa esim. tuotekoulutuksessa pääsee tekemään kierroksen jossain laitoksessa ja tarkastelemaan tuotteiden asennusta ja toimintaa. Virtuaaliympäristöä voitaisiin hyödyntää myös haasteellisten tuotteiden nostosuunnitelmissa ja kokoonpanotyön valmistelussa.
15	Kyllä tämä menee koko ajan siihen, että olisi parempi jos olisi tällöinen mahdollisuus.
16	Kaikkeen kokoonpanotyöskentelyyn valtavia mahdollisuuksia. Samoin layout muutokset.
17	Tehdaskierrokset.
18	Virtuaalitodellisuuden avulla voidaan pitää tehtaskierros vierailijoilla. Työpisteen käyttäjä voi tutustua myös oman työpisteeseen (lay-out muutoksen yhteydessä) ennen todellista muutosta.
19	Virtuaalitodellisuutta on mahdollista hyödyntää erityisesti myynnissä ja markkinoinnissa, mutta myös tuotesuunnittelussa sekä tehtaän suunnittelussa.

## Appendix 2: Feedback on the thesis by Neles in Finnish

### First feedback:

Olet syventynyt itsellesikin hieman vieraaseen aiheeseen hyvin ja määritellyt toimintamallia uudesta tavasta toimia. Olet ollut innostunut aiheesta ja sen luomista mahdollisuuksista. Opinnäytetyönä määritellyt tehdassuunnittelun prosessit ja ympäristö antaa erinomaiset mahdollisuudet hyödyntää VR:ää tulevaisuuden muutoshankkeissa tehtaalla. Suunnitteluympäristö antaa myös hyvät lähtökohdat uuden tehdaslaajennuksen suunnittelulle. Jokaiselle tilojen käyttäjälle (työntekijä, toimihenkilö) suunnitteluympäristö antaa mahdollisuuden tutustua uuteen toimintaympäristöön ja sen erilaisiin versioihin lähes kuin reaali maailmassa, koska VR:n avulla tilaan voi mennä sisälle ja katsella ympärille. Madollisuus toiminnallisuuden kehittämislle tulevaisuudessa on hyvät.

### Second feedback:

Opinnäytetyössä päästiin hyvin alkuperäiseen tavoitteeseen. Alekski toimi opinnäytetyön ajan oma-aloitteisesti ja itseohjautuvasti, joka teki ohjaajan työn helpoksi. Aleksin toiminnasta huokui selkeä kiinnostus aihealueeseen, joka näkyy myös itse työn tuloksissa. Työ toi esille niin hyviä kuin huonojakin puolia itse teknologiasta, joka tällä hetkellä on vielä hyvin alkuvaiheessa elinkaartaan. Hyviä puolia on selkeä visuaalisuus ja tilan helppo hahmottaminen 3D-ympäristössä. Tämä ei ole nykyisessä 2D-ympäristössä kovinkaan selkeää. Haasteista suurin on teknisen suunnittelun osalta mittatarkkuuden puuttuminen sekä se, että objekteja ei voida muokata suoraan ohjelmistossa. Jos nämä ominaisuudet saadaan tulevaisuudessa osaksi ohjelmistoa, 2D-suunnittelulle voidaan sanoa hyvästit.