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The adoption of Digital Twins: Drivers, enablers, barriers, challenges, and benefits

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Preface

This master's thesis has been written in the spring of 2023 and marks the end of our two-year master's education in Information Systems at the University of Agder. The purpose of this thesis is to acquire knowledge and be more familiar with Digital Twins. We both share an interest in new technology and concepts, which makes the Digital Twin a perfect topic for us. In fact, Digital Twins was a new term for us, until brainstorming for potential master thesis topics with family members in the autumn of 2022. Through quick research online, we read about its great benefits, which made us curious about why more organizations do not use this technology and utilize its potential. That was where we discovered that we were not alone in this unfamiliarity. As a result, this motivated us to contribute to awareness and build knowledge that can help organizations to get started with this concept for utilizing its many benefits. Our education is a mix of both technical and business-related courses; however, this thesis is scoped into the organizational perspective of adoption.

Although the learning curve has been steep, it has also been very interesting. Our gratitude for selecting this topic has been repeated throughout the entire process. This genuine interest in the topic has been a motivating factor, causing a hunger to continuously seek more knowledge. Not only has this made all interviews more interesting, but it has led to several of the conversations have gone outside the interview guide as a result of curiosity. However, we must acknowledge that the many meanings and interpretation has led to significant confusion and difficulties in understanding who is right. Nevertheless, several interviewees shared their appreciation for us researching and shedding light on the Digital Twin topic.

We want to give a special thanks to our supervisor Tim A. Majchrzak for all the support throughout the project period and inspiring us to follow our interests and ideas. All feedback and guidance have been much appreciated. We will also thank our collaboration partner Capgemini Norway, and especially our contact person Vegard Sætre that has contributed with interviewees and forming the thesis. Furthermore, we must thank our fellow students for together creating a pleasant everyday life with writing and inspiration, where there has been room for asking questions and helping each other. Nonetheless, all the interviewees that have provided us with valuable and interesting insight, thank you for making this research possible.

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Abstract

The Fourth Industrial Revolution provides a wave of smart innovative technologies, where the Digital Twin is one of them. A Digital Twin is seen as a digital replica of a physical asset, process, or system, allowing real-time monitoring, simulations, and analysis for better decision-making. Despite its benefits, few have implemented Digital Twins and begun utilizing its value. Thus, this thesis investigates how organizations can get started with a Digital Twin by looking at the different elements of the implementation process.

A systematic literature review was conducted to obtain a background foundation of Digital Twin adoption. The review aimed to identify what existing research had found as drivers and enablers, barriers, challenges during implementation, and benefits provided by a Digital Twin. To provide new research on the field, we followed a qualitative research method. Through 19 semi-structured interviews of Digital Twin experts, findings indicate that factors driving and enabling Digital Twin adoption include data access, staying competitive, improved asset management, and management support. The study also shows that costs, competence, and lack of incentives are the most significant challenges related to the implementation. Furthermore, it is important to be aware of your own needs and what you want the Digital Twin to solve, in order to measure a successful implementation. Interviewing experts with Digital Twin experience identified benefits such as proactive maintenance, improved decision-making, simulations, and increased efficiency. This study contributes to valuable perspectives on Digital Twin knowledge and its implications. Practitioners can use these findings to achieve awareness and knowledge related to implementation challenges, and further use this theory to see how the benefits of a Digital Twin can be realized.

Keywords: *Digital Twin, Adoption, Implementation, Drivers, Enablers, Barriers, Challenges, Benefits*

Table of contents

1 INTRODUCTION 9

1.1 MOTIVATION FOR THE STUDY 9
1.2 RESEARCH QUESTIONS 10
1.3 STRUCTURE OF THE REPORT 11

2 THEORETICAL BACKGROUND 12

2.1 DEFINITION 12
2.2 DRIVERS AND ENABLERS 14
2.2.1 Data access 14
2.2.2 Follow the trend 15
2.2.3 Competition 15
2.2.4 Technologies 16
2.2.5 People and culture 16
2.3 BARRIERS AND IMPLEMENTATION CHALLENGES 16
2.3.1 Technical challenges 17
2.3.2 Understanding the value 17
2.3.3 Cost 17
2.3.4 Complexity 18
2.3.5 Security 18
2.3.6 Data 18
2.3.7 Lack of one common definition 19
2.3.8 People and culture 19
2.4 BENEFITS 20
2.4.1 Real-time data 20
2.4.2 Efficiency 21
2.4.3 Predictions 21
2.4.4 Simulations 21
2.4.5 Decision-making 22
2.4.6 Sustainability 22

3 RESEARCH DESIGN 24

3.1 LITERATURE SEARCH 24
3.2 RESEARCH METHOD 28
3.2.1 Research design 29
3.2.2 Data collection 30
3.2.3 Data analysis 31
3.2.4 Validation 32
3.2.5 Ethical considerations 33

4 FINDINGS 34

4.1 DEFINITION 34
4.1.1 Buzzword 36
4.2 IMPLEMENTATION 36
4.2.1 Drivers and enablers 36
4.2.2 Barriers 38
4.2.3 Challenges 40
4.2.4 Implementation approach 43
4.2.5 Measurement of a successful implementation 46
4.3 BENEFITS 47
4.3.1 General value 47
4.3.2 Decision-making 49
4.3.3 Sustainability 51

4.3.4 Potential sectors *52*
4.4 STATUS 54
4.4.1 Digital Twin today *54*
4.4.2 Digital Twin forward *55*
5 DISCUSSION 57
5.1 FINDINGS COMPARED TO PREVIOUS LITERATURE 57
5.1.1 Definition *57*
5.1.2 Drivers and enablers *59*
5.1.3 Barriers *61*
5.1.4 Challenges *63*
5.1.5 Benefits *67*
5.2 IMPLICATIONS FOR RESEARCH AND PRACTICE 68
5.3 LIMITATIONS AND FUTURE WORK 69
6 CONCLUSION 72
7 REFERENCE LIST 74
8 APPENDIX 79
8.1 INTERVIEW GUIDE 79
8.2 STATEMENT OF CONSENT 81

List of figures

Figure 1 Digital Model, Digital Shadow and Digital Twin 13
Figure 2 A cloud of words to define a Digital Twin 14
Figure 3 Review process 24
Figure 4 Publications of Digital Twin papers in Scopus 26
Figure 5 Systematic literature review 27
Figure 6 Research design 29
Figure 7 Data collection process 31
Figure 8 Data analysis process 32
Figure 9 Different capability levels of a Digital Twin 35
Figure 10 Drivers and enablers for Digital Twin implementation 61
Figure 11 Data Information Knowledge Wisdom Pyramid 67
Figure 12 The adoption of Digital Twins.. 72

List of tables

Table 1 Search strings 25
Table 2 Concept-centric matrix 28
Table 3 Research sampling 30
Table 4 Recommendations to practitioners 69

Acronyms

DT	Digital Twin
IS	Information Systems
RQ	Research Question
VR	Virtual Reality
AR	Augmented Reality
IoT	Internet of Things
Industry 4.0	The Fourth Industrial Revolution
BIM	Building Information Modeling

1 INTRODUCTION

In today's light of the highly technological world, 3D models and prototyping of products are no longer enough to keep up with the competitive market. Furthermore, business and manufacturing systems are becoming more complex, which makes them increasingly difficult to understand. Despite the development from two-dimensional to three-dimensional, the current digital product definition has problems such as descriptions that do not involve manufacturing, operation, and maintenance stages that provide limited guidance for real products (Wu et al., 2020, p. 4901). Luckily, Digital Twin (DT) has come to solve these problems.

A Digital Twin is a virtual copy of something that exists in real life, which improves the understanding of the physical system (Enders & Hoßbach, 2019, p. 1). This digital copy uses sensor technology to gather information from the real world, that can be used to simulate and demonstrate the behavior of the physical system. With this flow of data, changes made in the real world are reflected in the Digital Twin (Rasheed et al., 2020, p. 21981). For instance, simulation can be done to check the effect of changes in elements such as design, process, temperature, time, or environment (Wu et al., 2020, p. 4903). In an ideal world, the Digital Twin will be indistinguishable from the real asset, both in appearance and behavior (Rasheed et al., 2020, p. 21981).

As a part of a new technological wave, a DT supports digital transformation by providing new business models and decision support systems (VanDerHorn & Mahadevan, 2021, p. 1). A Digital twin can anticipate and predict problems based on real-time data and further issue proactive measures accordingly (Voell et al., 2018, p. 241). This generates new opportunities and benefits that businesses can exploit. However, many companies do not see the value of implementing Digital Twin as a support system to assist their decision-making. The literature highlights the lack of real-life examples of a successful implementation where Digital Twin has provided a substantial benefit for the company. Even though several industries such as oil rigs, airports, and especially manufacturing businesses have proven the value of Digital Twin, other industries that have yet to implement DT are struggling to realize benefits.

1.1 Motivation for the study

Digital Twin was one of the "Top 10 Strategic Technology Trends" listed by Gartner from 2016 to 2019, and by 2031, is expected to have a value worth more than $183 billion

(Enders & Hoßbach, 2019, p. 1; Gartner, 2022; Wu et al., 2020, p. 4901). Being in The Fourth Industrial Revolution (Industry 4.0), companies are forced to follow the digital transformation and find new ways to innovate using these technologies to achieve competitive advantages (Saniuk et al., 2022, p. 14). To be able to drive competitiveness, Gartner (2022) argues that product leaders must build ecosystems and libraries of prebuilt functions and vertically marked templates. That DT being a timely topic is also reflected in the literature, where Digital Twin research papers have seen a significant increase in publishment in the last 5 years.

While DT has been widely researched within the engineering and computer science field, little research is to be found on Information Systems (IS). Consequently, the organizational perspective of implementing Digital Twins is lacking, as most of the existing research addresses the technical aspects. Although the Digital Twin concept has grown in popularity and attention, it is still underrepresented in Information System research (Enders & Hoßbach, 2019, p. 1). Therefore, our academic motivation is to shed light on the IS perspective and contribute to knowledge development from an organizational perspective. We also have a personal motivation which is driven by curiosity, interest and to increase our knowledge about this technology.

1.2 Research questions

Despite its many advantages, a disruptiveness of technology adoption still exists. As a result, we are interested in investigating the adoption, meanwhile having a core focus on the implementation challenges. Where an adoption is a one-time investment involving the acceptance of new concepts, an implementation can be done several times. While some companies can get scared of the costs related to the implementation of DT, others can have technical hurdles or face challenges related to learning and competency. Additionally, as elaborated by Rasheed et al. (2020), the diverseness and complexity of the Digital Twin concept make it nearly impossible to encompass all its aspects within a single article (p. 21981). Therefore, the current paper wanted to identify the important drivers and enablers for Digital Twin implementation and the barriers that prevent companies from initiating the implementation. In addition, the thesis investigates the potential implementation challenges companies must overcome to achieve the Digital Twins benefits. Overall, the thesis is indented to improving the knowledge of the Digital Twin concept and shed more light on the topic for both further research and implementation projects. In doing so, three research questions (RQ) were developed to guide the study:

RQ1: What are the main drivers and enablers in a Digital Twin implementation?

RQ2: What barriers and challenges are associated with Digital Twin implementation?

RQ3: What benefits can be obtained through a successful Digital Twin implementation?

1.3 Structure of the report

The report begins with presenting an overview of significant prior research which forms the background for our study. Furthermore, we will be accounting for how the research is designed, before presenting the findings of the study. Then, these findings are discussed before providing a conclusion on the three research questions.

2 THEORETICAL BACKGROUND

This chapter explores existing literature and identifies relevant findings from previous Digital Twin research. The chapter is divided into four subsections, representing the main findings from reviewing the literature. The subsections are structured to follow the concept-centric matrix, which is presented in Chapter 3. The definition of Digital Twin is a central and important aspect and is therefore included in addition to the concepts from the matrix.

2.1 Definition

Digital Twin is a disruptive topic due to the lack of one common definition (Broo & Schooling, 2021, pp. 2, 4; Loaiza & Cloutier, 2022, p. 13; VanDerHorn & Mahadevan, 2021, p. 2). Consequently, the many perceptions of what this is lead to confusion and disagreements. This prevents the understanding of the concept, which is an absolute necessaire if the intention is to implement it (Voell et al., 2018, p. 242). This shortage is where the problem starts, as it results in industries failing to realize its value, to the point of degrading it (Loaiza & Cloutier, 2022, p. 13).

Voell et al. (2018) suggest that the difficulty with finding a common definition is a result of the Digital Twin always being customized (p. 242). Combined with the lack of conceptual basis, Digital Twins' characteristics and requirements get hard to identify (Durão et al., 2018, p. 205). This can have a connection to the fact that different manufacturers use Digital Twin to different things, which might contribute to form the different perceptions and understandings. For instance, while some manufacturers intend to use the Digital Twin to improve product design, others seek to improve the quality of manufacturing by mapping the product throughout its life cycle (Durão et al., 2018, p. 209). Vieira et al. (2022) support this by stating that the increased interest for DT in multiple sectors, leads to distinct definitions depending on the context in which the term is used (p. 251).

In a study done by Broo and Schooling (2021), some participants emphasized that qualities such as real-time data transfer or feedback loops between the virtual and physical spaces should be included in the definition of the Digital Twin. Others did not agree that the Digital Twin needs such characteristics at all and referred to more abstract definitions such as:

"Being able to access information when you need it."

"A digital representation of whatever it is that we are managing."

However, their findings indicate that the definition not only differs between sectors, but even organizations within the same sector define the term differently (p. 4).

With the availability for exploring different scenarios and options which can support decision-making, the Digital Twin might also be considered as an implementation of a data-driven service (Meierhofer et al., 2021, p. 2). Shahzad et al. (2022) support that consideration by presenting a recent interpretation of the Digital Twin concept within a built environment. In this case, the DT is associated with the usage of digital representations of an asset to provide simulations and an information connection to a physical entity. Consequently, opportunities for data-centric decision-making in asset operation and management are enabled (p. 2).

Distinguishing between a Digital Model, Digital Shadow, and Digital Twins is often a theme related to the definition of Digital Twins. According to Vieira et al. (2022) it is the data flow that differentiates the three terms. While the model is just a representation where changes do not impact the two counterparts, the shadow includes a one-way data flow where changes in the physical object will be visible in the digital replica. The Digital Twin, on the other hand, is expected to have a two-way data flow where changes in both the physical and digital object will impact each other (p. 252).

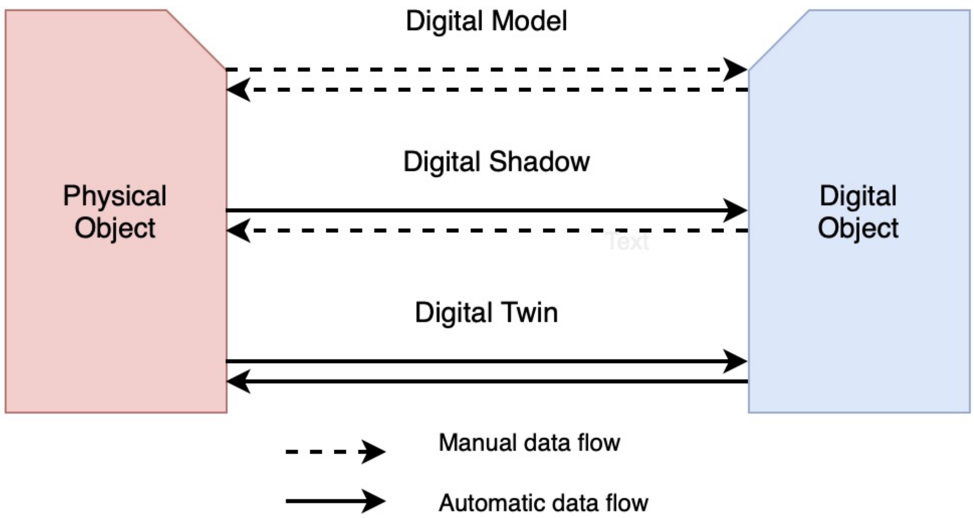

Figure 1 Digital Model, Digital Shadow and Digital Twin (Vieira et al., 2022, p. 252)

To highlight the many definitions, we created a cloud of words to illustrate which terms are most frequently used to define a Digital Twin. The cloud presents a result of 22 different definitions from existing literature, where the word *physical* is the most mentioned. The cloud also includes the words *replica, representation, realistic, real, current*[1],

[1] *Current* might not be a typical synonym; however, it is used for the same meaning in this context.

and *mirror*, which can be considered synonyms. Thus, several definitions might share the same meaning, although phrasing and choice of words vary. However, based on the word size, the cloud indicates that it is most common to define a Digital Twin using the terms *physical*, *digital* (or *virtual*), *object* (or *system*), and *data*. These terms can be found both in exclusive and in connected use.

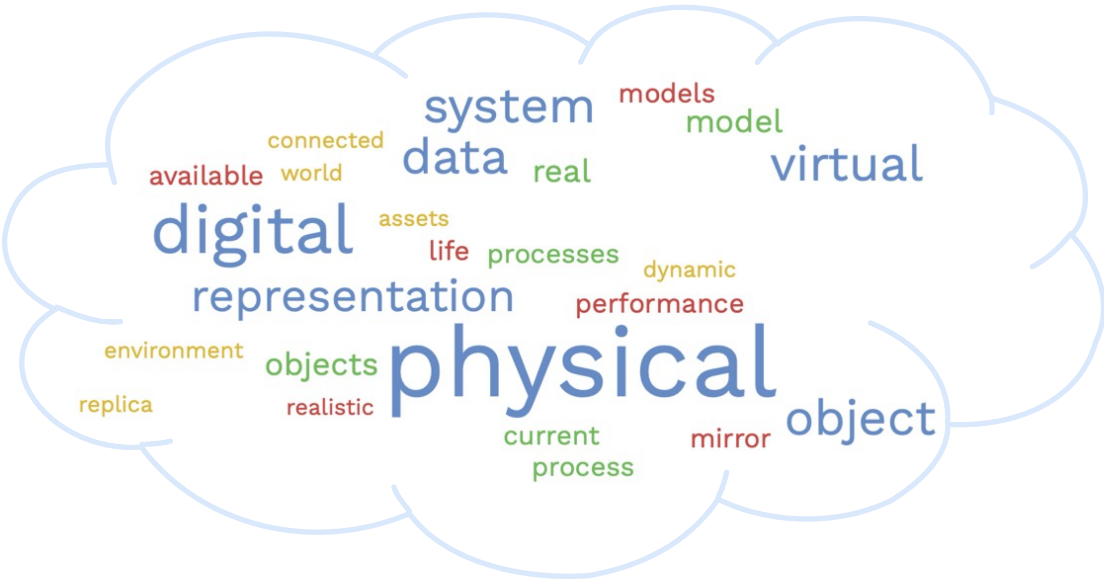

Figure 2 A cloud of words to define a Digital Twin

2.2 Drivers and enablers

The implementation of a Digital Twin is led by drivers and enablers. These are factors initiating the adoption to happen and what makes it progress and succeed. Drivers and enablers are early implementation efforts and will constitute key characteristics of Digital Twin initiatives (Vieira et al., 2022, p. 252). While enablers are the variables that make digital twin implementation feasible, drivers are the causes and forces that motivate businesses to initiate and fully implement it (Neto et al., 2020, p. 211).

The following section is divided into five subsections that represent the main findings of what drives and enables the Digital Twin according to existing literature. As not all literature distinguishes these terms, they will here be presented together.

2.2.1 Data access

Silo architecture is affecting the information flow, leading to restricted data availability. Having a Digital Twin to connect and integrate multiple data sources results in increased access to data. Such data access will enrich the organization with descriptions of the current and historic states of a system, reflecting trends in all areas (Chabanet et al., 2022, p. 3; Chircu et al., 2023, p. 6751). Werner et al. (2021) state that connectivity, modularity, and autonomy are key enablers of Digital Twins (p. 129). Furthermore, data access is also what enables a successful DT, as the correlation between structured and unstructured data is required (Cameron et al., 2018, p. 9). However, it is essential that the data is available and open to building such a system (Chircu et al., 2023, p. 6751).

Neto et al. (2020) identified process improvement initiatives as an internal driver toward Digital Twin projects. Data access will contribute to improving processes where increased information transparency and availability will result in better productivity and quality enhancements as well as reduced costs (p. 212).

2.2.2 Follow the trend

Trends often become a significant factor in why individuals and organizations act as they do. In addition to attending conferences and following news outlets on technological development, trend-spotting activities can also be a part of a company’s strategy (Broo & Schooling, 2021, p. 6). Following trends can be a positive driver in many ways, especially within technology as the industrial revolution progress and companies are forced to follow. Otherwise, technical debt could be a consequence. Assets that are aging will be a costly affair for society, as well as affecting the environment and the overall sustainability of the planet (Broo & Schooling, 2021, p. 1).

A trend can be categorized as an external driver, where the outside environment and competitors influence your direction. As a result of Digital Twins' rising popularity, the concept has become a buzzword, and organizations are driven towards the implementation in order to keep up with the global trend (Neto et al., 2020, p. 212).

2.2.3 Competition

Möhring et al. (2022) state that Digital Twins are one of the most important technologies enterprises should adopt to stay competitive (p. 229). Competition in the market is considered a key driver for motivating firms to cause the Digital Twin initiative. The constant flow of smarter technologies creates an ever-increasing level of business competition, which pressures firms to chase solutions that reduce costs and improve quality and productivity (Neto et al., 2020, p. 212). With Industry 4.0, digitization for optimizing processes and products is considered the key to success in strategic planning. Thereby, Digital Twins are suggested as the best solution for a successful digital transformation journey in industrial processes and businesses (Jawad et al., 2022, p. 2).

2.2.4 Technologies

Digital Twin has several enabling technologies that assist the visualization process and the collection of data. Some of the key enablers mentioned by experts are simulation, Internet of Things (IoT), and cybersecurity (Neto et al., 2020, p. 213). For the built environment, BIM is seen as an important enabler for the visualization and further development of Digital Twins (Vieira et al., 2022, p. 253). Other enablers for DT could be different technologies that allow it to move forward. Serbulova (2021) mentioned that the increasing demand for Digital Twin technologies is growing with the development of related technologies like industrial IoT, Cloud technologies, Virtual Reality (VR), and Augmented Reality (AR) applications (p. 8).

2.2.5 People and culture

The implementation of changes in a company will never be successful if the employees resist. Thus, people are seen as a primary driver in bringing about organizational transformation. People and their competence are also what enables the adoption of Digital Twin, as qualified staff with the skillset to manage and communicate the new technology are needed (Möhring et al., 2022, p. 18; Neto et al., 2020, p. 214). Furthermore, general challenges within the organizational landscape must be addressed (Möhring et al., 2022, p. 235). The organizational culture must contain strong leadership, hence the managerial commitment to long-term projects, as well as top management support and the capacity to make financial investments (Neto et al., 2020, p. 214). Moreover, it is important to remember that the Digital Twin should not be limited to one organizational location or domain (Meierhofer et al., 2021, p. 6; Möhring et al., 2022, p. 235). It is therefore critical to investigate and involve related stakeholders as they can be decisive for success or failure, as well as collaboration between the different organizational units. Successful implementation of Digital Twins is enabled by good interdisciplinary and cross-organizational collaboration (Meierhofer et al., 2021, p. 6; Möhring et al., 2022, p. 235).

2.3 Barriers and implementation challenges

In order to obtain the benefits of the Digital Twin, a successful implementation is required. However, several challenges and barriers hinder an organization from implementing a DT. In this section, we will highlight the main findings from the literature regarding the typical challenges and barriers that organizations often must overcome to achieve a successful implementation.

2.3.1 Technical challenges

Technical challenges were the most mentioned challenge regarding the implementation of a Digital Twin. This challenge was often related to the DT architecture, where several technical devices shall connect (Voell et al., 2018, p. 245). This connection brings a flow of data and information between both physical and virtual spaces (Loaiza & Cloutier, 2022, p. 1). To realize this connection, data must be collected and shared from different project stages, project actors, and tools (Shahzad et al., 2022, p. 14). It would therefore be beneficial to have compatible and adequate data standards. Loaiza and Cloutier (2022) emphasized the importance of standardizations by stating that standard technology keeps data flowing smoothly throughout a system (p. 13). Thus, this will help the DT to easier integrate and connect data across the different subsystems. Additionally, technology developments require the highest level of efficiency and effectiveness, when considering technology maturity which often impacts time and cost (VanDerHorn & Mahadevan, 2021, p. 9).

2.3.2 Understanding the value

Understanding the value of Digital Twins is essential if one is to implement the technology (Voell et al., 2018, p. 242). This is seen as the first problem to occur regarding the implementation phase, and it does not only require a visionary or missionary understanding of the concept but also the rest of the company (Voell et al., 2018, p. 242). Despite its novelty, some companies are doubting the benefits, while others have not even heard of DT or know very little about it (Loaiza & Cloutier, 2022, p. 13). However, the lack of one common definition leads to the main reason for companies not understanding or realizing its value (Loaiza & Cloutier, 2022, p. 13). Furthermore, DT has constraints to a wider adoption due to the lack of knowledge about the characteristics, functionalities, best practices, and benefits that they can provide, especially for SMEs (Pires et al., 2020, p. 1).

To prevent miscommunication across multiple interacting technical domains and stakeholders, the value of the DT idea needs to be communicated (VanDerHorn & Mahadevan, 2021, p. 9). Prototypes can be a good solution here, where a virtual representation is easier to understand (Voell et al., 2018, p. 247).

2.3.3 Cost

Costs are usually one of the most typical challenges for new and big projects. It is hard to estimate the amount of investment required for a successful DT implementation, especially with complex systems and the costly technologies required (Loaiza & Cloutier, 2022, p. 2). Bickford et al. (2020) suggest that it is natural to start with a simple DT first and let it evolve slowly when the cost and complexity of implementing DT can be cumbersome (p. 726). Furthermore, publications often ignore costs as one of the main barriers to implementing DT. The cost of a Digital Twin can be extremely high and prohibitive. However, DT may have a positive return on investment due to the significant cost of operations and maintenance (Bickford et al., 2020, p. 727).

2.3.4 Complexity

The literature highlights the complexity of implementing a Digital Twin. Some complexity challenges are more specific to single industries, while others are more generic. Chircu et al. (2023) highlight the complexity of implementation for cities when the DT is characterized by the increasing amount of data, networking, and interconnectivity. This makes it difficult to build models especially when you want to capture human behavior, opinions, preferences, and interactions (p. 6750). Although this example is related specifically to the DT of cities, it highlights an issue that makes most implementations complicated, which is the share volume of data that needs to be connected in the Twin.

2.3.5 Security

Security is identified as one of the big issues with Digital Twin adoption, especially when collecting data from several detached entities along the supply chain (Barni et al., 2018, p. 707; Saniuk et al., 2022, p. 11). Several articles highlight the challenge of data security with the large amount of data being processed in a DT. There is a concern about the possibility of data loss as well as taking control of the production process because of cyberattacks. Few articles mention any clear way to deal with security issues, however, they address the importance of awareness.

Data privacy and ownership can be an issue for DT when it limits access to data. However, designating roles and accessibility is essential to deal with issues related to intellectual property and legal considerations. Security and ownership have a huge impact on DT development and are important factors to consider. However, they should not limit the growth of Digital Twin development or hinder its scope (Shahzad et al., 2022, pp. 10, 11).

2.3.6 Data

Another hurdle is the challenge of data collection. Previous literature identified that many don’t use the data properly, a huge amount of data is collected, but only a fraction is used.

Since most of the value given by a DT is from the vast amount of data provided, it is important to establish a rigorous data collection, storage, and analysis process to build a strong dataset for the DT to draw insight (Bickford et al., 2020, p. 738).

Broo and Schooling (2021) identified that one of the challenges with implementing DT was connected to sharing of data. One of the experts interviewed in their study pointed:

> *"We need people to be more open to sharing their information and sharing it in a format that is machine-readable" (p. 6).*

A DT can be beneficial to everyone in the supply chain; however, this requires clarity in the sharing of data. This sharing and collaboration have good potential if mechanisms for fair rewards, allocation of responsibility, ensuring secure access, and protecting intellectual property rights (Cameron et al., 2018, p. 12). Broo and Schooling (2021) also identified the challenges of sharing data between systems within an organization. They argue that people often use different versions of the same software and sometimes it feels like people are almost deliberately making standards different when implementing. Which makes data sharing challenging across systems (p. 6).

2.3.7 Lack of one common definition

As discussed in Section 2.1, the absence of a universally accepted definition of Digital Twin poses a significant challenge to understanding the concept. Consequently, it becomes challenging to discern the requirements of a Digital Twin and how these should be implemented in projects. The lack of a precise definition also makes it difficult to determine the functionalities that a Digital Twin should incorporate. Despite the efforts of scholars to define this concept, there are disagreements that disturb the attainment of a standard definition. For instance, while Chabanet et al. (2022, p. 3) contend that a Digital Twin should not be limited to a mere virtual representation of a physical twin, which is essentially a Digital Shadow, Pires et al. (2020) suggest a broad definition that is based on various definitions from the existing literature:

> *"The digital copy of a physical object or system, that is connected and shares functional and/or operational data" (p. 310) .*

2.3.8 People and culture

Like most digital transformation projects, having a culture transformation strategy is essential (Broo & Schooling, 2021, p. 8). The articles showcased the importance of cultural change within an organization for the success of DT implementation. People are often resistant to change, this is often related to either the organizational culture or the nature of people (Neto et al., 2020, p. 214). Shahzad et al. (2022) mentioned that cultural change is slow for several reasons including inadequate senior-level buy-in and sufficient proven benefits (p. 13). Broo and Schooling (2021) suggested that even though the process of shifting the culture is quite comprehensive, it is necessary to enable the implementation of DT (p. 8).

Although existing literature expresses the importance of changing the culture within organizations, there are no clear guidelines on how to deal with cultural challenges. Broo and Schooling (2021) states that in order to have success with a DT, it is important to drive digital transformation in all parts of the organization (p. 7). This means that exploring digital transformation strategies might be a possibility for improving the challenge related to people and culture when implementing a DT.

Lastly, the literature highlighted the issue of having enough knowledge about Digital Twin. There is a lack of qualified staff as well as an absence of the topic in training and education. In order to further transfer knowledge and tackle this challenge, it is suggested to invest in staff training and external experts (Möhring et al., 2022, p. 235).

2.4 Benefits

For an implementation to make sense, it must be some proven benefits that will provide an enterprise with a return on investment afterward. This section will identify the most mentioned and proven benefits of adopting a Digital Twin from the literature.

2.4.1 Real-time data

What is special about a Digital Twin is the live update of information, where the model gets fed with real-time data from the physical object (Voell et al., 2018, p. 239). This real-time data works without requiring human-to-human interaction, which results in DT operations being autonomous (Loaiza & Cloutier, 2022, p. 2). The data is gathered from various sources, including advanced sensor technologies which describe the current and past states of the system (Chabanet et al., 2022, p. 3). The data collected from such technology can provide near real-time data which can contribute to more informed and up-to-date decision-making (Rasheed et al., 2020, p. 21981). Furthermore, it will support the diagnosis and prediction of the system operation to anticipate possible risks (Pires et al., 2020, p. 314).

2.4.2 Efficiency

Often, the Digital Twin aligns with an existing process and the advantage it provides is the digitalization of that process to provide further efficiency or automation (VanDerHorn & Mahadevan, 2021, p. 9). Tesla is a good example; they use a DT in order to optimize their software and detect problems. By following a data-driven software development process with the help of a DT, they allow for more efficient allocation of resources as well as significantly improved interaction with their electric car user (Serbulova, 2021, p. 7). DT can shorten time-to-market product cycles and thereby lower system development costs by modeling and controlling long-term interdependencies among business processes, information, or manufacturing systems (der Landwehr et al., 2021, p. 5). As a result, companies notice both faster project delivery and order delivery through the use of DT (Broo & Schooling, 2021, p. 5).

2.4.3 Predictions

The literature frequently mentions data analytics in connection to Digital Twins, and especially the possibility of doing predictions gets highlighted as a benefit. Predictions and optimizations of the system operation allow for anticipating possible risks or condition changes (Pires et al., 2020, p. 314). For example, operators of machines can perform maintenance before a part breaks down, due to the use of current and historical data to predict future or unknown events (Voell et al., 2018, p. 241). Predictive maintenance will not only lead to more productive work but will also lead to organizations saving money (Voell et al., 2018, p. 244). While maintenance based on routines gets replaced with maintenance based on needs, broken objects get identified before significant harm occurs.

2.4.4 Simulations

One of the discussed benefits of a Digital Twin is the opportunity to run simulations of the physical asset in a digital and safe environment. The Twin has the potential of running multi-scale probabilistic simulations of a vehicle or system by using the most suited models and sensor updates to mirror the life of the corresponding entity (Broo & Schooling, 2021, p. 2). Such simulation models represent specific proportions or the entire real environment (der Landwehr et al., 2021, p. 2). Moreover, a Digital Twin can run simulation experiments to predict and explain the condition of a system (der Landwehr et al., 2021, p. 5). Furthermore, simulation allows for versatile beneficial application to complex problems and has been employed in various business disciplines in managerial practice, such as inventory management, queuing analysis, production, maintenance, finance, marketing, and resource conservation (der Landwehr et al., 2021, p. 2).

Another aspect of simulations is the possibility to run so-called "what-if" scenarios which can offer more data-driven decision-making (Shahzad et al., 2022, p. 9). This scenario makes it possible to disturb the system to synthesize unexpected scenarios and study the response of the system, as well as the corresponding mitigation strategies. It is only possible to run a scenario like this via a Digital Twin without jeopardizing the real asset (Rasheed et al., 2020, p. 21982). Within the built environment specifically, assessing in advance could improve design and controlling performances regarding lighting, heating, space management, and functional workflow of building projects (Shahzad et al., 2022, p. 12).

2.4.5 Decision-making

Digital Twin provides broad insight due to the linkage between the real system and virtual representation (der Landwehr et al., 2021, p. 5). This insight is reflected by the benefits discussed above. Real-time data, digitalization of both processes and products, predictions, and simulations all provide companies with the ability to make data-driven decisions. However, in order to support better decisions, raw data must transform into information (Broo & Schooling, 2021, p. 5). Furthermore, the analytical and predictive capabilities make the Digital Twin a powerful decision-support tool allowing it to control the physical twin to some extent (Chabanet et al., 2022, p. 3).

DT and decision-making have endless possibilities for organizations and industries, where asset management is one example. Asset management focuses on balancing cost, opportunities, and risk against the desired performance. Asset management emphasizes the importance of risk decision-making over the lifecycle of an asset and the critical role of information to support those decisions. DT has the potential to support asset management by enhancing information about the entire lifecycle of an asset, thus opening up better decisions (Vieira et al., 2022, p. 253).

2.4.6 Sustainability

Sustainability statements are becoming a standard request, especially for customers of large organizations (Barni et al., 2018, p. 707). Digital Twin may assist organizations in reducing several sustainability issues such as optimization, raw material consumption, greenhouse gas emissions, and energy consumption (Chircu et al., 2023, p. 6749; Turan et al., 2022, p. 1). In a manufacturing context, DT may be the solution to decrease raw material consumption, mainly with temperature modeling. By using simulations in a manufacturing environment to support real-time quality control it can improve sustainability (Turan et al., 2022, p. 2). Zhao et al. (2022) investigated a case where the adoption of a DT in a facility management system of a hospital was set to improve sustainability. They found that an increase of 10% in staff satisfaction from the old building operation, as well as 1% of overall energy consumption, was saved every year, which contributes to a more sustainable operation of the hospital (p. 6).

Broo and Schooling (2021) highlight the issues with aging infrastructure which affects the environment and impacts the sustainability of the planet (p. 1). They emphasize the importance of bringing more attention to new sustainable development methods of designing, constructing, operating, and monitoring infrastructure. They believe a Digital Twin provides an opportunity to collect and integrate data to improve the sustainable development of infrastructure (Broo & Schooling, 2021, p. 2).

3 RESEARCH DESIGN

This chapter outlines the research methodology performed to address the research questions. Before undertaking a qualitative study, a systematic literature review was conducted to establish a comprehensive foundation. The first section of this chapter focuses on the literature review, which provides an overview of the current knowledge and understanding of the topic under investigation. Subsequently, the second section of this chapter delves into the study's design, describing how data was collected and analyzed. By explaining the research methodology, this chapter aims to establish the rigor and validity of the study's findings.

3.1 Literature search

Webster and Watson (2002) state that you must *"Analyze the past to prepare for the future"* (p. 1). In other words, by reviewing prior literature, researchers can gain a better understanding of the topic and pave the way for future advancements. Therefore, analyzing the past is a fundamental step in conducting an academic study. A systematic literature review was conducted in order to summarize the existing evidence concerning Digital Twin adoption. Reviewing the existing literature is also with the purpose of identifying gaps in current research, as well as answering the research questions by understanding what existing research has to say on the matter (Kitchenham & Charters, 2007, p. 6; Okoli & Schabram, 2010, p. 1). We divided the systematic review process into three main steps, inspired by Kitchenham and Charters (2007, pp. 12-14).

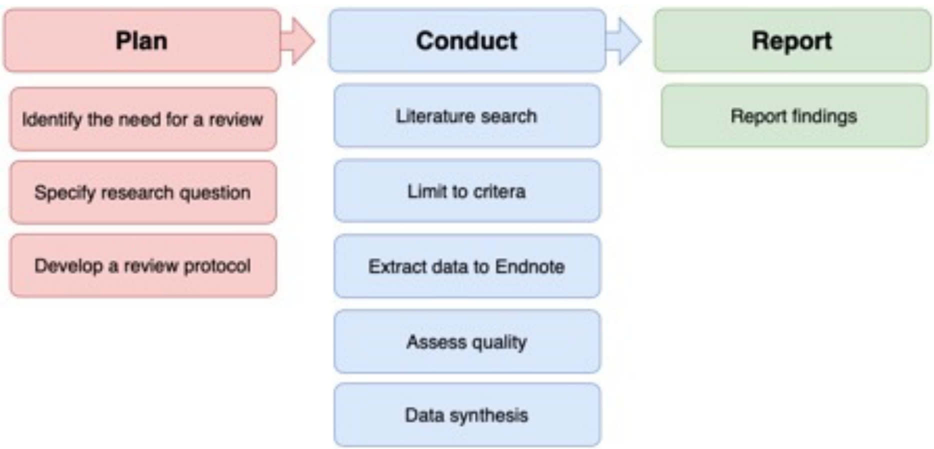

Figure 3 Review process

Planning the systematic review is convenient for identifying the intention and its purpose, as well as finding the suitable strategy (Okoli & Schabram, 2010, p. 7). The need for a review is driven by personal and academic motivation, in addition to framing a theoretical background on the topic. As a result, three research questions got formulated guiding the research direction. Furthermore, we developed a review protocol with the purpose of planning the search procedure (Okoli & Schabram, 2010, p. 7). The protocol worked as a valuable guidance, involving elaboration of search strings, selection criteria and quality assessment checklists (Kitchenham & Charters, 2007, p. 26).

Scopus was utilized for literature searches due to its user-friendliness and peer-reviewed content, in addition to being recommended by the University of Agder. The search has been an iterative process, beginning with the extraction of key concepts from the research questions and adding relevant synonyms. Several combinations have been tested in order to optimize the search and further achieve the most suitable outcome.

The result were three distinct search strings, optimized to cover the research questions best as possible. As Table 1 presents, the difference between Search string 1 and Search string 2 is that the first string seeks drivers and benefits, and the second seeks challenges regarding Digital Twin adoption. An option could therefore be to combine them using an OR-operation. However, that resulted in papers including both drivers, benefits and challenges got excluded. To avoid missing relevant data, we concluded with expanding the outcome by separating these into two distinct search strings, both focusing on Digital Twin adoption.

Table 1 Search strings

Search string 1
TITLE-ABS-KEY (("Digital Twin") AND (Adoption OR Procurement OR Implementation) AND (Benefits OR Advantage OR Competitive OR Value OR Profit OR Driver))
Search string 2
TITLE-ABS-KEY (("Digital Twin") AND (Adoption OR Procurement OR Implementation) AND (Challenges OR Barrier* OR Boundaries OR Hurdle OR Limit OR Obstacle))
Search string 3
CONF (ECIS OR AMCIS OR ICIS OR HICSS OR AIS OR PACIS) AND TITLE-ABS-KEY ("Digital Twin")

During the search, we notice a lack of Information Systems papers related to the Digital Twin topic. For this reason, we based Search string 3 on the IS conferences which are most relevant. This made it clear that Digital Twin has a significant gap within IS research, as combining these conferences with some of the words and synonyms from

Search strings 1 and 2 resulted in 0 or 1 document. Consequently, the third search string investigates the Digital Twin concept within IS research in general.

Digital Twin is not a new concept, however, a significant growth in the number of publications related to DT has been perceived in the last years (Pires et al., 2020, p. 309). For this reason, we have selected papers no older than 2018. The increased interest in Digital Twin adoption over the years is presented in Figure 4. The graph is based on papers in the Scopus library that include "Digital Twin" and "Adoption" or "Implementation" in the title, abstract, or keyword. The hype and interest lead to new research and literature being published in a continuous flow. Thus, there are good reasons to expect that the graph will increase in the coming years. Mark that Figure 4 is from January 2023, and the graph is therefore low as a result of being early in the present year.

Other selection criteria for the literature search were to only include papers written in English and documents of the type articles and conference papers. Furthermore, the papers should rely on empirical data and be peer-reviewed in order to assure high quality. Further exclusion is papers that do not cover the topic and are considered irrelevant.

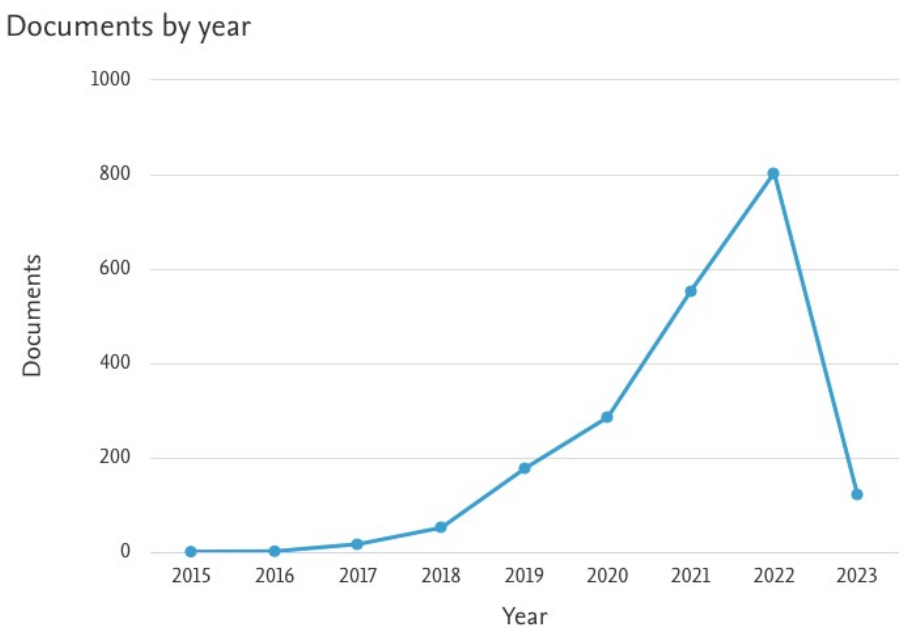

Figure 4 Publications of Digital Twin papers in Scopus

A model inspired by Danielsen et al. (2022, p. 4) is developed to illustrate the process of the systematic literature review, presented in Figure 5. The model represents the progression in step by step, where 999 documents got eliminated to 25 by following the systematic method. The search was conducted 23rd of January 2023 and the numbers are therefore valid from that date.

The three search strings provided a total of 998 documents, and an additional paper was obtained externally based on a recommendation from one of our interviewees. After the search was limited to our inclusion criteria, 794 documents were exported to Endnote to remove duplicates and perform further quality assessments. The screening process involved reading the titles, followed by the abstracts, and finally the full text of each paper. During this process, papers were excluded if they did not address the topic or were irrelevant to our thesis. As a result, 25 articles met our criteria.

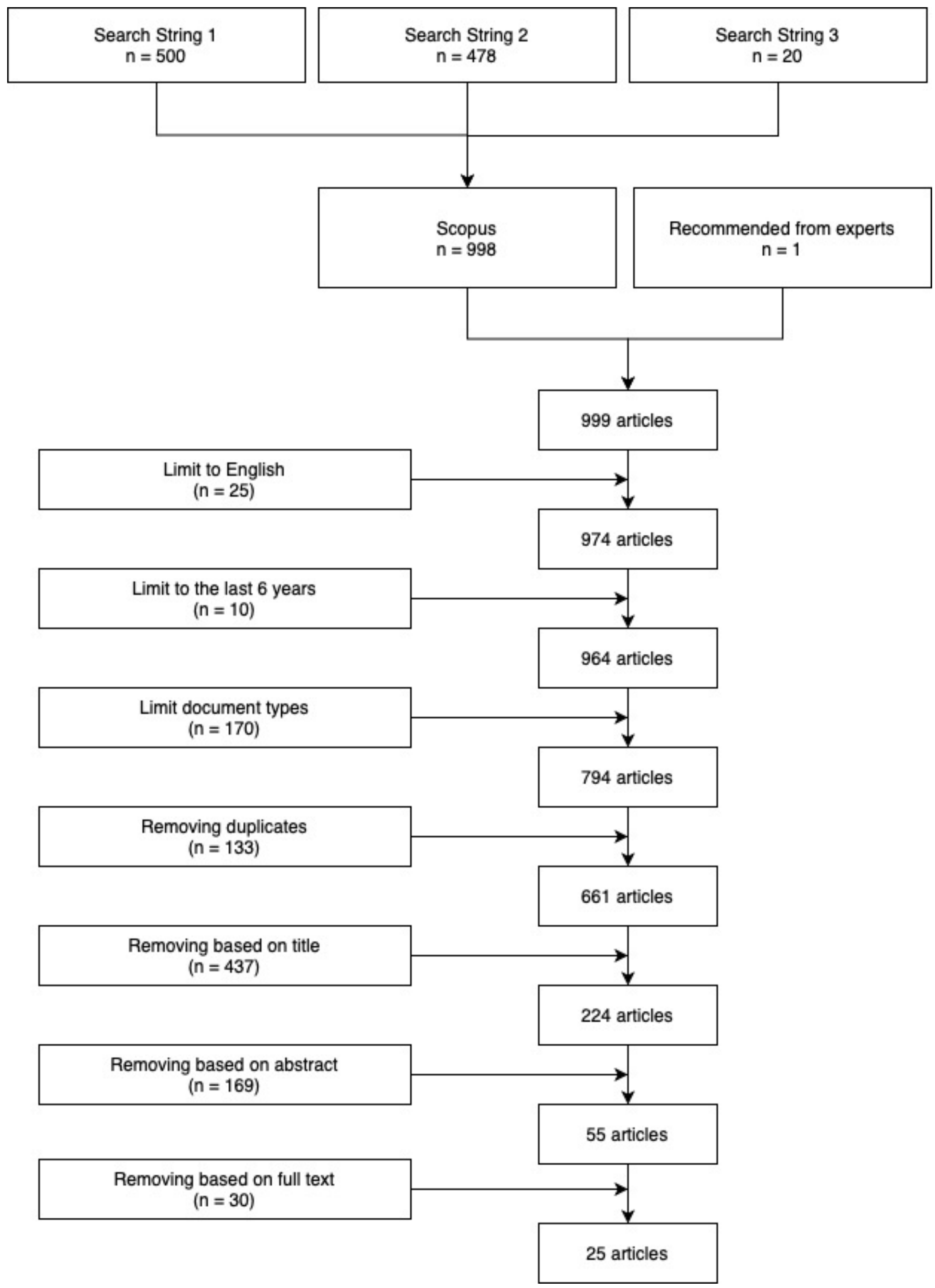

Figure 5 Systematic literature review

To synthesize the data collected, we are combining the facts, highlighting similarities and differences extracted from the studies through a concept-centric matrix (Kitchenham & Charters, 2007, p. 42; Okoli & Schabram, 2010, p. 7). The purpose is to extract the main concepts related to our RQs and analyze the outcome. We have categorized drivers and enablers, barriers and implementation challenges, and benefits as the main concepts, as we are interested in finding out how previous research has addressed the adoption of Digital Twins. The three concepts each include several subcategories that are discussed or mentioned in the papers. The crosses illustrate which paper that covers which subcategories.

Table 2 Concept-centric matrix

Category	References	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Concepts	Barni et al., (2018)	Bickford et al., (2020)	Broo & Schooling (2021)	Cameron et al., (2018)	Chabanet et al., (2022)	Chircu et al., (2023)	der Landwehr et al., (2021)	Durão et al., (2018)	Jawad et al., (2022)	Loaiza & Cloutier (2022)	Meierhofer et al., (2021)	Möhring et al., (2022)	Neto et al., (2020)	Pires et al., (2020)	Rasheed et al., (2020)	Rymarczyk (2020)	Saniuk, et al., (2022)	Serbulova (2021)	Shahzad et al., (2022)	Turan et al., (2022)	VanDerHorn et al., (2021)	Vieira et al., (2022)	Voell et al., (2018)	Werner et al., (2021)	Zhao et al., (2022)
Drivers and enablers	Data access				x	x	x			x	x			x												
Drivers and enablers	Follow the trend			x						x	x			x												
Drivers and enablers	Competition									x			x	x					x							
Drivers and enablers	Technologies		x			x				x				x		x			x	x		x	x		x	
Drivers and enablers	People and culture			x								x	x	x												
Barriers and implementation challenges	Technical	x	x		x	x					x			x		x		x	x	x		x		x	x	
Barriers and implementation challenges	Understand the value	x		x				x			x		x	x	x							x		x		
Barriers and implementation challenges	Complexity	x			x		x	x		x			x				x							x		
Barriers and implementation challenges	Costs		x		x						x		x					x				x				
Barriers and implementation challenges	Security	x											x		x	x	x	x		x		x			x	
Barriers and implementation challenges	Data		x	x	x	x		x	x		x		x	x		x	x					x			x	x
Barriers and implementation challenges	Definition	x		x	x				x		x								x			x		x		
Barriers and implementation challenges	People and culture			x	x								x	x	x	x				x			x			
Benefits	Real-time data	x		x	x	x	x		x	x				x	x	x		x	x	x	x		x	x		x
Benefits	Efficiency			x			x				x		x		x	x	x	x	x	x	x	x				x
Benefits	Predictions	x		x				x				x			x	x				x	x		x	x		x
Benefits	Simulations	x		x	x	x		x		x	x			x	x	x				x	x	x	x	x		x
Benefits	Decision-making	x		x	x		x	x		x	x	x			x	x		x	x	x		x	x	x		x
Benefits	Sustainability	x		x	x		x			x								x	x		x					x

3.2 Research method

While a quantitative research method handles numeric data such as the number of people or last year's profit, the qualitative approach deals with all other data types (Oates, 2006,

p. 36). The quantitative method use numbers to represent values and levels of a theoretical construct, whereas the qualitative approach designed to assist researchers in understanding phenomena in context (Recker, 2021, pp. 88, 114). As this study aims to get a better understanding of Digital Twins, the qualitative research method is the most suitable.

In a qualitative method, interviews are considered the most common and one of the most important data-gathering tools (Myers & Newman, 2007, p. 3). Three popular strategies for a qualitative study are case study, action research and ethnography (Recker, 2021, p. 123). For this thesis, it appears to be difficult to follow a case study when it is a challenge to find participants with specific cases that we can follow. Further, neither action research nor ethnography will provide us with the right information that we need for our research questions. Therefore, conducting a survey through interviews is the chosen research method.

3.2.1 Research design

People often automatically assume that surveys use questionnaires for generating data, it is however, also possible to use other data generation methods (Oates, 2006, p. 93; Recker, 2021, p. 101). The purpose of using the survey instrument for this research is to get a better understanding of the concept, which categorize this research an exploratory survey (Recker, 2021, p. 101). With the survey strategy, we have conducted semi-structured interviews. This format was beneficial as we could have an interview script that outlined the theme, topic, and issues. Furthermore, a semi-structured interview was preferred because it allows for some improvisations during the interview (Myers & Newman, 2007, p. 4). This is beneficial where questions could be customized and improvised based on the interview progresses. Nevertheless, having an interview guide made sense to guide the meetings and prepare the interviewees in advance.

Figure 6 presents the process for designing our research. Three RQs were developed, before choosing our research method for data collection. Lastly, we went through the literature to build up more knowledge about the topic before developing the interview guide.

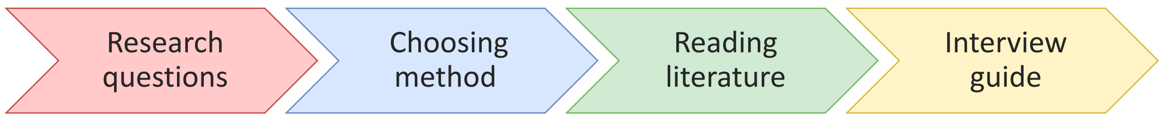

Figure 6 Research design

3.2.2 Data collection

Qualitative interviews allow comprehensive knowledge about the topic and Recker (2021) states key informants are particularly valuable as a source of information (p. 117). As we aim to address Digital Twin adoption, the most suitable sampling for this purpose were people with sufficient experience or knowledge on the domain. Our strategy for locating interview subjects has been by doing online research and collaborating with Capgemini Norway. The final selection ended with 19 participants from businesses that operate in Norway, where the majority were males. There are challenges related to identifying our own participants through online searches. For instance, there was a risk of ending up with participants without adequate experience for our study. Additionally, information about the knowledge of organizations and individuals is limited online. Furthermore, there is always a risk of a low response rate, which is why we decided to contact more people than originally needed. Nevertheless, our sampling has provided perspectives from different sectors on how the DT can contribute to business value. Whereas the length of the interviews varied from 28 minutes to 76 minutes, the average duration constitutes 48 minutes.

Table 3 Research sampling

Participant	**Gender**	**Duration**
1	Male	00:58:00
2	Male	00:43:24
3	Male	00:38:31
4	Female	00:55:03
5	Male	00:42:43
6	Male	00:44:11
7	Male	01:16:27
8	Female	00:40:48
9	Female	00:33:27
10	Male	00:28:23
11	Male	00:46:13
12	Male	00:56:50
13	Male	00:46:41
14	Male	00:35:56
15	Male	00:46:02
16	Female	00:51:33
17	Male	00:35:45
18	Male	00:49:12
19	Male	00:50:45

The interview guide was created in order to extract the necessary information needed to answer the research questions, while still being open for the participants to share information outside of the guide. The questions were based on personal curiosity, findings from the literature and with the purpose of addressing the research questions. The interview guide has followed the process dynamically, as improvements have been done iteratively.

Our interviews were done through Teams meetings when most participants were in different parts of Norway. There was only one exception which was a physical meeting held in Kristiansand. Each interview was scheduled to last up to one hour, however, most of them had a shorter duration, which is presented in Table 3. All the interviews were two-to-one with the focus on extracting as much knowledge as possible from each participant. Our interview process was as followed: Identify a potential expert and then make contact through email. When an expert approved to participate, a date time got scheduled, before further information was given. Each participant was informed through a statement of consent and the interview guide, which made them able to prepare. Lastly, the interview was conducted on the date scheduled. This process was repeated for each participant in the study.

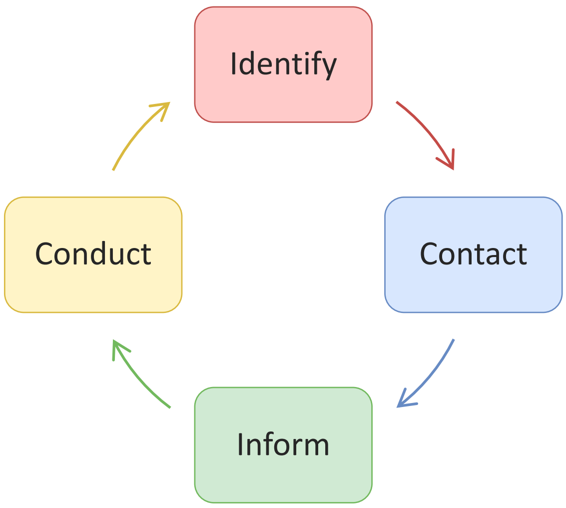

Figure 7 Data collection process

3.2.3 Data analysis

To show courtesy and respect to the people who were kind and participated in our interviews, we wanted to be fully present and following along during the interview. Taking sufficient notes can therefore be challenging and valuable information could have been lost. As a result, we decided to record the interviews in order to extract all relevant information provided in the interview. However, this required us to anonymize our interviewees.

After conducting the interviews, transcriptions of the recordings were made for further analysis. Teams were used to conduct each interview and to record the meetings. Teams own automatic transcription was quite troublesome, so it was decided to use Words automatic transcription instead. From earlier experiences, the automated transcription is not always accurate, which is why each transcript has been reviewed and corrected for any errors before further steps were taken. When all the transcriptions were completed, NVIVO was used to analyze our data. In NVIVO, codes were used to structure and categorize the answers. We decided to structure the codes to follow the interview guide. By doing so, we could easily divide quotes into correct categories in order to get a better overview of the findings. Using this method and tool, the data interpretation process was more efficient, and the data became easier to work with. After the coding was finished, the main findings from all interviews were ready to be processed and presented.

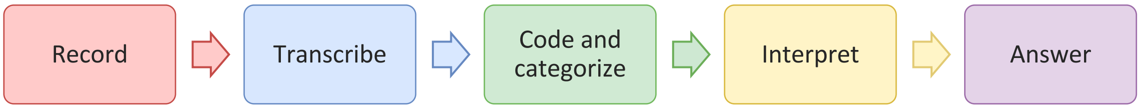

Figure 8 Data analysis process

3.2.4 Validation

Validating the findings is crucial because it demonstrates whether the collected data correspond to the actual meaning of the constructs we set out to measure (Recker, 2021, p. 93). Furthermore, it is essential to make sure the data is trustworthy, as there is no guarantee that what the interview subject tells us is correct or is "the right answer". However, we do not possess any solution to our questions so any information or perspectives given will prove usable. Regardless of the information given in the interviews, we will get a different point of view on Digital Twin. Validating the data collected is therefore an essential part of the research process.

One strategy for data validation is to compare the information provided by the subjects. If there are any similarities in the answers, it is more likely that the information is accurate. Another validation strategy that can be used is to look for any connections or similarities in the literature. As mentioned by Recker (2021), both theoretical and empirical assessments of validity are key to ensuring the validity of study results (p. 93). Lastly, background questions are included in the introduction of each interview to establish the experience of each expert.

3.2.5 Ethical considerations

Interviews might struggle to capture the ongoing practices when these are based on tactic knowledge that cannot be easily articulated. An ethical consideration for this research is whether a participant answers what they want us to hear, rather than their own opinion (Langley & Meziani, 2020, p. 371). Furthermore, since Information Systems research is a social science, the researcher is responsible for securing permission and attending to the interests of all the individuals involved in the study (Recker, 2021, p. 201). For this study, it is important to make sure all interview participants feel that their information is safe, which is why the data storage guidelines provided by NSD[2] are being followed. Therefore, the purpose of the data is presented at the start of each interview. Furthermore, all participants have been asked if they are comfortable with the meeting being recorded. It is important that all interviewees know what they are agreeing to when participating in a study, and that their information is used only by the researchers (Israel & Hay, 2006, p. 117). To end all interviews, each participant where asked if there was anything else they wanted to share with us related to the topic or the project in general. This opens for free speaking, where potential questions about the ethical considerations could be shared.

[2] NSD has been integrated with Sikt – Norwegian Agency for Shared Services in Education and Research while the thesis was written.

4 FINDINGS

The following section is presenting the research results conducted through the interviews. The chapter is structured following the interview guide, which begins by examining the definition of Digital Twin and how the term has become a buzzword. Subsequently, findings related to implementation aspects are presented before the value and potential sectors that would benefit from using the Digital Twin. Lastly, we provide a current status on Digital Twin in the Norwegian market today and findings related to how it may evolve in the future.

4.1 Definition

Previous research reports struggle to understand the Digital Twin technology due to the lack of one common definition (Loaiza & Cloutier, 2022, p. 2; VanDerHorn & Mahadevan, 2021, p. 1; Voell et al., 2018, p. 242). Not only does this lead to Digital Twin being hard to define, but it also results in difficulties in defining a successful DT implementation. For this reason, we were interested in asking our experts how they will define a Digital Twin.

While most of the participants defined the Digital Twin as a digital representation of something physical, some meant that this has no concrete answer. They elaborated that Digital Twin is not a technology, but more of a compilation term to recreate reality through a model. The collection of data presents a copy of the real world, which could be everything from the visual which is quite easy to see through a 3D model or a map, it can also be technical data, analytic data, or predictive models. The intention is to reflect or predict what the system is doing, over the entire lifecycle for different purposes. One stated that this is more of a concept of building a Digital Shadow and then making the shadow active.

Furthermore, it got stated that Digital Twin gets somewhat defined based on the case or problem you are going to solve. While others used the explanation of having the availability to both steer and simulate digitally, before testing in real life. In other words, a fully working 3D model. However, participants highlighted that the definition of Digital Twin is a discussed topic because there is no national or international standard deciding its requirements. One mentioned that the minimum criteria for claiming the DT was the physical representation and data that gets updated, not necessarily in real-time, but during the life cycle. Otherwise, it is just a Digital Model.

Findings indicate that participants within the construction industry are often drawing comparisons between Digital Twin and Building Information Modeling (BIM) related to the definition. Typical comparisons are by explaining the Digital Twin as an extension or a level up from BIM. By adding data that enables condition assessments in the BIM model, it becomes closer to a digital copy of the physical object. A participant stated:

> *"A Digital Twin means a digital representation of the building that shall contain necessary information or reference to information that covers all needs throughout the buildings lifespan, made available to those who need it, when they need it, where they need it and in the format they need it."*

There are also different levels that is used to define a Digital Twin. Figure 9 was presented during an interview and the model illustrates the evolution of the functional elements of a DT. Level 0 was explained to be disconnected Twins. A standalone model that are not connected with any data updates from the physical object. According to the literature, this is not referred to as a qualified DT, as the definition requires a data stream between the physical object and virtual representation. Furthermore, levels 1-5 are explained as connected levels, which means they have a data stream between the two parties. As the level gets higher so does the complexity of the system, with the last level being an automated DT.

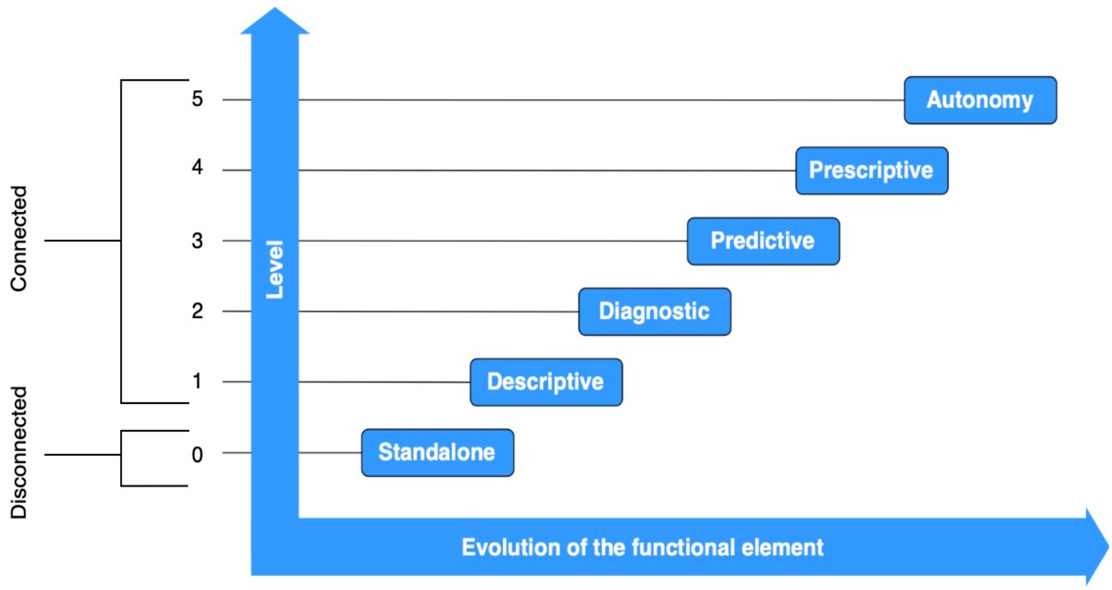

Figure 9 Different capability levels of a Digital Twin (Participant, personal communication, October 26, 2022)

4.1.1 Buzzword

Several participants referred to Digital Twin as a buzzword. The term has become a buzzword that is used with differing meanings. They elaborated that the visual interface or a Digital Shadow of a system providing information about a process and creating overview and holistic insight, has been talked about for years. It was stated that such technology has existed for more than 40 years and is therefore not novel, however, some companies have only recently begun calling this visual interface a Digital Twin. Because the term is fashionable and trendy, it is often used in business contexts to sell services and as an entrance to talk about collaboration and transparency across value chains. Consultants must adapt a solution to the problems the customers actually have. Often, there are managers who are short on time and need to improve something, then they have heard or read about Digital Twins and hired consultants to help. As a result, Digital Twins has probably been sold in 50 different ways over the last years. A participant claimed:

> *"Digital Twin is an abused word within the industry. Everybody claimed that this is a Digital Twin. Everybody had a different understanding of it without concretely knowing what a Digital Twin is and things have evolved from there."*

4.2 Implementation

The implementation phase is a critical aspect of the adoption of Digital Twins. We were interested in investigating what motivates organizations to adopt Digital Twins and identify the key factors that facilitate successful implementation, in other words, the drivers and enablers. Additionally, we examined which barriers that potentially can prevent organizations from implementing a Digital Twin, as well as the challenges that typically arise. Furthermore, we present a recommended approach to address these challenges, before showcasing how our experts measure the success of Digital Twin implementation.

4.2.1 Drivers and enablers

Various factors can drive the initiation and enable the successful implementation of a Digital Twin project. Our experts provided insights into some of these factors and identified the current focus areas within industries. Several drivers and enablers for a Digital Twin implementation were identified.

The first driver was the different advantages or improvements provided by a successful implementation. Three experts identified that increased effectiveness and surveillance of an asset or process was important drivers. By enabling workers to operate more effectively with digital tools, a massive gain in value for the organization can be seen, which emphasizes the value of optimizing work processes. Another expert supported this by saying:

> *"It is all about being most cost-effective as possible."*

The benefit of being able to plan and save resources was also considered a driver for a Digital Twin project. By operating an asset as sustainable as possible with data of quality, you can ensure that you make the correct decisions and have complete control. Another expert highlighted the value of real-time data, and the structure of all the complex data to create a realistic picture of the asset and that this could be a motive to implement a Digital Twin.

The change or business case for the organization was also considered an important driver. Several interviewees highlighted the importance of having a clear case or issue that needs to be solved which drives the Digital Twin project. One of the experts highlighted the importance of not expecting big results at the beginning of a launch. It was mentioned that:

> *"The real value is not gained from the implemented tool, but rather the change the organization has to do, the change in work processes that leads to value."*

Another expert mentioned different use cases related to remote operations of an asset. He argued that customers often seek to reduce the actual footprint on an asset for various reasons, but this must provide some kind of value to the customers. For instance, if a Digital Twin were already in place before the COVID-19 pandemic, it would have been a game changer as it can allow remote operation of an asset. Another important use case was the possibility of running training simulations on a digital asset, where testing on a digital module is beneficial to avoid endangering the real asset in case of malfunctions. Furthermore, it got highlighted that Digital Twin had a huge opportunity with maintenance. Digital Twins allows for operating remotely, which is beneficial for those jobs that are located in challenging environments. However, this would require a significant investment in acquiring accurate and real-time data from the physical asset.

Data structures and the possibility to collect all data in one place were identified as an enabler. It was mentioned that good data structure in the backend was a prerequisite for any Digital Twin implementation. The expert highlighted that the only reason they had any success with Digital Twin, was because they had exceptionally good data structure before investing in DT. He meant that good data and architecture was the most important aspect of the implementation. Another expert mentioned that the idea of collecting all data in one place can be tempting for many. However, it was important to know all the required work needed to integrate all systems in a Digital Twin and not get tempted to start such a process without the required perquisites.

The understanding and support from management were identified as essential drivers. One expert supported this by arguing that ownership and engagement from the leaders were necessary. The expert stated:

> *"They have to believe in the tool, and that this change will make a difference."*

This was mostly due to the significant effort and investment in developing a tool like Digital Twin, hence, without the right support from management it can prove difficult. Another expert supported this by saying that proper anchoring in management was important. A different expert mentioned the importance of holding overambitious managers in check. He meant that managers often go overboard after hearing about a new concept and get lost. They often forget that technology is supposed to assist or solve a concrete problem.

Lastly, a driving factor related to new and future trends was identified. Three participants mentioned the importance of following new trends in IT environments. One of them said that if a competitor invests in Digital Twin and you don't you might end up getting outperformed in your industry. She meant that you must update your business model with new and exciting technologies like Digital Twins. She identified that the desire to be the first in the field and develop new technology could be a driver for a Digital Twin implementation. Another expert addressed the same thing by stating:

> *"There has been done market analysis on Digital Twin, and we have figured out that this will have a huge value in the future. So, all you can do is follow this trend."*

The last expert supported this by saying it can be "cool" and "modern" to be one step ahead with new technologies like Digital Twin. By invest in DT before anyone else, you are more likely to stand out from your competitors.

4.2.2 Barriers

Barriers are another central part of the Digital Twin adoption, as they can prevent organizations from the implementation. Therefore, the identification and understanding of these barriers are essential for organizations to overcome them and increase their likelihood of success. This section present findings related to typical Digital Twin barriers.

The first barrier is connected to huge investment and expenses regarding Digital Twin implementation. More than half of our experts identified investment as the main barrier. Not only is it a big investment during implementation, but it is also an ongoing costly operation when your digital replica requires constant data updates. Furthermore, the experts emphasized the importance of realizing the value of Digital Twin in either saving or in optimization of processes. It got also mentioned that it was necessary to have a real business case before starting an initiative. Furthermore, it is important to have a concrete problem to solve in order to realize the value of the implementation. One expert highlighted the importance of situational awareness before investing. In some cases, you have assets at the end of their life cycle in which you will only get a few operational years with the implemented twin, then, it is valuable to implement a costly twin when only having a few years of the asset left. He meant that it was important to look at the business keys around the cost and the benefits provided. It got claimed that the investment expenses were often large for Digital Twin projects, thus it could be helpful to figure out how many years it will take to make up for the investment made.

The second barrier was related to culture change and how humans adapt to new implementations. Several of our experts wanted to emphasize the difficulties that come with change within an organization, and how this could be a barrier for many. One of the experts argued that the development of technologies was not a problem, it was the implementation and adaptation to the users that was challenging. Another expert addressed that there are a lot of uncertainties when changing a process and that it was important to think of the human factor. A different expert mentioned that people are often set in their ways and do not want to make changes in their work process, and that makes it hard to implement new technologies. She meant that training was a key element in order to solve the barriers related to cultural change. It got argued that age played a huge role in adaptation and change, it was said that younger people often accept new ways of working, while older people are often more stubborn. Furthermore, the issue with Digital Twins often being related to automation, which raises the question regarding layoffs and technologies "stealing" jobs from humans.

Data is one of the complex aspects of a Digital Twin implementation and can often be considered a barrier when the implementation can be cumbersome. Six of our experts identified data as a potential barrier for many organizations. It is important to include data of quality in the Twin, which several referred to as "shit in, shit out". If you included data that was not sufficient, it was no point in making a Twin. Another participant mentioned that there are a lot of different aspects with data regarding Digital Twin, so the complexity of data was a barrier on its own. It was also important to be able to trust the data in the Twin, meaning that the data presented were real-time or at least recently updated. Live data was seen as important for a better understanding and making accurate decisions and changes on the asset. One expert highlighted the difficulties with the building and administration of assets. He meant that the overall goal of the Digital Twin was to connect the data from different places and collect everything in one place in the cloud. However, it was almost impossible when there were different standards of data structure and sharing between the industries. Lastly, one expert addressed the difficulties with sensitive or crucial data, that cannot be shared. Although it is always possible to develop a Digital Twin with dummy data, but at some point, you need to use real data. Furthermore, difficulties with data sharing could be a reason why many would decide to not implement a Digital Twin.

Findings indicate that lack of knowledge is considered a barrier. The concern of organizations often lack knowledge on how to develop a Digital Twin was raised, especially now when there are so few providers. In most cases, you must hire someone to do the development, and that could prove difficult when few have sufficient experience or knowledge on implementation of Digital Twins. Another expert raised his concern regarding external providers trying to sell Digital Twins. He meant that they often are too eager to sell and do not understand the issue at hand. Therefore, a potential barrier for many organizations could be the lack of sufficient knowledge about Digital Twin. Thus, it can prove difficult to trust external parties. Two experts mentioned the issue of order competence. They said that customers who order systems like Digital Twins often does not know enough about the technology, which is resulting in unclear requests. It was important to understand what kind of competence is needed before starting an implementation phase, what knowledge does the organization possess in-house, and what is required from external vendors. One expert said:

> *"People often want things, but they have no idea what they want to use them for, there is no plan or anything."*

Furthermore, several participants mentioned the complexity associated to the Digital Twin implementation as a barrier. This was mostly connected to the management of data and different standards. One expert mentioned that if a process is complex, it can often be a barrier for many organizations. For Digital Twins this is often the case, as they can be challenging considering the amount of data, the uncertainty with definition and its actual proven value. Digital Twin can often be seen as a very complex technology and can be overwhelming. However, the reality is that most organizations often have all the required data, it is more about gathering everything in one place and creating a digital image which gives a sufficient overview of the asset. It is also worth mentioning that one expert addressed the concern of different industries are sometimes working in a challenging environment which can make it complex to implement DT, such as subsea services which do not always have internet connection. It got argued:

> *"It might be a problem many do not think about; however, you do not always have access to sufficient internet connection. Some work at locations that have poor or no connection which can make tools like Digital Twin challenging to use, and that can be seen as a barrier for some."*

4.2.3 Challenges

The implementation of any IT project is commonly associated with a range of challenges and our findings indicate that the Digital Twin is no exception. This section presents the challenges identified through our interviews.

The first challenge identified is connected to difficulties with data. Half of our participants mentioned that data standard was a huge issue when connecting the entire dataset from an organization into one system, such as a Digital Twin. The problem was often related to companies having different formats of data that do not work when integrated into one system. It was also mentioned that companies often have different needs and challenges, for instance, some have complicated systems which make it difficult to connect everything. Data governance was also mentioned as a significant challenge, where topics related to large amount of data and privacy got introduced. One participant said:

> *"There is something with having a GPS on you which intrudes the user´s right to privacy that has to be considered."*

It was also mentioned that it is important to have good access control on a system like this. Management needs to regulate so that only the respective operator has access to the necessary material to do the job. It was emphasized that good regulation of data was needed to protect the privacy of employees and users. Another expert meant that when implementing something like a Digital Twin in order to optimize a process, there had to be a governance which told the workers that this new method had to be utilized. If not, this new tool would never be used.

In similarity to potential barriers, people and culture is also a huge challenge when implementing a Digital Twin. Almost half of our participants mentioned the difficulties with change. They said that people often have difficulties in changing their way of work. One participant said:

> *"There are several reasons why workers prefer the old way of working, it can be that they have not had proper training in the new process, they can have some trouble with missing data, and it can be new and confusing, even though we have as a goal to make everything easy to use."*

However, some participants mentioned that changing processes is not necessarily a difficult thing. They meant that in some mature organizations, it is much easier to adapt to change. Four experts highlighted the importance of having a substantial increase in value or benefit with the new way of working. It was stated that it would be easier to change the culture if the benefits for Digital Twins were proven. Furthermore, cultural changes were necessary in order to successfully implement a Digital Twin. One expert did also highlight the issue with the trust in technologies. Implementing a Digital Twin leaves little room for mistakes before employees want to discard it. While a new employee can make many mistakes without having any repercussions, a faulty machine or technology have higher expectations. It was further emphasized the importance of making good interfaces which humans could understand.

Another important challenge was the aspects around costs and the fact that the development of a Digital Twin had to create value equal to the amount of money spent. Almost half of our participants addressed the issue of how expensive a Digital Twin is. One of the participants from the built environment highlighted their own experience of how expensive a Digital Twin can be, he said:

> *"A Digital Twin is very expensive to develop and integrate, but it is also very expensive to maintain."*

He elaborated further by explaining that the model provided by a Digital Twin creates added value in terms of possibilities and saved time, however, it does not provide any cost value. Several participants agreed with this by saying that it would take many years or almost be impossible to make up for the investment made in a Digital Twin in terms of cost. Lastly, the difficulties with getting enough financial support from upper management was mentioned. one stated:

> *"From my experience, if you say this will cost 1 million to develop, however, we will make 10 million, everyone agrees and give the green light. On the other hand, if we develop this, we can save 10 million, then management gets uncertain. So, it is difficult to calculate and make a good business case on Digital Twins which aims to save money and not make money."*

Many experts mentioned incentives as one of the most important challenges. The experts wanted to highlight the challenges of getting leaders to understand the need to drive Digital Twin forward in the industry. The challenge was related to many old leaders who had trouble understanding the value and opportunities of technology. On the other hand, it was also challenging to deal with over-ambitious projects and leaders. Some participants addressed their issue with doing too much at the same time, which often could ruin projects. One participant said:

> *"The ambitions often get too high, and people want to do more than what's reasonable. Typically projects where you take on too much at the same time, everything gets too expensive and will never work. It is better to focus on a small area or a small dataset and work effectively on that."*

A different expert supported this by saying:

> *"It is important to limit the focus area. You cannot take a massive project all at once, you must do it step by step."*

Another expert highlighted that if you start small it can be easier to scale up. One expert wanted to highlight that people often want to stay updated with cool new technologies, and that could often ruin projects when wanting to do too much. VR, AR, and HoloLens was used as examples of interfaces for Digital Twins that could be too advanced and make things more difficult rather than provide any value. It is important that the interface first and foremost should be suitable for the ones who will use the tool.

Several experts addressed the issue with time. It was said that Digital Twin projects are like any other IT project, they often go off track and spend more money and time than initially planned. One expert meant there were several reasons for this, especially for DT projects due to the lack of order competence. As a result, the developer often gets unclear instructions from the customers on what they want. Additionally, developers sometimes overestimate their knowledge and ability to deliver what is promised. Furthermore, it appears to be more difficult for large organizations to make big changes in work processes, while small organizations or private persons can adapt more easily. The experts underlined that it all depends on how large your project is, nevertheless, development always takes a lot of time. Moreover, the issue with optimization and automation projects often results in downsizing. It got argued:

> *"People don't realize how much time development takes. What happens is that you want to develop a Digital Twin, and in a few years, you want to reduce the number of ground workers. However, in a few years, the development is not finished and you still fire half of the workers, and then everything falls apart. People need to acknowledge that it is necessary to move slower and give more time for such projects."*

The last challenge was connected to the individual organization's maturity and readiness. Some of the experts addressed the issue of organizations not being mature. It was required to have a mature organization to comprehend a Digital Twin. This was closely related to leadership and the need to understand the value provided by a Digital Twin. Furthermore, some prerequisites had to be in place before starting a Digital Twin implementation. Data was the crux of it and had to be at a sufficient level before starting anything and that was tightly connected to the organization's maturity and readiness for an implementation phase. Another expert supported this by saying:

> *"Because Digital Twin is more about connecting things you can say that data structure and data platform projects are kind of prerequisite. They must be in place before even starting to think about a Digital Twin."*

4.2.4 Implementation approach

Due to the many implementation challenges, we were interested in hearing how the experts would recommend a DT implementation approach, given their current knowledge and experiences. This section presents the seven recommendations that were identified.

The first topic mentioned by most of the participants was the need for a use case. It is essential to identify a concrete problem or issue you want the Digital Twin would solve, before addressing how that problem can be solved as efficiently as possible. The experts mentioned that it was important to take a step back and figure out where the organization was today, in order to map out the needs and possibilities for a Digital Twin within the organization. One expert said:

> *"What I see in success with Digital Twin, is when you take a problem that needs to be solved or a process that is cumbersome, expensive, or outdated. Where I can see that a Digital Twin architecture can give a good return on money."*

Another expert supported this while also highlighting the importance of knowing the organization's status:

> *"You must overcome the barrier of what are we going to use this for. What is realistic for us to achieve? And you have to find out how much it will cost you to achieve what you want, and set boundaries in advance, will we go for Need to have or Nice to have."*

The second piece of advice was to make a clear business case before starting the implementation. This was mentioned as a crucial step toward a successful implementation and is correlated with the need for a use case. After identifying the problem, it must be developed a business case in which the organization can obtain value. It did not necessarily need to include exact numbers on cost savings, it could be more about staying relevant and keeping up with competitors, which could be enough value on its own. Some experts emphasized the importance of having a clear understanding of what you need and why. They meant that different questions like what to include, what is the value, what is the goal, and where lies the effective value, had to be addressed. It got argued that there was no point in starting a Digital Twin process if you don't know the purpose of the implementation.

The third suggestion was regarding data structure. Almost half of the participants mentioned the importance of having a good data structure already in place before beginning an implementation process. Multiple experts looked at data structures as a prerequisite for any Digital Twin project. It was argued that since DT can be a complex process of collecting data in one place, you had to meet certain data standards before being ready. One expert said:

> *"One thing I want to mention which is very important is that you need to have a good data foundation […] We have seen on some assets where the data foundation was not at a sufficient level, that the integration was poor."*

Another expert supported this by explaining how they approach an implementation:

> *"When we start, we do a data assessment by providing a checklist which states the bare minimum requirements needed to start the implementation."*

They also mentioned the importance of having knowledge about cloud technology and real-time database storage. Additionally, it was suggested that you should always build on the existing systems that are already in place at the organization and not start from scratch. Another expert supported this by saying:

> *"One of the worst things you can do is take a completely new system and simultaneously implement a Digital Twin. Then you have no one who understands the system and it makes everything more difficult."*

The fourth piece of advice was to start small and then scale up, and not move too fast forward. Almost half of our participants mentioned this as the proper approach to a Digital Twin implementation. One expert said:

> *"From my experience, most projects fail because they start too big. They try to do too much at the same time. Therefore, it can be an idea to start small, start with a small pump for example and see if that works."*

Another expert agreed with this by explaining from own experiences:

> *"Customers sometimes want to start big and have many ideas, however, we would never recommend that. We start small, wherein it is a small asset or a process, and then we prove the value there first."*

It was mentioned from another expert the possibility of evolving the Twin over time:

> *"I can imagine that many would start with a Digital Shadow of their asset and let it slowly develop over time to a Digital Twin."*

It was also mentioned that test cases could be a good approach for Digital Twin implementation. This could help prove the value without being expensive, as it is possible to test the Twins' value before investing large amounts.

The fifth topic was related to leadership. Many of the experts talked about support and investment from leaders as an important criterion for a successful Digital Twin project. However, only two experts addressed this directly when asked how they would approach an implementation phase. One of them talked directly about the support from management:

> *"It is so important to have the support from management. Especially leaders that understand the value of digitalization, and not use it only as a buzzword."*

The other expert believed that one of the most important criteria for a successful Digital Twin project was to have a project leader who is invested. He said:

> *"I think the most important thing is to have someone who wants to work with this project, to have like an ambassador for the implementation."*

The sixth recommendation was related to building competence within the Digital Twin concept. Order competence was mentioned as an essential factor that had to be improved, it was said that:

> *"From my experience, we lack order competence, we let the suppliers do what they want. And they often do things that sound good but would never work in practice."*

It was highlighted that a success criterion was having someone in the organization that understands the concept and knows what to do. If not, the organization had to build its competence or hire external experts.

As the seventh suggestion, many experts mentioned that it was important to look at Digital Twin as a long-term investment. It was important to have a future-oriented approach to the implementation. One expert highlighted it by saying:

> *"When deciding to implement a Digital Twin, you must think ahead. If you imagine the industry in 10 years, will it be common to have a Digital Twin then? It might be absurd if you don't have a Digital Twin in 10 years, you can never know completely but you must always think forward."*

4.2.5 Measurement of a successful implementation

The study wanted to identify how a successful implementation could be measured when a definition of the Digital Twin concept is hard to determine. Overall, our experts found it difficult to summarize one method of measuring but came up with some ideas on how it could be done.

Several experts stated that one way to assess success is to measure whether the implementation project met the predetermined expectations. Did the Digital Twin end up like planned or did you end up with something else? It got emphasized that it is important to clarify the expectations of the Digital Twin before starting the implementation project, in order to measure accordingly. For instance, control whether the performance met the expectations that was promised before the implementation. Furthermore, you should look at all the functionalities, to know if you ended up with a precise virtual representation of the asset.

Some of the interviewees did also mention the possibility of comparing the old processes with the new processes driven by the Digital Twin. An expert who today is operating with a functional Digital Twin in their everyday work mentioned that it was possible to measure each case and see if the new method were more effective. Where tasks are performed in less time due to the Digital Twin, the implementation was considered successful. The expert emphasized that it was the new way of working that brought business value and not necessarily the Twin itself, although it enabled the new working process. Another expert supported this by saying:

> *"The technology must be used by the workers and then you have everything that comes with change management. "*

She further highlighted the difficulties with adopting a new work process, and the struggles with making the workers adapt to the change.

Another way of measuring success was through customer feedback. An expert with experience in delivering Digital Twin told that when satisfied customers came back to improve and further develop the Twin, they considered the project as successful. Not only does this shows that the Digital Twin is working, but it also means that the expectations were met.

Related to buildings and properties, it was mentioned that it was important that the Digital Twin is useful throughout the buildings lifespan in order to be successful. It got stated that there was no point in including a DT in the building process if it was not utilized further in the administration phase of the building.

4.3 Benefits

Investigating the benefits of Digital Twins is interesting to see what can motivate organizations towards an adoption. However, a successful implementation is required to obtain the benefits. Findings indicate that the implementation of Digital Twins can provide great benefits, as long as it is done right. The section is divided into first presenting the value of Digital Twins, how it can be beneficial for decision-making and sustainability before providing examples of who should consider adoption.

4.3.1 General value

The core value of Digital Twin is all about saving time and working smarter. Through simulations, predictions, and real-time data, both products and processes are optimized. However, it got argued that:

> *"The time saved is not worth anything unless you use that time for something else sensible. Either reduced hours spent or improved product."*

The incoming flow of real-time data provides a broad insight, allowing monitoring and hence increased control. Improvements get easier to create and problem-solving gets more effective:

> *"Problem-solving will be more intuitive when you get it in a format that is closer to reality."*

The collection of data integrates perspectives from different sources into one system, providing valuable information that had been hard to collect otherwise. Findings indicate that in some advanced systems, there are often difficult to achieve a sufficient overview and a big part of the accidents that occur in plants causes information overload. But with

Digital Twin the information will be easier to handle. Having people who watch and contextualize the data and the models behind the digital representation to calculate and notice abnormalities, a holistic picture gets created. Over time, historical data will make it easier to notice causal relationships.

DT can also provide an architecture that makes it possible to institutionalize analytic tasks which were previously done by individual projects or on demand. To quote an interviewee:

> *"If you suddenly get a problem with your plant, you have to perform several tasks like collect data to find out what went wrong, try to figure out why it happened, find relevant information in archives, and many more tasks and then fix the problem."*

It got highlighted that with this DT architecture, you already possess all this information. When an incident occurs, you can identify the problem faster and correct it. Additionally, incidents can be prevented from happening in the first place and maintenance can be done based on needs, rather than regularly ruled by dates and routines. It is not only more productive, but it also serves to sharpen the concentration by directing attention towards the most significant risks and areas with a tendency to potential errors.

While costs also are found as a barrier and implementation challenge, several participants highlighted costs as a benefit. The more data the Twin can collect, the more subscriptions on IT systems and other applications can be cut. Costs are also saved through maintenance, or so-called Turnarounds, which is a planned period of maintenance activities on plants. One of the participants exemplified an experience, where one turnaround event recovered the investment of the DT implementation with a savings on a "few millions".

The Digital Twin can autonomize processes that normally is done manually by employees, such as monitoring. Participants exemplified that normally, people are walking around on huge plants looking for errors, while the DT can monitor the whole plant and automatically provide notifications in case of errors. It got also mentioned that this increases the efficiency of the inspection itself, and maybe more importantly, increases the quality of what you do.

Digital Twins can also be beneficial for training, where simulating scenarios can be an easier and more effective way of teaching and learning employees. An interviewee mentioned:

> *"What is interesting is that simulators are often advanced tools used by engineers. But through the Twin, we want to make these tools more accessible to people who are working on the floor, who actually make that change. Then, we avoid the lag time, in the means of an employee noticing something, then you have to simulate it, assess it, etc., before you can implement the change. If you can implement the change there and then, for example on a Friday before the weekend, you have already saved that*

> *electricity over the weekend, and so on. Small margins, but these are the margins we are chasing because small margins mean a lot."*

Findings also indicate that Digital Twins is very valuable for documentation, by having all information collected in one place. Seeing the object in a visual format provides an overview and control, also where the system can be enriched with descriptive data about different parts. Thus, replacements are easier to implement, as the Digital Twin provides all the information required for ordering a new replica of the defective part. Such visual representation is also easier to read and easier to find for the different people that have access to the object throughout its life cycle. The Twin does furthermore provide great documentation for people not working nearby the physical object. For instance, employees onshore can stay updated about the plant placed offshore or builders that work far away from where the building is being built.

Overall, it is important to have in mind that the benefits of a Digital Twin are not gained in the first week or the first month. This is value over time.

4.3.2 Decision-making

Having all data about the physical object gathered in one system opens for better interdisciplinary collaboration,

> *"Where employees work with the different subjects it will be easier to see the relations when you interact in the same model". Another one continued "You skip this "Go to SharePoint and search for a document" and then you find 15 different versions, sort of. So that part will be avoided. So, the foundation of information will be more similar, and everyone are having the same documentation."*

The foundation for agreement and a common understanding is therefore increased, which will contribute to making better decisions.

The greatest initiatives providing high value within product optimization were stated to be predictions and ensuring uptime at the plants, based on the combination of data and data sources in a visualization. Because it is all about collecting data that makes you work in a different way. Two examples were given:

> *"If you have monitoring and discover an error, then you warn an asset that 'this pump has some signals and early warnings'. However, if you are not using that information to change or do something, it has zero value."*

> *"At the end of the day, this is all about decision-making. This system, once you manifest the data in a contextualized manner, that's wherein you start getting the value wherein it starts announcing the decision making."*

Numerous decisions can be made by a Digital Twin. It may concern how to design a production plant or make better decisions regarding capacity needs, operations, maintenance, or training, for instance. What is special about Digital Twins related to decision-making is the real-time information it provides. Real-time data is beneficial for quicker decisions because it reflects the current state of situations. Then, future errors are easier to steer and correct. Real-time data is more suitable for steering the physical object, compared to monthly reports describing the condition for the previous month. In order to steer something, it is advantageous to receive state or situation reports at the moment things happen to easier and quickly correct the course. Examples are components and equipment that are about to fail, that you get decision support from the Digital Twin for when you have to intervene, and when you may not need to.

Digital Twins is also beneficial for decision-making in terms of making more correct decisions. Large amounts of data are collected, creating a solid decision basis. Participants argued that the idea with Digital Twin is to use data to predict different needs. Hence, getting the right information and actual data without having to guess things is essential. You can concretize and take decisions based on facts. Also, as actual data is collected over time, patterns can be identified, and you are more able to make the right decisions. This is about saving money and making decisions that save resources. That is why you have a DT, to understand the physical object before errors or accidents occur. One stated:

> *"Hours are saved and actually safer work because you are more certain that the decision you make is the right decision."*

Others mentioned simulating scenarios, that when you simulate a big number of scenarios, it gets easier å figure out which scenario is correct and the most effective related to the goal that is set. Additionally, simulating scenarios makes you in a better position to make decisions to change the physical environment. As a result, more intelligent decisions can be made.

However, regardless of how supportive the Digital Twin is for decision-making, it is important to not remove the people. The people working at the factory will always be able to give context to the data. An example was given:

> *"If you have a Digital Twin and are about to make a decision, involve your people. Say that the temperature has reduced, what is happening? Ask your staff and they can tell you it is because of the high electricity costs so they reduced the temperature in that room. And also, because Lars is on holiday this week."*

In other words, the human factor is central in order to sufficiently understand the data. A participant stated:

> *"I would say that thinking about a Digital Twin without bringing good decision makers and good people to interpret the data. You will get an inferior Digital Twin."*

4.3.3 Sustainability

Findings indicate a connection between Digital Twin and sustainability. Nevertheless, how Digital Twin can contribute to sustainability depends on the purpose. While one claimed that the Twin is not necessarily a sustainable driver itself but can have a positive effect if sustainability is one of the motivators, the majority shared a common agreement regarding Digital Twin being a significant tool for sustainability. The importance of being sustainable got further highlighted by a statement regarding commitment:

> *"Sustainability must always be one of the elements you build in your business case. That is a commitment you are more obliged to do now than you were before."*

The most mentioned sustainable benefit was regarding the utilization of resources. By repairing and taking service more actively, you avoid replacing parts. When service and maintenance are needed will be visible in the Digital Twin by monitoring the physical object through sensors. Such predictive maintenance will better exploit the resources, rather than scheduled maintenance. Working after needs will also be beneficial in case of correcting mistakes before any environmental consequences, such as oil leaks for instance. Furthermore, it is important to avoid unnecessary replacements or investments, in order to not waste resources or materials. This is about making the right decisions and the right investment at the right time. Utilizing resources is beneficial for economical sustainability, as well as avoiding maintenance backlog which consumes a lot of resources and significant reparations expenses.

Digital Twins can also contribute to social sustainability for instance by monitoring buildings. Participants exemplified how the Digital Twin can monitor how buildings are used throughout the day by both the tenants and the public. With such monitoring over time, decisions to improve common areas can be done. For example, if common areas are not being used in the evening, they can be rented out to ideal charities.

The Digital Twin allows proactivity. Simulations identify shortages, hence, objects can be designed to reduce fuel consumption, such as cars or airplanes. Furthermore, the Twin can contribute to making better decisions regarding the choice of materials. Being aware of what materials to use can contribute significantly to making a more sustainable choice. In the context of building and construction practices, recommendations have been put forth regarding the consideration of factors such as carbon footprint and life cycle costs, with a view to promoting environmental sustainability. Moreover, the emergence of certification schemes such as BREEAM has further highlighted the significance of such considerations in this domain. BREEAM, an international standard developed to assess the sustainability of buildings and infrastructure, offers certifications for environmentally sustainable buildings (BRE Group, 2023). Having control over which materials are used will make it easier to recycle and know what can be reused when renovating. Reuse where it is possible to reduce waste. Having information about the materials stored in the Digital Twin is also beneficial in order to know how much the materials manage. A participant told:

> *"There was someone who was about to demolish a building and add more floors. But then they laser-scanned the building and saw what it was made of and measured the bearing capacity of the concrete floors. It turned out that they did not need to demolish, they could build 3 floors up on what was there already. As a result, a lot of CO2 is saved in concrete, as well as cash because it costs to demolish and build new."*

Most parts of the sustainable gain are extracted through optimization. The more you manage to optimize the physical object you replicate, the less you need to intervene or expand further:

> *"Every optimization is good. It is beneficial for the environment, for the surroundings and it is beneficial for the people working there."*

Optimization is also beneficial for avoiding downtime and improve the objects' lifespan, one argued:

> *"We want the things we have to last as long as possible, we don't want to build new things, we want it to last forever, if possible. And by using as few resources as possible."*

The Digital Twin can also be used for energy optimization and product optimization. By tracking energy consumption and being more aware of parts using an unnecessary amount of energy, it is easier to know where to interact to reduce the consumption. As a society, we do not want to use more than we need and optimizing objects such as the power grid and buildings, for instance, will contribute positively. Examples were given regarding buildings involving several floors, where having one employee working in one floor and the rest of the employees working on another floor is unsustainable. In such cases, energy consumption, ventilation, electricity, and heat must be turned on for one person, in addition to the need for washing. Another example regarded optimizing the flow of electricity by utilize the existing power grid, lines and masts and not have to replace and build new ones that harm the environment. Overall, the Digital Twin is valuable for sustainability by tracking, monitoring, optimizing objects so it is possible to steer the objects to achieve the optimal effect of energy.

4.3.4 Potential sectors

In order to gain a better understanding of the Digital Twin concept, we asked our interviewees who should use or consider such technology. While sectors like energy, manufacturing, and construction were the most mentioned, a few did also say that almost any organization should use Digital Twins. However, all participants agreed that this depends on the case and the problem you need to solve, rather than the type of sector or organization.

Within the energy sector, the benefits of having a Digital Twin on an oil rig got exemplified, where the digital copy can recreate movements and a flow of real-time data is going live from offshore to onshore. Others showcased the opportunities with windmills:

> *"When it comes to wind power, I am more optimistic. Because it is now possible to create sensors, not only for one turbine, but for an entire wind park, create good algorithms and then create systems that develop over time."*

The system can optimize power production, minimize wear and tear, and do condition-based maintenance.

> *"If something happens out in the North Sea in November, you can't be sure you'll get it repaired before May due to the winter weather and so on."*

Having a damaged wing right before this period without knowing, a huge amount of energy gets lost as a result of the long reparation time. DT got therefore argued to be a key technology for doing this more economically and a central part of utilizing the potential of such wind parks.

The Digital Twin will also be beneficial within the process industry and manufacturing. For instance, in the car production industry, where having a digital representation on each car component enables suppliers to take crash tests and hence determine which components need to be optimized. Such crash tests will also enable optimizations on car constructions, as well as measuring exhaustion to see what the components withstand. Not to mention aerospace, which is where the Digital Twins has much of its origin. Using DT technology on an aircraft engine, the need for maintenance can be predicted. In case of vibrations or abnormal behavior, the maintenance request is triggered.

Regarding the measurement of performance, the Digital Twin will also provide benefits within the construction industry. By monitoring buildings, decisions related to ventilation and the use of energy can be supported. Nonetheless, the use of a Digital Twin to build things forces you to think about the whole life cycle, as well as good project documentation. It was also mentioned a great potential in smart buildings, which already includes sensors and IoT technology. Furthermore, smart cities are a current topic related to DT, where creating a visual holistic overview of the city to better utilize its potential. The traffic and power grid can be optimized, buildings can be built and placed strategically regarding where the citizens enjoy themselves, as well as climate changes such as increased water levels in the coming years.

In general, actors handling critical infrastructure are potential sectors for utilizing Digital Twins. Hereby power grid, healthcare, agriculture, forestry, and fishing industry. One participant argued:

> *"Everything critical in case of shut down. Either critical for the organization, the overall society, or the consumers. The more critical it is, the more important it is to have this holistic overview and the opportunity for simulating future scenarios."*

4.4 Status

Even though the RQs are not aiming to identify the status of Digital Twins, the interviews conducted makes it possible to map. Through the findings, we were able to create an overview of Digital Twins' current status in the Norwegian industry, as well as how it will evolve in the years to come. First, this section summarizes today's status before presenting the experts' future predictions.

4.4.1 Digital Twin today

Related to the current conditions, participants raised their concerns regarding the technology used in a Digital Twin. They meant that today's technology was not good enough to meet the requirements for a Digital Twin development, although there was emphasized that it could only take a few years. It was also mentioned that DT is not something new and the technology itself was quite old, in addition to being tightly connected to the evolution of IoT. Another interviewee mentioned the lack of maturity within their industry regarding technological standards and work practices, and that the development of a Digital Twin would therefore be troublesome.

Several participants mentioned that they believe their industry was more than far enough on the technological journey to be able to develop a Digital Twin. It was stated:

> *"You can access quite cheap sensors, easy sensors to get the data that you need with the quality required. I don't believe this is where the problem lies."*

Another participant backed this up by saying that the technology is there and that it is rarely the technology that is the problem. Although, it could still be cumbersome. However, the research finds the energy industry as more established than other sectors, as they today are having the platform, software, hardware, and a fully operative DT. It is therefore clear that the technology is not an obstacle.

On the other hand, some believed that there is nothing that can be called a fully operating Digital Twin by their definition of the concept. They say that industries are in a state which is located somewhere between a Digital Shadow and a Digital Twin. It was emphasized that when most talk about Digital Twins, they are talking about Digital Models. Another expert mentioned the same thing:

> *"Most of the Digital Twins I have seen only have one-way communications, you create an image with data that you can base your analysis and simulations on. However, you will have to manually go in and do the changes."*

It was further explained that the concept of Digital Twin is just a buzzword for something that already exists in some industries, due to the requirement of monitoring some assets with live data. The possibility of people being confused by the DT concept and not knowing the difference between a Digital Model and a Digital Twin was also identified as a concern in some industries.

Due to the lack of order competence, few are ordering Digital Twin as a product or service. As a result, providers are focusing on preparing for future demands. Others are however, focusing more on the competence of the customers. It was stated:

> *"Many do not realize why they should order a Digital Twin, what does it mean? What does it cost? Are there different levels of a DT for building owners that are ambitus and those who are not?"*

It was further highlighted that the competence to order a Digital Twin is not ready for their industry and that it was important to understand why you want to use a DT, both for the developer and the customer.

Lastly, it was highlighted that a certain maturity was needed to develop a Digital Twin. Some participants mentioned that from their realization most industries and businesses are waiting to see what others do before starting their own Digital Twin journey. They want to learn from other people's experiences before risking anything themselves. However, many are interested in Digital Twins and want to invest although it is lacking some maturity in the field.

4.4.2 Digital Twin forward

The research identified several thoughts about how Digital Twin will move forward in the years to come. Some experts claimed that Digital Twin was a topic that would be talked about more and more in the coming years. They also addressed the importance of growing the market and giving it more time. The competence of what it is and how it can be used, needed to grow. Another expert said that Digital Twins would become more common, without knowing how fast it would grow. Furthermore, some mentioned that it was hard to identify if the Twins of the future would be very complex or simple, however, this would develop with the technological evolution.

It was mentioned that the energy sector, specifically oil and gas, was so much further ahead than the rest. This meant that their development in the coming years was very different. The reason for this was that production optimization in oil in gas was more important than in any other industry. For other businesses, it is hard to measure and justify the costly investment with Digital Twins, because the consequences of not having it are not severe. One expert said:

> *"I believe that the oil and gas industry will develop this to a greater extent than any other industry, simply because it can be measured more directly in how much money you save by limiting the downtime. While in the built environment it is hard to justify the investment when the consequences of not operating optimally are not severe."*

A few experts meant that in the coming years, Digital Twin would grow to be something more advanced. It was said that the systems will be more integrated in the future and have a more natural part of how we operate different systems and processes. Furthermore, technologies like VR, AR and HoloLens would become a huge part of the Digital Twin evolution. Other experts meant that if you did not develop your Digital Twin today you would be lacking in the future when all other competitors have their version. One expert elaborated that their focus now was to improve on the existing version and explore new use cases when they meant that Digital Twin could have endless possibilities.

Lastly, several experts shared their views on when they thought significant change would occur. The majority of participants knew that Digital Twin in general would have an increase in development and attention. Some believed it would only take a few years, while others thought it was hard to determine. It was also emphasized that with a digitalization project, the value is typically not realized right away, and you must therefore be patient to see the value provided by the Digital Twin. Having that said, each expert talked from their experience in their sector and made clear that the further development of the concept was individual for each specific industry.

5 DISCUSSION

We will here discuss the findings of the study to analyze the data gathered and insight gained from the qualitative research. Through the discussion, we aim to provide a comprehensive understanding of Digital Twins adoption. Furthermore, we reflect on the study's implication to the field of research, as well as its limitations, and suggest potential avenues for future research.

5.1 Findings compared to previous literature

Conducting a qualitative research method, several interesting aspects were found. The results will here be discussed, in accordance with the structure outlined in the Findings chapter. Firstly, the discussion begins with the Digital Twin's definition, followed by the drivers and enablers. Moving forward, the different implementation aspects are showcased, including an examination of the challenges and opportunities that arise during the implementation process and exploring the various factors that affect successful implementation. Lastly, we discuss the benefits found.

5.1.1 Definition

Through reviewing existing literature, we discovered that the definition of Digital Twins is a common disagreement among experts. Instead of searching for a final definition, we are interested in what is required to be named a Digital Twin. In similarities with the literature, the interviews did also provide different answers to what DT is. An observation is that the definition and its required elements vary among the different sectors. For instance, while the construction industry frequently draws parallels between Digital Twins and BIM, the energy sector tends to approach the concept from a more advanced perspective. However, Durão et al. (2018, p. 209) and Vieira et al. (2022, p. 251) argues that this is a result of the growing interest across multiple sectors, leading to the DT being used for different things and hence, distinct definitions depending on the context in which the term is used.

The existence of multiple interpretations regarding the definition of Digital Twins has led to confusion related to its essential requirements. This raises the question of how one can assess the achievement of a successful implementation when the requirements are not clearly defined. Additionally, how do we distinguish between what is considered a Digital Twin or not? As previously mentioned, many individuals establish a connection between DT and BIM. However, according to Vieira et al. (2022), BIM does not satisfy the criteria outlined in the existing literature to be considered a true DT (p. 252). The authors argue that while BIM can manage digital information in a 3D format and serve as an information model for assets or systems, it does not fulfill the requirements to be a DT. While most share an opinion of no harmonized definition and thus, requirements, Vieira et al. (2022) state that to be considered a DT, it must not only include all the necessary data about the real asset or system, but also the connection to the physical object (p. 252).

This is, however, a discussion related to the topic of Digital Models, Shadows, and Twins. These three terms are often mentioned related to the definition of Digital Twins, from both our interviewees and the literature. The terms are often used interchangeably; hence, the Twin-term is said to be abused in this relation. It is stated that several of today's Twins might be more of a Digital Model or Digital Shadow. Such statements might be rooted in the fact that most of today's Twins have a digital representation that does not have the opportunity to give feedback to the physical twin, in other words, the two-sided data flow.

With the lack of a common definition, Digital Twin faces the same problem that we have seen with the digital transformation term. It becomes some kind of buzzword that managements use to keep up with the changes in digital strategies. Several participants motioned that Digital Twins has become a popular term after a certain hype has been built around the terminology. As a result, people believe that this hype has pushed organizations to implement something they believe to be a Digital Twin, while the reality might reflect something else. Consequently, it naturally affects the Digital Twin definition when people are pushed to do something new and exciting without having the proper knowledge or experience on the topic. However, a definition of the different levels of a Digital Twin could help organizations realize the value, as well as clarify the concept in order to avoid the buzzword categorization.

As outlined in 4.1 Definition, most interviewees defined the Digital Twin as a digital representation of something physical. Although this definition is broadly applicable, it remains rather abstract, leaving much to interpretation and potentially serving as a temporary working definition for the term. Nonetheless, this definition is consistent with existing literature on the subject and aligns with the most common descriptors used to define Digital Twins in our word cloud analysis (see Figure 2). However, if a broad definition of Digital Twins becomes an internationally accepted standard, it is unlikely that this will resolve the issue of ambiguity surrounding the requisite features of the concept.

The many meanings make it difficult to know whom that is right and thereby what viewpoint to work from. While some individuals consider Digital Twins to be an umbrella term and broad concept that does not refer to any specific technology, there are sectors, such as the energy industry, that have made considerable progress in developing their Twins. Interestingly, it is often those outside of these industries who argue that Digital

Twin is not a clearly defined technology. Furthermore, it is worth considering why it is important to establish a clear definition for Digital Twin. The primary reason is to establish a common language and an international standard to ensure that everyone is operating with the same understanding. Although Broo and Schooling (2021, p. 6) found that the definition vary within the same sector, our study indicates that a common understanding within the industry is beginning to form, even though it is not quite there yet.

However, after investigating Digital Twin adoption and its implementation challenges, we notice that the definition causes problems in later phases. Customers are struggling to order a Digital Twin as a result of unclarity in what to order or expect. A comprehensive understanding of the concept might therefore be the foundational obstacle regarding its implementation challenges. The current condition of the term leads to a feeling of almost speaking about different concepts. While several claims that sensor technology is an enabler in the Digital Twin implementation, others mean that the real-time data from sensors are not necessary as long as the data gets updated within the object's life cycle. However, Digital Twin is not a shelf item, it gets customized to the customer's business case. It might, regardless, make sense to emphasize the differences between a Digital Model, a Digital Shadow, and a Digital Twin in order to differentiate and further determine their requirements. We mean that the requirements are the most important aspect of establishing a common understanding of the Digital Twin, and the journey for achieving a common language should therefore begin with determining these. When international requirements, and maybe later national customizations are determined, the definition should be identified thereafter.

5.1.2 Drivers and enablers

Throughout this research, we have seen that drivers and enablers are concepts that coexist with each other and can therefore be hard to separate. In the interviews, we noticed that the terms were often used together, which indicates that some of the different factors might work as both. In this section, we will discuss the drivers and enablers in comparison to the literature to obtain a comprehensive understanding of the results and answer RQ1.

Data is seen as an important factor for a Digital Twin implementation. The literature describes data access as an enabler when it is required to feed the Twin with information. However, our findings do also describe data as a driver when connecting all available data in a Digital Twin can be a motivation for organizations to implement a DT. Having that said, a good data structure is identified in the findings as a prerequisite for a Digital Twin implementation. Some even state that it is not possible to succeed if a sufficient data structure is in place before the implementation. Thus, data will have to be a main enabler for Digital Twin implementation when it is an essential part of the process. Although good data standards are an important enabler, the result provided by a Digital Twin when connecting the organization's data in one place can still be seen as a driver. This means that data can be identified as an essential driver and enabler for the adoption of Digital Twin according to our findings and the literature.

Following trends and keeping up with evolution can be a common reason why organizations invest time and money in a concept. Many organizations try to follow and show interest in new trends, typically to avoid falling behind other actors in the field or to evolve the organization. Being influenced by new trends can be seen as a driver as it motivates the organization to grow. This is described by the literature as an external driver. Our findings show that most organizations now are at a stage where they participate in conferences and show interest in Digital Twin to keep up with the evolution of the technology and be ready if it takes the market by storm. This is described by the literature as a positive driver that forces organizations to evolve. Our findings indicate that organizations are influenced by the hype of Digital Twin, which drives many to invest time and resources in acquiring knowledge. Another reason to follow trends is to keep up with competition, which the literature considers as a main driver for Digital Twin implementation. Our study shows that an important driver for Digital Twin is to identify the possible future of the concept. We found that Digital Twin might be a technology that could be mandatory in some years in order to stay competitive in the field. Thus, following trends and keeping up with the competition can be seen as important drivers for Digital Twin implementations.

The literature highlights that different Industry 4.0 technologies like IoT, VR, AR, and sensors are important enablers for a Digital Twin implementation. Some of these technologies are essential to provide the Twin with the necessary elements to function as intended. Examples of this could be sensor technology. In order to obtain real-time data, the Twin is required to have sensor technologies on the physical asset that feeds the Digital copy with information. However, which technology enables the Twin depends on the level of complexity. Not all Twins need live data, which means that it does not necessarily need sensors, VR, AR or other similar technologies to function as intended. Our findings reveal little regarding the role of technologies as enablers. Even though this indicates that some of these technologies might not be essential in order to implement a Digital Twin, it does enable more advanced functionality.

Furthermore, the findings highlight the different benefits a Digital Twin can provide for an organization and that these benefits can be seen as drivers. The different benefits identified both from the literature and the findings show an organization what possibilities they can get from a Digital Twin and can be a motivator for Digital Twin implementation. When looking at general IT adoption we can see some similarities. Fawzi and Subriadi (2023) identified that increasing productivity, reduced costs and increasing efficiency are general IT adoption drivers, which are identified in our findings and literature as benefits provided by Digital Twins (p. 5).

Managers and change were identified as main drivers for Digital Twin implementation in the literature and this study. Our research shows that the implementation of a Digital Twin brings significant change to the organization. The literature identifies people as one of the main drivers because the adoption of new technology will never work if the workers resist change. Furthermore, both the literature and findings mention support from management as a main driver when resistance from management makes a Digital Twin implementation almost impossible. In addition, the literature argues that cross-collaboration within the organization is a main enabler for success. This means that for a Digital Twin implementation to succeed, the organization needs support from management, people who welcome positive change and collaboration between these two.

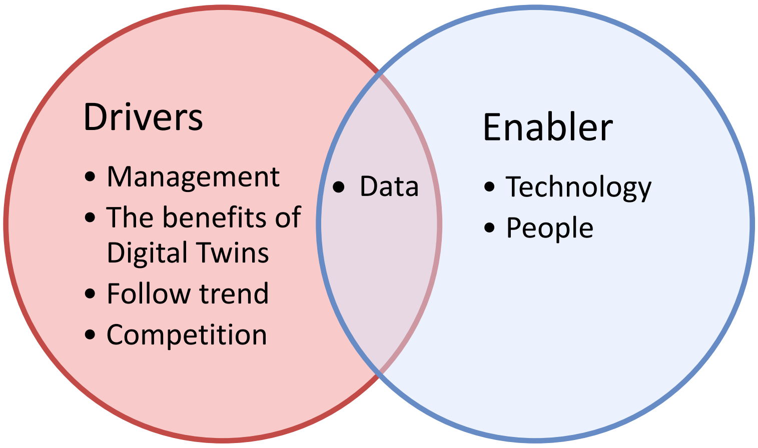

Figure 10 Drivers and enablers for Digital Twin implementation

5.1.3 Barriers

This thesis identifies several barriers which can prevent organizations from starting their Digital Twin adoption. As seen through the interviews, the many challenges related to the implementation are also identified as the main barriers. In this section, the barriers are discussed in order to answer RQ2.

Through analyzing the data, we have identified that the number one barrier to a Digital Twin implementation is cost. Nonetheless, additional factors influence this result. For instance, one of the reasons that a Digital Twin implementation is costly can be the lack of knowledge related to the concept and how it is implemented. Furthermore, from what is seen in the literature and through this study, few have experiences in developing a Digital Twin. This means that there are few examples of such histories. With little experience comes much room for improvement in the whole implementation process. This means that cost could be significantly improved for Digital Twin implementation in the years to come. Especially when looking at the increased amount of literature on the concept, and the excitement from the different industries.

The literature emphasizes the need to change the culture within the organization to ensure success with DT. While the literature focusing on stating the need to change and the importance of doing so, there was little explanation on why this was specific to DT.

From our findings, it was identified that a Digital Twin project is often about changing a process of work. This means that the implementation of a DT could draw similarities to a digital transformation project. Furthermore, DT could enable massive changes for an organization which requires a lot of time and effort in order to succeed. This could be the reason many identify the cultural aspect as a major Digital Twin barrier.

From both the literature and findings we can see a close connection between data and complexity. One of the main barriers that can hinder an organization from implementing a Digital Twin is the complexity of the adoption process. The literature highlights the difficulties with managing data, which focus on the complex process of integrating all systems and data formats into the Digital Twin. Our findings can support the literature with the fact that most participants who had no experience with DT implementation saw data as a complex part of the implementation. Those who had experience with DT implementation, on the other hand, knew that having good data standards and systems before starting the implementation led to an easier transition. This highlights that building more knowledge on DT implementation could result in minimizing barriers such as data complexity. Although data complexity can be minimized, it is still one barrier that prevents many from adopting a DT. As securing a solid data foundation is a demanding task, it is likely to be one of the factors regarding the implementation process that can appear overwhelming.

By examine the barriers for IT adoption, we can determine whether these shares any similarities with the barriers identified to the Digital Twin adoption. Firstly, we can see clear patterns in cultural change. IT adoption in general requires change and education in new systems that are replacing the old. Butler and Sellbom (2002) identified that learning new technologies is seen as a major barrier to IT adoption, which is also found as a barrier for Digital Twin. Their study also identifies that technological malfunction was seen as a significant problem in the context of IT adoption for learning (p. 5). Although we cannot say for sure that this is a barrier specific to DT, one of our interviewees mentioned this as a challenge when reliability for new technology has high expectations to always function properly. Furthermore, Fawzi and Subriadi (2023) identified that lack of financial resources, competent human resources, and employees are common barriers to IT adoption, which are also found as barriers to DT adoption. They also mention lack of coordination and government support as common barriers, which is not relevant for DT (p. 5). By analyzing the literature, we can see that Digital Twin adoption has many similarities to general IT adoption. However, some barriers are more specific for DT projects like the complexity of data, as not all IT projects involve the implementation or connections of massive systems and data sources.

5.1.4 Challenges

By comparing the study's findings with existing literature, this section aims to discuss the different implementation challenges in order to further address RQ2.

5.1.4.1 Technology requirements

Our study detected disagreement related to technological requirements. While many said that the current technologies are more than enough to develop a fully functional Digital Twin, others meant that some aspects were still missing. It is difficult to find reasons why people disagree on this topic. Nevertheless, it is possible to identify some patterns in our research. First and foremost, those who meant that the technology was not ready had little experience with a developed Twin. However, experts with implementation experiences proved a more convincing argument by talking about their own operational Digital Twin. Another reason for the disagreement could be the definition of a DT. If one understanding is that a Digital Twin requires two-way communication, while another perception is a digital module of a physical asset, it becomes evident that these two perspectives are referring to distinct technological concepts. This confusion can be the source of the different opinions on technology requirements. Another possible reason for this disagreement can be the experience and evolution of the concept within the different sectors. Through the research of this thesis, we have seen the differences in how far the industries have come. The energy sector has been working with Digital Twin development for quite some time, while other industries like construction and management of buildings have less experience. Having that said, the literature mentions little about the technology requirements. It might be possible that previous literature does not identify technology as an obstacle to Digital Twin implementation, however, this is merely our interpretation.

5.1.4.2 Security

Throughout the research, we have tried to not guide any of the participants with leading questions which can result in bias and misinformation. Having that said, in the interview's security was rarely mentioned as a challenge. Nevertheless, security challenges were an important topic that was mentioned by several articles. This raises the question whether security pose a real challenge for Digital Twins. It can be argued that the reason for the lack of security attention is that it is not specific to Digital Twin implementation, as security is always an important topic when talking about digitalization and IT projects.

The Digital Twin implementation process is mentioned by many as the collection of data in one place and the creation of a digital image. If this is the case, security should be a central role when developing a Digital Twin. The literature also mentions that security for Digital Twins is important because of the amount of data stored. Data is seen as an important resource in the modern business world, hence why security is so important. Moreover, it can be argued that security issues are more of a concern related to operation and not implementation.

Another aspect could be that our participants did not want to specify their security protocols when they might be afraid of touching on sensitive information. The participants talked from their own experiences and could potentially leak company policies on security. However, this remains speculations and the lack of security attention in the interviews could be a coincidence. Lastly, by analyzing the literature with our findings there are no direct differences in security issues compared to other IT projects. Despite the inherent ability of Digital Twins to efficiently handle substantial volumes of data collected from various sources, the aspect of security assumes a critical role and remains a major concern across all IT projects. For instance, Rasheed et al. (2020) mention security and privacy to being major challenges for the implementation of any IoT devices (p. 21995).

5.1.4.3 Time

Even though our research found time as a challenge related to Digital Twin, the literature says nothing about time challenges. This could be because time is nothing specific to DT projects when most IT adoptions are known for poor time management. It was argued by our experts that the issue could be connected to competence, meaning that the lack of competence hinders an efficient implementation when few parties have sufficient knowledge on how to do it properly. Furthermore, IT projects have a reputation for typically not meeting the deadline, often becoming too complex and taking up more time and resources than initially planned. For Digital Twin this is no exception, nevertheless, some specific aspects are outlined. For instance, Digital Twin implementation is seen as a very expensive process, which is highlighted through our findings and from the literature. Also, Digital Twin projects are seen as very complex, which means that assessing the time needed to complete such a project will probably be difficult. Furthermore, experts suggested that a Digital Twin implementation should always start small and scale up. This could mean that such projects can be an ongoing change within the organization. An idea could be to have milestones with small improvement’s to constantly improve the existing Digital Twin. This could also minimize the cost by eliminating the unnecessary risk of failing the project. This opens for the Digital Twin to grow with the maturity and competence of the organization. Having that said, the implementation must create value for the organization even in the early stages of development.

5.1.4.4 Culture and adaptation

Both the literature and finding in this thesis highlight the different issues regarding cultural changes and adaptation. It was identified that Digital Twin is like regular digital transformation processes, which often can be challenging when it comes to cultural change. In one of the interviews, it was identified that often when it comes to technology that changes a work process, people have a low tolerance for errors or mistakes. If a new technology glitches one time and makes the user experience poor early in the implementation, then users often get frustrated, and it can switch their attitude on the whole process. This issue emphasizes the importance of having a proper and interactive user interface that gives the user an experience they can understand. When it comes to Digital Twins specifically, the main goal is to get a better insight into data and create an overview that gives a better understanding of a process or object. Thus, if the Digital Twin provides a poor experience, it will most likely meet many challenges with adaptation from users in the organization. Although good user experience is something every IT project must have, it can provide further issues to an already complex and difficult process. Being aware of the change in culture is important in order to make Digital Twin adoption within an organization easier.

5.1.4.5 Top three challenges during the implementation of Digital Twins

During the interviews, the experts were asked to rank the top three challenges with DT implementation. It was identified that cost, competence, and incentives were the biggest challenges. Although data were mentioned by most participants, when asked to rank the most critical issues it was rarely brought up. This could be a coincidence; however, data might not be as challenging as initially thought.

Costs was the most mentioned challenge for a Digital Twin implementation throughout the interviews. The literature also mentions this as one of the more challenging elements when implementing a Digital Twin. Costs are probably looked at as the main challenge because huge investments are difficult and demanding for an organization, additionally DT must improve some processes within the enterprise to be worth the investment. On the other hand, the literature claims that Digital Twins can save costs by optimizing processes, however, this should be measured before starting an implementation. In the interviews, it was identified that costs are varying among the industries. One example to showcase this is the oil and gas industry, which loses large amounts of money if the production stops. This means that the value provided by a Digital Twin is significant, as it can operate and control the oil rig more efficiently and prevent unexpected downtime. Furthermore, the expenses used in implementing a Digital Twin can be seen as valuable when it prevents critical issues for the operation. This is probably why Digital Twin has become popular in production industries as well. In other industries where it can be more challenging to measure savings, the investment might be difficult to justify. In industries where you cannot create value in terms of cost savings, you will have to look at what other values a Digital Twin creates for the organization, in order to justify the investment. This can be optimization, more efficient work processes, a better overview of the asset, and the possibility of remote operation.

Competence was the second most mentioned challenge and is found as a huge issue within industries. Many actors lack knowledge of Digital Twins, which results in much uncertainty and confusion. There are few providers today that have sufficient experience in DT implementation, although this depends on what can be defined as a Digital Twin. Some providers deliver different systems which are called a Digital Twin; however, this gets customized to each use case and can therefore include different systems. Even though Digital Twins should be tailored to each organization, there must be some standards that define its basics. The literature highlights some issues with competence, which causes organizations to struggle with understanding the value of a Digital Twin. However, our findings show that competence is something that both customers and providers struggle with. Hence, by building a better understanding of Digital Twins, the adoption process can become less complex and confusing. This can be improved by creating concrete standards for Digital Twin requirements. In addition, many of the articles mention that Digital Twin technology is nothing new. In the latest years, the concept has gained massive traction and is now a focus area for many within the IT world. This is shown by the increasing number of articles written about DT in the last years as well as from what we have taken from the interviews. Hopefully, the increase of attention will eliminate the lack of competence issue in only a few years.

Incentives were the third most mentioned challenge. The lack of incentives provides obstacles for the implementation process. A possible reason for why this challenge was frequently mentioned in the interviews could be that there are much uncertainty and many barriers with Digital Twins, which could lead to a lack of incentive. The literature addresses the importance of having a clear vision and understanding of DT and how it can provide value for the organization. It also emphasizes that the entire organization needs to understand the concept and why it is implemented in order to have any success. Furthermore, the findings support the literature when almost half of the participants mentioned similar challenges. This means that it is important to have a missionary who drives the implementation of a DT in the organization. Without anyone who guides the implementation and the adaptation, a Digital Twin project will struggle. There must be someone who proves the value for all divisions, which could be someone within the management. The importance of having managerial support is highlighted in both the literature and our findings. The Digital Twin initiative should be led by a leader having this as a core responsibility, in order to contribute to encouragement regarding the implementation.

5.1.5 *Benefits*

The implementation phase is considered a key element to gain any business value out of a DT. As the benefits is identified as a potential driver, it is an interesting and relevant aspect in understanding the concept. However, to validate our findings it is necessary to compare with the literature, hence, this section aims to answer RQ3.

It is interesting how the costs are found both as a barrier, implementation challenge, and benefit. This demonstrates how differently individuals and industries perceive the same factor; for some, as a barrier that prevents them from implementing the Digital Twin, but for others, a benefit saving them a lot of money. Not only does this highlight the different meanings related to this topic, but it also showcases the different experiences.

Considering the amount of literature researching Digital Twin in the different sectors, most is to find within the energy, production, and process industry. Our findings indicate that the production industry demonstrates the highest level of expertise and advancement in the Digital Twin domain. This may be linked to the significant implications of downtime. Leveraging Digital Twin technology allows for optimizations that effectively prevent downtime, a benefit frequently highlighted in our study. As discussed in Section 5.1.4.5, the significance of this gets particularly crucial in industries such as oil rigs, where a mere few minutes of downtime can result in substantial financial losses. By comparison, the consequences of a non-functional elevator are limited to people using the stairs instead. Consequently, the varying levels of criticality associated with downtime can have an effect on how far various industries have progressed within the Digital Twin.

Another frequently mentioned benefit in both this study's interviews and existing literature is the advantage of having the Digital Twin collect data from several sources. However, the data itself is not worth anything unless you make sense of the it. Hence, the most important value driver is the transformation of bringing data into insight. It is not until you understand what you see that it is valuable and make better decisions. This can relate to the Data Information Knowledge Wisdom Pyramid (DIKW Pyramid) presented in Figure 11. When data is given context, it is no longer raw data, but information. By also providing it with meaning, for example based on experience, it attains the status of knowledge. If you also assign insight into the area, you can call it wisdom. Given a specific goal, it becomes a decision.

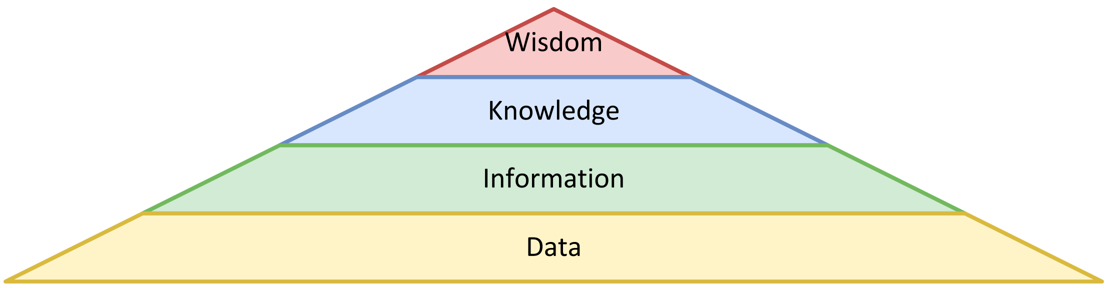

Figure 11 Data Information Knowledge Wisdom Pyramid

The utilization of Digital Twin technology for conducting simulations is widely acknowledged as a valuable asset, as evidenced by its frequent mention in both existing literature and our interview findings. Simulations enable the exploration of hypothetical scenarios, offering substantial benefits in forecasting future events. Nevertheless, it is crucial to recognize that numerous accidents or incidents arise unexpectedly, avoiding proactive preparation until they occur. Consequently, simulations without of human interactions and creative thinking are likely to yield limited value. It is precisely the creative element within simulations that holds the potential for substantial advantages, primarily manifested in the capacity to devise innovative and relevant simulation scenarios.

Sustainability represents a fundamental dimension in all projects, and Digital Twin is no different. Given the contemporary global emphasis on sustainability, society is increasingly urging younger generations to adopt more environmentally conscious thinking. Consequently, disregarding sustainability not only carries the risk of diminished popularity but also poses a threat of being surpassed by more environmentally conscious competitors. Utilizing the Digital Twin facilitates the optimization of physical objects to minimize emissions and enables organizations to undertake sustainable measures in optimizing production, such as generating their own energy. For instance, investments can be made in solar cells, solar collectors, geothermal heating, or pellet production. Leveraging the Digital Twin, simulations can be conducted to determine the most sustainable energy producer to be employed at any given time, aiming to achieve the optimal environmentally friendly solution.

During an interview, the topic of BREEAM certification was raised in relation to sustainability. While BREEAM serves as an international framework, there is a national adaptation called BREEAM-NOR customized for Norwegian conditions, regulations, and best practices (Grønn Byggallianse, 2023). This can be relevant where the integration of BREEAM criteria and standards into the Digital Twin enables simulations of environmental and sustainable scenarios, evaluating the building's performance. This enables an evaluation of how the building will perform in relation to the BREEAM criteria. The Digital Twin contributes to enhancing the effectiveness and precision of the BREEAM process, while also providing a more comprehensive approach to sustainability in construction projects. However, this is not limited to the BREEAM certifications, the Digital Twin can also be helpful with other similar certifications.

5.2 Implications for research and practice

Motivated by contributing to the IS research field, this thesis has focused on identifying how organizations can get started with Digital Twins. We have discovered several benefits, challenges, barriers, and drivers with the implementation of DT by researching empirical studies and interviewing experts. By including experts' perspectives on management awareness, the report addresses this shortcoming by providing an overview of implementation challenges from an organizational perspective. This fills the literature gap, as most of previous literature focuses on challenges related to the technical and engineering perspective as mentioned in the Introduction chapter.

This study contributes to practice by providing an overview of the different elements of DT adoption. This could be helpful to practitioners to understand the concept of Digital Twins from an organizational setting. The insight provided allows awareness which contributes to any manager or company interested in implementing a DT can be better prepared. Being familiar with the potential challenges might especially be beneficial to avoid companies following such a technological trend without being mature enough. Hence, before initiating the adoption every company should ensure that they can manage to overcome the challenges addressed in this thesis. Furthermore, spreading knowledge and showing interest in the concept helps improve the attention of Digital Twin which can provide the concept with more growth and population. By learning more about Digital Twin we can understand if the concept has any unique features in the process which is different from other digital transformation processes. If not, it means that it is possible to look at more general digital transformation processes for guidelines on how to implement a Digital Twin. Specific prerequisites are recommended to practitioners, presented in Table 4. These are divided into three main steps, provided by our experts to advise for a Digital Twin implementation approach.

Table 4 Recommendations to practitioners

Prerequisites	**Recommendations to practitioners**
Define	• Use case. • Business case.
Ensure	• Good data structure. • Managerial support. • Sufficient understanding of the concept.
Acknowledge	• Start small before scaling up. • This is a long-term investment.

5.3 Limitations and future work

In order to ensure a comprehensive evaluation of the study, it is important to consider the limitations that may impact the interpretation of the results. A key limitation of this study is the anonymity of the participants, which prevents us from naming and referencing specific projects. This limitation may reduce the strength of the arguments presented as the underlying assumptions of the projects provide a foundation for the arguments made. By being able to specifically reference the projects, the study could potentially enhance its validity by providing more concrete evidence for the claims made, allowing us to state: "This is the case because of X, Y, and Z factors". Instead, the study is limited to presenting general arguments without being able to provide specific examples to support its claims, which may reduce the persuasiveness and impact of the study's findings.

Other limitations are the number of interviewees and the fact that 15 out of the 19 interviewees are males. This can lead to biased results and difficulty with generalizing. The reason for not including more females to obtain a more balanced sampling is a result of Digital Twins being a limited topic itself. Finding a sufficient number of samplings with enough experience and knowledge is difficult as the current knowledge in society is limited.

Limitations of the topic raises challenges with finding relevant literature to develop a sufficient background foundation. Although much literature now is constantly posted, there is a lack of literature related to the Digital Twin organizational perspective. However, much is to be found within the technical implications related to its implementation, feasibility, and solutions. While empirical studies on Digital Twins are being continuously published, the majority provides the technical perspective. During the systematic literature search, it was found that most articles that seemed suitable for this thesis were literature reviews and not empirical data. Thus, empirical studies on Digital Twin from an organizational perspective are needed.

Digital Twin as a topic has also been a limitation in terms of the nature of hype around the technology. As with most hyped technologies, it quickly becomes a buzzword that few understand adequately. As a result, this made the definition of Digital Twin a central theme of the thesis, as it became clear that the lack of a common definition was a challenge for implementation. The hype of Digital Twin has therefore shaped the thesis to focus more on topics such as definition rather than focus specifically on implementation.

The study is additionally constrained by temporal limitations, whereby an extended duration would have facilitated a more comprehensive and exhaustive investigation. Given a greater time frame, the research could have engaged deeper into each sector, exploring specific implementation factors that may demonstrate varying degrees of relevance across sectors. Additionally, this study is not limited to one specific sector or industry. However, we do not have any participants representing the manufacturing industry, which is found through the literature to be one of the most experienced within the Digital Twin domain. Even though there might be none or a few Norwegian manufacturing companies with sufficient experience which could have contributed to this research, this can still be considered a significant limitation of the topic. Moreover, it is worth mentioning that the literature covers an international perspective, while our findings deal with the Norwegian industry. Comparing them creates a limitation, as some challenges might be specific to Norway.

Further research is necessary to contribute to Digital Twins' maturity and growth. Firstly, more research must be done to be able to define a Digital Twin to reduce its implementation challenges. Even though some articles have aimed to address a common definition, confusion in both the literature and industries still exist. While further research can contribute to developing a clear definition, practitioners must make use of the information provided. Hopefully, the natural evolution of Digital Twin can make it easier to define as more organizations get experience. Furthermore, this thesis has identified that different sectors have different use cases for a Digital Twin, which makes research within specific sectors necessary to create a more concrete framework suitable for each industry. By following a case study of Digital Twin adoption, a more detailed level of insight could be provided. Hence, this is recommended for further research. Furthermore, this study focused on identifying different implementation factors, however, further research must be done on how to address them in order to obtain the benefits.

6 CONCLUSION

In this thesis, we have investigated how organizations can get started with Digital Twins. Our research focuses on identifying the factors that drive and enable the implementation, what challenges that can arise, and what benefits come from a successful implementation. The findings are a result of reviewing existing literature, in addition to conducting 19 semi-structured interviews with Digital Twins experts. To present the key findings of this study and address the three research questions, we developed a model named Figure 12. The model demonstrates the relationship between the three RQs, which together constitute the adoption of Digital Twins.

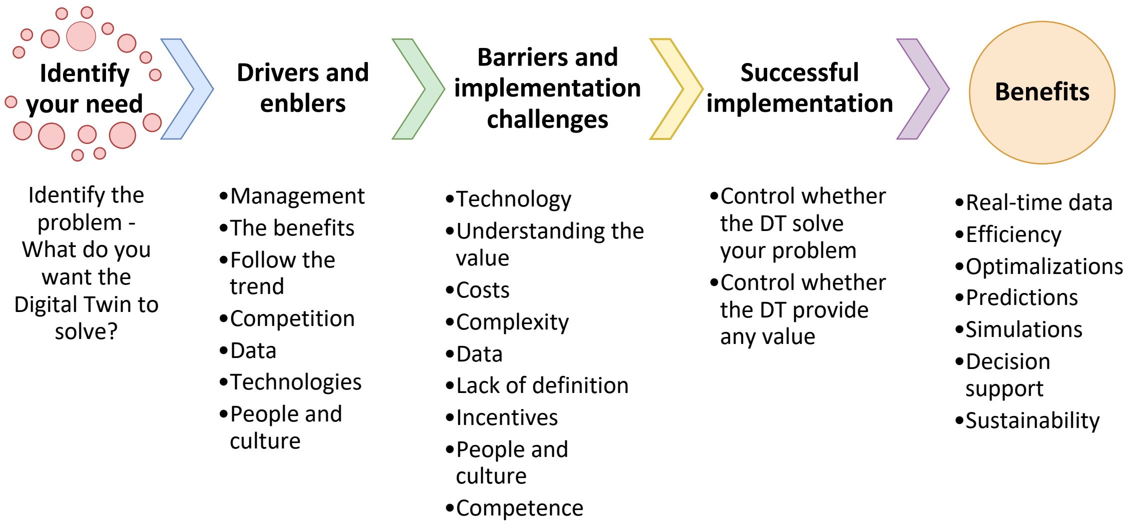

Figure 12 The adoption of Digital Twins

First, the business must establish its need for a DT and determine what issue the DT is intended to address. When the need is identified, different drivers can be motivating the organizations towards implementation and enablers contributes to making it possible. To answer RQ1, the main drivers and enablers are identified as management, benefits provided by the Digital Twin, following the trend, competition, data, technologies, and people and culture.

Then, for a business to derive any benefit from a DT, it must undergo a phase of implementation. Barriers and challenges that are associated with Digital Twin implementation and constitute RQ2 are technology, understanding the value, costs, complexity, data, lack of definition, incentives, people and culture, and competence. Notably, the three most significant challenges were costs, competence, and incentives. Before beginning the initiative toward DT adoption, it is essential to be aware of these issues to address them as effectively as possible. We believe that when companies are made more aware of the problems outlined in this article, they will be able to make smarter decisions to prevent a failed implementation.

In addition, an organization must assess whether the DT solves the predetermined problem area and provides any value, to determine whether the implementation was successful. If the implementation can be considered successful, business value can be obtained from numerous potential benefits. RQ3 can be answered as real-time data, increased efficiency, perform optimalizations, predictions, simulations, support decision-making, and sustainability.

Although this paper presents a number of possible benefits that a DT might offer to a business, the problem is how to obtain them. Findings contributes to both theory and practice by providing specific recommendations for initiating the Digital Twin adoption, which may be useful for those who wish to undertake a similar endeavor. It can also be used as a basis for further development by practitioners and researchers.

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8 APPENDIX

8.1 Interview guide

Intervjuguide

Oppstart

- Signere samtykkeerklæring og diskutere eventuelle uklarheter.
- Fortell om hensikten med prosjektet og hva dataen vil brukes til.
  - Hensikt: Studere hvordan organisasjoner kan komme i gang/adoptere DT og dra utnytte av de mange fordelene.
  - Dataen: Dataene vi samler fra intervjuer vil gi oss verdifull innsikt fra eksperter på området. Med denne dataen kan vi muligens til slutt finne et mønster på typiske fallgruver som går igjen og videreføre eventuelle suksesshistorier.
- Samtykke av opptak for transkribering.
- Redegjør for anonymitet
- Introduksjon av oss og spør om deltaker kan introdusere seg.

Intervjuspørsmål:

Digital Tvilling

1. Hva er dine erfaringer med DT?
   a. Har du erfaring med implementering av DT? **Hvis nei, gå til 2.**
      i. Kan du fortelle om dette, hva var utfordringene?
      ii. Basert på erfaringene, er det noe du ville gjort annerledes om du skulle gjort det igjen?
      iii. Hvordan måles en vellykket implementering?
      iv. Har du opplevd en implementering som mislyktes? Hvis ja, hva avgjorde at den mislyktes?
2. Hvordan vil du definere Digital tvilling?
3. Hvordan ser en typisk Digital Tvilling ut?

Implementering

4. Hva tror du er de største drivende faktorene for implementering av DT?

5. Hvilke barrierer tror du hindrer bedrifter i å implementere DT?

6. Hvilke utfordringer tenker du kan oppstå under implementasjonen?

    a. Hva er de tre største hindringene for en vellykket implementering?

7. Dersom en bedrift har lyst til å komme i gang med DT, hvordan tenker du de burde gå frem?

Gevinstrealisering

8. Hvilken nytte tenker du Digital Tvilling gir til bedrifter?

    a. Hvordan kan DT bidra til beslutningstøtte?

    b. Hvordan kan DT bidra til bærekraft?

    c. Hvem mener du har størst nytte av å implementere DT? (f.eks sektor/bransje, str. på bedrift)

Avslutt intervjuet

- Nå har vi snakket om en del innenfor fagfeltet, er det noe annet du mener ville vært sentralt for oss?
- Vet du om noen relatert til dette, som vi kunne snakket med?
- Har du noen spørsmål til oss?
- Takk for tiden og at du ville bidra til vår masteroppgave
- Opplys om at det er lav terskel for å ta kontakt med oss ved spørsmål eller uklarheter i etterkant.

8.2 Statement of consent

Vil du delta i forskningsprosjektet *" The adoption of Digital Twins: Drivers, enablers, challenges, and benefits"*?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Prosjektet er en masteroppgave som blir gjennomført av Jon Stareng Henningsen og Sina Engan, som en del av masterstudiet Informasjonssystemer ved Universitetet i Agder. Veileder for prosjekter er Tim A. Majchrzak. Formålet med oppgaven er å utforske hvordan organisasjoner kan komme i gang med Digital Tvilling og finne ut av hvilke utfordringer som kan hindre en vellykket implementering og derav utnyttelsen av de mange fordelene.

Hvem er ansvarlig for forskningsprosjektet?

Universitetet i Agder er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Utvalget er trukket basert på utvalgskriterier som kunnskap og/eller arbeidserfaring med Digital Tvilling. Utvalget er funnet gjennom søk gjennomført av master gruppen eller av kontakt gjennom Capgemini Kristiansand. Capgemini er ikke ansvarlig for oppgaven, men fungerer som en samarbeidspartner med gruppen for å finne aktører som kan stille opp på intervju. Utvalget vil være på 10-15 deltakere.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det at du deltar på et intervju. Det vil ta deg ca. 1 time. Intervjuet inneholder spørsmål om dine erfaringer og kunnskap om digital tvilling. Dine svar fra intervjuet blir lagret elektronisk. Det vil bli tatt lydopptak av intervjuet.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- De som vil ha tilgang ved behandlingsansvarlig institusjon er veiledere og prosjektgruppen.

- Navnet og kontaktopplysningene dine vil vi erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data. Datamaterialet vil lagres i en privat sky.

Deltakeren vil ikke kunne gjenkjennes i publikasjonen.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?
Prosjektet vil etter planen avsluttes når oppgaven blir godkjent, som regnes å være 2.juni. Etter prosjektslutt vil datamaterialet med dine personopplysninger slettes.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Universitetet i Agder har Personverntjenester vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Tim A. Majchrzak ved Universitetet i Agder på mail: timam@uia.no
- Vårt personvernombud: Universitetet i Agder, personvernombud@uia.no

Hvis du har spørsmål knyttet til Personverntjenester sin vurdering av prosjektet, kan du ta kontakt med:

- Personverntjenester på e post (personverntjenester@sikt.no) eller på telefon: 73 98 40 40.

Med vennlig hilsen,
Tim A. Majchrzak *Jon Stareng Henningsen* *Sina Engan*

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *«The adoption of Digital Twins: Drivers, enablers, challenges, and benefits»*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta på intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

----
(Signert av prosjektdeltaker, dato, sted)