Høgskulen på Vestlandet

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Antall ord *:	24024
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Jeg bekrefter at jeg har registrert oppgavetittelen på norsk og engelsk i StudentWeb og vet at denne vil stå på vitnemålet mitt *:	Ja

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MASTER'S THESIS

The Industrial Metaverse - Perspectives from the Automation Industry

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Master of Science in Business: Marketing and Innovation

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Prelude

This thesis represents our final work in the master program MSC - Innovation and Marketing at Western Norway University of Applied Sciences in Sogndal.

These two years have given us challenges, experiences, and friendships we would not want to trade for anything in the world. Being able to dive into almost any type of research you want means a lot for freedom and motivation. Especially as we experienced a growing interest in digital technologies. The future looks exciting, and we feel well-equipped to start this new chapter of our lives.

We would like to take a moment to appreciate our supervisor Atanu K. Nath for being thorough and extremely helpful during writing. We have gotten a lot of constructive criticism that has helped shape this thesis into something that we are very proud of. Then we would also like to extend our utmost gratitude to the participants that set aside time to answer our questions. This would never have been possible without you, and we were honestly surprised by how eager and positive everyone was to participate. Every one of you have made significant contributions to this work!

Abstract

The thesis explores how organizations within the automation industry would implement the Industrial Metaverse and if they see any value in it. To answer the thesis question, 7 participants from 4 organizations spanning 3 continents were recruited. All participants occupied senior roles in their respective organizations. The thesis analyzed each case separately as well as having them compared for further discussion.

The findings and subsequent discussion showed that the paradigm is still in its very early stages and is not actively being implemented in the majority of the cases. However, all cases did see some potential value and benefits by implementing it to varying degrees in the future. They identified the most valuable use cases to be within R&D and sales processes. However, challenges regarding cost, knowledge, standardization, natural interaction, and cybersecurity have to be solved before the Industrial Metaverse can be realized.

This work has contributed to defining both the use cases and challenges of the automation industry within the Industrial Metaverse. It is meant to contribute practically to interview participants and others in the automation industry, providing a nuanced overview of the buzzword Industrial Metaverse. Finally, this thesis may also be used in further development of the enabling technologies and associated applications

Keywords: *Automation Industry, Digital Twin, Industrial Metaverse, Industry 4.0, Simulation, Technology Adoption.*

Sammendrag

Masteroppgaven utforsker hvordan organisasjoner innenfor automasjons industrien kan implementere det Industrielle Metaverset, og om de ser noe verdi i det. For å besvare problemstillingen, ble 7 deltakere fra 4 organisasjoner over 3 kontinent rekruttert. Alle deltakerne hadde sjefsroller i sin organisasjon. Oppgaven analyserte hvert case for seg selv i tillegg til å sammenligne dem for videre diskusjon.

Funnene og påfølgende diskusjon viste at paradigmet fortsatt er i en veldig tidlig fase, og at det ikke aktivt ble jobbet med av majoriteten av casene. Derimot så alle casene noe potensiell verdi og fordeler ved å implementere det Industrielle Metaverset i varierende grad i fremtiden. De identifiserte de viktigste bruksområdene til å være innenfor FoU og salgsprosesser. Det er imidlertid flere utfordringer som må løses før det Industrielle Metaverset kan realiseres. Disse utfordringene er innenfor pris, kunnskap, standardisering, naturlig interaksjon og datasikkerhet.

Dette arbeidet har bidratt til å definere bruksområder og utfordringer for automasjons industrien i det Industrielle Metaverset. Videre er det ment å bidra både praktisk for deltakerne og andre i automasjons industrien, dette ved å bidra til et nyansert bilde av trenden som er det Industrielle Metaverset. Til slutt kan oppgaven bidra til videreutvikling av muliggjørende teknologier og assosierte bruksområder.

Nøkkelord: *Automasjons industri, Digital Tvilling, Det Industrielle Metaverset, Industri 4.0, Simulering, Teknologiadopsjon.*

Content List

1.0 Introduction

This first chapter will give an introduction to the theme, relevant topics, motivation and goal of the thesis. This will then be followed up by defining the research statement as well as introducing the different assumptions and limitations made. Lastly, a disposition of the thesis is given, to help any readers get an overview of what is to come.

1.1 Introduction

The fourth industrial revolution, also known as Industry 4.0, is characterized by the implementation of advanced technologies into traditional manufacturing and industrial practices (Kagermann, 2015). One technology that is rapidly evolving and becoming more important, is Digital Twins (Kagermann, 2015; Kagermann & Wahlster, 2022). A Digital Twin (DT) is a digital representation of a physical object, process, or service, and is used to monitor or predict performance (Liu et al., 2021; Hassani et al., 2022). While DTs are worked with in two-dimensional mediums today, the next step is to interact with them in the metaverse and through three-dimensional mediums (Aloqaily et al., 2022).

The idea of a digital reality can be traced back to the early 80s with the movie “Tron” from 1982 and the Neuromancer novel from 1984 which popularized the term “cyberspace” (McKinsey & Company, 2022). The Metaverse was a term later coined by sci-fi author Neal Stephenson in the novel Snow Crash in 1992, where it is defined as a massive virtual environment parallel to the physical world, in which users get to interact through digital avatars (Lee et al., 2021). This is becoming increasingly important in Industry 4.0 as a way to create new forms of engagement, communication, and commerce (Kagermann & Wahlster, 2022). Transitioning from ideas to novels, movies to games, the technology has indeed gained momentum, making the metaverse a reality instead of fiction for the mid-range wealthy consumer (Radoff, 2021).

The metaverse also has more than one aspect to it, in the Microsoft Ignite (2022, 3:00) youtube video the host distinguished the metaverse into three categories: The Consumer Metaverse, the Commercial Metaverse, and the Industrial Metaverse. Arguably, the Consumer Metaverse has been one of the major driving forces for developing enabling technology for the Metaverse. Because of these developments, the Industrial Metaverse is gaining a lot of interest (McKinsey & Company, 2022; Aloqaily et al., 2022).

The motivation for this research comes from the growing attention and investment in the Metaverse, as well as the potential for it to significantly impact various aspects of the industry such as employee engagement, customer experience, and product innovation (McKinsey & Company, 2022). Additionally, in a recent survey administered by Mckinsey & Company (2023), shows that companies around the world are likely to spend up to 25% of their capital over the next five years on robotics and automation. Furthermore, recent breakthroughs in technology development including 5G, Artificial Intelligence (AI), and Virtual Reality (VR) (Jiang. et. al., 2022) are causing investors to pour billions of dollars into its further development and seem excited about its emergence (McKinsey & Company, 2022). In fact, it's arguably one of the most discussed and anticipated technologies to date.

Prior research on Industry 4.0 has explored the implications of smart manufacturing for the industry, but research on the Metaverse in the industry is scarce. This study aims to address this gap in knowledge by exploring the potential impact of the Metaverse on the automation industry. One point where we know the Metaverse and Industry 4.0 share common ground is in the use of Extended Reality (XR) technologies such as Augmented Reality (AR) and VR. Therefore, the purpose of this study will be to examine the potential impact of the Metaverse on the automation industry, specifically in the context of Industry 4.0.

Industry 4.0 has been heavily researched in recent years (Kagermann & Wahlster, 2022; Lasi et al., 2014), and the Internet of Things (IoT) and Cyber-physical Systems (CPS) have broadly become more familiar terms among practitioners in the automation industry. In newly built factories, adopting these bridging technologies is the new high-end standard as it improves various aspects like increased quality control and efficiency (Kagermann & Wahlster, 2022). The use of DT simulations is growing and is expected to have an even bigger impact in the future (Kagermann & Wahlster, 2022). In terms of the Metaverse it can be understood as an expansion of the DTs in the field of people and society (Lv et. al., 2022).

By applying the Metaverse to industry applications, the Industrial Metaverse can hold many key advantages for manufacturers. These advantages may range from better visualization of systems, easy adjustments on large-scale systems, and enhanced collaboration and learning among employees, (Lee & Kundu, 2022; Ghobakhloo, 2019; Mystakidis (2022). In a broader sense, research points to an improvement in interaction, instruction, indoctrination, investigation, and control (Lee & Kundu, 2022). In summary, there are many ‘smart factories’ that incorporate basic principles of Industry 4.0 and are searching for the next big thing. The Industrial Metaverse technologies are still under development and certainly have the potential to impact the automation industry in various ways within the near future.

The main contribution of this thesis is to provide a deeper understanding of the potential impact of the Industrial Metaverse on the automation industry and to identify specific ways in which companies can leverage the technology for their benefit. Additionally, the study aims to contribute to both practice and theory by identifying the specific ways in which companies can leverage the Industrial Metaverse for their benefit and by examining the value of the technology in the automation industry.

1.2 Research statement

As the title reveals, this thesis seeks to explore the current value of the Industrial Metaverse. Because of the Metaverse’s vague definition and constant evolution, an assessment of its value based on industry feedback and research papers can be helpful information for companies thinking of adopting such technology.

With this in mind, the paper has chosen the following research statement:

“How can the Industrial Metaverse be implemented in the automation industry, and what is the value of the technology in this context?”

To help answer the thesis statement a few sub-questions have been devised. By answering the sub-questions, a good foundation to answer the thesis statement will be formed. The thesis will use the TOE framework by Tornatzky & Fleischer (1990) to help cover the most important aspects of technology diffusion in organizations. More about the TOE (Technological, Organizational, and Environment) framework will be discussed in the literature review. Each subquestion will represent one of these contexts, which results in these three subquestions:

Technological context:

SQ1: What technical capabilities and features does the Industrial Metaverse offer that can be implemented in the automation industry?

Organizational context:

SQ2: How do organizations in the automation industry organize themselves to implement the Industrial Metaverse, and what are the key challenges they face in doing so?

Business environmental context:

SQ3: How do external factors influence the implementation and perceived value of the Industrial Metaverse in the automation industry?

1.3 Assumptions and limitations

This research will be conducted within a timespan of about 5 months. This limits our ability to monitor the current development in technology trends to which we draw more accurate conclusions. Additionally, because of the time limitation primary data collection may not prove sufficient in forming completely valid results.

The participants are recruited through the professional network of case 1, which is knowledgeable on the topic. With this in mind, another issue arises, as other participants may not have a sufficient understanding of the particular topic that is being investigated.

It is important to emphasize that the themes of this paper are volatile and still evolving. Therefore, the content of this thesis must be understood in the context of the present day. As it stands, the aforementioned Consumer Metaverse is not doing too well. According to the report results by Anderson & Rainie (2022), 46 % of experts' predictions on the trajectory of the Metaverse expect that the technology will not be much more refined or truly immersive by 2040. One assumption then, is the question of whether the same underlying factors that limit the success of the gaming or Consumer Metaverse, also have an effect in the Industrial Metaverse.

1.4 Disposition of the paper

This marks the end of chapter 1, the introduction. Before reading on, a brief overview of the paper's disposition will be presented. In Chapter 2, the literature review will in depth explain the most important concepts for understanding the thesis statement. Mainly, this will consist of presenting theory and literature related to the Metaverse and Industry 4.0. In chapter 3, the thesis will present the research method that is used and how we proceed with our scientific approach to the chosen topic. Within this chapter, a description of the qualitative research method, the chosen data collection method, and the reasoning of the questionnaire will be presented. Then the data collection will take place following the discussion of the case selection method. To finish this chapter, the thesis will be discussing the validity and reliability of the data. Chapter 4 will discuss the results and completion of the interviews. Then in chapter 5, there will be a discussion answering the sub-questions based on findings and theory. Finally, in chapter 6, the thesis will arrive at its conclusions and explain its theoretical and practical implications.

2.0 Literature review

This chapter serves to explain the theoretical background of the thesis. All of the theories necessary to comprehend the thesis' value and discussions will be included and explained. Therefore, the thesis includes theory about Industry 4.0 which serves to explain the context, the Metaverse, and its industrial value. Lastly, the TOE framework serves as a structural framework for the thesis.

2.1 Industry 4.0

Industry 4.0, also referred to as the fourth industrial revolution, was first introduced as part of Germany's cutting-edge technology program for the industrial sector (Kagermann et al., 2013). The previous three industrial revolutions brought about mechanization, the utilization of electricity, and digitization in manufacturing. Industry 4.0 now incorporates smart objects in the form of machines and products into the industrial sector (Lasi et al., 2014). Challenges posed by general economic, political, and societal factors have prompted this paradigm shift. More specifically the adoption of Industry 4.0 is driven by the need for shorter development periods, on-demand individualization, flexibility, decentralization, and resource efficiency (Lasi et al., 2014). By solving these challenges, companies can gain significant competitive advantages. For example, solving the need for shorter development periods and decentralization will lead to a lower "time to market" for products, allowing companies to react quickly to new trends and capitalize on them (Lasi et al., 2014). Since Industry 4.0's first introduction in 2011, many companies have actively worked toward its adoption (Kagermann & Wahlster, 2022). Mainly, these are larger companies with a lot of funds to invest in the development of their factories. A study from Norway shows that the oil and gas industry is at the forefront of Industry 4.0 adoption in Norway, with other industries and particularly SMEs (small & medium-sized enterprises) falling behind (Mogos et al., 2019). SMEs have been shown to be the ones struggling most with adopting Industry 4.0 technologies, but they are also the most important to get on board the adoption process (Stentoft et al., 2019; Matt et al., 2020).

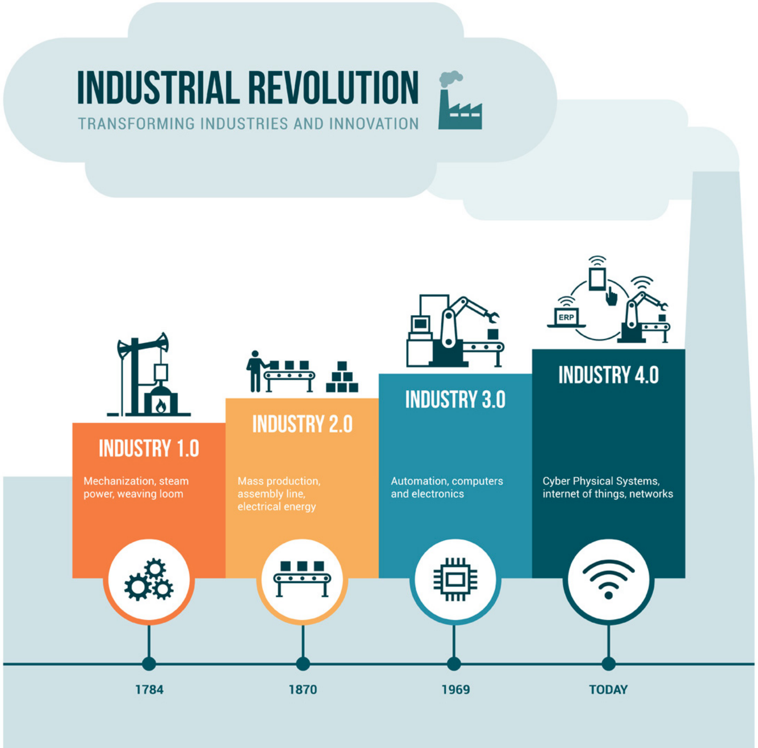

Figure 1. Illustration from the fourth industrial revolution by Klaus Schwab (2017).

2.1.1 Enabling technologies of Industry 4.0

The implementation of "smart objects" in the industrial sector is made possible by the Internet of Things (IoT), specifically its industrial adaptation, the Industrial Internet of Things (IIoT) (Sisinni et al., 2018). IoT involves connecting everyday items like lamps and speakers to the internet, while IIoT focuses on connecting machines to information technology and business processes (Sisinni et al., 2018). This allows for the collection of large amounts of data, providing executives with more information to make decisions.

Cyber-physical systems (CPS) integrate computation in machines, where embedded computers and networks monitor and control the physical processes (Lee, 2008). Thanks to integrated computing such as sensors and actuators, the physical machine and its processes can be recreated in a digital environment to the point where it is indistinguishable from software (Lasi et al., 2014). This results in the creation of a digital representation of the machine, known as a "Digital Twin," which can be used for testing, preventative maintenance, and more (Sisinni et al., 2018; Lasi et al., 2014; Liu et al., 2021). Thanks to advanced machine learning and artificial intelligence (AI) techniques, DTs are becoming more sophisticated and capable of handling increasingly complex systems and processes. leading to improved efficiency, reduced downtime, and increased profitability for automation industries (Barricelli et al., 2019).

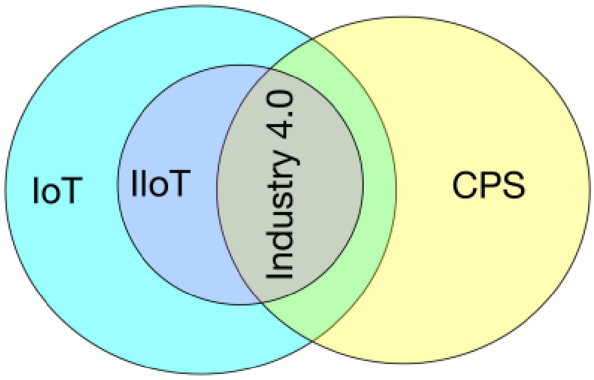

Figure 2. IoT, IIoT, Industry 4.0, and CPS are illustrated in the Venn diagram by Sisinni et al. (2018).

CPS and IIoT are key components of Industry 4.0, as illustrated in figure 2, and together they form the foundation from which the Industry 4.0 paradigm emerges (Sisinni et al., 2018). IIoT brings the notion that all parts of the production should be connected with other machines and people in the factory, while CPS allows for physical processes to be communicated, monitored, and controlled digitally (Lee, 2008; Sisinni et al., 2018). This allows the needs mentioned earlier to be met. However, these technologies are not easy to implement, requiring the integration of various information, digital, and operation technologies (IDOT) (Sisinni et al., 2018; Wan et al., 2016; Ghobakhloo, 2020).

However, CPS and IIoT are not the only enabling technologies, there are many technologies that make up the Industry 4.0 paradigm. They can all be characterized by one or several design principles; decentralization, horizontal integration, vertical integration, interoperability, modularity, product & service individualization, real-time capability, service orientation, smart factory, smart product, and virtualization (Ghobakhloo, 2020). Some of the more known technologies include additive manufacturing (3D printing), artificial intelligence (AI), cloud computing, simulations, and autonomous robotics.

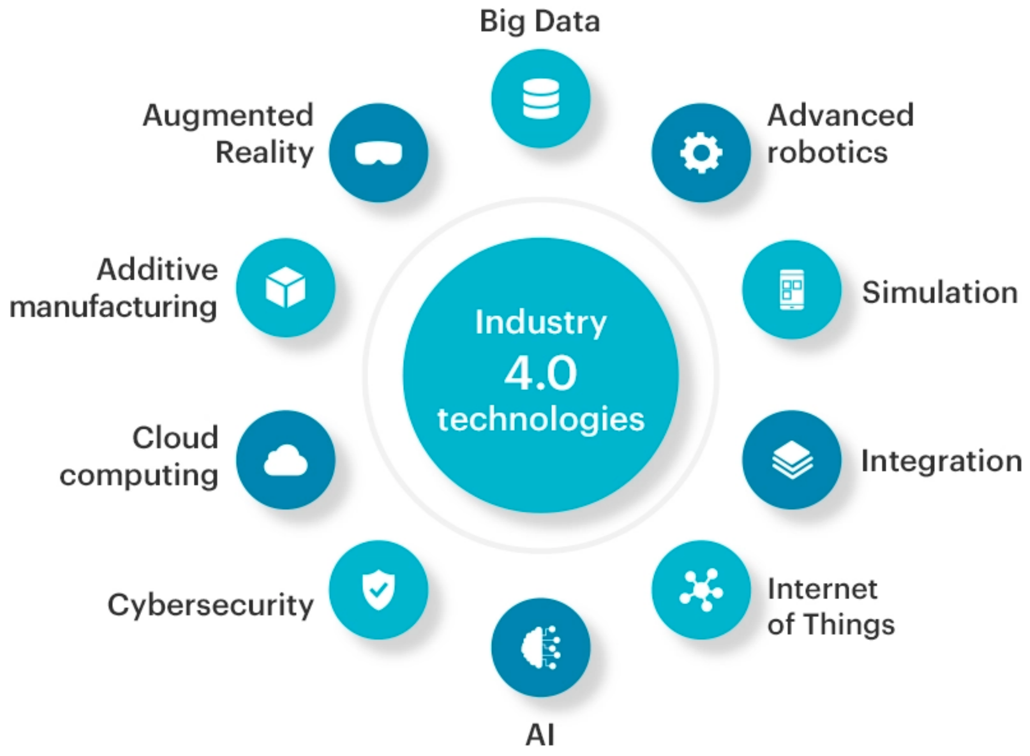

Figure 3. Industry 4.0 technologies (Business Process Incubator, 2022).

While the figure is far from exhaustive of technologies in Industry 4.0, there are some other Industry 4.0 technologies worth mentioning; DT, RFID, nanotechnology, CPS, VR, semantic technologies, and computer-aided design (CAD) (Ghobakhloo, 2020; Bai et al., 2020; Dalenogare et al., 2018).

DT especially is a technology that has gained significant attention in Industry 4.0 due to its potential to bridge the physical and digital worlds (Liu et al., 2021; Hassani et al., 2022). It involves creating a virtual representation of a physical product, process, or system that is continuously updated with real-time data from the physical counterpart. As mentioned before, this enables real-time monitoring, control, and optimization of physical systems, leading to improved efficiency, reduced downtime, better sustainability, and lower maintenance costs (Barricelli, 2019; Pires et al., 2019; Hassani et al., 2022). However, the successful implementation of DTs requires the integration of multiple technologies, including IoT sensors, cloud computing, AI, and simulation models (Liu et al., 2021; Pires et al., 2019). Additionally, data security and privacy issues need to be addressed to ensure the protection of sensitive information collected from the physical systems. Therefore, businesses should carefully evaluate their specific needs and capabilities before adopting DT technology as part of their Industry 4.0 strategy (Barricelli, 2019).

Most Industry 4.0 technologies, just like DTs, rely on and are interdependent on other technologies. Therefore, the key to successful implementation lies in understanding and integrating the technologies that solve the businesses' specific needs (Ghobakhloo, 2022). Because of this, adopting only one Industry 4.0 technology does not mean that a business is Industry 4.0 compliant. For businesses where it makes sense to use DTs and XR technologies, they might consider diving into the Metaverse.

2.1.2 Future of Industry 4.0

The integration of CPS and IIoT is already prevalent in newly constructed industrial facilities and has been gaining traction in existing facilities as well (Kagermann & Wahlster, 2022). However, many industrial facilities in developing nations are yet to catch up due to a lack of infrastructure, competence, and national support (Raj et al., 2020). Despite this, researchers and market leaders are always looking to develop and implement cutting-edge technologies (Lasi et al., 2014; Kagermann & Wahlster, 2022).

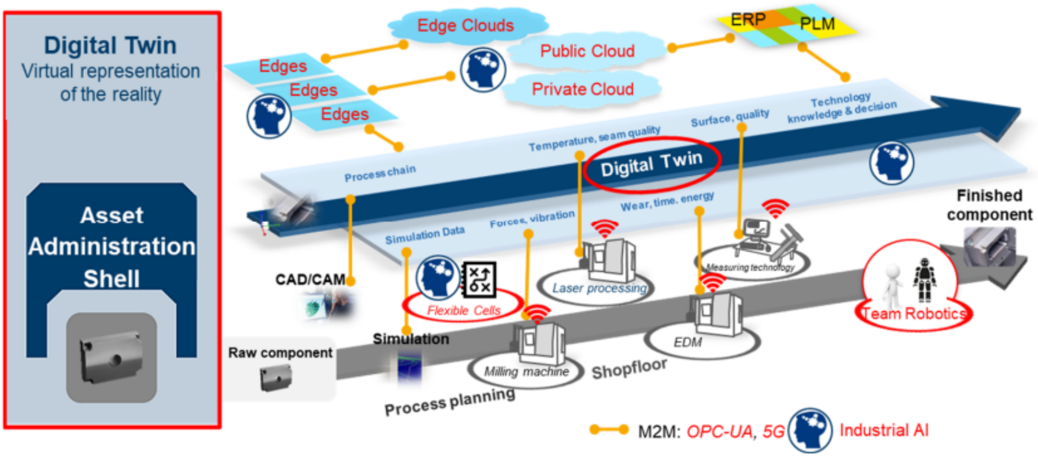

Figure 4. Future megatrends of Industry 4.0 by Kagermann & Wahlster (2022).

Kagermann & Wahlster (2022), the pioneers behind the term "Industry 4.0", have identified the potential future megatrends in Industry 4.0 (or Industry 4.1). The six megatrends are Industrial AI, Edge computing, 5G technology, Team Robotics, autonomous intralogistics systems, and trustworthy data infrastructures. Given that DTs are predicted to be an important enabler for many of these in production planning, the need to interact with them also arises. The question then is if interaction through traditional computers is enough, or if the Industrial Metaverse can solve the need for added interaction.

2.2 What is The Metaverse?

The Metaverse was first coined in 1992 and has in recent years gained a lot of attention among consumers, businesses, and academics, see figure 5. It builds on three previous technological innovation waves that most people are familiar with (Mystakidis, 2022). This includes the introduction of the personal computer, the internet, and mobile devices. Further research and development in the competitive technology market have led to the interest in spatial and immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). As a result of converging technologies that enable multisensory interactions with digital environments, objects, and people, the Metaverse is considered a new paradigm within computer science innovation (Mystakidis, 2022). Within this space, users will be immersed in a post-reality universe that merges physical reality with digital virtuality in real time (Mystakidis, 2022; Radoff, 2021). In accordance with previous data science revolutions, this paradigm proposes new implications for everyday life by changing and enhancing communication, interactions, and social transactions.

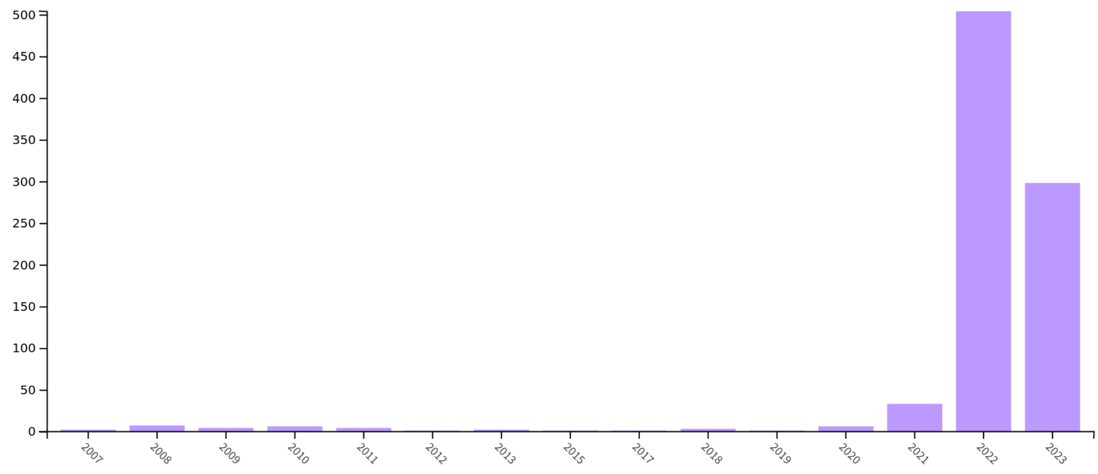

Figure 5. Published articles on “Metaverse”. Retrieved from Web of Science 18.05.2023.

2.2.1 Extended reality

To understand the makeup of the Metaverse, one must comprehend the key concepts of VR, AR, and MR. This is what the Metaverse is based on and is widely recognized under the umbrella term Extended Reality or Cross Reality (XR) (Mystakidis, 2022; Lee et al., 2021). XR can be understood as multiple immersive technologies that range from partial immersion experiences to near-complete immersion in a digital environment with the use of multi-sensory equipment.

The latter is located at one end of the XR spectrum, known as VR, where the user utilizes specialized equipment to access a virtual environment. A VR system places a participant into a digital 3D environment world (Slater & Sanchez-Vives, 2016; Alpala et al., 2022). It does so by exposing perspective-projected images to each individual eye, forming the correct parallax (Slater & Sanchez-Vives, 2016), and giving the participant a sense of depth. Additionally, head tracking should further update what the participant will hear and see, but also have the ability to interact with the world through the use of for example 3D tracked gloves or some type of controller (Slater & Sanchez-Vives, 2016). VR is also believed to be a good platform for learning and interacting in virtual worlds, while still being relatively low-cost (Alpala et al., 2022).

On the other side of the spectrum, there is AR, which involves superimposing digital information onto the real-world environment, creating a blend of real and virtual objects in real-time (Bimber & Raskar, 2005; Azuma, 1997). AR devices can be in the form of mobile devices, smart glasses, or head-mounted displays, which overlay digital graphics and sensory input over the real world (Bimber & Raskar, 2005; Azuma, 1997). Unlike VR, AR does not completely replace the real world, but rather enhances it with additional information, and allows for a greater degree of interaction between the digital and the physical world. AR is a rapidly growing field and has numerous potential applications in areas such as education, gaming, tourism, and more (Azuma, 1997; Mekni & Lemieux, 2014).

Lastly, there is also Mixed Reality (MR) which is a hybrid of VR and AR, where virtual and real objects co-exist and interact in a shared environment (Mystakidis, 2022; Lee et al., 2021).

2.2.2 Enabling technologies for Metaverse

Alongside XR technologies, which are most frequently associated with the Metaverse, there are also several other technologies enabling it. These technologies are AI, blockchain, computer vision, 5G networking, edge computing, user interactivity, and lastly IoT (Lee et al., 2021). Interestingly, the Metaverse shares many of the same enabling technologies as Industry 4.0. The two technologies that differ are computer vision and user interactivity technologies.

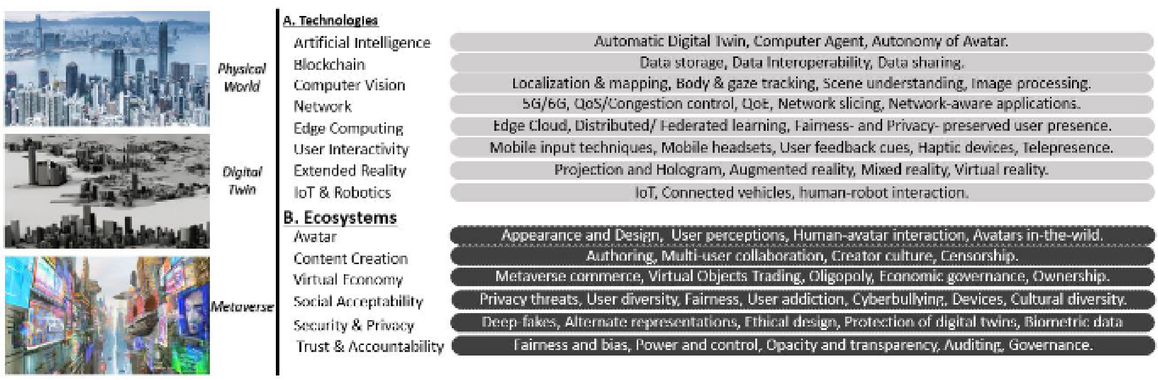

Figure 6. Technologies and considerations in different ecosystems of the Metaverse (Lee, 2021).

Computer vision in the Metaverse is about mapping and recognizing the environments around the user, tracking body movements or facial expressions, and lastly, image processing (Lee et al., 2021). Computer vision can among other things be used to track your expressions and movement, and then mimic it on your digital avatar (Meta, n.d). Computer vision is used alongside robots for tracking products and people, but also for quality control (Villalba-Diez et al., 2019; Javaid et al., 2022). Often computer vision is embedded as sensors, so this technology would be categorized as a part of CPS (Lee, 2008).

User interactivity technologies include mobile input techniques, mobile headsets, haptic devices, and the yet visionary idea of telepresence (Lee et al., 2021). Some of these might provide value in the industrial context. Mobile input technologies try to explore new ways to interact with digital interfaces, for example through fabric or embedded chips in your arm (Lee et al., 2021). Mobile headsets on the other hand are exploring ways to display these interfaces through mobile technologies, most common must be standalone headsets like the Oculus Quest Pro which has its own mobile processing unit. This means that it does not have to be connected to external hardware like computers (Meta, n.d). However, mainstream XR devices used to access the Metaverse may be emerging in the form of contact lenses or brain computers (McKinsey & Company, 2022). Lastly, haptic feedback technologies can simulate the touch, feel, and impact of digital assets (Lee et al., 2021). For VR gaming, haptic vests, gloves, and even full-body suits have been developed (Israr et al., 2012).

As we can see, the Industrial Metaverse and Industry 4.0 paradigms share many of the same enabling technologies, but are mostly differentiated by use case. In a way, Industry 4.0 is revolutionizing the industrial workspace, while the Metaverse is trying to revolutionize the way we consume and interact with the internet. Both are enabled by the same underlying technologies.

2.2.3 Layers of the Metaverse

Radoff (2021) published an article on the Metaverse value chain. Here, the Metaverse is divided into seven layers as shown in figure 7. In black and gray we can see that the enabling technologies from the previous paragraph are listed. In dark blue, we see that XR and software solutions are connecting the enabling technologies to the Metaverse ecosystem. The ecosystem represents the layers that users will interact with, where they can experience, discover and create (Radoff, 2021; Duan et al., 2021).

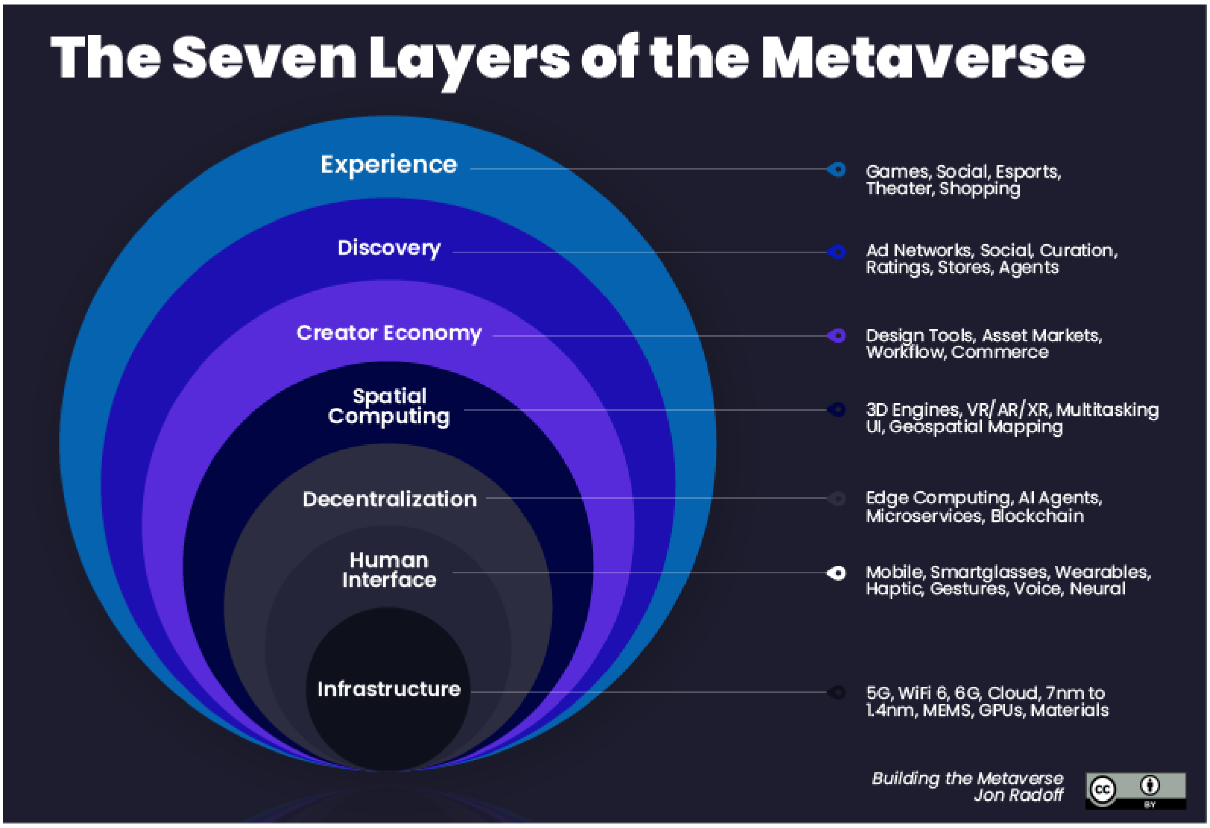

Figure 7. The seven layers of the Metaverse (Radoff, 2021).

While Radoffs (2021) illustration is very comprehensible and displays the different layers of the Metaverse, the thesis requires more of a macro perspective on the layers of the Metaverse. In the paper by Duan et al. (2021), the 7 layers were reduced to three main layers; infrastructure, interaction, and the ecosystem. In addition, it shows how infrastructure is based in the physical world while the ecosystem is based in the virtual world. Meanwhile, interaction is the intersection between them (Duan et al., 2021). The macro perspective of the Metaverse can be seen in figure 8 below.

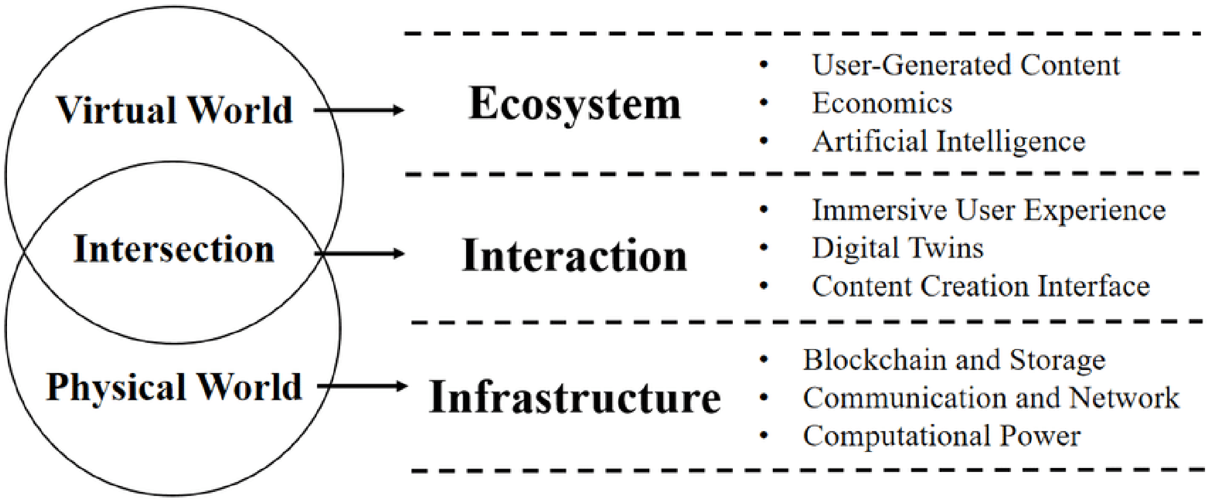

Figure 8. Macro view of the Metaverse (Duan et al., 2021).

A key takeaway from these models is that the mediums of interaction between the virtual and physical world need not only be with XR technologies or graphical means (Duan et al., 2021; Radoff, 2021). The immersive user experience that gives the Metaverse value also comes from social immersion and the interaction between users (Radoff, 2021). The Metaverse will likely have many use cases, from education and patient counseling to sales and industry demos (Mystakidis, 2022; Lee et al., 2021; Radoff, 2021; Duan et al., 2021; Hennig-Thurau & Ognibeni, 2022). While interaction and infrastructure will remain largely unchanged between the different use cases, the thesis suggests that the ecosystem layer will be very different. And perhaps this is where the value creation for the automation industry will happen. If so, how does the macro perspective of Metaverse in the automation industry look?

2.3 The Industrial Metaverse

Microsoft has defined three realms also called areas of innovation within the Metaverse. These are the Consumer Metaverse (gaming, social experiences, and entertainment), the Commercial Metaverse (immersion and collaboration in the work environment), and lastly the Industrial Metaverse (Microsoft Ignite, 2022, 3:00). Microsoft defines the Industrial Metaverse as a paradigm that "enables humans and AI to work together to design, build, operate, and optimize physical systems using digital technologies" (Microsoft, 2023, 5:40). The Industrial Metaverse is not only a term used by Microsoft, but is also emerging in academic papers. Just recently, IEEE issued a call for papers on the Industrial Metaverse for smart manufacturing (IEEE, 2023).

The article by Lee & Kundu (2022) presents the concept of the Industrial Metaverse specifically for smart manufacturing systems and highlights the potential advantages and challenges associated with implementation. They define the Industrial Metaverse application as “a systematic discipline which combines hardware, e.g. sensors, VR headsets, data conversions through analytics/machine learning, time histories through cyberinfrastructure, cognition through human-machine interface and configuration through the metaverse” (Lee & Kundu, 2022, p. 1).”

To put this definition into simpler terms, the Industrial Metaverse application is a way of using technology to connect physical objects like sensors and VR headsets. This technology can analyze data and learn from it, keeping track of what happened in the past. It also allows people to interact with machines in a more natural way. Finally, the application can be customized to fit specific needs through the use of a digital space of the Metaverse.

The paper by Zheng et al. (2022) discusses the connotation of the Industrial Metaverse, its features, technologies, applications, and challenges. Their work suggests a different definition, which is that the “Industrial Metaverse is a new man-in-loop digital twin system of the real industrial economy, through the interconnection of industrial digital resources, supported by DT, XR, NFT, NLP, as well as AI technologies, and driven by real-time information in the industry” (Zheng et al., 2022, p. 240).

Their suggested definition also emphasizes that the Industrial Metaverse digitally simulates aspects of the industrial economy, including workers, equipment resources, production, maintenance, and trade (Zheng et al., 2022). By combining different technologies and resources, the Industrial Metaverse creates a collaborative space where people can work together and manage industrial products throughout their life cycle (Zheng et al., 2022).

Both definitions of Lee & Kundu (2022) and Zheng et al. (2022) share the common emphasis of leveraging technology to improve industrial processes and create more efficient and collaborative workspaces. Specifically, they both focus on the technology that enables real-time human-machine interaction and social collaboration within an immersive digital space.

2.3.1 Why is the Industrial Metaverse different?

But how does the Industrial Metaverse differ from the other technologies mentioned? The work of Zheng et al. (2022) continues to help distinguish between the Industrial Metaverse and simulations, DTs, and the normal metaverse, by listing unique features of the Industrial Metaverse. Figure 9, derived from Zheng et al. (2022), presents these differences visually in a venn diagram.

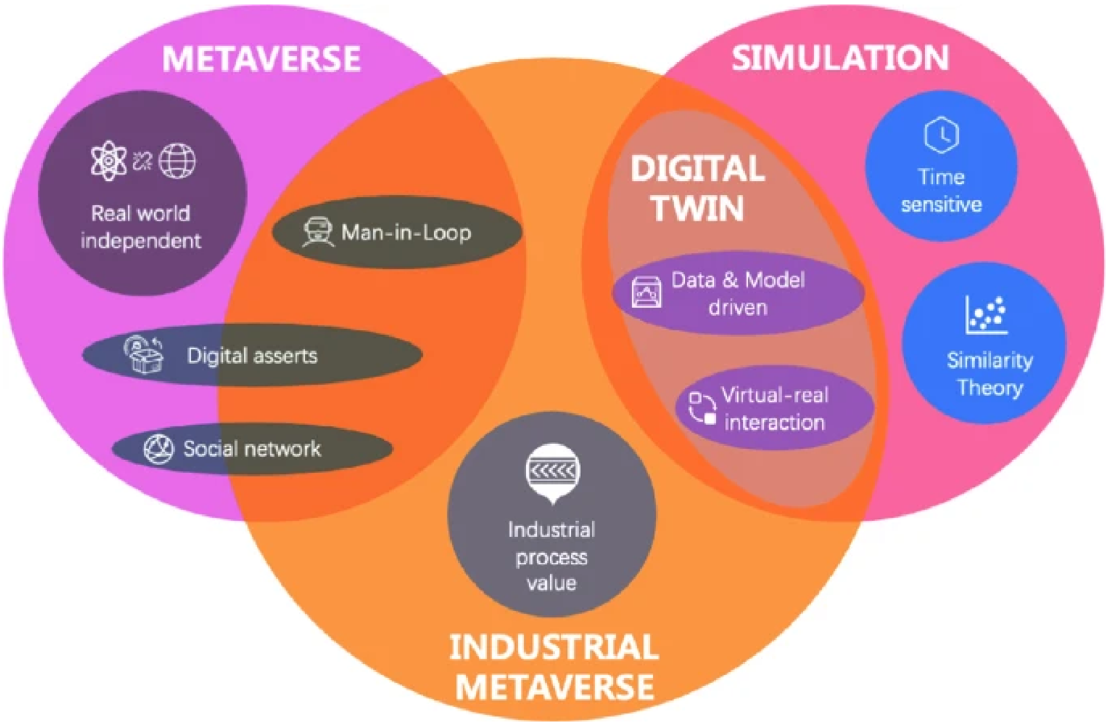

Figure 9. The relationship between Industrial Metaverse, DT, and simulation (Zheng et al., 2022).

Firstly, the man-in-loop feature means that workers become able to work on the entire stages, like product development, design, and production, through digital avatars (Zheng et al., 2022). By being “in-loop”, it is understood as humans being a part of a process and are capable of making important decisions that need human reasoning and interaction. Furthermore, different processes impact the quality, cost and lifetime of products. To create digital representations of industrial products in the Industrial Metaverse, it also becomes necessary to include information about the manufacturing process as a part of the identification of the product. By doing this companies can create a digital stand-in that accurately represents their product and allows them to explore new ways to improve their manufacturing process (Zheng et al., 2022).

As an important component of the Consumer Metaverse, social networking is also vital in the Industrial Metaverse segment. The feature allows for workers to communicate and collaborate in the shared virtual space. Another important feature pointed out by Zheng et al. (2022) within B2C situations, customers can connect to the Industrial Metaverse to experience an immersive tour of the industrial production line. Another distinct feature of the Industrial Metaverse is what Zheng et al. (2022) call virtual-real interaction, which is about how the technology allows people to virtually interact with industrial entities in an immersive way. This opens up for many of the desired industrial benefits such as increased efficiency and quality in teamwork and problem-solving among workers and ultimately saves costs in certain areas of operations (Zheng et al., 2022).

The Industrial Metaverse also contributes to decentralization in the industrial world, which means that the distribution of power or the decision-making authority will be in the hands of individual enterprises and users (Zheng et al., 2022; Deloitte China, 2022). From a financial perspective, this is archived through the mentioned blockchain technology NFTs and other decentralized finance tools. This technology can improve both financial security and transparency by eliminating intermediaries and providing unchangeable records of transactions (Zheng et al., 2022). Through the lens of the industrial perspective, decentralization can prevent monopolies and enhance innovation, competition, and collaboration (Zheng et al., 2022). Lastly, while a higher dimensional space is the end goal of the Industrial Metaverse, it is theorized to first appear as many scattered metaverses for each industry (Jiang et al., 2022; Deloitte China, 2022).

2.3.2 Key technologies

The Industrial Metaverse naturally builds on all of the enabling technologies of Industry 4.0 and the Metaverse. There are four main types of technologies defined by Zheng et al (2022). These four are natural interaction, industrial process simulation, industrial value realization, and large-scale information processing and transmission. Drawing parallels to Duan et al. (2021) macro perspective of the Metaverse, industrial process simulation technologies form the ecosystem in which one wants to interact with. Natural interaction technologies are the means to interact with the virtual ecosystem, while the industrial value realization technologies and large-scale information processing and transmission form the infrastructure.

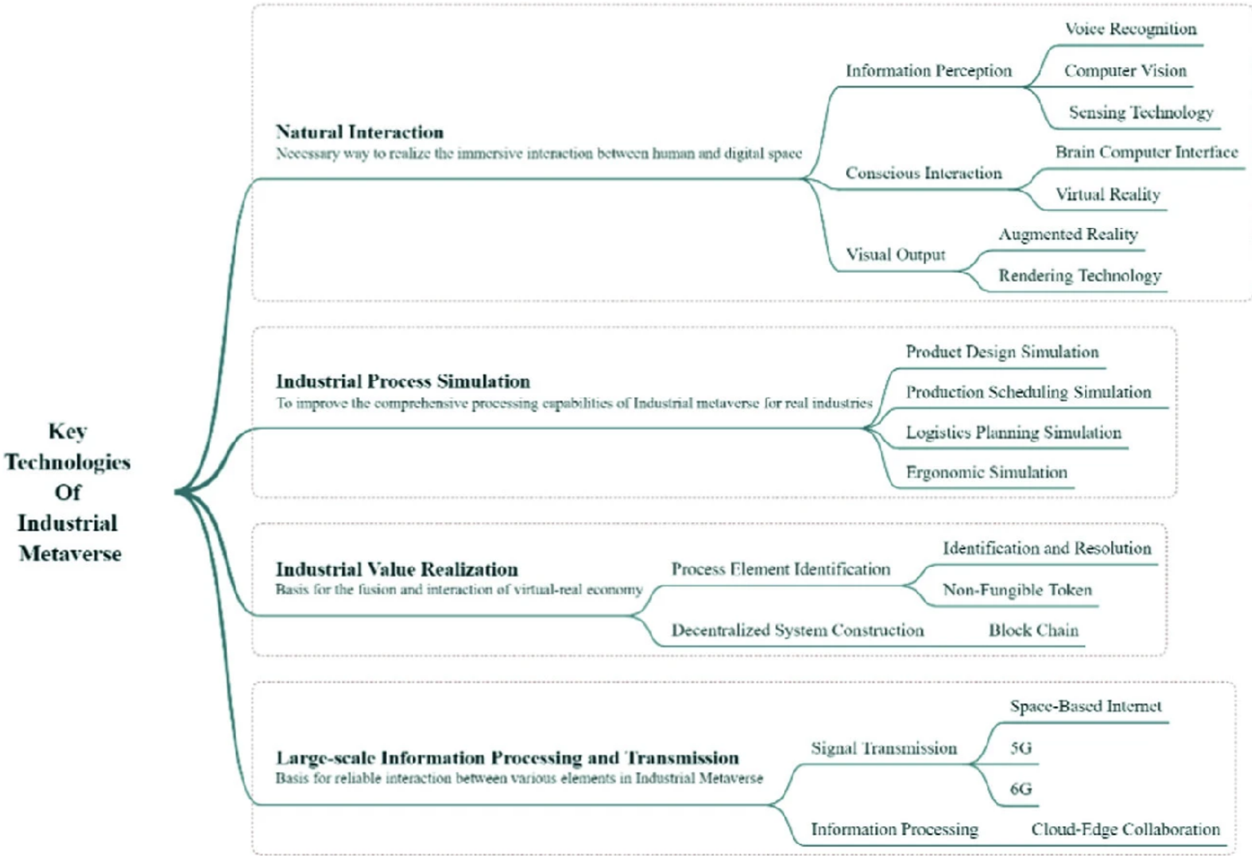

Figure 10. Key technologies of the Industrial Metaverse (Zheng et al., 2022).

2.3.3 Applications

Furthermore, Zheng (2022) created an overview of some future predicted applications of the Industrial Metaverse. The model represents the level of system granularity on the X-axis and the product life cycle on the Y-axis. What strictly separates the Industrial Metaverse application from the likes of DTs, CPS or XR systems is the inclusion of man-in-loop interaction and industrial value transaction (Zheng et al., 2019). For example, having virtual user participation in the design process, defined as R&D Virtual Crowdsourcing, can help suppliers clearly define features and solutions already in the design process. Examples of prototypes on the Industrial Metaverse today are Siemens Xcelerator + NVIDIA Omniverse, BMW iFactory, and NASA JPL’s Metaverse (Jiang et al., 2022).

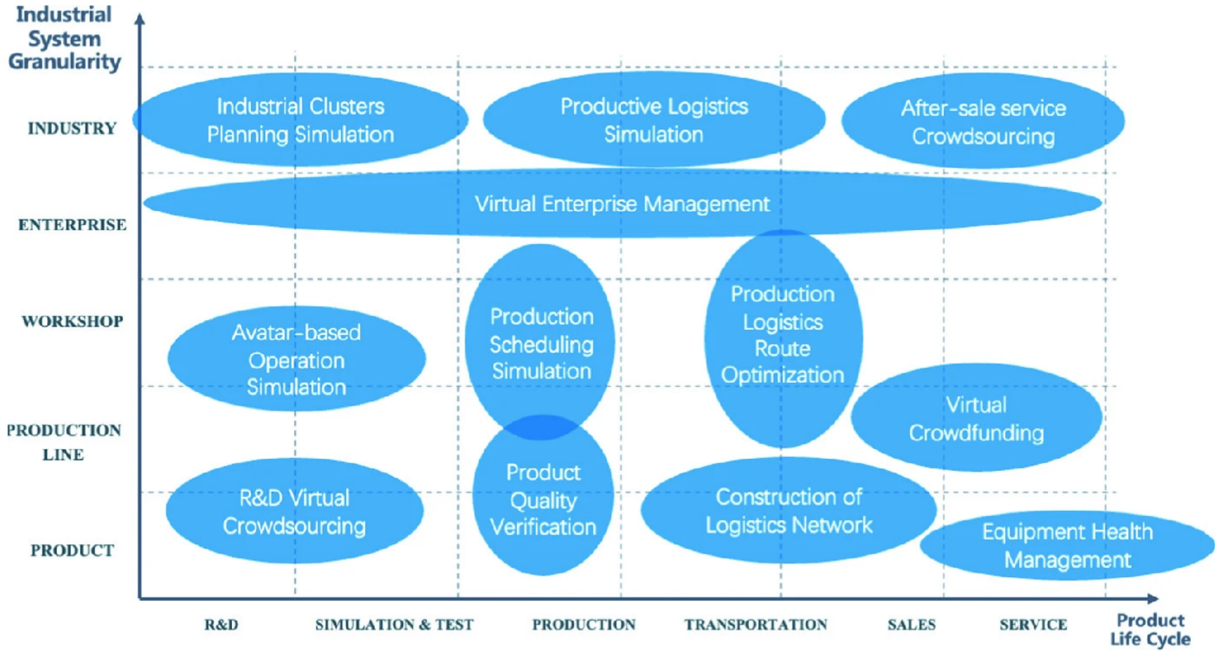

Figure 11. Part of the predictable future applications of the Industrial Metaverse (Zheng et al., 2022).

2.3.4 Challenges

Finally, Zheng et al. (2022) identify a few challenges from a technological, application, and ecology perspective. In terms of hardware and XR software, there is the issue of achieving natural interaction between workers and engineers in a minimally invasive way within the Industrial Metaverse (Zheng et al., 2022). The amounts of industrial processes are complicated and detailed. Hence, it requires detailed, accurate, and functional models in order to simulate (Zheng et al., 2022). When it comes to industrial value realization, there is the issue of identifying and pricing digital assets in an acceptable and safe way (Zheng et al., 2022). Finally, to support all of the Industrial Metaverse users, this whole paradigm has to be based on a sound foundation that facilitates a highly effective transmission of information to ensure the immersive experience (Zheng et al., 2022). Challenges regarding the application of the Industrial Metaverse, are mainly about figuring out the user-centered digital system that all users can utilize across industries (Zheng et al., 2022). However, this might take a long time as some argue that most people cannot keep up with the rapid evolution of digital technologies such as the Metaverse (Figueiredo, 2022) And finally, there is the challenge of technology ecology, meaning that the different key technologies have not yet matured and are still under development (Zheng et al., 2022).

In conclusion, the concept of the Industrial Metaverse is a rapidly developing area of research that holds great promise for revolutionizing the industrial world. With its unique features and benefits, the Industrial Metaverse is set to play a significant role in smart manufacturing systems, offering new opportunities for collaboration, communication, and cost savings. While there are still many challenges to be addressed, including issues of data privacy and security, the potential of the Industrial Metaverse to reshape the industrial economy cannot be ignored. As companies continue to invest in the technology and researchers explore its potential, it is expected to see many exciting developments in the years ahead.

2.4 The TOE framework

With the advent of new technologies and the rapid pace of change in the business world, organizations are facing new challenges in adopting and implementing innovative technologies. To address this issue, researchers have developed several frameworks to better understand what influences businesses to adopt and implement new technologies. One of these frameworks is the TOE framework.

According to Tornatzky & Fleischer (1990), there are three elements of an organization's context that influence the process by which it adopts and implements technological innovations. This includes the technology context, organizational context, and the environmental context. The TOE framework suggests that the adoption of new technologies is influenced by the interaction of these three components and that organizations should consider all three components when making decisions about adopting new technologies.

The technology-organization-environment framework has seen many use cases, such as the work of Ghobakhloo (2022). This study provides a greater understanding of the factors that may affect SMEs adoption of Industry 4.0 technologies. The framework has proved useful for identifying and classifying determinants and their underlying components, which allows for a greater understanding of how businesses decide to adopt new technologies. A google scholar search reveals almost 3700 articles published between the time period 2020 and 2022 mentioning the “TOE framework.” This indicates, despite being developed in the 90s, that the framework is still both highly and increasingly relevant in academic work looking into technology adoption. The following chapters will in more depth explain and explore each of the components included in the TOE framework.

2.4.1 Technology context

The technological context within the TOE framework refers to the characteristics of the available technology and how it fits with current technologies used by the organization (Tornatzky & Fleischer, 1990). The technological context of an organization will affect the organization's willingness to learn and adapt new innovations (Tornatzky & Fleischer, 1990). For instance, some organizations may be technologically stagnant as their facility has matured to a modern level (Tornatzky & Fleischer, 1990). In this context, it may be difficult to spend resources on new and available industrial innovations, since this would simply not be cost-effective. On the other hand, there are also organizations that need to pay attention and constantly evaluate the development in technology, in order to uphold their competitive edge in the market (Tornatzky & Fleischer, 1990).

The characteristics of available technology, as described by Tornatzy & Fleischer in their book, have been further investigated by Rogers (1995). His work provides a deeper understanding of and a suggestion of five important attributes of innovation and how they can be sufficiently described. More importantly, the work shows that an individual receiver's perception of these attributes predicts an innovation's rate of adoption, meaning the relative speed at which an innovation is adopted by people (Rogers, 1995). The finding in his paper points to that 49 to 87 percent of the variance in the rate of adoption is explained by subcomponents described by Rogers (1995). The subcomponents are:

- Relative advantage: The degree to which a technology is perceived as better than the existing technology or process.
- Compatibility: The degree to which a technology is perceived to be compatible with existing values, systems, and processes of an organization.
- Complexity: The degree to which a technology is perceived to be difficult to understand and use.

- Trialability: The degree to which a technology can be experimented with on a limited basis before adoption.
- Observability: Refers to the degree to which the results of technology adoption are visible and measurable.

To really understand why some organizations are on the lookout and frequently adopt new technology and why some do not, one must control the available technology as a moderating variable. A way to manage this is to focus research on organizations that operate in the same industry (Tornatzky & Fleischer, 1990). The pool of available technology for these organizations will theoretically be of the same size and thus control the differences in availability across industries (Tornatzky & Fleischer, 1990). This thesis focuses its attention on organizations operating underneath the automation industry as described earlier in the study and is therefore considered to be controlled for.

2.4.2 Organizational context

The organizational context within the TOE framework refers to the internal characteristics of an organization (Tornatzky & Fleischer, 1990). This important context also affects the organizations' willingness and ability to adopt new innovations. Following Tornatzky & Fleischer (1990), their findings indicate that the organizational context includes several descriptive measures: Formal and informal linking structures, communication processes, organization size, and slack resources available in the company.

The comprehensive meta-analysis by Damanpour (1991), shows positive associations between organizational innovation and the determinants; specialization, functional differentiation, professionalism, managerial attitude towards change, technical knowledge resources, administrative intensity, slack resources, and external and internal communication. In contrast to the work of Tornatzky & Fleischer (1990), Damanpour (1991) presents an extended list of important determinants that influence an organization's ability and willingness to adopt new innovations. Below is a presentation of the organizational determinants found by Damanpour (1991) that facilitate innovation adoption:

- Specialization: Represent different specialties found in an organization.

- Functional differentiation: Represents the extent to which an organization is divided into different units.
- Professionalism: Represents the professional knowledge of the organizational members.
- Managerial attitude towards change: Reflects the members’ attitude towards change.
- Technical knowledge resources: Reflects the organizations’ technical resources and technical potential.
- Administrative intensity: Reflects the ratio of managers versus total employees of an organization.
- Slack resources: Reflects the resources an organization has beyond what it minimally needs to maintain operations.
- External communication: Reflects the ability of an organization to be in contact with and scan its task environment.
- Internal communication: Reflects the extent of communication among organizational units or groups.

In addition to the identified determinants, the paper by Damanpour (1991) also examined the impact of four important moderating variables. These moderating variables moderate the relationship between organizational determinants and organizational innovativeness. The moderating variables are the type of organization, type of innovation, stage of adoption, and scope of innovation (Damanpour, 1991)

2.4.3 Business Environmental context

The last element of an organization's context that influences an organization to adopt and implement innovative technologies is the environmental context (Tornatzky & Fleischer, 1990). It refers to the industry characteristics and market structure, technology support infrastructure, and government regulation, which consider a few important sub-components (Tornatzky & Fleischer, 1990).

The industry characteristics and the market structure includes the intensity of competition, customer-supplier relations, market uncertainty or volatility, dimensions of competition, and industry life cycle (Tornatzky & Fleischer, 1990). Industries with high levels of competition are more likely to adopt new technologies in order to gain a competitive advantage (Tornatzky & Fleischer, 1990). On the other hand, industries with monopolies may not feel the same pressure to adopt new technologies, as they may have established market power and customer loyalty (Tornatzky & Fleischer, 1990). Additionally, the characteristics like industry size, growth rate, and level of regulation, can also affect an organization's decision to adopt new technologies (Tornatzky & Fleischer, 1990).

According to Tornatzky & Fleischer (1990), the technology support infrastructure includes labor costs, skills of the available labor force, and access to suppliers of technology-related services. The availability of technical expertise and resources can also affect an organization's ability to adopt new technologies. Organizations that operate within industries with established technology infrastructure and support, meaning the quality and availability of external resources, may have an easier time bringing new technology into their facilities (Tornatzky & Fleischer, 1990). In contrast, organizations may struggle to adopt new technologies as they may have to invest significant resources to develop their own infrastructure and expertise.

Finally, government regulations can also play an important role in the adoption of new technologies, particularly in industries with high levels of regulation. Government regulations may act as a barrier to the adoption of new technologies, as organizations may have to comply with strict regulations or obtain government approval before adopting new technologies (Tornatzky & Fleischer, 1990). On the other hand, governmental regulations can also act as an incentive for organizations to change and adopt new technologies, particularly if the government offers incentives or subsidies for adopting certain technologies (Tornatzky & Fleischer, 1990).

3.0 Research methods

The choice of research methods reflects the purpose of the study. Revisiting the research statement, the thesis seeks to explore how the Industrial Metaverse might be implemented, and what its value is. This chapter will begin choosing the appropriate design and method, before looking at the selection of cases for this particular thesis. Then, the data collection design and method will be elaborated before an explanation surrounding the making of the interview protocol will be presented. The next chapters will discuss potential weaknesses in the data collection, its analytical approach, the treatment of data, followed by ethical considerations in regard to this thesis. Finally, a discussion surrounding the validity and reliability will take place as the final sub-chapters.

3.1 Choice of research design and method

The study tries to answer broad and open-ended questions about the Industrial Metaverse. There is little research on the topic, and therefore asking the experts working in the automation industry is a good approach to answering the thesis statement. These factors make an exploratory research design applicable to the thesis (Saunders et al., 2019, p.186). Furthermore, the ontological position of this thesis is that the value is subjective to individual cases. Therefore the focus is on the organization's representatives' perceived value of this new paradigm, and how they practically would want to implement it.

Given the subjective nature of the study, it closely aligns with interpretivism. Interpretivism sees human interaction and meaning as different from physical phenomena in the way that there is no single reality or truth and therefore seeks to create new and better understandings of the social world and its contexts (Saunders et al., 2015, p. 137). Its ontological stance is that reality is complex and socially constructed. There are multiple meanings and interpretations of everything. Questionnaires or structured interviews would not be able to capture the interpretation and value of the Industrial Metaverse (Saunders et al., 2019, p. 145). The focus should be on contributing new perceptions, interpretations or understandings (Saunders et al., 2019, p. 145).

Based on this thesis philosophy, qualitative research is the most suited method as it is an interpretive approach (Christensen et al., 2014, p. 68). Qualitative research is mostly reliant on the gathering of non-numeric data such as text, words, images, or documents (Christensen et al., 2014, p. 364). In addition, it's also a research approach that examines concepts in terms of their meaning and interpretation in specific contexts of inquiry (Ketokivi & Choi, 2014).

Within qualitative research, a case study is a method in which the researcher focuses on providing rich descriptions of single or multiple cases (Christensen et al., 2014, p 377). According to Christensen et al. (2015, p. 377), a case is described as a bounded system such as one person, a group, an organization, an activity, a process, or an event. This means that when studying a case, it is important to consider the various elements or factors that contribute to its overall functioning and behavior, as well as the relationships between these elements. On a general level, a case study can be a research approach well suited for theory generation, testing, and elaboration (Ketokivi & Choi, 2014). In relation to the TOE framework explained in the previous thesis chapter, the logic of the thesis seeks to elaborate this theory in the context of the Industrial Metaverse.

3.2 Selection of cases

The selection of cases will be reliant on the professional network and knowledge of case 1, as initial contact was made with them. Case 1 develops and sells software for collaborative robots in the automation industry, and can therefore be labeled as a component vendor. The thesis aims to collect data from organizations of different sizes and with different roles in this industry. Here is a quick explanation of the different roles:

Insights from case 1 show that organizations can be labeled distributors, integrators, end customers, and component vendors. As mentioned, case 1 is a component vendor selling software, but there are also other vendors selling hardware components that play a crucial role. Normally, component vendors sell their products to distributors who keep a catalog of different components and resell these to either end customers or integrators. Integrators are the ones in closest proximity to the end customers. They sell, build, install, and perform service on the automation solutions that end customers need. Lastly, end customers are the organizations who are seeking to buy automation solutions for their factories.

In practice, the thesis embraces replication logic for the selection of cases. Which is about confirming the findings from the first case, by conducting more cases to try and replicate or predict new findings (Yin, 2014, p. 57). Initial ideas and motivation for this thesis derived from case 1, therefore it is natural to interview them first. From there, similar results will be expected given that the participants are partners of case 1 and that they operate in the same industry, which is called literal replication (Yin, 2014, p. 57). For good external validity, it is also recommended to use theoretical replication, whereby cases are selected to predict contrasting results for anticipatable reasons (Yin, 2014, p. 57). Anticipatable reasons in this thesis might be the organizational characteristics of the participants, such as geographical location, size, and strategy.

The potential case organizations will be reached out to by mail, asking if they would like to participate in the study. The mail will contain a short introduction about the thesis and an information letter about the study. The information letter also contains a consent form, and follows the template by Sikt, the Norwegian Agency for Shared Services in Education and Research. The organizations can decide for themselves if they want to be anonymous or not.

3.3 Data collection design and method

There are different types of case study designs such as intrinsic, instrumental, and collective case studies (Christensen et al., 2014, p 377). An intrinsic case study is only interested in understanding one particular case, while instrumental case studies are interested in understanding something more general than the particular case (Christensen et al., 2014, p 377). Collective (comparative) case studies, however, are interested in examining a bounded system comparatively. This ultimately means that the study can provide holistic information about a general phenomenon, but also that the results can be generalized to other cases (Christensen et al., 2014, p 379). Additionally, there are many ways to collect data in qualitative methods, each with its own strengths and weaknesses. The most common ways to collect data, are tests, questionnaires, interviews, focus groups, observation, and secondary data (Christensen et al., 2014,). The thesis statement is complex, and in-depth information is required to fully answer it.

3.3.1 Data collection design

Collective, also known as comparative case study design, is argued to be a fitting data collection design for the current study. The main reasoning for this is that the design involves looking at several bounded systems independently, and further comparing and contrasting them. The primary focus of this study is to investigate how multiple organizations perceive the value of the Industrial Metaverse. By looking for similarities and differences in these perceptions, the findings become, to a certain degree, generalizable to similar organizations within the automation industry (Christensen et al., 2014, p 379).

3.3.2 Data collection method

Interviews are chosen as the most suitable data collection method. The rationale for this is that interviews can be conducted both face-to-face and digitally via solutions like Zoom, Teams, or other video chat applications. Digital interviews will be necessary due to the large geographical distribution of the respondents for the study. In addition, there is neither time nor financial resources to travel for physical meetings. Furthermore, interviews are very good for measuring attitudes and most contents of interest, while they enable the interviewer to probe and pose follow-up questions. Interviews are frequently used in case studies and are one of the most important methods of gathering evidence (Yin, 2014, p. 110). It allows for in-depth data collection of the topic at hand and allows for subjective opinions to be addressed (Christensen et al., 2014). The method can also provide high measurement validity, given that the interview protocol is adequately constructed and tested.

3.4 Making the interview protocol

When conducting interviews, it is normal to create an interview protocol. This is a script-like document that will help researchers systematically read questions and record the participants' answers (Christensen et al., 2014, p. 340). Moreover, in case studies interviews are often more fluid than rigid (Yin, 2014, p. 110; Rubin & Rubin, 2011).

Interviews can be both very structured or highly flexible, dependent on what kind of information the researcher is after. The interviews conducted in this interview will be semi-structured, which means that they will follow a predetermined list of themes (Saunders et al., 2019, p. 437). In this case, that means following the structure of the TOE framework so that the constructs can be illuminated. The constructs are Industrial Metaverse value, organizational innovation, and the influence of external factors. So the first questions will be about the technological context and the perceived value of the Industrial Metaverse. The second part will explore the organizational context; how organizations implement the Industrial Metaverse and what challenges they face. Lastly, the business environmental aspect will be covered, revealing if and how organizations perceive value and implementation intentions are affected by competition and trends. Given that the thesis follows an interpretive approach, the interview will be relatively flexible (Saunders et al., 2019, p. 438). This means that the themes of the interview can be adjusted according to the flow and context of the conversation, and it lets the interviewee answer more freely and opens the possibility to explore new themes (Saunders et al., 2019). Due to thesis limitations, such as time horizon and resources, the interviews will last approximately 1 hour.

The questions themselves do not stem from any past empirical work, but are inspired by a few selected components of the TOE framework. In addition to asking questions about the technological, organizational, and business environmental contexts, participants will also be asked some introductory and summarizing questions. In the introduction, they will be asked questions about their organization's role and what their definition of the Industrial Metaverse is. At the end, they will be asked to answer a question closely related to the thesis statement based on the interview/discussion. Lastly, it is important to specify that the interviewees will be representatives that represent an organization. Therefore the questions need to be about the organization, not the individuals being interviewed (Yin, 2014, p. 92).

3.5 Weaknesses in data collection

Due to convenience, it was easier to recruit one organization and then use its network to recruit others within the automation industry. This can be a weakness, as the total accumulation of data will be linked to one specialized field, instead of being completely independent of each other. As a result, this could be seen as having unwanted bias effects that influence the data collection. Furthermore, the data collection method and case selection are based on what is most convenient due to the limited time horizon and financial resources. In itself, interviews can be expensive and are generally a lengthy process (Christensen et al., 2014, p. 73).

Additional weaknesses tied to interviews are further presented by Christensen et al. (2015, p. 73) and Saunders et al. (2019, p. 447). Reactive effects by the interviewee can be an important aspect during the interviews, as some may unconsciously want to appear as modern, technologically capable, and updated. This is described by Saunders et al. (2019, p. 447) as the response or interviewee bias, which can be caused by the interviewees' perceptions of the interviewer. Interviewees may also affect the data collection negatively due to poor recall and the ability to articulate perspectives accurately (Christensen et al., 2014, p. 73).

On the other hand, the interviewers may in turn distort data because of personal biases or poor interviewing skills (Christensen et al. (2015, p. 73). This is related to what Saunders et al. (2019, p. 447) describe as interviewer bias. The interviewer bias means that the interviewer's own comments, tone, or non-verbal cues may influence the interviewees' perception of the interviewer, and further influence the response of the questions asked. A final form of bias mentioned by Saunders et al. (2019, p. 448) that may weaken the data collection, is the participation bias. This bias refers to the participants declining willingness to participate in an interview because of the increasing amount of time required to complete an interview. Based on the different forms of biases, Saunders et al. (2019) point to quality issues with semi-structured and in-depth interviews. They emphasize the concern regarding the lack of standardization of a semi-structured interview, which contributes to the variance of information given to respondents which further can result in poor reliability of the study.

Another important aspect tied to the weaknesses of data collection may arise from cultural differences between the interviewers and the interviewees. Gobo (2011) argues that research interview results stem from individualistic societies and that findings may not be applicable to other societies with different cultural orientations. The current thesis will interview representatives that will represent their organizations that are located within North America, Oceania, and northern Europe. Cultural differences may therefore be an important aspect to keep in mind going forward with the interviews, results, and analysis.

Generalizability/transferability is also a constraint due to the data collection method. Here, Saunders et al. (2019, p. 449) are referring to the extent to which the findings of the study can be applicable to other settings. This study includes analyses of only a small number of interview cases, which is the major reason why generalizability is a weakness. However, the primary aim of the study is not to generalize, but rather to explore and explain to provide insight into a particular phenomenon. The aim is rather to use the insights to contribute to the development of new theories and for organizations looking into the Industrial Metaverse.

Lastly, Saunders et al. (2019, p. 449) highlight the issue of validity/credibility, which refers to the extent to which the researchers have indeed gained insights into the participants' knowledge and experience, and further withdrawn accurate meanings based on the semi-structured interviews. A way to counter this issue is to make sure to explore meanings during an interview, and to make sure that both parties have a mutual understanding of the emerging perspectives (Saunders et al., 2019, p. 449).

3.6 Analytical approach and treatment of data

The thesis will follow both within-case analysis and cross-case analysis. This in practice means that the data collected from the interviews will be analyzed separately per case, but also compared to the other cases (Christensen et al., 2014, p. 379).

As the thesis and questionnaire follow the structure of the TOE framework, the analytical strategy will as well. This can be called a case description, where the case study is organized according to a descriptive framework (Yin, 2014, p. 139). This thesis is as mentioned exploratory, but the descriptive framework helps the thesis organize and structure the complex nature of the Industrial Metaverse. This is a valid strategy (Yin, 2014, p. 140).

For the within-case analysis, each case will follow the contexts defined by the TOE framework and their respective constructs formed by the sub-questions of the thesis. In other words, the interview is structured so that the participants are answering the subquestions. For the cross-case analysis, a word table will be used to help draw conclusions about similarities and differences between the cases. Word tables are very useful for displaying data between cases based on one or more given categories (Yin, 2014, p. 165). Since the thesis has no hypotheses, the categories used to compare the data between cases are not selected beforehand. Instead, they will be selected after all interviews are completed.

During the transcription process, the authors used the free automatic speech recognition system "Whisper AI" developed by OpenAI (OpenAI, 2022). While free, it still requires a certain degree of computer knowledge to install, set up, and fully utilize. The authors experienced that with powerful computer hardware, Whisper AI could transcribe the interviews in around 5 minutes with less than 1% margin of error for English interviews and approximately 10% margin of error for northern European languages. This drastically reduced time spent transcribing, and the authors along with participants corrected all errors found. The transcriptions were done with a consumer-grade GPU with 16 GB of VRAM, and the following parameters were selected: Model: large-v2, language: English/Other, task: transcribe, device: cuda.

3.7 Ethical considerations

The thesis has applied for and been greenlighted by Sikt, the Norwegian Agency for Shared Services in Education and Research. This means that all participants have received an information letter, been given the opportunity to ask questions, and have signed an agreement that lets the thesis collect the required information during interviews. As such, the thesis has both institutional approval and collected informed consent. Therefore the participants also have the right to decide if they want to be anonymous, withdraw confidential information, and proofread the final product of their contributions.

3.8 Validity and reliability

Before moving on to the results and analysis chapter, the validity and reliability of the thesis will be discussed as this affects the quality of the thesis and the conclusions. Good research validity says something about how accurately the thesis is answering its statement, while reliability is how congruent the measures of data collection are (Saunders et al., 2019, p. 213). A widely used example is comparing research to archery, where hitting the center of the target represents validity and the collection of several arrow shots represents reliability. To ensure good validity, good reliability is required (Saunders et al., 2019, p. 213). Yin (2014, p. 45) explains that four tests are sufficient to determine good research quality in case studies. These four are construct validity, internal validity, external validity, and reliability. However, internal validity is not relevant as it is only for explanatory or causal studies (Yin, 2014, p. 45).

3.8.1 Validity

Construct validity is how well the correct operational measures for the concept being studied are identified (Yin, 2014, p. 46). Some recommended tactics to achieve this are to use multiple sources of evidence, establish a chain of evidence, and have key informants review the final case study report. The largest weakness of this thesis is that only interviews are used as a method of data collection. However, interviews were decided as the best way to get good data given the limitations of the thesis. Maintaining a chain of evidence is related to the interviews and the data collection reliability, whereby it should be possible to track down the evidence used to arrive at the conclusions of this thesis (Yin, 2014, p. 127). While the thesis provides a study protocol for readers to see, the source material cannot be shared freely without the participants' consent. This of course is also a weakness of the thesis. Lastly, participants will be asked to review their case reports to ensure accurate representation, thereby increasing validity.

External validity is about how a study's findings can be generalized (Yin, 2014, p. 46). While generalization is not the main goal of the thesis, it is trying to explain how the Industrial Metaverse could be valuable for the entire automation industry. As such, effort has been made to ensure good external validity. This has been done by using a theoretical framework for technology adoption, the TOE framework. And the selection of cases has been done using replication logic, which assumes that the cases will give similar data. While generalizability is commonly referred to as statistical generalization, where large sample sizes are used, this thesis is using an analytical generalization. Analytical generalization strives to identify patterns and themes in the case study that can form generalizable theories (Yin, 2014, pp. 40, 48). This then forms a kind of working hypothesis that can be reinterpreted or tested in other case studies at a later point (Yin, 2014, pp. 41, 48; Cronbach, 1975).

3.8.2 Reliability

Lastly, reliability is about whether the same results and conclusions of the thesis can be reached if other researchers were to follow the same procedures (Yin, 2014, p. 48). For this reason, the thesis has an interview protocol and also explains all the steps taken to conduct the research in detail. This way, other researchers can copy or iterate upon the case study and see if they arrive at the same conclusion. Another way to increase the thesis reliability is to create a case study database where other researchers can access the case reports, and also add case reports of their own (Yin, 2014, pp. 49, 123). It was decided not to do this, as the cases of this thesis are not extremely in-depth and also lack method-triangulation of data collection. Of course, the limitations of the thesis are also a deciding factor.

4.0 Results

This chapter will show the findings of the data collection and analyze the results. Firstly, all cases will be given a short introduction, followed by a complete participants overview. Then the thesis will conduct a within-case analysis of each case before the findings will be compared using the cross-case analysis method.

4.1 Introduction of cases

Case 1 is a small startup in northern Europe. They have mainly taken the role of a component vendor. They sell software to other companies in the value chain. In addition to selling software, they are developing a platform to connect end customers and solution providers. The other cases use the product and service that case 1 makes. They can be classified as early adopters, and are very positive towards the Industrial Metaverse.

Case 2 is a company in northern Europe that delivers automation and robotic solutions and is labelled as an integrator/distributor. They are called integrators, as they help their customers install new automation and robotics solutions. At the same time, they are also called distributors, as they also offer complete automation and robotics solutions based on their partners' offerings such as case 1's software.

Case 3 is an SME in North America that focuses primarily on palletizing and material handling solutions. They are a system integrator with a particularly strong presence in bag handling. They are a well-established company with two larger parent companies. Furthermore, they also have projects outside of North America.

Case 4 is an SME in Oceania consisting mainly of production automation engineers with a focus on end-of-the-line solutions. This involves product labelling, identification, coding, inspection, material handling, palletizing systems, ERP integration, supply chain traceability and more. They can be labelled as an integrator.

4.2 Participants overview

Originally the paper set out to recruit one participant per case. However, some organizations wanted to join with multiple participants to fully cover all aspects of the thesis. For simplicity's sake, the participants have been coded based on which case they belong to and their titles. For example, CTO2 is the Chief Technical Officer of case 2, etc. The full overview can be seen in table 1 below. Participants will be referred to by their ID from now on.

Table 1. Table of participants

Cases:	**Title:**	**ID:**
Case 1:	Chief Innovation Officer	CIO1
Case 2:	Chief Executive Officer	CEO2
	Chief Technical Officer	CTO2
Case 3:	President	P3
	Engineer Manager	EM3
	Director of Sales and Marketing	DSM3
Case 4:	Chief Executive Officer	CEO4

4.3 Case 1: Software component vendor

From case 1 there was one interviewee, the CIO of the company. The interview was conducted in a northern European language, so all quotations are translated.

CIO1's understanding and definition of the Industrial Metaverse are based on how megacorporations like Siemens and Microsoft see it, but this view of the Industrial Metaverse makes sense for case 1. CIO1 believes the Industrial Metaverse is a totalitarian DT of an industrial system where humans cannot be present, but sometimes use XR technologies to see what is happening. The participant showed a good understanding of the Metaverse enabling technologies, describing IoT, DTs, and sensors.

On the other hand, the Metaverse is viewed as many independent Metaverses for each organization and or factory, but the notion that it might be connected all over the globe in the future is there. The short-term focus seems to be on vertical integration in the organizations, and each factory has its own Industrial Metaverse. CIO1's view looks to be quite congruent with the thesis' operational definition of the Industrial Metaverse.

Moving on to the technical context, it is clear that case 1 perceives some value in the Industrial Metaverse for increased insight, simulation, testing, and analyzing industrial systems. They would like to implement it as the ultimate simulation tool, which is only natural as their products heavily rely on DT simulations. CIO1 is also comparing the Industrial Metaverse to the Matrix movies, where certain aspects can only be manipulated or perceived in the digital domain. However, it is still unknown how we can get to that stage, but making the digital world as accurate as possible is a key factor.

> *It is the perfect simulator of everything you wish to test, before you do it. (CIO1)*

When asked to give some examples of how the Metaverse might be implemented or has been implemented today, CIO1 again mentions Siemens, which says that they have a DT model of their entire factory. CIO1 then proceeded to explain that there are two ways to implement the Industrial Metaverse, one is the "top-down" approach using sensors in between every machine to monitor the inputs and outputs of them. The other is the "bottom-up" having each machine be a DT that can transmit internal data as well as the inputs and outputs. While the "top-down" approach is the easiest, a "bottom-up" approach is believed to be necessary to fully utilize the Industrial Metaverse.

> *..I believe in the ideal Metaverse, you have to view each machine, and it has to be replicated to use this data method. (CIO1)*

CIO1 further explained how the "bottom-up" approach is better than the "top-down" approach for troubleshooting and testing. An example that Microsoft used in a video with the "top-down" approach, showed Microsoft reading from their data that there was an issue with machine number "3". Then they put together a team to find out what was wrong with that machine. However, with the "bottom-up" approach the engineers would already know what was wrong with the machine. Then one engineer could test and simulate alternative configurations on that machine to figure out the most optimal settings. CIO1 moves on to explain how they want to make a plug-and-play solution for the Industrial Metaverse, and how this paradigm will require incredibly many players working together to achieve.

Moving on to the organizational context, fragmentation, compatibility and knowledge are identified as challenges in implementing the Industrial Metaverse. CIO1 exemplified that if you took a random 40-year-old factory today where the management had not taken digital capabilities into account, then there would be a heap of different proprietary systems. So to put this into a new system would be challenging. Knowledge was perceived to be especially challenging. Because so much knowledge is required from employees, partners and other actors in the value chain to bring the Industrial Metaverse to life. Even if an external consulting company came and set everything up for the factory, would they have enough knowledge to fully utilize its capabilities? This is a bottleneck CIO1 believes not a lot of people think about. Within case 1 they try to solve these challenges by solving one small problem at a time. By convincing customers and partners to adopt one digital model at a time, like their own product, they will eventually end up with a production facility that has a web of different DT technologies. However, CIO1 argues this is a better problem to have than today's fragmentation. CIO1 believes they have solved this problem, and it is very important for them to provide simulations or some sort of upfront validation as their product was difficult to sell.

External factors such as partners, customers and trends are known to heavily influence case 1 priorities and what they work towards, as would be natural for a component vendor. CIO1 went as far as to say that their product development is ultimately based on external factors in one way or another and that their product is a result of the needs of customers they have met. They are using DT technology to improve processes between actors in the entire value chain. As such, it also affects their strategic position and the decision to create a platform based on DTs and simulations.

> *It is kind of difficult to explain, but at the core of our strategy we have Digital Twin technology. (CIO1)*

Lastly, CIO1 was asked if the Industrial Metaverse had any value for the automation industry. CIO1 emphasizes that there is a lot of value and it is just a matter of time. Production will get more flexible and more available for smaller factories. However, CIO1 also points out that change is needed in today's production methodology to make this work. The development of this is further exemplified by the industrial revolution spanning 40 years, this revolution will also take time and DT technology will be a very important ingredient going forward.

> *New methodology is needed, and the digital methodology can be optimized beyond comprehension compared to what is being done today. (CIO1)*

It is clear that case 1 is very excited for the Industrial Metaverse, and is actively working towards making it a reality. From their perspective, the Industrial Metaverse is certainly valuable and already being implemented. CIO1 emphasized increased insight, testing, analyzing and optimizing as key technical advantages, making it the perfect simulator. At the same time fragmentation, compatibility and knowledge are challenges that need to be addressed, which will take time.

4.4 Case 2: Integrator & Distributor

The case 2 interview was conducted in a northern European language with two interviewees at the same time. It was their wish to participate simultaneously to provide the best possible answers. The interviewees showed limited understanding of the term Industrial Metaverse.

They think of it as building a digital representation of a factory or a solution to be used for advanced testing and visualization. Their understanding is deeply rooted in DT technology and simulation but is a little lacking in interactivity. However, they mentioned FAT and SAT which involves a lot of communication with customers. Their understanding was considered sufficient enough. They also identified some of the possibilities of the technology such as designing and testing.

In terms of key capabilities and functions, they emphasize its ability to check and test if a project is possible to do. They also mention the possibility of getting a holistic view by acquiring data through this technology. In addition, they imply that it may be a solution that can be helpful for them in being more effective, more quality assured and decreasing risk and complexity. However, it is also argued that a face-to-face conversation has strong value and that their customers are currently not ready for technology like this.

> *I think that many of our customers are lightyears away from this issue. (CEO2)*

Further, the participants elaborate a bit more on some of the technical benefits they think exist within the Industrial Metaverse. The idea of having a digital and detailed model of the facilities or solution is highlighted as beneficial in most of their integration projects. In addition, it is also emphasized that some of the current processes within their projects are very manual, insinuating that a solution that integrates principles of the Industrial Metaverse could be a valuable tool for making more rational decisions. However, it is also specified that the company wants "to work as rationally as possible", insinuating that adopting such technologies today, is not a rational thing to do. This might be because of the lack of mature XR technologies, no demand from customers and some scepticism towards the term Metaverse.

Moving on with the organizational context, the interview object acknowledges today's rapid pace in the development of technological innovations that are relevant to them as an organization. In terms of making organized efforts to look into these technologies, they seem to have an ad hoc approach. For them, it seems that seeing clear signs of positive cost-benefits concerning this technology is an important driver for them to adopt. However, they do emphasize the relevance of working visually and find a good way to document processes.

> *I think we are interested as an organization in adopting new tools as quickly as they are available. And as soon as we see the cost-benefit. (CEO2)*

In terms of how they plan to tackle these challenges, the ad hoc approach to technology adoption gets strengthened further into the interview. CEO2 believes they have it in their DNA to be development-oriented and always look for improvements, without necessarily formalizing it in the projects. CEO2 further states that it is more of a culture than it is a strategy.

Finally, we are moving into the last question within the business environment context. Here, they argue that they do get some input from their external surroundings. External factors and development outside of the case company affect their decision to adopt new technology in general. CEO2 explains that they have inputs from several suppliers, and are attending trade shows and keeping an eye on trends. CEO2 terms the different inputs as listening posts they are closely monitoring. While they are paying attention, CTO2 again brings up the rational approach, and talks about finding the right time to implement new technologies.

> *We try to be curious by looking at what's new on the market, but at the same time have a rational approach to it. Not just dive into anything new as the first guinea pig. (CTO2)*

Further, some thoughts were expressed surrounding the potential valuable effects of adopting such technology in terms of branding and sales. CEO2 emphasizes that in regards to SMEs, the drive has to come from them and not the customers. However, bigger customers and suppliers are thought to maybe drive this process.

> *I also think it's going to have a sales effect. It is branding for us, being a company with a more modern way of approaching solutions. (CEO2)*

In the concluding part of the interview, they acknowledge some value for the suppliers by using the DT technology they use today, associating it as a part of the Industrial Metaverse. It helps them manage the process of selling solutions more effectively, while also decreasing the costs of testing different automation and robotics designs for their customers. At the same time, while they emphasize that a lot is happening in the market technology-wise, the adoption of these technologies for many is happening at a much slower rate. In addition to this, they have an understanding that new technologies like the Industrial Metaverse are likely a bit above people's heads at the time. That being said, they also think that it may be a reality when the technology "ripens". Finally, they also think that this type of technology adoption is probably different from industry to industry and that the size of the company has a big say in whether they adopt such solutions. Especially for organizations with less than 1 billion in turnover, which have a more practical focus and lack the competence to implement digital technologies.

> *It is the old ways of selling and doing projects that matters. So it is surprising in a way, how slow the change is happening. At the same time we see a few tools that we use that we didn't think of just three years ago, but are very useful for us now. (CEO2)*

Based on the case 2 interview, the Industrial Metaverse is viewed as beneficial for organizations much like themselves. It may increase sales efficiency, aid with branding and decrease costs and risk. It may also aid in designing new solutions for their customers and be a helpful tool for working more visually, which is in their eyes "super relevant". However, they do not view it as relevant enough yet. They rather view the Industrial Metaverse as a technology that is a bit ahead of its time, thinking of the practical everyday life of selling and doing projects. Their approach to adopting such technology is an ad hoc type of approach. They eventually are likely to adopt such technology whenever the CTO of the company sees the cost-benefit and trends in the market suggest that the time is ripe. The implementation of this technology towards SME customers needs to come from the case company and not the other way around. At the same time, the case company looks at bigger companies and trends in the market, acting as a fast follower.

4.5 Case 3: Integrator

Case 3 consists of three participants and each of them was separately interviewed in English. At their request, the company participated with three of their most senior members, including their coming organizational president, engineer manager, and director of sales and marketing. The following results are drawn from a mixture of these three interviews, making the primary data contribution from this case particularly rich. Because of this, their collective contribution provided a more accurate organizational perception of the current matters being investigated.

While neither of the participants had heard of the Industrial Metaverse, they had some knowledge of the Metaverse. Combining their work experience with this knowledge, they were able to identify 3D models, simulation tools, and VR/AR as the main building blocks of the Industrial Metaverse. This was deemed an acceptable understanding of the Industrial Metaverse. EM3 also mentioned reading and watching the movie Ready Player One, which reflected his view on the Metaverse. EM3 was also the only participant particularly concerned about human interaction in the Industrial Metaverse. DSM3 might also have touched on this bit, referencing the Industrial Metaverse as a virtual forum. Furthermore, DSM3 thinks that it is currently changing the way people think about how to sell things and approach customers. To summarize their views, the Industrial Metaverse is a more advanced simulation environment in which interaction is possible but also adds value in the form of faster sales processes and more accurate results.

> *I think it is changing the way we think about how we want to sell things and approach our customers. (DSM3)*

In the technological context of the Industrial Metaverse, P3 focuses on the drive that has been emerging lately to represent manufacturing facilities digitally. P3 further states that the reason for this emergence is because of the ability to digitally and accurately represent the whole manufacturing facility, including utilities and equipment. EM3 and DSM3 agree with this but are also highlighting testing for the development process and visualization for the sales process as important factors. For testing, EM3 described a scenario where they would test a pallet dispenser, and if they encountered a bug in the system, one could simply reset the dispenser with a click of a button in a virtual simulation tool. This was much preferred instead of manually and physically loading heavy pallets back into the dispenser. This allows debugging in a virtual environment before it even goes on the shop floor or adding customers' hardware to do a FAT without ever needing to ship hardware or travel.

The participants had no trouble coming up with examples of how the Industrial Metaverse can be implemented or has been implemented today. P3 gave an example of a factory being virtually represented in the semiconductor industry. With the factory being three floors high and having a lot of sensitive equipment, the virtual representation needed to be very detailed and precise. So not only did they look at the inputs and outputs of the machines, but they also modelled the structural strength of the facility and also vibration sensitivity. Separating equipment that generated vibrations from equipment sensitive to vibration was very important to ensure that they could perform at an optimal level.

Further, EM3 touched on the interaction and immersive aspect of the Industrial Metaverse, where it could serve as a platform to train engineers, showcase equipment and do FAT’s or host tradeshows. This is also similar to what DSM3 imagines the Industrial Metaverse would offer in the future regarding FAT. DSM3’s example focuses on using AR technology at a specific place, while EM3 appears to be speaking of VR and remote access.

As for the organizational context, the company is not trying to formally implement the Industrial Metaverse at the moment. However, EM3 implies that they are slowly moving in this direction with the use of simulation tools. At the same time, these tools are emphasized to be more of an internal and functional tool for testing or showcasing, rather than being a collaborative and immersive workspace like the Industrial Metaverse is imagined to be. P3 understands that there is a difference in customer demand, and believes there will be more demand in the future as digitalization continues to be more important. Right now, customers are just beginning to ask for block models, but not yet DTs. Case 2 appears to be in a good strategic spot at the moment, as DSM3 implied that they can now start exploring and that they have already done so through a partnership with case 1.

..but I would say in general, they are just beginning to ask for that, and it's just the more sophisticated customers that are asking for it. (P3)

When asked about what challenges the organization or other organizations might face when implementing the Industrial Metaverse, neither P3, EM3 nor DSM3 were able to think of anything right away. However, when asked about more specific technologies related to the Industrial Metaverse they were able to come up with a few challenges. Concerning AR, P3 identified cost, availability of talent and complexity as challenges. When it comes to their internal simulation tool, EM3 emphasized that learning, amount of expertise and time consumption as central challenges. Similarly to EM3 concerns, DSM3 talked about how case 3 would have to train or recruit employees with the right set of skills for the Industrial Metaverse. At the moment they are reliant on partnerships to do this.

From our point of view, we are looking at building more, I'll call it digital-friendly models or representations, primarily from a marketing and sales point of view, not so much from a technical solutions point of view for our customers. (P3)

More importantly EM3 was also concerned if collaborating within the Metaverse with simulations would be just another "Teams" meeting once the novelty wore off. This thought arose because EM3 had participated in an online event in AltspaceVR during the pandemic.

Nonetheless, it was imagined to not be highly prioritized in the adoption of the Industrial Metaverse, but more as a secondary bonus.

Moving onto the business environmental context of case 3, it clearly shows that as an integrator of technology, they are heavily influenced by what their customers are asking for. They are always looking out for new technology and trying to pay attention to market trends, whether it is through LinkedIn or attending trade shows. They are a fast follower and are going to patiently wait for the right moment to adopt new technology. DSM3 believes that being a fairly conservative organization with measured approaches is why they are successful today. Additionally, from a competitive standpoint, DSM3 states that they have not yet seen the emergence of the Industrial Metaverse as a particularly useful tool. Note that the president EM3 is mentioning, is their current president that will be replaced by P3.

Yeah, I think, you know, we're not generally like an industry leader, like our, our president, he likes to call us a fast follower. [...] So I think with the Metaverse to be

> *the same thing with, you know, waiting until there's kind of a critical mass of people that are adopting it. (EM3)*

Finally, summarizing case 3, it seems they do see value in the Industrial Metaverse, but it has not yet matured enough for most customers. Interestingly, P3 has been working with simulation technology for almost three decades and has followed its evolution since then. P3 specifically emphasizes that there have not been a whole lot of advancements in technology for the past 25 years and that it remains to be showing real return on investment. EM3 again mentioned the FAT and light training as being an area where the Industrial Metaverse could be valuable. DSM3 emphasizes the recent technological advancements and acknowledges that in the future the industry may indeed enjoy benefits surrounding the key principles of the Industrial Metaverse.

> *I think where we're heading is going to be something completely different. And I do think that there's going to be value to that. (DSM3)*

Based on these three interviews, Case 3 can be said to be waiting for the right time, instead of actively trying to work towards the Industrial Metaverse. Case 3 identified several technical advantages such as digitally representing the whole facility. They highlighted testing for development and visualization for the sales process as important factors. It was also mentioned that it could be used to train engineers and showcase equipment and do digital FATs and tradeshows. Moreover, there were several challenges identified, such as costs, availability of talent, complexity, and time consumption. In terms of business environmental context, case 3 emphasized that they are influenced by what their customers are asking for. As a final thought, advancements in technology development have been slow for the past 25 years, but recent years have seen some more progression.

4.6 Case 4: Integrator & distributor

Even though CEO4 hasn't heard much about the term Industrial Metaverse, the interviewee does have a very good understanding of it - referencing Mark Zuckerberg's attempt to monetize the Metaverse concept. However, CEO4 is not convinced that the consumer Metaverse in the form of an alternate parallel digital reality will be a hit. From an industrial perspective, the emphasis is on the ability to rapidly model DTs of production lines for concept proofing. This can be used to work with customers to develop projects, and aid in developing complete solutions.

As for the technology context of the interview, it was mentioned a few technological capabilities and features. Firstly, CEO4 highlights the important difference between a 3D model and a DT. Essentially, a 3D model is the block of used space, while the functional model integrates the flow of processes within the presented object or solution. Specifically, simulating the IO (input/output) on a digital system or looking into the interaction between different components in a production line, are mentioned as key functional aspects. From a sales process perspective, the Industrial Metaverse can be helpful being able to clearly articulate and visualize to the customer what you are trying to archive. This can shorten the cycle time, reduce design costs, be more cost-effective, and reduce project risk, all of which allow for more aggressive pricing.

> *But just from a solution development side of things, making sure you're identifying all the problems before you get to the point where you're even finalizing a costing and an actual commercial proposal for the customer, there's huge value in that. (CEO4)*

However, while elaborating on these mentioned aspects, many challenges are also highlighted. A key issue drawn from CEO4 is that companies are not interested in sharing exact copies of their intellectual properties. Hence, there is a security issue concerning the Industrial Metaverse. Further, there is the point about standardization. For this technology to work across companies in the whole industry, CEO4 emphasizes the need for standardization. The interviewee highlights this, by for example integrating two different components into a system in a simulated digital environment. In this case, both the digital components and the system need to be following this standard for compatibility reasons. The CEO4 also points to the high cost of putting together production line solutions for the customers through the Industrial Metaverse. With smaller projects, it is argued that it is currently not feasible. However, it might be for projects with much higher cost, (20-30 million dollar production line), high tech and custom projects. In addition, increased complexity seems to be an added issue by including such a tool. The interviewee also argues that there is already a “big enough challenge” to share digital models of components among customers.

> *And first of all, most businesses aren't going to be particularly interested in throwing out what is essentially their intellectual property. You put out a fully functional three*

> *dimensional model, you've basically given away a big chunk of your intellectual property to a certain extent. (CEO4)*

Within the organizational context, the term Industrial Metaverse is something that is not used within the company. However, they have CAD designers who model up their solutions to visualize constraints and degrees of freedom to the various elements. That way they can show how different components interact with each other on a relatively basic level. As far as making a more advanced, kinematic model that includes everything within it, they seldom do that because of the costs, high labour and resource requirements. CEO4 argues that there is almost always no point in doing that. The CEO4 further emphasizes collaboration between companies in the industry in terms of establishing standards for implementing the models. These new standards need to account for not only their physical modelling but also their logical function, the IO and more. Today, there are highly variable results using different vendors' simulation tools.

> *If you're building something that you're intending to produce millions of, fine. But when you're basically modeling a single one-off custom system, you have to draw a line as to how far you go. (CEO4)*

Other issues are also highlighted. Companies reject remote access to equipment on the production lines for security reasons. Therefore, they have customers spending hundreds of thousands to fly technicians all over the country. Additionally, CEO4 also emphasizes that a digital representation has a limit to how beneficial it can be in terms of modelling the real world. For example, what happens if someone forgets a tool on the conveyor belt that is jamming it? The tool is not included in the virtual world, but you would know which machine is acting up. In which case it would be better to go there physically, not in an immersive virtual environment. Additionally, from an organizational perspective, defining functional IO and behaviours increases complexity. This further needs certain standards for what is acceptable to share with an unknown party. A prescribed set of standards that dictate a certain level of functionality, making sure the company is not giving away their intellectual property. Today, vendors often have their own simulation tools which work well only for their own components and their particular environment. Instead of having one unified standard for this, many vendors are trying to control this space. The solution then, CEO4 argues, is fixed, open and accepted standards.

Moving on to the final context, the business environment, the CEO4 starts highlighting market challenges with his idea of the Industrial Metaverse. The main issue brought forward regarding this context is the drive for a small number of large businesses wanting to own this space. On its own, this creates issues, as it does not contribute to the collective good of the industry as a whole.

Summarizing the interview, CEO4 concludes that there is possible value in the Industrial Metaverse, although it depends on how it is defined. The interviewee emphasizes that solving the standardization issue, for interconnecting digital models across the industry at a "basic level", would provide huge benefits. However, going as far as creating fully virtual representations of real-world production lines in operation, would not capture any significant value.

> *At a basic level, that would provide a huge benefit. And then, you know, being able to build fully functional kinematic models that include IO and expected behaviors, etc., in a simple way between different vendors components that would just be massively valuable. (CEO4)*

Based on this interview, it can be said that Case 4 is skeptical about the emergence of the Industrial Metaverse. Several technological advantages from both a sales process and a development perspective were mentioned. In addition, there were many challenges, like digital security, digital limitation, high costs, labour and resource consumption. that in sum, makes the whole paradigm seem unlikely to provide real benefits. However, solving the mentioned issues at a basic level may in turn provide massive value to the industry as a whole.

4.7 Comparative analysis

Since the interviews were conducted using the TOE framework, the results are very neatly organized and comparable. The comparison between the cases will therefore follow the structure of the interview protocol to continue the consistent structural layout of the thesis. Moreover, the general findings from each case will be condensed into word tables which should make it easier to compare.

4.7.1 Perceptions of the Industrial Metaverse

Firstly, it is important to note that each participant has slightly different definitions and perceptions of the Industrial Metaverse. For most of the participants, it is the first time they are using the term, even if they were able to resonate themselves to an acceptable understanding. This is somewhat expected since both the term Metaverse and Industrial Metaverse are currently loosely defined. The simplest definition is the one by Microsoft, which states that it “enables humans and AI to work together to design, build, operate, and optimize physical systems using digital technologies” (Microsoft, 2023, 5:40). The definitions by Zheng et al (2022) and Lee & Kundu (2022) specified these digital technologies to be technologies such as DTs, AI, XR, NFT’s, big data to name a few. The key takeaway from those definitions is that the Industrial Metaverse is leveraging digital technologies to improve industrial processes and create more efficient and collaborative workspaces. Specifically, through real-time human-machine interaction and social collaboration within an immersive digital space.

All of the cases emphasized simulations with 3D assets or DTs in their definitions, which seems to be important for them. So the idea that the Industrial Metaverse is an advancement of simulation technologies is there. However, not all participants brought up XR technologies in their interviews, only CIO1 and EM3, CEO4 specifically brought up those technologies in the interviews. Then again, the interaction does not necessarily have to happen through XR technologies (Radoff, 2021). Cases 1, 2 and 4 also brought up the notion that 3D assets and DTs should be readily available, whether through open standards or some kind of forum or platform.

Table 2. Comparison of Industrial Metaverse understandings.

	Industrial Metaverse
Case 1	Digital universe where machines and data make up a totalitarian DT, but humans have the option to enter with VR/AR technologies. It is the ultimate simulation paradigm. Not much focus on interaction between humans, but on testing and simulation. Strongly influenced by the views of Siemens and Microsoft.
Case 2	They had heard of the Industrial Metaverse but were not very familiar with it. Resonated that it must be a more advanced simulation environment where one can build digital manufacturing facilities and import different 3D models to test, simulate and validate.
Case 3	One of the participants had heard the term Industrial Metaverse, while the two others were familiar with the concept through other terms. They were able to show an understanding of it by combining experience with the Metaverse concept. It is perceived as the result of a long history of building simulation systems for manufacturing environments. Mostly for testing.
Case 4	The ability to rapidly model 3D DTs of production lines from a proof of concept perspective, which can further be used for developing solutions. However, does not believe in this becoming a full-fledged alternate reality like what the Metaverse is thought to be.

4.7.2 Technological context analysis

The perceived technological value of the Industrial Metaverse has been formed from their roles in the automation industry. All of the participants specialize in integrating end-of-line automation solutions, but case 2 and 4 also work on other aspects of the production line. This means that there is a lot of emphasis on simulation, testing and feasibility, which are use cases particularly valuable for development and sales.

From a technical standpoint, all cases agree that the Industrial Metaverse has the potential to bring value in different ways. Being able to a certain degree to make digital replications of production environments can bring several implications for organizational operations across industries. In general, there is an agreement of increased insight and getting a holistic view of an industrial process.

Firstly it's about the transition from physical and manual tasks to more digitized processes. This is particularly emphasized by case 2, which can help in increasing efficiency and quality while decreasing risk and complexity. Case 3 and 4 further explores these valuable benefits from both a sales and development perspective.

From a sales perspective, it is believed that clearly articulating and visualizing solutions for customers has great value. All cases believed there are or could be benefits to improving the sales process. Specifically, FAT was mentioned in case 2 and 3 as an important stage in the sales process which could see improvements by implementing such technology. Case 4 further explains that it can help reduce sales cycle time, design costs, be more cost-effective and reduce project risk. In sum, this may even allow for more aggressive pricing.

From a development perspective, all cases talked about aspects that are considered important steps in developing a product. Case 1 emphasized testing troubleshooting, optimizing and analysis of systems through DT simulations. Case 2 values the ability to check and test the feasibility of solutions, which is helpful in almost all of their projects. Case 3 was focused on the ability to plan out production processes, and testing as a way to optimize and improve which would reduce risk. Case 4 was more focused on the ability to rapidly model production lines for concept proofing. Case 4 also addressed the value of discovering issues early in solution development and coming up with an actual commercial proposal.

In contrast to case 2's belief that there can be less complexity, case 4 argues otherwise. CEO4 states that there will be increased complexity in a process which is already complex for many. As EM3 stated, there is quite a learning curve to know how to use adjacent simulation tools. However, there is a general agreement that implementing a full industrial metaverse tool is too early, considering their customers and the state of technology in general.

As there was much focus on sales and the development of solutions from all the cases, there was generally less focus on the immersive and collaborative functions of the technology. Case 1 had a more man-to-machine type of focus, while case 2 mentioned in the interview that it is very relevant to work visually with customers. EM3 in case 3 specifically touched on immersion, training and potential for tradeshows, which the interviewee mentioned as an aspect of implementing the Industrial Metaverse.

Table 3. Comparison of perceived technological value.

	Technological
Case 1	Sees a lot of value in the Industrial Metaverse. Creating DTs of entire factories. Effectivizing the sales process. Sees the Industrial Metaverse as the ultimate simulation environment.
Case 2	The Industrial Metaverse could be valuable for making more rational development decisions. There is a lot of testing that needs to be done that would be easier to do in digital environments. Also to do feasibility analyses like FAT and SAT.
Case 3	Sees value in using the Industrial Metaverse to test and optimize design and sales processes. Creating DTs of production environments. Especially valuable for doing FAT.
Case 4	Sees a lot of value in the Industrial Metaverse if it is open source, and not proprietary. Must be easy to create, access and use models in a simulation environment. Sees no value in making the Industrial Metaverse truly interconnected.

4.7.3 Organizational context analysis

When it comes to the implementation of the Industrial Metaverse, only case 1 is actively working towards it. Though, they are aware it takes a collaborative effort to realize it. Cases 2 and 3 are sitting on the fence, and waiting to see if the Industrial Metaverse will be something their customers are asking for. Lastly, case 4 is very interested in advanced simulation technologies, but is skeptical about the Industrial Metaverse as the correct term or path for them. Regardless of their view of the Industrial Metaverse, they have in common that they all already utilize simulation technologies to some extent.

When it comes to challenges, all cases seem to agree that cost and human capital are central challenges to overcome. Meanwhile, cases 2, 3 and 4 have the challenge of customers not knowing about or asking for Industrial Metaverse capabilities. Moreover, EM3 was also worried if the collaborative workspace part of the Industrial Metaverse would be better, or just end up as another "Teams" meeting once the novelty wore off. CEO4 was also skeptical about how the cybersecurity aspects of the Industrial Metaverse would be solved. Because sharing DTs is giving away a lot of the company's intellectual property. In addition, CEO4 pointed out that there is a limit to how useful simulation in itself is, and that external variables that are not simulated will always affect the result. This is a concern also shared by CIO1. However, CIO1 believed a good DT of an industrial environment should always be corrected by the physical environment in a continuous feedback loop. Lastly, Case 2 mentioned the value of having “face-to-face” conversations when working with customers, and that it is an aspect that is always going to be present.

Table 4. Comparison of implementation of the Industrial Metaverse.

	Organizational
Case 1	Is actively trying to work towards the Industrial Metaverse. Trying to make their product Metaverse-ready. Sees fragmentation, compatibility and knowledge as challenges to overcome amongst customers and partners.
Case 2	Are not yet actively working towards the Industrial Metaverse, and want to take a rational approach. Are instead relying on an ad-hoc organizational culture to pick it up if it becomes relevant. Most of their customers are “lightyears” behind this paradigm.
Case 3	Are not going to implement the Industrial Metaverse as it is now, but want to be a fast follower in case the paradigm hits a critical mass of adoption. Mentions cost, human resources and knowledge as challenges.
Case 4	They do not use the term Industrial Metaverse but are working a lot with digital models and rarely DTs. They are looking to use it more often if it becomes easier, but most of the time it is too time consuming and expensive. They are also worried about revealing too much of their products by sharing DTs and want better cybersecurity solutions in place to solve this.

4.7.4 Business environmental context analysis

In the business environment, it is clear that all the cases are focused on movements in the market. As case 1 puts it, external forces are what their product development is based on, which further helps them work on their strategic positioning and decision-making processes. Case 2 emphasizes that they are influenced by external factors and that development in technology ultimately affects their decision to adopt new technology in general. External forces that influence their decision-making are mentioned by case 1, 2 and 3. All of them mentioned customers, partners and market trends as important inputs of information that are used to get a sense of their surrounding business environment.

An interesting challenge within the business environment raised by case 4, is the reality that a small number of large corporations want to own the Industrial Metaverse space. It is an ongoing competition among them, going for the monopoly position. Case 4 argues that one organization can't own this space, while simultaneously benefitting the industry as a whole.

Table 5. Comparison of influence by external factors

	Business Environmental
Case 1	All actions and decisions are influenced by external factors. Actively trying to position themselves in advantageous positions.
Case 2	They have a lot of partners and suppliers around the world that they refer to as listening posts. So they are actively paying attention to what is out there and will implement technologies if it's interesting and fits with them as a company.
Case 3	Will work more towards the Industrial Metaverse if there is demand for it. Currently, only larger and more sophisticated customers seem to be interested. However, their main market segment is SMEs in traditional industries.
Case 4	Is paying attention to the rest of the industry and customers. CEO4 raised the challenge of the small number of large companies wanting to take a monopoly position within an Industrial Metaverse paradigm. A lot of challenges need to be solved externally before they will implement it.

4.7.5 Summary

At the end of each interview session, participants were asked to conclude if they think the Industrial Metaverse had any value or not based on what they had already said. While all cases believed it had value, there were some restraints. First off, one must remember that this is from their defined perception of what the Industrial Metaverse is, which some participants had not put a lot of thought into. Secondly, for all but case 1, the perceived value was not without some restraints. Case 1 strongly believes that the Industrial Metaverse is the way forward, although it is a revolution that will take time. Meanwhile, case 2 and 3 both see some value in it but believe it is too early for them and their customers. Lastly, Case 4 does not necessarily believe that a total adoption of the Industrial Metaverse will provide significant benefits for organizations. Instead, case 4 stresses that the basic implementation is where the value is at.

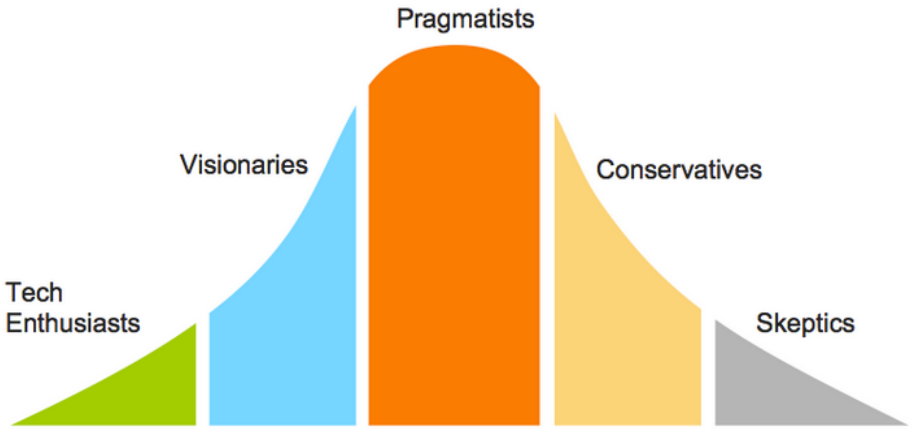

Figure 12. Illustration of the technology adoption life cycle (Moore, 2014).

When it comes to implementing the Industrial Metaverse, all the cases fit nicely within the technology adoption life cycle by Moore (2014). Case 1 is very positive towards implementation, but is not the first to implement the paradigm. Therefore, they fit under the visionaries' label. Meanwhile, case 2 fits under the pragmatist's label. As they want to implement it early, but still take a "rational approach." Case 3 seemed to have differing internal perceptions of how they adopt technology, with P3 and EM3 indicating that they are fast followers while DSM3 stated that they have always had a conservative approach. Overall, the impression was that they were more on the conservative side, so they fit best under the conservative label. Lastly, case 4 was without a doubt very skeptical towards the Industrial Metaverse, and therefore placed accordingly.

Table 6. Comparison of concluding thoughts.

	Summary
Case 1	Sees a lot of value in the Industrial Metaverse and is already working towards implementing it. Simulations are a core aspect of their business model and strategy. Can be called visionary.
Case 2	Sees the potential value of the Industrial Metaverse. However, their customers are not ready for it yet. But they believe it will be more prevalent in the future. Can be called pragmatic.
Case 3	Sees the potential value of the Industrial Metaverse, but is more interested in taking a measured approach. Can be called conservative.
Case 4	Sees a lot of value in the basic implementation of the Industrial Metaverse. However, they believe that creating full DTs of production lines is unlikely and they are not sure if it will provide any real value. Can be called a sceptic.

5.0 Discussion

The following chapters will discuss the findings against the TOE Framework and theory surrounding the Industrial Metaverse and Industry 4.0. The TOE framework has served sufficiently as a descriptive framework for this thesis and it will shape the discussion chapter as well. The interviews flowed in the same general direction which is what allows for comparable results and ultimately the foundation of the discussion chapter. The main threat to validity is whether or not the participants perceive the Industrial Metaverse in the same way. All the participants had a good understanding of simulation technologies and DTs since they all work with them. In addition, they had varying knowledge of the Metaverse. According to the Venn diagram by Zheng et al (2022), these two concepts are what define the Industrial Metaverse, and this is the reason why their knowledge was deemed sufficient to include in the thesis.

5.1 Technological value

Looking back at the core theory of what this thesis is built upon, the TOE framework, the technological context refers to the characteristics of the available technology and how it fits with current technologies used by the organization (Tornatzky & Fleischer, 1990). The characteristics, availability, and suitability further affect businesses' willingness to learn and decisions to implement new technology (Tornatzky & Fleischer, 1990). By placing this understanding into the context of the Industrial Metaverse as a potential technological tool that can be implemented in the automation industry, the results of the interviews will help us better understand the current state and the technological value it brings to companies within the automation industry. Hence, subquestion 1 can therefore be reviewed and discussed with the acquired primary data and the technological context.

> SQ1: *What technical capabilities and features does the Industrial Metaverse offer that can be implemented in the automation industry?*

With the data gathered from the interviews, evidence suggests that there are many technical capabilities and features that the Industrial Metaverse offer for the automation industry. Concerning figure 11 by Zheng et al. (2022), it seems the automation industry sees value in applications within the R&D, testing, and sales perspectives in the product life cycle.

However, this is mostly on the product and production line levels. All cases are clear, based on their understanding of the Industrial Metaverse definition, that this paradigm can bring value in different ways. Making use of Rogers' (1995) subcomponents of innovations, we can further organize and discuss these findings. Starting with perceived relative advantage, the first sub-component of innovations, all of the following points can be viewed as the perceived advantages relative to currently used technology.

5.1.1 Perceived relative advantage

A general emphasis is laid upon the technological capability of making users more insightful and getting a more holistic view of a solution proposal. The use of the Industrial Metaverse is thought to help transition manual tasks to more digitized processes that can further increase efficiency and quality while decreasing risk (Zheng et al, 2022). This seems to be true for all cases from both a sales and development perspective. From a sales perspective, the feature of visualizing solutions for customers is emphasized to have great value. It could improve the sales process by reducing sales cycle time, and design costs, and being more cost-effective while reducing project risk. From a development perspective, DT technology by itself is emphasized as having great value. Specifically, it helps in planning, testing, troubleshooting, optimizing, and analysis of systems and determining the feasibility of solutions which would reduce risk in product development (Zheng et al, 2022).

5.1.2 Compatibility

Next is the subcomponent of compatibility. Is the technology perceived as compatible with existing values, systems, and processes? According to CIO1 and CEO4, there is a lack of compatibility and standardized processes in today's industry. Evidence from cases 2, 3, and 4 suggests that the full integration of the Industrial Metaverse as a tool is an irrational idea for the time being. The reason for this seems to lie mostly in low customer demand for such tools to aid in planning and designing new solutions. However, all cases are already using DT technology, which as we know is part of the Industrial Metaverse and Industry 4.0 (Zheng et al., 2022; Barricelli, 2019; Pires et al., 2019). Therefore, one could argue that the next steps in improving internal processes and external collaboration would be moving closer to what we know as the Industrial Metaverse. This would then include the functional DT models, but also having humans being part of this shared immersive space, able to collaborate, interact and make reasoned and rapid decisions (Zheng et al., 2022).

5.1.3 Complexity

In terms of complexity, evidence suggests that there may be two sides to this. Indeed, most cases perceive the Industrial Metaverse to be a complex ingredient to mix into already complex matters. CEO4, CEO2, and CTO2 would argue that it might be too complex. Research on Industry 4.0 which shares many of the same enabling technologies supports this (Sisinni et al., 2018; Wan et al., 2016; Ghobakhloo, 2020). However, CEO4 also argues that if the continued development of the Industrial Metaverse is one of the common good for the industry as a whole, an open and standardized solution, one could argue that it could lower complexity and more easily provide advantages for businesses. EM3 also mentioned that even with existing tools for engineering, one needs to spend many hours learning how to use these programs. Therefore a business must be willing to invest and spend resources in increasing competence among employees to enjoy these advantages. The conclusion then, in terms of complexity, is that it may be out of reach for most companies considering the resources it may require to see the cost-benefit.

5.1.4 Trialability

For the subcomponent of trialability, there is the question of whether this technology is even available for the case companies. From what is known through the theory chapter, we know that the enabling technologies for the Metaverse exist. We're talking about the XR technologies, AI, blockchain, computer vision, 5G networking, edge computing, user connectivity, and IoT (Lee et al., 2021; Meta, n.d; Villalba-Diez et al., 2019; Javaid et al., 2022; Lee, 2008; Israr et al., 2012). But having truly interconnected, man-in-loop, industrial transaction Metaverse applications that assess the different levels of system granularities and the different stages in product life cycles, there is little evidence of its existence. However, Zheng et al. (2022) predict the increased development of these applications in the near future. In conclusion, it seems that the true Industrial Metaverse currently is a technology that only exists in fragments for most companies, due to lack of available applications.

5.1.5 Observability

Finally, the observability of the technology is limited. As discussed in the previous paragraph about trialability, it may not even fully exist at the time of writing. As Zheng et al. (2022) states, lots of the so-called Industrial Metaverse applications they reviewed in their work were just DTs, CPS, or merely XR systems. However, it is not impossible to imagine that larger corporations like Microsoft are attempting to make their version of this where it "enables humans and AI to work together to design, build, operate, and optimize physical systems using digital technologies" (Microsoft, 2023, 5:40) This would allow smaller companies to adopt and observe the outcomes of adoption. However, having a large corporation like Microsoft owning this Industrial Metaverse space could cause other challenges that will be discussed in the "5.3 Influence of external factors" chapter.

5.1.6 Answering sub-question 1

Based on the discussion surrounding the technological capabilities and features of the Industrial Metaverse, several important aspects can be beneficial in the automation industry. It can aid in creating increased insight, increase efficiency, and quality while decreasing risk both from a sales and development perspective. Especially the increased visual experience and simulation aspect has been emphasized as important. However, Evidence suggests that there is a lack of compatibility and standardization, making it difficult and even irrational to implement for the time being. In addition, it is also understood as a technology that would increase complexity rather than provide any real cost-benefit, hence being "out of reach" for most companies. Furthermore, companies don't have the option to try or observe a fully integrated Industrial Metaverse solution. It may only exist in fragments with enabling technologies, like the DT which all of the cases were familiar with.

5.2 Implementation and challenges

The second sub-question was formulated from the organizational context of the TOE framework. The organizational context says something about the internal characteristics of an organization's ability and willingness to change (Tornatzky & Fleischer, 1990). The TOE framework had several descriptive measures that Damanpour (1991) extended upon, which was then called organizational determinants. From the results, the organizational determinants; managerial attitude towards change, external communication, internal communication, specialization, and technical knowledge resources, were deemed relevant. These are again moderated by four variables which are the type of organization, type of innovation, stage of adoption, and scope of adoption. Due to the scope of this thesis, the number of organizational determinants included and considered have been reduced to those relevant for implementation, challenges, and organizing. In addition, the discussion can only reflect the results found in the interview process. With this in mind, we can discuss sub-question 2:

> SQ2: *How do organizations in the automation industry organize themselves to implement the Industrial Metaverse, and what are the key challenges they face in doing so?*

5.2.1 Implementation

The first part of sub-question 2 asks how organizations in the automation industry organize themselves to implement the Industrial Metaverse. The result showed that only case 1 specifically did this, while the rest referred to how they implement new technologies in general. This is evidence of the immaturity of the Industrial Metaverse, and the discussion will reflect this finding.

Despite the lack of direction toward the Industrial Metaverse, that is not to say that the cases have a negative managerial attitude toward change (Damanpour, 1991). Certainly, case 1 is very positive to change, but cases 2, 3, and 4 are also actively looking to optimize their workflow and sales process. It is just that they are not sure if the Industrial Metaverse is the right choice at the moment. The way the 4 cases organize themselves to implement the Industrial Metaverse is inherently different from each other. And it brings about many different approaches. Case 1 for example is trying to future-proof their product so that it will be plug-and-play for organizations when they start to implement the Industrial Metaverse. Others, like case 3 are reviewing existing workflows as they expand into new market segments. Case 2 is relying on an innovative organizational culture to pick up new technologies which reflect the organizational determinant of good internal communication (Damanpour, 1991). In addition, they have so-called “listening posts” around the globe in the form of suppliers, partners, etc., that would help them stay updated on trends. The fact that many of the participants even had knowledge of the Metaverse and in some cases had heard of the Industrial Metaverse, suggests that they are good at external communication, which is another organizational determinant (Damanpour, 1991). DSM3 mentioned paying a lot of attention to new technologies on LinkedIn, which is certainly an important channel in different business environments.

Given the type of organization that the cases are, either a tech startup or integrator of technology, they have to constantly look into new technologies to be competitive (Damanpour, 1991). In regards to the scope of adoption, smaller organizations are more selective with the technologies they adopt and expect them to contribute to increased success. Whereas large organizations are more likely to adopt many high-cost innovations within a small time frame (Damanpour, 1991). For the case organizations themselves, which are SMEs, this seems to be very accurate. Case 1 believes the Industrial Metaverse will contribute to significantly increased success, while the others do not. Furthermore, CEO2 and P3 believe that it is the larger and more sophisticated customers that are going to drive the adoption of the Industrial Metaverse. P3 specifically mentioned the customers in the semiconductor industry and aero industry as sophisticated where they want to utilize advanced simulation technologies. And CEO2 talked about seeing a clear divide in technology adoption between companies that made more than a billion dollars and those that made less. This notion is also supported by research on the adoption of Industry 4.0 (Mogos et al., 2019; Stentoft et al., 2019; Matt et al., 2020).

5.2.2 Challenges

The second part of subquestion 2 asks about what challenges there are in implementing the Industrial Metaverse. All the cases could identify challenges related to implementing the

Industrial Metaverse or its key technologies of it. Regarding the most common challenge, cost**,** P3 has yet to see a real return on investment for organizations adopting simulation solutions in industrial facilities. Even though it seems to have the promise it could reduce cost, CEO4 argues that introducing such technologies adds a layer of complexity and cost that is unnecessary for most projects. CEO4, P3, and CEO2 all seem to believe that the high cost makes it most valuable for multi-million dollar production lines, and therefore that is where the adoption is happening first. Moving away from production lines and on to individual machine level, the time and effort and cost it takes to create functional DTs is still high. So even when the organization has the technical knowledge and resources to do it, it will only be worth it if they plan to sell larger volumes of their solution (Damanpour, 1991). CEO4 does not believe it is cost-effective for one-off custom solutions. This might also be a reason why case 1 is adopting the Industrial Metaverse because they mainly only have one product to sell.

In regards to knowledge, convincing partners and customers to work towards the Industrial Metaverse is a major hurdle according to CIO1. Instead, CIO1 likes the “how to eat an elephant” approach by starting small. Case 1 is trying to show the benefits of the Industrial Metaverse through their products and services in the hope that it will transfer to other areas of operation. In particular, their simulation process has proved to drastically shorten sales cycles, and DSM3 mentioned looking into adopting this process for sales of their other products. CEO2 and CTO2 also believe that knowledge is a challenge in implementing the Industrial Metaverse, stating that most of their customers are lightyears behind this concept. This might indicate that they lack slack resources or the understanding to catch up (Damanpour, 1991; Figueiredo, 2022). This is also congruent with the adoption of Industry 4.0 (Mogos et al, 2019). Case 2 is open to optimizing their workflows, but selling solutions for the Industrial Metaverse to SMEs was out of the question at this time. The same goes for cases 3 and 4. Even if cases 2, 3, and 4 were to sell these solutions, or if end customers had the help of consultant firms, CIO1 was unsure if end customers would even have the knowledge of what to do with the technology or how to fully utilize it. Case 2 would have to invest in more human capital and skills if they were to implement the Industrial Metaverse according to DSM3 and P3. In addition, EM3 could testify that the learning curve of a simulation tool they are using is very steep and that he is struggling to use it sometimes.

Natural interaction in the Industrial Metaverse is a challenge previously identified in the paper by Zheng et al (2022), which some participants briefly mentioned but did not iterate upon. Except for EM3, who was concerned if the Industrial Metaverse would continue to have its interactive appeal once the novelty wore off. EM3 stated it might end up as just another “Teams meeting”. It is not certain that everyone wishes for more options to virtually interact with one another. Case 4 for example, mentioned having a “video-off” policy in digital meetings. CEO2 and CTO2 also remarked that one must never forget the value of face-to-face communication.

Standardization, compatibility, and fragmentation are other challenging aspects of implementing the Industrial Metaverse. CIO1 and CEO4 were particularly concerned about these aspects. Many factories today seemingly have a web of different systems and hardware that cannot necessarily be connected digitally, and even if they were, it’s not certain that they could communicate in an Industrial Metaverse. Even just sharing digital models between firms is reported by CEO4 to be quite challenging at times, since there are so many different file types and methods of sharing. However, there are some opposing perceptions of how this could be solved between CEO4 and CIO1. CIO1 believes that having a web of different DT hardware is an improvement from today's situation. On the other hand, CEO4 wants standardized and open solutions for creating and sharing DTs if there is to be any point to it. From the Industry 4.0 perspective, an industry standard for communication between CPS is the OPC UA communication protocol (Kagermann & Wahlster, 2022).

In the context of sharing models and open standardized solutions, CEO4 was concerned about the cybersecurity aspect of it. If you share a DT of your solution you are effectively also sharing your intellectual property, sharing the digital security concerns of Barricelli (2019). Creating trustworthy data infrastructures is also one of the future megatrends within Industry 4.0 identified by Kagermann & Wahlster (2022). The Industrial Metaverse hopes to solve this with NFTs and blockchain technologies (Zheng et al., 2022), as NFTs can serve as a virtual certificate that authenticates virtual assets (Wang et al., 2021). Another aspect of cybersecurity is how to safely enable remote access and control of machines, CEO4 explains that most customers do not connect their production lines to the internet because of fear of cybercrime. This is a challenge that must be solved, as the value of implementing the Industrial Metaverse might not outweigh the risk of being targeted by cybercrime.

5.2.3 Answering sub-question 2

To summarize and answer subquestion 2, three out of four cases are not organizing themself to implement the Industrial Metaverse. Case 1 which did it mainly out of necessity to provide a proof of concept during the sales process, and are trying to exploit the value of DT technology. From the case's point of view, there were many challenges with the main two being the cost of implementation and knowledge of how to utilize it. Other than these, there were also challenges related to interaction, standardization, and cybersecurity.

5.3 Influence of external factors

The final sub-question was formulated using the environmental context of the TOE framework. The environmental context is referring to the industry characteristics, the market structure, technology support infrastructure, and governmental regulations. With the primary data acquired through the interviews and the theory surrounding the influence of external factors, we can review and discuss the final sub-question of this study.

SQ3: *How do external factors influence the implementation and perceived value of the Industrial Metaverse in the automation Industry?*

All the cases are paying attention to their external business environment and are interested in being up to date on potential relevant technology and trends within the industry. Based on the interviews, it appears that the external environment has a strong influence on technology adoption and implementation. However, there are some differences in how they perceive this influence.

Case 1 emphasized that almost all their actions and decisions were influenced by external factors. These external factors can be partners, customers, and marked trends. Case 2 had similar descriptions regarding external factors while also being focussed on having a rational approach to new technology by not being the earliest adopter. Case 3 is also heavily influenced by external factors, specifically their customers were mentioned to be an important influencer, along with market trends, social media, and trade shows. In addition, it is also mentioned that having more companies adopting it would serve as an influence or a driver to implement the Industrial Metaverse. This pragmatic/conservative approach can be viewed as a way to mitigate investment risk regarding the technology implementation.

The answers in the interviews seem to be congruent with the theory. Referring back to Rogers (1995), the most influence may come from industry leaders, such as larger and more well-known companies. For example, CIO1's understanding of the Industrial Metaverse has been influenced by Siemens and Microsoft's views of what the paradigm entails. Large companies are also more likely to adopt high-cost technology. On the other hand, SMEs such as the companies used in this study, are more likely to be more restrictive and only adopt when there is clear evidence regarding benefit for the company. (Damanpour, 1991). However, once they have decided to implement it, the lack of available talents might affect an organization's ability to implement the Industrial Metaverse (Tornatzky & Fleischer, 1990). DSM3 and P3 mentioned that they would need to recruit new employees with the right skills if they were to implement it themselves. A different aspect was explored by CEO4 concerning the influence of external factors. CEO4 does not believe that an eventual Industrial Metaverse will provide much value if there are just a handful of big actors dominating the market, effectively locking it behind paywalls. However, this view is very congruent with the theory of the Industrial Metaverse and how it contributes to decentralization in industries (Zheng et al., 2022). For example by using open-source development, NFT, and blockchain technology. Decentralization can prevent monopolies and enhance innovation, competition, and collaboration (Zheng et al., 2022).

5.3.1 Answering sub-question 3

Regarding sub-question 3, evidence suggests that external factors surrounding companies have a strong influence. In particular, larger opinion leading companies are believed to be explaining both the sense of relevancy and also companies' understanding of it. Then there are also partners, customers, and market trends who are believed to influence companies further. In time, this may eventually drive more companies into taking the necessary steps to implement the technology into their organizational processes. Finally, both few and big actors are thought to be competing in taking the lead and owning the Industrial Metaverse space. Although this may not be the ideal vision of how it should be. This will also serve as an external force that dictates the future of what the Industrial Metaverse will look like, which ultimately affects the companies' process by which they adopt and implement this technological innovation.

6.0 Conclusions

In the previous chapter the sub-questions were discussed and answered, and the main takeaways from them lay the foundation of how the thesis statement is answered.

"*How can the Industrial Metaverse be implemented in the automation industry, and what is the value of the technology in this context?*"

The Industrial Metaverse can be implemented in the automation industry as an open immersive platform to share, sell and simulate solutions and production lines, which provides increased quality, efficiency and decreases project risk within sales and development processes.

Findings and theory show that the Industrial Metaverse, in its true sense, does not yet exist. Instead, it is fragmented amongst all its key technologies, many of which are still immature or under development. Across all cases, it was a common understanding that the technology is currently underdeveloped for full-scale implementation and that early adoption might be irrational. Therefore, each organization has to make its assessment and implement it at a time when it aligns with the strategy.

However, some organizations are still trying to implement this bleeding-edge technology. The characteristics of these organizations are either 1) They have a lot of slack resources and work with sophisticated products. Or 2) The industrial Metaverse already closely aligns with their strategy and core competency like with case 1. On the other hand, some organizations like case 4 might view a full implementation as unrealistic and of little significance but still view the basic implementation as very valuable. In which case, they are leaning towards the right side of the Venn diagram (figure 9) by Zheng et al. (2022), and distancing themselves from the Metaverse idea.

Even though the technology is currently evolving, there are many perceived technical capabilities and features of the Industrial Metaverse that were identified in this thesis. The increased visual experience and simulation have been especially emphasized as important aspects. All cases stressed the value of these aspects in sales and R&D processes, where it can aid in increasing insight, efficiency, and quality while decreasing project risk. More specifically, it could greatly improve the design, testing, and FAT/SAT processes.

The common challenges that all the cases mentioned were reducing the cost of technologies and making them easier to use. More importantly, the technologies must also be compatible with each other so that end users won't have a large challenge with putting them all together to create an Industrial Metaverse. Lastly, theory and findings show that sharing DTs and connecting production lines to the internet for remote access introduces risk to cybersecurity.

All cases were in agreement that external business environment forces had a strong influencing impact on organizations. Larger, opinion-leading companies, can explain the sense of relevancy. These large companies may also affect the trajectory of technology development and perhaps the very definition of the Industrial Metaverse itself. At the same time partners, customers, and market trends were identified to be important sources of information, affecting each organization's perception of the technology. Combined, these forces affect a company's processes by which they adopt and implement this technological innovation.

The Industrial Metaverse is one of many new digital paradigms emerging in modern industries. Whether it is called the Industrial Metaverse, Industry 4.0 or 5.0 might be beside the point. What is certain, is that these cases from the automation industry are looking to optimize their workflow, and DT simulations are an important puzzle piece in achieving this. There may indeed be an industrial revolution happening, but it will take time. After all, the first industrial revolution spanned 40 years.

6.1 Theoretical implications

This thesis has a few theoretical implications. Firstly, the thesis has defined the main use cases of the Industrial Metaverse within the automation industry and why this leads to value. Additionally, there are many aspects and use cases of the Industrial Metaverse that have not been brought up at all. This signifies that the Industrial Metaverse has different use cases for different industries, and therefore must be viewed as such based on the context the research is done in.

Secondly, there have been several challenges relating to the implementation and creation of the Industrial Metaverse. Especially, evidence in this thesis suggests that high cost and complexity are hindering factors for companies to adopt such technologies. Further theoretical work should therefore include these variables when looking into the implementation of the Industrial Metaverse or adjacent technologies.

Thirdly, the thesis has identified a relationship between the big industry leaders who are pushing for the Industrial Metaverse, the organizations in the automation industry, and manufacturing SMEs. The industry leaders with sophisticated production lines are pushing demand for digital technologies in manufacturing which the automation industry has to deliver. On the other hand, SMEs are not able to implement digital technologies by themself and require help to implement them. It seems the automation industry has to manage both technology pull from larger industry leaders and technology push towards SMEs at the same time.

Lastly, the TOE framework by Tornatzky & Fleischer (1990) has served well as a descriptive framework for the implementation of the Industrial Metaverse. This confirms that the TOE framework can be used as a structural framework in the context of identifying value by adopting the Industrial Metaverse.

6.2 Managerial implications

As well as contributing to theory, the thesis has also tried to contribute practically to interview participants and others in the automation industry. The first contribution has been to demystify the buzzword Industrial Metaverse. By highlighting differences between Industry 4.0 and the Industrial Metaverse, one might perhaps understand the value of natural interaction in complex industrial environments. This might help organizations with strategic decisions on whether they want to implement the Industrial Metaverse or not.

The second contribution is presenting differentiating views on the Industrial Metaverse. By comparing organizations that have a positive, neutral, and skeptical view of the paradigm the thesis hopes to show a balanced and objective understanding of what it is, and what its limitations and challenges are. In addition, the thesis has shown different examples of how the Industrial Metaverse might be applied in practice.

Finally, this thesis is contributing by presenting an updated perspective by some companies in the automation industry regarding the Industrial Metaverse. These findings may therefore be, in part, used as input for further development of the technology or industrial applications.

6.3 Limitations

As well as the initial limitations described in chapter 1.3, a few more limitations were discovered during data collection and discussion.

The interview protocol was quite short and could have contained more in-depth questions to get even better data collection. The longest interview was just under 30 minutes, even though they were planned to last for 1 hour. In particular, more time could have been spent on establishing a thorough understanding of the participants' perceptions of the Metaverse and the Industrial Metaverse. Two participants mentioned they would have liked a definition at the beginning of the interview so they could have answered better. However, the interviewers did not want to risk contaminating their perceptions.

Furthermore, the partnership status between some of the cases might have led to skewed results. Particularly as all the cases have a large focus on end-of-line packaging solutions. More different opinions and examples would perhaps have emerged if the thesis were to look at organizations with different specializations as well.

6.4 Suggestions for further research

Because of the thesis limitations, it is suggested to do further research on organizations with different specializations and niches within the automation industry. This might confirm the thesis findings or discover new insights.

This study was specifically interested in perspectives from the automation industry. Therefore, looking into other industries may provide an even more holistic and nuanced understanding of the paradigm. Especially as not all aspects of the Industrial Metaverse seemed to be very important for organizations within the automation industry, such as AI, aggregated data and predictive maintenance.

Furthermore, it would be interesting to look more in-depth at different organization characteristics to see what determines early adoption of the Industrial Metaverse. For instance, Ghobakhloo (2022) was able to construct a roadmap that describes important determinants promoting the adoption of Industry 4.0 technology among SMEs.

Lastly, a meta-analysis of all major paradigms within advanced manufacturing applications might be useful to understand their differences or perhaps likeness. It seems there are many terms for implementing the same key technologies with minor differences, and as such it might be valuable to start a discussion of which terms are the most semantically correct to use.

7.0 References

Aloqaily, M., Bouachir, O., Karray, F., Ridhawi, I. A., & Saddik, A. E. (2022). Integrating DT and Advanced Intelligent Technologies to Realize the Metaverse. *IEEE Consumer Electronics Magazine*, 1–8. https://doi.org/10.1109/MCE.2022.3212570

Alpala, L. O., Quiroga-Parra, D. J., Torres, J. C., & Peluffo-Ordóñez, D. H. (2022). Smart Factory Using Virtual Reality and Online Multi-User: Towards a Metaverse for Experimental Frameworks. *Applied Sciences*, *12*(12), 6258. https://doi.org/10.3390/app12126258

Anderson, J., & Rainie, L. (2022, June 30). *The Metaverse in 2040*. Pew Research Center. https://www.pewresearch.org/internet/2022/06/30/the-metaverse-in-2040/

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence: Teleoperators & Virtual Environments*, *6*(4), 355–385.

Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics*, *229*, 107776. https://doi.org/10.1016/j.ijpe.2020.107776

Barricelli, B. R., Casiraghi, E., & Fogli, D. (2019). A Survey on DT: Definitions, Characteristics, Applications, and Design Implications. *IEEE Access*, *7*, 167653–167671. https://doi.org/10.1109/ACCESS.2019.2953499

Bimber, O., & Raskar, R. (2005). *Spatial Augmented Reality: Merging real and virtual worlds*. A K Peters.

Business Process Incubator. (2022, July 26). *Industry 4.0 Technologies*. https://www.businessprocessincubator.com/content/industry-4-0-technologies/

Christensen, L. B., Johnson, B., & Turner, L. A. (2014). *Research methods, design, and analysis* (Twelfth Edition). Pearson.

Cronbach, L. J. (1975). Beyond the two disciplines of scientific psychology. *American Psychologist*, *30*(2), 116–127. https://doi.org/10.1037/h0076829

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383–394. https://doi.org/10.1016/j.ijpe.2018.08.019

Damanpour, F. (1991). ORGANIZATIONAL INNOVATION: A META-ANALYSIS OF EFFECTS OF DETERMINANTS AND MODERATORS. *Academy of Management Journal*, *34*(3), 555–590. https://doi.org/10.2307/256406

Deloitte China. (2022). *Metaverse report—Future is here. Global XR Industry Insight.* Deloitte. https://www2.deloitte.com/cn/en/pages/technology-media-and-telecommunications/articles/metaverse-whitepaper.html

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., & Cai, W. (2021). Metaverse for Social Good: A University Campus Prototype. *Proceedings of the 29th ACM International Conference on Multimedia*, 153–161. https://doi.org/10.1145/3474085.3479238

Figueiredo, S. C. (2023). Rhetoric in the metaverse. *Convergence: The International Journal of Research into New Media Technologies*, *29*(1), 81–96. https://doi.org/10.1177/13548565221138399

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production*, *252*, 119869. https://doi.org/10.1016/j.jclepro.2019.119869

Ghobakhloo, M., Iranmanesh, M., Vilkas, M., Grybauskas, A., & Amran, A. (2022). Drivers and barriers of Industry 4.0 technology adoption among manufacturing SMEs: A systematic review and transformation roadmap. *Journal of Manufacturing Technology Management*, *33*(6), 1029–1058. https://doi.org/10.1108/JMTM-12-2021-0505

Gobo, G. (2011). Glocalizing methodology? The encounter between local methodologies. *International Journal of Social Research Methodology*, *14*(6), 417–437. https://doi.org/10.1080/13645579.2011.611379

Hassani, H., Huang, X., & MacFeely, S. (2022). Enabling DTs to Support the UN SDGs. *Big Data and Cognitive Computing*, *6*(4), 115. https://doi.org/10.3390/bdcc6040115

Hennig-Thurau, T., & Ognibeni, B. (2022). Metaverse Marketing. *NIM Marketing Intelligence Review*, *14*(2), 43–47. https://doi.org/10.2478/nimmir-2022-0016

IEEE. (2023). Call for Papers: Industrial Metaverse for Smart Manufacturing. *IEEE Transactions on Cybernetics*, *53*(2), 1375–1375. https://doi.org/10.1109/TCYB.2023.3236421

Israr, A., Kim, S.-C., Stec, J., & Poupyrev, I. (2012). Surround haptics: Tactile feedback for immersive gaming experiences. *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, 1087–1090. https://doi.org/10.1145/2212776.2212392

Javaid, M., Haleem, A., Singh, R. P., Rab, S., & Suman, R. (2022). Exploring impact and features of machine vision for progressive industry 4.0 culture. *Sensors International*, *3*, 100132. https://doi.org/10.1016/j.sintl.2021.100132

Jiang, Y., Kaynak, O., Luo, H., Liu, M., & Yin, S. (2022). *Industrial Metaverse: Solutions from a higher-dimensional world* [Preprint]. https://doi.org/10.36227/techrxiv.21547644.v1

Kagermann, H. (2015). Change Through Digitization—Value Creation in the Age of Industry 4.0. In H. Albach, H. Meffert, A. Pinkwart, & R. Reichwald (Eds.), *Management of Permanent Change* (pp. 23–45). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-05014-6_2

Kagermann, H., & Wahlster, W. (2022). Ten Years of Industrie 4.0. *Sci*, *4*(3), 26. https://doi.org/10.3390/sci4030026

Ketokivi, M., & Choi, T. (2014a). Renaissance of case research as a scientific method. *Journal of Operations Management*, *32*(5), 232–240. https://doi.org/10.1016/j.jom.2014.03.004

Ketokivi, M., & Choi, T. (2014b). Renaissance of case research as a scientific method. *Journal of Operations Management*, *32*(5), 232–240. https://doi.org/10.1016/j.jom.2014.03.004

Kusiak, A. (2018). Smart manufacturing. *International Journal of Production Research*, *56*(1–2), 508–517. https://doi.org/10.1080/00207543.2017.1351644

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. https://doi.org/10.1007/s12599-014-0334-4

Lee, E. A. (2008). Cyber Physical Systems: Design Challenges. *2008 11th IEEE International Symposium on Object and Component-Oriented Real-Time Distributed Computing (ISORC)*, 363–369. https://doi.org/10.1109/ISORC.2008.25

Lee, J., & Kundu, P. (2022). Integrated cyber-physical systems and industrial metaverse for remote manufacturing. *Manufacturing Letters*, *34*, 12–15. https://doi.org/10.1016/j.mfglet.2022.08.012

Lee, L.-H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., & Hui, P. (2021). *All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda* (arXiv:2110.05352). arXiv. http://arxiv.org/abs/2110.05352

Liu, M., Fang, S., Dong, H., & Xu, C. (2021). Review of DT about concepts, technologies, and industrial applications. *Journal of Manufacturing Systems*, *58*, 346–361. https://doi.org/10.1016/j.jmsy.2020.06.017

Matt, D. T., Modrák, V., & Zsifkovits, H. (Eds.). (2020). *Industry 4.0 for SMEs: Challenges, Opportunities and Requirements*. Springer International Publishing. https://doi.org/10.1007/978-3-030-25425-4

McKinsey & Company. (2022). *Value creation in the metaverse: The real business of the virtual world.* McKinsey Global Publishing. https://www.mckinsey.com/~/media/mckinsey/business%20functions/marketing%20and%20sales/our%20insights/value%20creation%20in%20the%20metaverse/Value-creation-in-the-metaverse.pdf

McKinsey & Company. (2023). *Industrials & Electronics Practice: Unlocking the industrial potential of robotics and automation.* McKinsey Global Publishing. https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/o ur%20insights/unlocking%20the%20industrial%20potential%20of%20robotics%20and%20automation/unlocking-the-industrial-potential-of-robotics-and-automation-final.pdf

Mekni, M., & Lemieux, A. (2014). Augmented Reality: Applications, Challenges and Future Trends. *Applied Computational Science*, *20*, 205–214.

Meta. (n.d.). *This is Meta Quest Pro*. https://www.meta.com/no/en/quest/quest-pro/

Microsoft (Director). (2022, October 11). *The Industrial Metaverse* [Video]. https://www.youtube.com/watch?v=wAlcX7QaWkc

Microsoft Ignite (Director). (2022, October 20). *The Industrial Metaverse* [Video]. https://www.youtube.com/watch?v=oo16phgcALQ

Mogos, M. F., Eleftheriadis, R. J., & Myklebust, O. (2019). Enablers and inhibitors of Industry 4.0: Results from a survey of industrial companies in Norway. *Procedia CIRP*, *81*, 624–629. https://doi.org/10.1016/j.procir.2019.03.166

Moore, G. A. (2014). *Crossing the chasm: Marketing and selling disruptive products to mainstream customers* (Third edition). HarperBusiness, an imprint of HarperCollins Publishers.

Mystakidis, S. (2022). Metaverse. *Encyclopedia*, *2*(1), 486–497. https://doi.org/10.3390/encyclopedia2010031

OpenAI. (2022, September 21). Introducing Whisper. *OpenAI*. https://openai.com/research/whisper

Pires, F., Cachada, A., Barbosa, J., Moreira, A. P., & Leitao, P. (2019). DT in Industry 4.0: Technologies, Applications and Challenges. *2019 IEEE 17th International Conference on Industrial Informatics (INDIN)*, 721–726. https://doi.org/10.1109/INDIN41052.2019.8972134

Radoff, J. (2021, April 7). The Metaverse Value-Chain. *Medium*. https://medium.com/building-the-metaverse/the-metaverse-value-chain-afcf9e09e3a7

Rogers, E. M. (1995). Diffusion of Innovations: Modifications of a Model for Telecommunications. In M.-W. Stoetzer & A. Mahler (Eds.), *Die Diffusion von Innovationen in der Telekommunikation* (pp. 25–38). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-79868-9_2

Rubin, H. J., & Rubin, I. (2012). *Qualitative interviewing: The art of hearing data* (3rd ed). SAGE.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2015). *Research methods for business students* (Seventh edition). Pearson Education.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (Eighth Edition). Pearson.

Schwab, K. (2016). *The fourth industrial revolution* (First U.S. edition). Crown Business.

Sisinni, E., Saifullah, A., Han, S., Jennehag, U., & Gidlund, M. (2018). Industrial Internet of Things: Challenges, Opportunities, and Directions. *IEEE Transactions on Industrial Informatics*, *14*(11), 4724–4734. https://doi.org/10.1109/TII.2018.2852491

Stentoft, J., Jensen, K. W., Philipsen, K., & Haug, A. (2019). *Drivers and Barriers for Industry 4.0 Readiness and Practice: A SME Perspective with Empirical Evidence*. Hawaii International Conference on System Sciences. https://doi.org/10.24251/HICSS.2019.619

Stephenson, N. (1992). *Snow crash*. Bantam Books.

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *The processes of technological innovation*. Lexington Books.

Villalba-Diez, J., Schmidt, D., Gevers, R., Ordieres-Meré, J., Buchwitz, M., & Wellbrock, W. (2019). Deep Learning for Industrial Computer Vision Quality Control in the Printing Industry 4.0. *Sensors*, *19*(18), 3987. https://doi.org/10.3390/s19183987

Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. (2016). Software-Defined Industrial Internet of Things in the Context of Industry 4.0. *IEEE Sensors Journal*, 1–1. https://doi.org/10.1109/JSEN.2016.2565621

Wang, Q., Li, R., Wang, Q., & Chen, S. (2021). *Non-Fungible Token (NFT): Overview, Evaluation, Opportunities and Challenges* (arXiv:2105.07447). arXiv. http://arxiv.org/abs/2105.07447

Yin, R. K. (2014). *Case study research: Design and methods* (Fifth edition). SAGE.

Zheng, Z., Li, T., Li, B., Chai, X., Song, W., Chen, N., Zhou, Y., Lin, Y., & Li, R. (2022). Industrial Metaverse: Connotation, Features, Technologies, Applications and Challenges. In W. Fan, L. Zhang, N. Li, & X. Song (Eds.), *Methods and Applications for Modeling and Simulation of Complex Systems* (Vol. 1712, pp. 239–263). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-9198-1_19

8.0 Appendices

This chapter includes the interview protocol, definition list and proof from SIKT that the thesis could process personal information about the participants.

8.1 Interview Protocol

Interview protocol:

Constructs: Value of Industrial Metaverse, Organizational innovation, Influence of external factors.

1. Introduction: *5 min*
   - Can you tell us a bit about your organization's role in the automation industry?
   - Have you heard of the industrial metaverse before? And if so, what is your understanding of it?
2. Technological context (SQ1) *15 min*
   - In your opinion, what technical capabilities and features does the industrial metaverse offer that can be implemented in the automation industry?
   - Can you give any examples of how these capabilities and features can or has been applied in the automation industry?
3. Organizational context (SQ2) *15 min*
   - How does your organization currently organize itself to implement the industrial metaverse, if at all?
   - What are some of the key challenges organizations face when trying to implement the industrial metaverse?
   - How have you, or how do you intend to face these challenges?
   - How important is it to solve these challenges?
4. Business environmental context (SQ3) *15 min*
   - Are there any external factors outside of the company that influences the adoption of the Industrial Metaverse?
   - If there are any external factors, how do you think these forces may affect your organization's strategic positioning within the Industrial Metaverse?
5. Conclusion: *10 min*

- Based on our discussion, do you think the industrial metaverse can provide value to the automation industry? Why or why not?
- Are there any additional comments or insights you would like to share about the industrial metaverse or its implementation in the automation industry?

8.2 Definition list

Industry 4.0 - Refers to the fourth industrial revolution characterized by the integration of advanced technologies such as CPS, artificial intelligence, robotics, and the Internet of things (IoT) into the manufacturing process to improve efficiency and productivity (Kagermann & Wahlster, 2022).

Cyber-physical Systems (CPS) - Integrates computation in machines, where embedded computers and networks monitor and control the physical processes (Lee, 2008)

Digital Twin (DT) - A digital representation of a physical object, process or service, and is used to monitor or predict performance (Liu et al., 2021; Hassani et al., 2022).

Simulations - "The combination of complete physical mechanisms and deterministic laws to calculate the next state according to the current boundary and state" (Zheng et al., 2022, p. 1).

Factory acceptance test (FAT) - Testing that is done to make sure that the automation solution works within specifications and expectations before it is delivered to the end customer.

Site acceptance test (SAT) - Testing that is done at the factory location to determine if it functions as intended.

Metaverse - Not clearly defined yet. A working definition can be the next iteration of the internet that seamlessly combines our digital and physical lives (McKinsey & Company, 2022). As a result of converging technologies that enable multisensory interactions with digital environments, objects and people, the Metaverse is considered a new paradigm within computer science innovation (Mystakidis, 2022). Within this space, users will be immersed in a post-reality universe that merges physical reality with digital virtuality in real-time (Mystakidis, 2022; Radoff, 2021)

Industrial Metaverse - "Industrial Metaverse is a new man-in-loop digital twin system of the real industrial economy, through the interconnection of industrial digital resources, supported by DT, XR, NFT, NPL, as well as AI technologies, and driven by real-time information in industry" (Zheng et al., 2022, p. 240).

Internet of Things (IoT) and Industrial Internet of Things (IIoT) - IoT involves connecting everyday items like lamps and speakers to the Internet, while IIoT focuses on connecting machines to information technology and business processes (Sisinni et al., 2018).

Extended Reality (XR) - The umbrella term for the immersive technologies VR, AR and MR (Mystakidis, 2022; Lee et al., 2021)

Virtual Reality (VR) - A VR system places a participant into a digital 3D environment world (Slater & Sanchez-Vives, 2016; Alpala et al., 2022).

Augmented Reality (AR) - Involves superimposing digital information onto the real-world environment, creating a blend of real and virtual objects in real-time (Bimber & Raskar, 2005)

Mixed Reality (MR) - A combination between AR and VR. (Mystakidis, 2022)

Non-Fungible-Tokens (NFT) - A type of cryptocurrency that is derived from the smart contracts of Ethereum, suitable for identifying something or someone in a unique way (Wang et al., 2021)

Blockchain - A distributed and attached-only database that maintains a list of data records linked and protected using cryptographic protocols (Zheng et al, 2022; Lee et al, 2021).

Smart Manufacturing - Smart manufacturing is an emerging form of production integrating different digital technologies such as CPS, IoT, sensors and predictive engineering. Industry 4.0 is originally Germany's strategy for smart manufacturing (Kusiak, 2018; Kagermann, 2015).

Small & medium-sized enterprise (SME) - A company with less than 250 employees with a turnover of less than EUR 50 million, and an annual balance sheet that does not exceed EUR 43 million (Stentoft et al., 2019).

8.3 Assessment of processing of personal data

Sikt

Assessment of processing of personal data

Reference number	Assessment type	Date
828619	Standard	29.03.2023

Project title
Metaverse in the context of Industry 4.0

Data controller (institution responsible for the project)
Høgskulen på Vestlandet / Fakultet for økonomi og samfunnsvitskap / Institutt for økonomi og administrasjon

Project leader
Atanu Kumar Nath

Student
Lars Røyrhus

Project period
01.01.2023 - 20.05.2023

Categories of personal data
General

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 20.05.2023.

Notification Form

Comment
OM VURDERINGEN
Sikt har en avtale med institusjonen du forsker eller studerer ved. Denne avtalen innebærer at vi skal gi deg råd slik at behandlingen av personopplysninger i prosjektet ditt er lovlig etter personvernregelverket.

FØLG DIN INSTITUSJONS RETNINGSLINJER
Vi har vurdert at du har lovlig grunnlag til å behandle personopplysningene, men husk at det er institusjonen du er ansatt/student ved som avgjør hvilke databehandlere du kan bruke og hvordan du må lagre og sikre data i ditt prosjekt. Husk å bruke leverandører som din institusjon har avtale med (f.eks. ved skylagring, nettspørreskjema, videosamtale el.)

Personverntjenester legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til oss ved å oppdatere meldeskjemaet. Se våre nettsider om hvilke endringer du må melde: https://sikt.no/melde-endringar-i-meldeskjema

OPPFØLGING AV PROSJEKTET
Vi vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!