Deliberate and Emergent Strategies for Digital Twin Utilization
A PLM-Principal’s Perspective

Felix Wågberg
Abstract

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The industry has during the past decades been changing towards digitalization at a rapid pace, adapting new frameworks and digital solutions, with the thrive to improve efficiency, and output quality. This thesis covers how a hyped industry concept, digital twin, in context of smart manufacturing, could be applied in this changing climate. Focus is put on what strategies a Product Lifecycle Management (PLM) principal could adapt when approaching the utilization of digital twins, in a customer setting.

The research project, using a qualitative exploration format, incorporated a thorough review of journal articles and standards, interconnected with conducted interviews with industry experts, in order to develop two strategies on how to approach the concept of digital twins.

The two-part strategies were formed on the basis of Mintzberg (1978) emergent and deliberate strategies. The former, consisted of IDEF0 function modeling diagramming, where a digital twin business process was portrayed, based on the literature review and interview data. The latter, approached the digital twin application challenge in a theoretical manner, based on the concept’s high risk and uncertainty, incorporating organizational structure theory and innovation theory. The two strategies showed two different paths to approach the digital twin phenomena and how to, both theoretically and practically, adapt digital twins in a customer setting.
Popular Science Summary

The concept of digital twin has grown during the past years where the technical aspect of creating a virtual copy of a product or process is present within the manufacturing part of industry. A digital twin is essentially created when it is produced or used within e.g. manufacturing and a trace of data is initiated. The data-trace, combined with real time connected data from e.g. a machine within production, can be used to initiate virtual simulations. The simulations carried out virtually using the digital twin of a machine, could give information to the machine operators, information that could be used to predictively change the machine’s parts, improving production efficiency without having to physically do anything prior the simulations.

Within this research the project, the mentioned digital twin concept has been investigated through interviewing industry experts within various domains based on three types of stakeholders; consultants, software developers, and end users (production companies). The information gathered from the interviews enabled a connection with present literature on digital twins within a manufacturing context to investigate how a principal in general could attack the concept in a customer setting (i.e. from a consultancy perspective).

Based on the interview data, an analysis of relevant literature on digital twins/product lifecycle management/smart manufacturing, and organizational as well as innovation theory, a two-part strategy has been formed within this research. The former consists on the basis of a consultancy company implying, “We can deliver the digital twin concept within a customer setting”, whereas low uncertainty applies to that particular use case, and a deliberate strategy can be used. The deliberate strategy within the research results consists of a roadmap of various functions that needs to be met in order to deliver a digital twin implementation package towards a customer. The latter part of the result consists of suggestions on how to structure an organization or part of an organization in order to enable the use of digital twins e.g. pilot projects that emerge from different outsets within the organization, inevitably driving digital solutions towards a customer setting.
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<td>Product Lifecycle Management</td>
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<tr>
<td>MES</td>
<td>Manufacturing Execution System</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<td>PDM</td>
<td>Product Data Management</td>
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<tr>
<td>CPS</td>
<td>Cyber-physical System</td>
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<td>CPPS</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<td>PPC</td>
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1. Introduction

The introductory chapter highlights the research background, and what it aims to answer. The chapter also specifies why it is carried out as well as what gaps it fills within current research.

1.1 Background

The industry is continuously changing, adapting new frameworks and solutions, striving to improve efficiency and quality of their output (Qi & Tao, 2018). In recent years industry has been digitalizing at a fast pace, paving the way for new solutions such as digital twins, using large amount of stored data. Together with the day and age increased focus on environmental aspects, these innovations within the industry context are crucial for the development within the Product Lifecycle Management (PLM) domain. By using digital twins, virtual representations of physical products and processes, organizations are able with data integration to enable reduced costs, increased productivity and quality output (El Saddik, 2018). However, the use of digital twins is, as of the 21st century, a new application that has not yet been applied within the PLM domain, leaving room for research on digital twins’ applicability on product lifecycle management (Qi & Tao, 2018). In addition, as the topic of digital twins is immature within an industry context, nonetheless within the PLM domain, there is a limited amount of research done on the topic. Research up to now investigates how digital twins could be enabled, and how possible information models and object models could be developed. Consequently, this research fills a gap within current literature, focusing on how the concept of digital twins interconnected with the PLM domain could be adapted within a customer setting.

This research project will therefore investigate the area on how to apply a digital solution such as digital twin with regards to how lifecycle based digital twins can be applied towards decision making within the context of smart manufacturing. Furthermore, focus will be put on business strategies on digital twins, to a principal’s advantage when working with digital twins in a customer setting. The project could be important for industry best practice, and knowledge advancements within the PLM domain. The project is done in collaboration with a PLM software company, which subsequently is used as a case study how organizations could work with digital twin strategies. Proceeding research questions are formulated accordingly.

The collaborating software company Eurostep, is a Swedish founded company that operates within the PLM domain, and have been the main contributor in the design and deliverance of Product Lifecycle Support (PLCS) regarding the standard (ISO 10303-239) standard components. The PLCS standard has the aim to handle vast amount of information by interconnecting data from design, operation, and support- stakeholders (PLCSlib, 2010). Subsequently, the company’s main objective is providing innovative software solutions to solve product lifecycle management problems in a secure manner (Eurostep, 2019). Eurostep’s product solutions, that makes their offering possible, are based on their award-winning ShareAspace Nova platform which in hand is built on PLCS, which enables data collaboration among stakeholders in an efficient and secure manner (Eurostep, 2019). The ShareAspace platform, running on Microsoft technology, is applicable by different involved stakeholders and has the advantage of incorporating companies existing systems, not
excluding them. Eurostep is with their ShareAspace platform applications established, and acts across different industries, such as aerospace, automotive, energy, infrastructure, buildings and telecom.

1.2 Purpose and research questions

The important role of Product Lifecycle Management is increasing within the industry today, mainly due to digitalization nowadays which gives organizations the ability to integrate information into PLM systems more efficiently (Holligan, et al., 2017). However, problems arise when organizations try to integrate the vast amount of data gathered from i.e. manufacturing processes with PLM systems. The solution to these problems could be achieved by having digital twins connected to the manufacturing process, which when applied with big data will help make important operating decisions, improving efficiency, performance, and opt for a convenient way of adapting smart manufacturing. In summary, this research could give a better understanding of lifecycle digital twins and their role within a customer setting. The following questions have been formed based on the project scope and will be investigated throughout the project through collecting interview data from industry practitioners and conducting a thorough literature review. Guiding the project are two leading questions aiming to give a deep understanding about the subject and the perceived problems:

Questions at issue

1. What digital twin strategies could a PLM-principal adopt in context of smart manufacturing?
2. How could digital twins be applied in a customer setting?

1.3 Disposition and design of the study

The study begins with declaring, describing, and reviewing literature regarding the project’s main concepts: industry 4.0, product lifecycle management, digital twins, and digital threads. Proceeding the literature review, the research methodology is discussed, where the researcher’s point of departure and work process is explained in detail. Furthermore, the project’s data, derived from the carried-out interviews, is presented. The main goal within this empirical chapter is to present the views and opinions regarding the project’s main topics from various industry practitioners with as little bias as possible from the researcher. The analysis chapter, proceeding the empirical chapter, starts with a stakeholder analysis, declaring stakeholders that are incorporated within a generic digital twin use case. The analysis chapter in conjunction with the result chapter aims at combining the knowledge and information gathered within the literature review, interviews, and theory, subsequently forming two business strategies that could be used when companies initiate their approach on the digital twin concept in a customer setting. The latter part of the report, the conclusion chapter, discusses what has been answered, connecting the research’s findings with the project’s research questions, ethical implications, and how the research topic could be approached within future research.
1.4 Delimitations

The research project included limitations surrounding the conducted interviews, biasness, and ethics. The interviews were conducted on the basis of three different stakeholders; consultant, software developer, and end users. However, the respondents that took part mainly derived from consultancy firms which could affect the research bias where conclusions have been taken on a small number of end user and software developer perspective. This limitation could have affected the research’s results and analysis, however, due to having conducted 1-hour qualitative interviews, every part of the respondents given information have been viewed upon and deemed valuable, which in hand could add value to the research. Furthermore, the topic of data saturation when using qualitative interviews could favour the chosen interview strategy, whereas although a seemingly small number of end users were interviewed, the information was in parts surrounding digital twins, operations, and technology perspective seemingly the same. Therefore, interviewing additional end users, may not have given more insight on these topics. Another aspect, when interpreting and during transliteration there is always a chance of bias when conducting a qualitative research. This limitation was deemed solved, by thoroughly transcribing the conducted interviews from respective tape recordings, making sure not to add irrelevant information, a process that was given 8-hours/interview. Consequently, the empirical data section has been limited in the case of research bias.

Ethical implications were present during the research project mainly concerning the conducted interviews. In order to cope with the interviewees in an ethical manner, prior the interviews were conducted the respondents were made aware of the research’s scope, company collaboration, choice of being anonymous, and that the session was tape recorded. Proceeding the interviews being taped and transliterated, the transcribed interviews were sent to respective respondent to be reviewed and commented before it was used within the report.
2. Literature review

This section of the report is aimed at highlighting concepts relevant to the research and at giving the reader a deeper understanding about the concepts. The layout contains three main sections. The first section aims at defining the core concepts used within the research. The second section declares research of the defined concepts, in-depth information. The last and third section includes concretization of theory relevant to the study, which will have an influence on the study’s result.

2.1 Defining Industry 4.0 and Advanced manufacturing technologies

The first and second industrial revolutions occurred during the late 18th to late 19th century and with innovations such as steam-power, new machines were developed and enabled factories to output a great amount of products at a fast pace, manufacturing was now a fact (Ahuett-Garza & Kurfess, 2018). Continuing, in the 1970s, the third industrial revolution was present, further development regarding IT systems made it possible to start using computers in manufacturing processes, Computer Integrated Manufacturing (CIM) was born (Vaidya, et al., 2018). Industry 3.0 had solely the goal to remove the human factor i.e. blue-collar workers from the manufacturing equation using automated systems. At present day, the industry has evaluated the latter revolution, starting yet again a revolution called industry 4.0, shifting from the goal of having a workerless production, integrating smart systems with human interaction.

With today’s industry 4.0, organizations have started to set focus on controlling products entire life cycles. This not only improves manufacturing in general, making it more efficient, but also enables a clear focus on customers, meeting their needs regarding; delivery, product recycling, maintenance, and research and development (Ahuett-Garza & Kurfess, 2018). In order to make this a reality, digitalization is a key factor, creating a production system which gathers large amount of data from the production floor to be examined, analysed and put to use when making important automated decisions. In detail, industry 4.0 has three main drivers; cloud-based manufacturing, Internet of Things, and Smart Manufacturing (Vaidya, et al., 2018). These drivers are the enablers of Industry 4.0 and makes it possible to convert existing machines to learn and evaluate, creating an intelligent and digitalized manufacturing system of the future. Internet of Things, one of the main technologies of Industry 4.0, is widely known as a communication network for physical entities using standardized data language and is made possible through cheap processors and sensors with capabilities to generate large amount of data.

Smart manufacturing i.e. intelligent manufacturing is a broad term and refers to the revamped production within manufacturing, using the full potential of information as well as manufacturing technologies available today (Zhong, et al., 2017). Furthermore, the concept of smart manufacturing is realized by the integration of new models on existing manufacturing platforms, taking the entire life cycle of a product in consideration. Life cycle management has become an important part, and aims, in context of smart manufacturing, to use decision models, sensors, and data analytics in order to create a reactive and predictive manufacturing environment that captures the essence of industry 4.0, meeting customer requirements.
Although smart manufacturing having different definitions, the basic concept shown in figure 1 is portraying how it is widely perceived in the eyes of the industry (Kusiak, 2018). Manufacturing equipment is connected to an interface through sensors, where the data thereafter is transferred to a cyberspace. Within the cyberspace, system intelligence with its utilized software analyse the collected data, transferring decisions on perceived issues within the manufacturing process through a standard of connectivity to the local intelligence hub. Local intelligence receives the decisions and transfers the now filtered data back to the interface, cyberspace and back to the manufacturing equipment, closing the smart manufacturing loop, a cyber-physical system (CPS). However, the specific architecture where the data is translated to a common language is in today’s industry challenging, and for many an important focus.

![Figure 1](image.png)

**Figure 1.** Portraying Kusiak’s interpretation of a smart manufacturing system (Kusiak, 2018, p. 510)

### 2.2 Defining Product lifecycle management

A concept that has been overlooked or not understood by manufacturing organizations in the past is product lifecycle management (PLM) (Ameri & Dutta, 2005). However, nowadays, with organizations growing understanding of their products’ success in the market, PLM has been realized as a tool to ensure the process of product realization. In essence, PLM is a concept that, through the life cycle of products, streamlines information concerning a product and its processes, which then could give valuable information about product maintenance and process efficacy. To grasp the concept of product lifecycle management, one must understand the background of PLM and where it derives from. Starting in the 1980s, the use of computers started to boom and computer aided design (CAD) enabled endless possibilities within industrial design as well as manufacturing. These possibilities were grounded in now being able to create virtual designs on a computer, cutting costs and problems that could arise within the manufacturing process. Although the use of computer aided design was an enabler within industry, the system also created data management problems, which opted for a solution. The solutions at hand were the emergence of product data managements systems (PDM), with the aim of controlling and examining the design process so that all the created data was ensured security and backlogs. Although PDM systems delivered solid solutions that aided the increased use of product data software, it started an evolution of data management functions, from document and project management to workflow management. This continuous change led to a new concept in the 1990s, product lifecycle management, enabling an additional scope to data management, going beyond the
design process and now into the entire product lifecycle, making use of information from development, manufacturing, and recycling phases. The use of PLM realized new areas which PDM could not fill, with focus on knowledge management instead of just data management.

Product lifecycle management is commonly explained as a concept of the 21st century although it is not new (Grieves, 2009). Consideration of a product’s four phases; create, build, support and dispose, have been around since manufacturers called themselves manufacturers. However, nowadays together with the advancements in technology, a product’s information could more easily be gathered and stored. PLM as a system uses information from the four phases of a product in order to determine waste of e.g. time and material within the supply chain, which in accordance to Grieves states product lifecycle management as a system opting for lean thinking. In addition, with the 21st century technology development of computers, the use of PLM could ultimately create a virtualized product or process by combining information from a product’s lifecycle. A virtualized product or process could vastly change how organizations operate and facilitate their product development process and maintenance, something that wasn’t at all possible before, although using the same principles of PLM as today.

John Stark (2011) claims that product lifecycle management is a holistic approach regarding the management of products within organizations, and is facilitated during the product’s different phases, ranging from development and design to manufacture and disposal (Stark, 2011). Stark explains PLM from a viewpoint where a product is managed through its three main parts; Beginning-of-Life (BOL) constituting the development of a product, from idea generation, design, and manufacturing the product, Middle-of-Life (MOL) including the use, support, and maintenance of the product, and End-of-Life (EOL) the final phase, where products are retired, disposed or recycled. These various cycles of a product are in PLM managed together, thus closing the product loop, and creating a holistic approach.

According to Ameri and Durra (2005), the age of reducing costs and increasing operational efficiency as a competitive advantage has ended and a focus on value creation for customers through product innovation and operational excellence is a fact. Achieving such competitive advantage, Ameri and Durra argue that PLM is the answer, incorporating all the needs for a shifting industry, enabling competitive advantages of the 21st century.

2.3 Defining Digital twins and the Digital thread concept

Within the context of a digitalizing industry, automation is a central subject, and is nowadays widely talked about in publications and by companies within the industry. A small but nonetheless important part of creating a truly automated manufacturing system, executing difficult tasks, is the digital twin (Rosen, et al., 2015). The digital twin concept enables through integration, a virtual copy of physical entities i.e. products and processes that interacts with the real world in real time which opens up possibilities for simulations, and error control to name a few. Rosen et al, defines the digital twin as “the enabler” of an autonomous industry, by integrating gathered data from all stages within a product’s life cycle, during; modularity (design, planning), autonomy (production, execution), and connectivity (production intelligence, closed-loop optimization). Although a misconception
of digital twins as just data, digital twins are by-products of data, consisting of a collection of
digital artefacts containing meta and semantics information.

The ideation of using a duplication of an object is not new, NASA used this concept
during the 1960s Apollo program by creating and building two spacecraft copies (Rosen, et al., 2015). The concept was the same as today, using the duplicate product to simulate
conditions in order to foresee problems that could occur, and solving them in an efficient
manner. The spacecraft twin was not only used prior the initiated Apollo mission, but also
when the spacecraft was airborne, testing possible manoeuvres on the “ground” before they
were realized by the astronauts in space.

The digital twin concept has since the early 21st century been defined in many ways by
various authors, starting with Dr Michael Grieves in 2003 where he touched on the idea of
creating products and production processes virtually. In order to be specific, the definition of
a digital twin is set, in accordance to Haag and Anderl (2019); a digital/virtual representation
of a physical, individual product or process. The digital twins are in constant development,
interconnected via data with the physical entity it is representing throughout the entire
lifecycle. This is possible through constantly gathering data, establishing real time connection
with the individual devices, representing properties, conditions, and behaviour.

As the concept of a digital twin is immature, it has not been possible within industry to
realize the idea in practice since the past 10 years. However, constant development within
computer integration, the ability to create a virtual copy of a physical entity is not far away
(Schleich, et al., 2017). Furthermore, improvements and innovations within the IT sector
have increased capabilities concerning advanced sensors and microchips to follow a
product’s lifecycle virtually, which paves the way for a digital twin and ensure its
capabilities. Digital twin capabilities could consist of not only simulate scenarios, preventing
errors in design and manufacturing, but also due to the collection of data in real time, predict
product behaviour in the hands of a consumer, which could vastly change how the industry
designs new products.

In the era of industry 4.0 the industry is moving from automated systems to autonomous
systems. The problem with automated systems, which entails this shift in focus, concerns the
bottleneck of having to engineer every sequence within the system, only being able to
execute fixed problems (Rosen, et al., 2015). However, with the emergence of new systems,
groups of machines are abundant of carefully engineering sequences able to carry out tasks,
automously. The Digital twin is therefore a key concept needed, gathering information
from the PLM process in its entirety, enabling autonomous systems with explicit machine
knowledge and machine learning to understand tasks without any explicit programming. As a
result, the autonomous systems with the use of the digital twin concept can in real time
reactively change and deploy tasks surrounding the manufacturing systems, achieving
efficiency and error handling with little to no supervision.

Digital threads are heavily connected to PLM and acts as a complementary tool to digital
twins. The threads are made of every data point collected throughout a product lifecycle
(Gould, 2018). Connecting a product’s digital threads with a real time virtual copy of a
product, a digital twin, the product could both be configured in real time as well as be traced
back in its lifecycle to understand why something have gone wrong. For instance, imagine
that a car manufacturer recently released newly manufactured cars. The virtual/digital twin of
a car from this manufactured batch alerts the car company’s service engineers that the engine light constantly is on, and that the car is not working properly. Proceeding, the service engineers uses the malfunctioning car’s digital thread, tracing back alongside its product lifecycle, and finds out that during a specific process in production a hose connected to the engine was not mounted properly. Together with the digital twin, alerting about an error in a car, to be able to trace back in a product’s lifecycle using digital threads, the car company’s service engineers can take the decision to only recall a specific number of cars that went through that specific malfunctioning manufacturing process.

2.4 Converging to a smarter industry

Nowadays manufacturers globally have a challenge at their hands with the abrupt change for a smarter industry. Although there are capabilities available, such as sensors and wireless technology that aids manufacturers in the process of collecting data, the data is mainly collected and organizations in general do not know what to do with it (Kusiak, 2017). This leaves valuable data in the cloud, which could be used to position a manufacturer within a smarter industry, but in order to do so companies need to efficiently and accurately interpret the data as to take their organization’s processes and products to the next industry level. Kusiak believes that the lack of software and modelling systems stands as the main problems adapting smart manufacturing, where modelling is crucial when analysing the vast amount of data collected. Examples of opportunities are explained by Kusiak as anticipation of delays, impacts on processes, and prevention of situational problems within a production line. The convergence to a smarter industry, having the ability to foresee when components within an organization are deemed to fail could especially change how organizations within low yield industries operate, increasing profits.

Kusiak not only claims that smart manufacturing is on the rise, but also that a shift in business structure is occurring as we speak. For instance, this means that instead of a manufacturer owning equipment, the equipment is leased, and maintenance is outsourced, which is done through other stakeholders autonomously adapting the capabilities of a digital twin. However, even though the technology is present and back-end companies are ready to take on the technical aspects of a converging smarter industry, the industry is unprepared, not knowing when, what, and where to measure data (Kusiak, 2017). Kusiak claims with his research that in order to facilitate these problems within industry, collaboration is needed across different industry stakeholders, nonetheless researchers, creating a space where developers from organizations and research institutes can come together, developing solutions in unison. This need derives from manufacturers obliviousness to smart manufacturing practicalities, a gap that researchers could fill by not just pushing technology, such as deep learning and artificial intelligence, instead consider the applicability within industry, concerning manufacturers. Whereas manufacturers real need according to Kusiak is not to see the visions of the available technology, they want specificities in the sense of sensor usage, which and where to incorporate this although academic low-tech hardware in a production line. Apart from organizations having needs to facilitate a convergence to smart manufacturing, generally the lack of experience puts the change on hold. This disruption is embedded in misbeliefs, where organizations mistakenly overestimate their database volume, thinking that it cannot be analysed due to its size, misinformation concerning the legalities of
data handling, prioritizing quality over quantity, and irregular measurements cannot be used. Moreover, Kusiak is quite clear that confusion of how long data should be stored is a common occurrence, as well as data collecting frequency, which both should be standardized in order to pave the way for crucial modelling, a must for an evolving smarter manufacturing.

Baur and Wee (2015) shows with their survey that different manufacturing organizations have a tendency of collecting large amount of data. Although collecting many data points from their operations increases the possibilities and applications of smart manufacturing and industry 4.0, Baur and Wee acknowledges that problems occur concerning data transfer, storage, and architecture. One mentioned example concerns an oil-corporation that had been collecting 30,000 data points throughout the corporation’s entire oil drilling process (Baur & Wee, 2015). Most of the data or in fact 99% of the data points were lost, due to data storage, transmission and most importantly their data architecture. Nevertheless, the 1% data collected aided the company managers vastly. Apart from having issues with data transfer, Baur and Wee’s report in conjunction with Krusiak’s analysis, shows occurring problems concerning organizations’ use of data, what data to collect and analyse, most crucial data, and which technology to pursue. Aiding this challenge, a digital compass, see figure 2, could be used, which aims at finding relevant drivers to solve organizational problems and adapt to smart manufacturing, portraying the value drivers and its correlating industry 4.0 applications.

![Digital compass model](image)

*Figure 2. Digital compass model, Baur and Wee’s visualization of value drivers in connection with industry 4.0 applications (Baur & Wee, 2015 p. 3)*
The convergence to smart manufacturing has not only changed how manufacturers operate, according to Baur and Wee business models have also started to change. For manufacturers to stay alive in the competitive arena, they have to adapt accordingly. Baur and Wee list in their analysis three options/applications to be aware of as well as keeping track when competitors try to enact. To begin with, platforms can be created that aim to streamline information in a manufacturing context by connecting stakeholders and their data. There is an example of Nvidia creating an entire ecosystem internally within the company to facilitate various resources for software engineers, making their processor-business more efficient.

Further emerging business models concerns the shift in companies Capital Expenditure (CAPEX) to Operational Expenses (OPEX). For instance, Baur and Wee state that instead of manufacturing companies owning equipment, they use leasing or pay-by-use as a new operational strategy. Manufacturers nowadays have well-grounded knowledge within their offered products and operating processes, although with the emergence of smart manufacturing, where big data plays a big role in operations management and efficiency control, expertise is needed concerning the added value of their data. This is offered by multiple consultancy companies, licensing out software that aims at concretizing data and add value to manufacturers.

Even though advanced manufacturing technology is quite new, there are examples of industrial practices and tools. Predix is a tool developed by General Electric (GE) and derives from their company practice (Chen, 2017). GE claims in their product briefing report that Predix Platform stands as their base for running digital industrial solutions (General Electric, 2018). The platform is supposed to establish a connection between different entities, streamlining their individual data to achieve efficiency capabilities regarding costs and operations. GE acknowledges within their report that challenges within this field which could create problems are the actual connection of devices and to transfer that collected data in a secure manner. GE’s tool Predix, although being marketed as being able to connect products and enable intelligent environments, has been criticized due to its need of being further developed in order to be applicable by industry practitioners, among the manufacturers wanting to adopt advanced manufacturing technology (Chen, 2017). Siemens has put out another industrial tool, Intosite, with the purpose to establish connections between manufacturing workers, trying to fill the challenge of integrating the endless knowhow knowledge from experienced workers into the evolving advanced manufacturing technology (Carmi, 2018). Carmi claims that in order to improve smart manufacturing, people within the domain needs to start discussing manufacturing concretely, including the right people, and nowadays according to Carmi that stands as a big challenge for large organizations. This problem derives from large organizations being scattered, as their operations exist around the globe, and thus discussions among peers to improve their operations becomes more difficult. Siemens take on this communication problem is to, with the use of their Intosite tool, create virtual meeting points, basically a standalone website that gathers information about IT systems and factories, creating a virtual platform to discuss and look over issues within their manufacturing. Furthermore, Carmi (2018) claims that Intosite, can create factory models. The models available consists of a 2D model/layout of a factory, created through CAD modelling where factory process flows are mapped, followed by a 3D model which is used to navigate through the factory. Users of the platform have own ID’s connected to their work
role, giving access to variant information, concerning zones, sites and processes, depending on who’s logged in. This technology portrayed by Siemens, is not an easy task to implement within factories, as the need of integrating various factory systems with their proprietary software is so vast, it quickly creates challenges (Chen, 2017). Chen also states that Intosite, to be effective and closely related to advanced manufacturing technology, should more clearly adapt to predictive analytics. Along with GE and Siemens, PTC introduced their Industrial Internet of Things (IIoT) platform ThingWorx. ThingWorx, aims to tackle the challenge of implementing advanced manufacturing technology within organizations. PTC claims that ThingWorx is the ideal platform for realizing advanced manufacturing technologies through IIoT. The platform consists of five parts; Foundation, Analytics, Industrial connectivity, ThingModel, and Vuforia Studio, which works together to, in PTC’s opinion, pave the way for IoT solutions in manufacturing (PTC, 2019). ThingModel is portrayed by PTC as being the key for the entire platform, representing physical entities, connecting the platform’s applications together.

As for all the tools mentioned that could be used for implementation of IoT solutions within smart manufacturing, benefits as well as drawbacks can be seen. Research presented by Probst, et al. (2019) included a survey where students and teachers at an Austrian college tested the ThingWorx platform. Results from the survey showed that in relation to a stationary CAD program, where its interface can be learned and studied building an expertise, ThingWorx platform’s interface could change overnight, creating problems whereas support and technicians for such an IoT platform is lacking, which could lead to bottlenecks (Probst, et al., 2019).

Perspectives on the change within industry and smart manufacturing, a lot of articles where authors push views on the opportunities of industry 4.0 is present, however there are many challenges which needs to be addressed in order to establish practical views on what’s possible in today’s industry (Vaidya, et al., 2018). Vaidya, et al. however, presents a detailed view on industry 4.0 in a manufacturing context, recognizing the opportunities with automated production processes and improved mechanical systems. Vaidya further acknowledges challenges that acts as fundamental problems when the manufacturing industry is in an immature, autonomy implementing phase. In order to fully adapt automation in manufacturing, capabilities need to be further developed. Vaidya, et al. explains these capability challenges with a few examples, focusing mainly on challenges surrounding the collection and use of data. For instance, there are intelligent wireless networks (IWN) available, which acts as a bridge between smart entities (machines, robots, sensors), communicating collected data points with gateways and access points, and subsequently to ERP systems, which are superior in relation to the wireless sensor networks used within manufacturing today (Li, et al., 2017). Vaidya claims that there needs to be further development when adapting to the large amount of communication needed in the manufacturing systems of industry 4.0. The recorded data must reach the high level of quality and integrity needed, providing repositories for data as well as taking account of the various semantics in data analytics. In context of data integration, challenges also include system modelling, which is nowadays complex, integrating vast amount of data with different quality, frequency, and size. Vaidya, et al. further claims that in order to achieve a viable system modelling for current digitalization, it should be viewed upon as a separate part and
individual manufacturing system. An additional instrumental factor is the large amount of funds that is needed to digitize an industrial company. Subsequently, according to Vaidya, et al. this could remove SME from the equation, increasing the gaps from organizations that have the financial capabilities at hand. Zhong, et al. (2017) recognizes challenges and nonetheless the importance of creating a generic framework within industry. Claiming that such a framework where standardization of sensors, wireless-communication, system models could increase applicability within industry and enhance the advancement at a faster pace.
2.5 Digital twin applications

Smart manufacturing services have increased the productivity of manufacturing operations by creating new business processes and operations. However, an obstacle, perceived by many is integrating that of a physical and cyber operation, creating a Cyber-physical system (CPS) (Qi, et al., 2018). Hence, overcoming that obstacle Qi, et al. claims that digital twins stands as the solution. Furthermore, the key is believed to combine smart manufacturing services with digital twins in order to realize smart manufacturing, where realizing a digital twin requires real time data transfer. This can be done through having e.g. a manufacturing environment connected with sensors and communication capabilities. Thereafter data is transferred to the specified virtual copy of a physical manufacturing equipment (Kunath & Winkler, 2018). In order to enact on the instructions following simulations and data analysis using the digital twin, actuators within the manufacturing system must be implemented. However, it is claimed by Kunath and Winkler that operating and using digital twins within the organization without a standardized approach could become a problem.

Kunath and Winkler recognizes digital twins as already being specified as a part of a CPS, as well as the applicability of a digital twin constituting decision making, with the purpose of automating that process using virtual simulations. The interrelation between the physical world and information world is depicted by Kunath and Winkler’s visualization of a connected manufacturing system, see figure 3. The model describes the connection of the various production planning and control (PPC) systems in both worlds (Kunath & Winkler, 2018) (Schleich, et al., 2017). Main differences concern data processing within the digital twin system contra- data mining and communication within the physical system.

![Figure 3. Visualization of a digital twin-connected manufacturing system (Kunath & Winkler, 2018, p. 228)
Kunath and Winkler’s description of a digital twin manufacturing system correlates with many researchers’ perception of digital twins within manufacturing. However, some views on the digital twin concept is more detailed and explain the digital twin’s application within different levels of an organization or factory. For instance, Qi, et al. (2018) perceive digital twins as being applied within different levels, breaking up the applications of the concept between equipment level (unit level), production level (system level), and facility level (system level), in context of smart manufacturing, see figure 4.

The unit level consists of manufacturing equipment e.g. production robots, each being connected to a virtual copy. Consequently, the system level, consisting of a physical production line has a virtual copy. The physical objects composed within the unit and system level gathers data (descriptions, functions, equipment status), and communicates it to the virtual twins, which concretizes the data, drives simulations and feeds it back to the physical entity. The system level consists of various unit levels, consequently multiple system levels constitutes a system of system level.

IDC (2018) share these views to some extent, where applying digital twin as a solution within an organization is applicable ranging from lightweight to detailed implementations, see figure 5. At the lowest light weighted levels; digital visualization and digital development, digital twins are applied only to assist in ideation, innovation, and collaboration with e.g. externally with customers and internally within the organizational processes of design, service, and maintenance (IDC, 2018). Subsequently the next two implementation
levels; digital twin enterprise and digital twin ecosystem, the digital twin is applied by further connecting the tool with real-time data retrieved from the physical asset, enabling proactive improvements within product and asset operation. These levels, although applied at a more detailed level continues to incorporate both internal and external stakeholders as previous light weighted levels. At the highest, most detailed level; digital twin orchestration, the full digitizing capabilities is applicable (IDC, 2018), where for instance decision support is enabled throughout an entire network of digital twins (equipment, products, plant, entire facility) with similarities to Qi, et al. (2018) descriptive system level model.

In highlight of adapting digital twins in various levels, Parrot and Warshaw concurs and opts for, when creating and using digital twins, to start in a smaller scale, solve operational problems, gain value, and then further develop the solution, eventually implementing it throughout the organization (Parrott & Warshaw, 2017). However, within other research, in a manufacturing context, the digital twin per se is not viewed upon as differentiated in levels (Zhuang, et al., 2018). Instead digital twin driven production is seen by Zhuang, et al. as a sequential stage within the evolution of manufacturing management, with capabilities of predictive manufacturing. Preceding technology consists of real-time manufacturing, IoT driven manufacturing. Whereas, the next step succeeding predictive manufacturing concerns digital twin- combined with artificial intelligent- driven manufacturing.

2.5.1 Digital twin: Practical examples

Botkina, et al. (2018) research on applying a digital twin of a production tool has shown possibilities within the digital twin domain. The main perceived obstacles were identified as collection of lifecycle data and information exchange concerning the many stages that are included within production. The former obstacle, in this case, where a cutting tool was to be replicated as a digital twin, was solved by using the ISO standard 13399 format, enabling the tools incorporated in the research to have the same configuration of data, improving data-collection quality and flow efficiency. The latter obstacle was handled by using an information system architecture, LISA, developed by KTH Royal Institute of Technology. LISA is described as a system architecture that enables the same message formats between production instances, solving the difficulties when exchanging data (Botkina, et al., 2018).
Botkina, et al. claims that by using a standardized data collection, in conjunction with a common information model, a digital twin of a production tool can be created. However, at what digital twin application level, lightweight or detailed, mentioned by IDC (2018) is not discussed.

Apart from having differences concerning digital twin definition among industry stakeholders, there are examples of industry practitioners having different views on how to apply digital twins in general. Most profound examples are brought forth by Schleich, et al. (2017), where PTC aims at perfecting the cyber-physical linkage, Dassault Systemes aims on performance in connection with their design-phase, Siemens on their manufacturing quality and efficiency, and GE with the aim to monitoring products’ life performance (Schleich, et al., 2017). In addition, according to Aras (2018) a digital twin is essentially created when manufacturing of a physical product begins and receives an identification (Aras, 2018). Prior, it is not an actual digital twin, rather a digital model of a design that is planned. Proceeding, when the physical entity is manufactured, a digital twin configuration is realized that changes in line with its usage.

Furthermore, conventionally when talking about digital twins, the applications are in correlation with one stakeholder, and thus resulting with the use of only one processing system (Wang & Wang, 2018). However, Wang and Wang (2018) claims with their research on the remanufacturing applications of digital twins, that the requirements are superior, meaning that multiple stakeholders are involved, and history and current data needs to be tracked and shared among them. In order to accomplish such communication, focus is put on establishing a concurrent system architecture and standard data-model aimed at connecting stakeholder’s data during a product’s entire lifecycle. In addition, Olivotti, et al. (2018) claims that due to the data input is coming from various stakeholders, collaboration is a must for the digital twin concept to work at full capacity. For instance, supplier of parts, machine-builder, and machine-user all have different detailed information concerning; parts, how parts interact within the built machine, and consequently the data generated by machine usage.

When creating digital twins for industry in context of manufacturing, systems such as ERP and MES that assist with managing operations data are essential (Olivotti, et al., 2018). However, due to PPC systems such as ERP and MES being incapable of processing sensor data interconnected with digital twins, creates problems. A solution is to incorporate a data and management storage that processes the sensor data before it is connected to such support systems (Zhuang, et al., 2018). However, building a comprehensive management system is of high importance with regards on acquiring the capabilities of a digital twin, thereby enabling efficiency and optimization within manufacturing and design systems. In order to accomplish such a management system, integration of life cycle data using a PLM system is crucial (Rosen, et al., 2015).

2.6 Business structure, Strategy and Innovation

Organisational innovation is a business characteristic that stands as the basis for how a firm in a continuous form, adapts and enacts on technological process and product innovation (Salavou, et al., 2004). Based on large organizations, innovation depends heavily on how market-oriented an organization is, constantly adapting to customer requirements within the market (Narver & Slater, 1990, in Salavou, et al., 2004). Salavou, et al. study on 150
European small and medium-sized organizations within a manufacturing context shows that they rely heavily on how the market is shaped and structured. Consequently, an industry landscape with barriers to entry has shown a significant dependency on how firms innovate.

Underlined of organizational innovation and adaptation to the change within industry is organizational structure. The structure of a firm is interconnected with its behaviouristics and how it reacts to changes within an industry context (DeCanio, et al., 2000). DeCanio, et al. claims that the structure a firm operates from affect performance measures, which in hand connects to the speed of innovation adoption. With their research, examining diffusion of innovation within an organization, DeCanio, et al. claims to have found strong links between the organizational structure and performance, where lack of structural focus will lead to inefficient adaptation and diffusion of innovation, due to external factors. Mintzberg (1980) developed a typology where he depicts a business structure by explaining five basic parts; operating core, strategic apex, middle line, technostructure, and support staff. The operating core contains the stakeholders i.e. employees within an organization that directly affects the production and thus acts as a base for the organization (Mintzberg, 1980). The strategic apex, a structural part which contains the decision-making actors within an organization, top managers including their staff. Stakeholders within the organization that bridges the gap between the strategic apex and operating core, and acts as an authority, is called the middle line. Technostructure, the fourth basic structure part of an organization, is made of analytic staff, mostly accountants, and planners. Lastly the part structure support staff consists of organization stakeholders that aims at supporting the business indirectly, such stakeholders could be human relations, and legislation.

These five basic elements depict Mintzberg’s “configurations of structures”, where each of the element drives a different kind of organizational structure. For example, a business or organization that works with heavily standardized processes is led mainly through its technostructure, and results in an organization that opts for centralized decision making, a machine bureaucracy (Mintzberg, 1980). Another example in contrast to the latter, the operating core, majority of employees drives the operations. The decision making is therefore decentralized throughout the organization, with minimized control from managers, which enacts a seemingly autonomous organization where employees are relied on their expertise, a professional bureaucracy. These are two examples where decision making parameters are central to how the organization operates, however organizational structure and operations also depends on whether the organization is structured vertically and horizontally, affecting how the stakeholders within the business works together. Vertical operations are more inclined to work separately where horizontally operated businesses are more inclined to work together. Although Mintzberg’s typology is seen by many to be of high importance, and validated, however there are some critique to have in mind when using the typology framework. For instance, Oliveira (2012) stresses that the change within modern organizations have led to a shift in organizational structural capabilities, e.g. Mintzberg’s machine bureaucracy is nowadays not only regarded as a structure only adaptable by large mature organizations.
2.6.1 Deliberate and emergent strategies

Strategy has as with all concepts been defined in many ways over the years in research. Nonetheless commonalities can be drawn among those, leaving a generic definition of strategy in its simplicity as a deliberate guidance inevitably leading to future decision making within an organization (Mintzberg, 1978). Mintzberg mentions in his research on Patterns of Strategy that although a simplified definition on strategy can be taken, it still arises problems when there is a circulation of definitions across various industries and sectors, regarding strategy positioning as a plan. For instance, the problematics deriving from this dilemma, when forming a strategy within an organization, using an explicit set of guiding bullet-points, the formed strategy is according to Mintzberg (1978), most likely resulting in inefficiency and abstract assumptions. Mintzberg’s assumptions on strategy, led to a generalization, and two categories of strategy; intended strategy, and realized strategy. The former concerns strategy in general and is explained as a streamline of decisions as a pattern, and over time a strategy is formed. Breaking down these categories Mintzberg formed the famous; deliberate and emergent strategies, see figure 6. Intended strategies which in retrospect have been in some form used and implemented, are concerned as deliberate strategies, whereas an intended strategy that has been scrapped due to e.g. high complexity, is categorized as unrealized strategy. Emergent strategies, however, differentiate from the former in the case of realized strategies that were not planned and instead emerged from different outsets within the organization. When forming a strategy for an organization it is of importance to contemplate on the differences and where they apply. As an example, Mintzberg mentions that deliberate strategies have a higher rate of success when they are formed by industry experts, with deep knowledge about the industry where the organization operates within, more precisely being able to predict the business environment.

![Figure 6. Theory and concept of deliberate and emergent strategies (Mintzberg, 1978, p. 945)](image)

Practical research has been done on the topics of emergent and deliberate strategies, further discussing when a certain strategy should be pursued. Bouncken, et al., conducted research on 140 firms within the IT industry to get an understanding when they used emergent and deliberate strategies and how it worked for the organizations in question. Findings showed, in relation to an innovation orientation, that in cases of low uncertainty a deliberate strategy should be used to achieve market success, and emergent strategy is suited...
in cases of high uncertainty (Bouncken, et al., 2010). Similarities between Bouncken’s, et al, findings and Mintzberg’s strategy theory are profound, Mintzberg stresses in a theoretical manner the positioning and success rates of emergent and deliberate strategies, whereas Bouncken’s, et al., research shows with quantitative data from 140 IT firms that practical examples correspond to that theory. Furthermore, Bouncken, et al., claims that their quantitative research not only specifies what positioning a strategy should have in what cases, but also that in accordance to a deliberate strategy in cases of low uncertainty, firms should apply road-mapping and strategic market assessments to gain market access. However, in cases of high uncertainty and the use of emergent strategies, importance lies within the use of improvisation and adaptation to exchange of information among firms.

2.6.2 Elements of Technological Innovations

To grasp concepts surrounding innovation, a clarification of what an innovation really is, is needed. With distinction from an invention, a development of an idea surrounding a product or process with new capabilities, an innovation is “The practical implementation of an idea into a new device or process” (Schilling, 2013, p. 18). Although an innovation has a seemingly straightforward definition there are different types of innovations in context of the derivative, from a current product state, declared by Schilling (2013). The two most distinctive kinds of innovations are; radical and incremental. Where the former is an entirely new innovation, which in relation to technology could revolutionize how something is used or perceived. Depending in what context, the new innovation could be segmented to the world, an organization, or a customer segment (Schilling, 2013). The latter insinuates that an innovation occurs in small incremental steps or improvements on an existing product or process. This means that an incremental innovation does not imply that an entirely new product has been developed, but instead minor improvements have been made. For example, if a television manufacturer, after introducing a Liquid Crystal Display (LCD) monitor, with incremental innovation introduces an Organic light-emitting diode (OLED) screen improving the television’s resolution capabilities. A radical innovation could be the move from a traditional tv using Cathode Ray Tube (CRT) technology and moving towards LCD technology, radically changing the television industry.

Creative destruction, a concept that depicts the destructive force of innovation and organizations’ survival in a changing climate. Developed by Joseph Schumpeter in the 1940s, the theory on creative destruction derives from the ideas of capitalism and its forces on organizations. A firm that does not innovate is therefore inevitably being replaced by new organizations that adapts with new technological innovations (Schumpeter, 1942, in Kingston, 2013). According to Kingston (2013) this creates a dilemma, whereas firms that are profitable, being able to invest in technological innovation instead choose to stay alive, relying on their current successful operation and don’t innovate. This is eminent due to innovation investments being expensive but mostly due to the high risk and uncertainty (Kingston, 2013). Jovanovic and Tse (2007) acknowledge that creative destruction occurs and in waves. As a result of creative destruction, industry is affected with a shift in producers, where old firms are exchanged with new firms, referred to as shakeouts (Jovanovic & Tse, 2007). With Jovanovic and Tse’s research, shakeouts have shown to happen frequently within
industries where technological change occurs at a fast pace. Although, creative destruction is believed to be proven by Jovanovic and Tse’s research, creative destruction theory has been heavily criticized throughout the years (Schiavone & De Falco, 2016). A distinguished standpoint against creative destruction is that new technologies and disruptive innovations do not disrupt markets and companies within. Instead, organizations using old technology when new technology is emerging are believed to transform their products and processes, adapting and taking advantage of the new industry landscape (Pavitt, 1998, in Schiavone & De Falco, 2016). Creative destruction can also be hemmed by affected firms that have a robust technology framework and by using collaboration, resource allocation, and investing in old technologies creative destruction can be avoided (Schiavone & De Falco, 2016).

Disruptive innovations could be seen as a derivative and a key trigger to creative destruction theory. Derived from Christensen and Bower’s (1996) research on failure of leading firms, disruptive innovations show as one of the reasons why saturated organizations fail. Although having strong customer focus and technology capabilities they still seem to fail in developing technology innovations and entering emerging markets within their industry. The concept of disruptive innovations or disruptive technologies is explained as a radical innovation that changes market trajectories, which vastly affects performance (Christensen & Bower, 1996). In accordance with Christensen and Bower, disruptive innovations rarely get introduced in already established markets. Instead they usually operate in emergent markets within a wide range of industries (Rosenbloom and Christensen, 1995, in Christensen and Bower, 1996). However, the problem does not seem to lie within the organization’s ability to innovate. Instead the failure is depicted through the decision of what innovation types to carry out. The types of innovations are according to Christensen and Bower mainly a derivative from the firm’s customers, where in cases of customers vaguely stressing requirements, pointing the firm in the wrong direction, not choosing to focus on disruptive technology innovations. Therefore, it is claimed by Christensen and Bower that staying close to your customers isn’t always the way to go.

Diffusion of innovation is conceptualized as to how an innovation is communicated and adopted by a social system over time (Rogers, 1983). The exchange of information that is communicated throughout a social system could for example constitute the communication between a consultant and a client. Where the client approaches the consultancy firm with a problem, and the consultant recommends an innovation. The problem then arises when trying to estimate the success rate, uncertainty, and adoption rate of that solution, and when to implement that solution to a social system successfully. Although the theory of diffusion may seem uncomplicated, there are crucial elements that constitutes the adoption rate of an innovation (Rogers, 1983). The main elements described by Rogers (1983) are the innovation itself, communication channels, time, and social system. An innovation can be evaluated by the consultant (change agent) as to the likelihood it is to successfully become adopted, in correlation with its desirability. The evaluation of the innovation’s diffusion rate relates to its relative advantage of preceding solutions, how compatible it is with current industry practices, the innovation’s complexity, and trialability. Trialability refers to the innovation’s degree to be experimented at a smaller, inexpensive way before fully implementing the suggested solution. An innovation that is regarded to have a greater advantage within these criteria, is claimed by Rogers (1983) to have the abilities to be adopted at a more rapid pace.
and could therefore be proceeded with. This is interconnected to the rate of adoption, where the examined innovation is plotted. The plot itself visualizes at what relative speed the innovation is adopted in relation to time and a percentage of the stakeholders within a social system (percentage of adopters), see figure 7. Rogers (1983) depicts and defines a social system as interconnected stakeholders which are engaged in a process of solving a problem, where commonalities are their end goals. An example of such a social system could be a consultant engaging with a client, or an entire company engaging with a supplier or manufacturer. Understanding what social system that surrounds the innovation to estimate its adoption and therefore success rate is crucial.

![Figure 7](image)

*Figure 7, Graph displaying an innovation’s adoption curve in relation to percent of adopters and time, inspiration from (Rogers, 1983)*
3. Research methodology

This chapter explains the methodology used throughout the project. Including the project’s layout, tools used, and data collection.

3.1 Methodology disposition

The research methodology is based on a qualitative exploration approach, whereas the research questions are continuously explored throughout the project. Furthermore, conclusions have been drawn based on a deeper understanding about the subject, following the qualitative methodology of collecting data, and the interviewed stakeholders reasoning in conjunction with the reviewed literature. In summary, the research was conducted as visualized in figure 8. The introductory courses, held by the collaborating principal, gave a much-needed introduction to the principal’s PLM domain as well as what integration and collaboration of data among industry stakeholders entails. During the literature review process, reviewing of articles, conducting interviews, and finding relative theory and concepts were interrelated, resulting in an iterative process, where new findings within interviews could be applied when examining theory and journal articles. During the analysis, empirical data, derived from qualitative interviews were analysed in conjunction with the reviewed theory and literature, resulting in a two-part strategy. The first part, deliberate strategy aims, at systematically portraying a model on how a principal could approach the digital twin concept in a customer setting. The second part, emergent strategy, aims at theoretically approaching the digital twin concept.

3.1.1 Collection of qualitative data

The interview questions for each qualitative interview were based on the first pilot interview guide carried out early in the project. The interview guide, see Appendix 1, included 9 questions, aimed at getting professional insight on the research topic, as well as connecting to the established research questions. Proceeding the first pilot interview, interviews were held in a similar manner to not distort the collected data. However, due to having interviewees with different background and expertise within different fields, follow-up questions were added, and in some cases, as to interviewing a professional within the organization SIS (Swedish Standards Institute) specific questions were included within the interview guide. Specifics were needed according to the researcher because of organization’s difference in nature, whereas compared to previous interviewees being primarily consultants.
and product managers. The interview participants were aimed at adding up to 2-3 respondents from each stakeholder group; software developer, consultancy company, and end user. Respondents that participated in the study are presented in table 1.

Table 1. List of interviewees participating within the research

<table>
<thead>
<tr>
<th>#</th>
<th>Respondent</th>
<th>Organization</th>
<th>Current position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jane Doe</td>
<td>Software and Production Company</td>
<td>Digital Product Manager</td>
</tr>
<tr>
<td>2</td>
<td>Emilia Ingemarsdotter</td>
<td>Delft University</td>
<td>PhD Researcher</td>
</tr>
<tr>
<td>3</td>
<td>Martin Larsson</td>
<td>Deloitte</td>
<td>Partner Consulting</td>
</tr>
<tr>
<td>4</td>
<td>Mikael Hjalmarsson</td>
<td>Swedish Standards Institute</td>
<td>Project Manager Information Technology</td>
</tr>
<tr>
<td>5</td>
<td>Torben Schwartz</td>
<td>Erhvervshus Sydjylland</td>
<td>Consultant Business Development</td>
</tr>
<tr>
<td>6</td>
<td>Anders Carlsson</td>
<td>Volvo cars</td>
<td>Technical Expert</td>
</tr>
<tr>
<td>7</td>
<td>Fredrik Björk</td>
<td>Sweco Industry AB</td>
<td>Digital Strategy Manager</td>
</tr>
<tr>
<td>8</td>
<td>Richard Morén</td>
<td>Stora Enso</td>
<td>Technology and Investment Manager</td>
</tr>
</tbody>
</table>

Because of the interview data is concretized with some bias as to the similarities, differences and interesting facts among the interviews, the project’s reliability could be directly affected. However, due to the data being thoroughly filtered, the validity becomes affected positively, by digging deep into the subject at hand and putting the interviewees words in correlation with each other. Which in hand has resulted in an explorative approach throughout the analysis, consequently answering the developed research questions in a more precise matter.

3.1.2 IDEF0 function diagramming: Forming a deliberate strategy

As part of the research results, aiming at concretizing different activities in conjunction with various functions of a digital twin use case, an IDEF0 diagram has been used. IDEF0 diagramming derives from a standardized way of conducting function modelling in order to display and visualize actions, decisions, and subsequently activities concerning a business process within e.g. an organization (ISO 31320-1, 2012). The modelled process may, in correlation with the ISO standard 31320, include various system, which are dependent on different actors and the relationships among them, such as machines, workers, and equipment. An IDEF0 diagram is essentially a graphical language and a comprehensive model used, as basis when defining different courses of actions within an organization and could help when designing and portraying an entirely new implementation of a system or business process. During the development of this project’s IDEF0 diagram, with connections on how to apply digital twins in a customer setting, the ISO standard 31320 was used, and consequently the rules specified within the standard were followed to the best of abilities. Main rules contained the structure and correlation between the different IDEF0 diagrams. The basis of the IDEF0 diagram consists of a context diagram, see figure 9, representing the modelled top-level function.
The context diagram named A-0 must have attached; input, control, output and mechanism, see table 2. The context diagram is consequently broken down, and decomposed within additional diagrams, referred to as child-diagrams, being able to develop a detailed business process. Due to restrictions, the diagram examples depicted within the ISO 31320 standard is not reproduced within this report.

Table 2, Definitions of the IDEF0 diagram-attachments (Fenn, 2007, p. 15)

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>I#</td>
<td>Input</td>
<td>The input for the function itself, stating what should be transformed within the function producing a desired output.</td>
</tr>
<tr>
<td>C#</td>
<td>Control</td>
<td>Description of conditions that controls what is produced by the function i.e. output.</td>
</tr>
<tr>
<td>O#</td>
<td>Output</td>
<td>Description of what is actually produced by the function itself.</td>
</tr>
<tr>
<td>M#</td>
<td>Mechanism</td>
<td>Represents the agent required to carry out the specified function.</td>
</tr>
</tbody>
</table>

3.1.3 Evaluating a new technology

As digital twins stand as a new industry 4.0 application tool, the concept has been researched throughout the project with basis on industry expectations in relation to time. In order to accomplish such an estimation, interviewees, established as different stakeholder types, have been consulted in the matter by plotting their expectations within a Gartner Hype Cycle. The referred Hype Cycle, see figure 10, is a tool used by technology planners to evaluate technology, its emergence and application within e.g. industry.
The main method for an analysis using the cycle has its basis within a technology’s maturity and hype (Fenn, 2007). Letting the interviewees plot their opinions from various parts of industry has shown to be valuable when assessing digital twins as a technology. In order to assess the maturity of a technology the plotted symbols are related to four different time indicators. These indicators have the sole purpose of estimating how the interviewee see the technology being applicable to the industry i.e. when it should reach the plateau of productivity. The cycle itself consists of a graph divided into five stages; innovation trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity. The first stage, innovation trigger, represents when a technology has emerged on the market and is being discussed within e.g. industry. During the second stage, peak of inflated expectations, leaders within the technology at hand, conducts pilot projects, where some succeed but the majority of tests fail. The third stage, trough of disillusionment, the inflated expectations, followed by the pilot project failures, fails to uphold the expectations, where majority of stakeholders could start to lose interest concerning the technology. During the slope of enlightenment, the applicability, and risks connected with the technology are estimated and tested by a range of organizations still seeing the possibilities within the technology. Lastly, when the technology finally reaches the plateau of productivity, the experimental projects shows results, more practical examples can be seen within industry and the majority of organizations are now as well seeing the possibilities of the technology, adoption of the technology by the masses is now beginning.

Figure 10, The Gartner Hype Cycle model, used for evaluating technology, illustration inspired by (Fenn, 2007, p. 4)
4. Empirical findings

This chapter presents the interview data gathered throughout the project, consisting of two main parts, aimed at separating aspects on industry and digital twins.

4.1 The Industry 4.0 revolution and Digitalization

The industry has changed noticeably during the past 2 years. For example, the appointment of new positions within industry are taking place, such as Chief Digital Officer (CDO) (Doe, 2019). Although the possibilities with industry 4.0 applications are easy to grasp. It is much harder to realize the practicalities it entails (Ingemarsdotter, 2019). As an example, preceding industry 4.0, automation using e.g. robots in production was the hype. Volvo Cars was at the forefront, working heavily towards automated factories, an industry 3.0 company, which has led Volvo Cars to have their factory equipment connected and computerized (Carlsson, 2019). A common opinion among industry stakeholders is that the technical aspects and capabilities enabling industry 4.0 is already present, and it will only accelerate from here on end (Schwartz, 2019, Björk, 2019). The big obstacle is organisation culture, involving and getting the whole organization to the same mindset. Morén, a technology and investment manager at Stora Enso, feels that at present time within industry change, digitalization is moving too slow, where too much time has been spent on searching and point-based efforts (Morén, 2019). However, the digitalization transition within industry is quite clear, according to Schwartz (2019), a consultant within business development. Early on within the digitalization era, organizations digitalized business processes by providing more traditional IT systems and doing the same in the industrial environment. This was then only something that larger companies were doing due to being expensive for smaller or medium sized businesses. That has changed in the last few years with the upcoming of industry 4.0. Technology has improved and the cost for making digital solutions for industrial companies have gone down, leaving it more attractive for smaller business to go into this field (Schwartz, 2019).

With respect to different industry stakeholders, different views follow. For instance, from a consultancy perspective these applications concern more than just automation. It’s also about minimizing costs by having more automated functions, how companies could increase efficiency, and create new business models (Larsson, 2019). Companies, from a production point of view, having many manual sequential processes could for instance use digitalization in predicting equipment efficiency, maintenance, and maximize their machines’ yield. Subsequently retrieving more efficiency out of the assets available, building predictive solutions. From a standard institute perspective however, in connection with Industry 4.0 and digitization, it is believed that importance lie with keeping track of the various objects, which enables the relationships to be linked both to the descriptive object and also to the manufacturing object (Hjalmarson, 2019). This means that you get the right properties and the right information linked to the object depending on which context you are looking at. From a design perspective, the object has certain properties you need to highlight, from an order perspective the second subset of properties, and if it is from a production perspective, you have further sub-sets. However, Hjalmarson claims that it is still seemingly the same object you are talking about, which creates a dilemma. As well as from a standardizing
perspective and company perspective it is important to keep track on relations and objects, describing different interfaces, and in order to exchange the gathered information, create an understanding of a common language, and a common platform. However, highlighted by Stora Enso, the problem many organizations have regarding digitalization, is that there are many different platforms for different types of control systems. Which means that finding a common platform is complex (Morén, 2019). For instance, neither Sweco Industry nor any of their clients have an IoT platform, enabling digital solutions (Björk, 2019). Practical examples consist of using traditional MES, connecting it to other systems.

Although establishing platforms stands as an eminent challenge Torben Schwartz developed a digital platform for an industrial company, where the customer/end user was a technical services company. The analogue part of the company’s offering to customers were to have electricians go out and fix whatever needs to be fixed within a factory. After discussion with this client, digital tools were developed, in order to, in an efficient manner identify service needs and integrate it into the developed digital platform (Schwartz, 2019). Operators then had a mobile app where they could register service needs and a backend system for planning and dispatching different service assignments to internal and/or external partners. This was all connected and accessible through the developed platform, with the aim of diagnosing and pinpointing where in the factory there was an operational need to optimize for bottlenecks in the production.

4.1.1 Competence and technology shift

That industry is changing is a common belief among the interviewed stakeholders. Interconnected with this comes new challenges. Firstly, the same type of expertise within industry is shifting, jobs will be replaced, a shift in competence one could say (Larsson, 2019). Secondly, the industry is undergoing a technology-shift, where things become much cheaper, general products that can be used in factories (Carlsson, 2019). In highlight of these challenges, Anders Carlsson, a technical expert at Volvo Cars explains that they are currently trying to build up an infrastructure for the company by finding people with expertise high up in the organization.

This dilemma, according to Schwartz (2019) connects to one of the biggest barriers concerning digital twins, where a lot of people that have been working in areas for a long time and used to a certain method, now need to do things differently to get the benefits of the digital twin functionalities. It is seen as a cultural problem, one of the biggest issues within industry 4.0. In summary the technology is there already but you need to turn the minds and heads of all the people involved in order to get a successful transition (Morén, 2019) (Schwartz, 2019). For instance, with the movement towards a more automated operation Volvo Cars ran into successes as well as failures (Carlsson, 2019). The failures affected parts of the organization. Especially when nowadays new technology solutions are at question. Workers that have been at Volvo Cars for over 30 years are against certain technology implementation in relation to digitalization initiatives, where they don’t see the efficiency potential, only possible errors. Anders Carlsson sympathizes with their resistance, nonetheless due to Volvo Cars producing products in line with customer’s orders, a pull
system, which makes the company sensitive to disruption within the factory. Therefore, the implementations that are to take place needs to be accurate and reliable.

4.1.2 Perspectives on Digital solutions

Digital solutions are at a fast pace already being deployed among customers within industry. Whereas Doe (2019) explains that due to their software and production company already possessing production facilities and software development capabilities, where software tests inhouse is possible which thereafter could enable a deployment of a working digital solution to their customers. This situation enables such a software and production company to adapt new technology at a fast pace. Ingemarsdotter (2019) adds to this claim, where newly developed products gain more digital capabilities, a new dimension is added within organizations. Differentiated from the physical dimension, this new digital dimension demands a change, pushed within work-processes and expertise. An organizational obstacle then becomes to create value from collected data. This also entails a vast focus on services, apart from the development of physical products, leading to closer and longer customer relations, and a co-creation of services (Ingemarsdotter, 2019).

A lot of organizations within industry today have a high degree of ambiguity with regards to digitalization. However, when Larsson (2019) consults with such companies and scratch the surface, it often turns out that their industry 4.0 applications are more leaning towards proof of concepts, pilot projects, rather than complete solutions (Larsson, 2019). Therefore, a point of departure for Deloitte, is to investigate how a client-company could approach digitalization by making a maturity-assessment, trying to get an understanding where they are situated in correlation to industry-standard. Proceeding the investigation, Deloitte establishes a roadmap together with the company (Larsson, 2019). After the case roadmap has been established, Larsson (2019) as a Deloitte consultant explains that usually digitalization strategies and solutions are formed by looking at client’s operational architecture, backend systems, Manufacturing Execution System (MES) and programmable Logic Controller (PLC), and how these systems are interconnected with the company’s Enterprise Resource Planning (ERP) system. A stack up against functions, by researching, analysing, and realizing a developed roadmap towards an implementation project.

A general problem perceived by Carlsson (2019) concerning digitalization is data-handling. Volvo Cars are generating large amounts of information. The information-data gathered is used today to control and act on alarms, a reactive approach (Carlsson, 2019). The data is gathered through thousands of connected devices, each day, and is deleted after 8 hours. Carlsson claims that as an end user of digital solutions, initially, focus should be put on the processes when collecting data and turning it to an information-density.

Digitalization as a digital assistance has been around industry during the past 40-50 years. However, there’s a difference of being digital and doing digital (Björk, 2019). Looking at the private sector, being digital, is a fact, living among digitalization and using digital tools without thinking of it. Industry on the other hand, according to Björk, is currently doing digital, where digital solutions and complex control systems in facilities are present, but they currently are separate, where data is not interrelated. The full potential isn’t used with regards to collection and analysis of data.
4.1.3 Collaboration

Concerning new technologies that have not yet been fully defined or concretized by most industry stakeholders is, however, believed to be an obstacle. In order to deal with such a dilemma, industry practitioners may turn to customers for collaboration (Doe, 2019). Joining forces has shown to be effective concerning products still in the development phase, which in hand enables to split costs and increase efficiency. This view is shared with Sweco Industry, claiming that one way of driving digitalization, especially within industry and as a consultancy company, is to connect and collaborate with external partners (Björk, 2019). For instance, digitalization implementation projects are made possible as a consultancy company collaborating with software developers (Larsson, 2019). Where the software developer provides e.g. IoT platforms and sensor technology. Apart from collaborating with e.g. customers, industry organizations working with the development of new technology applications could turn to internal development projects alongside the organizational structure, creating start-ups with their own autonomy and decision making, able to handle their own technology projects (Doe, 2019).

4.2 Industry stakeholders on Digital Twins

Apart from providing information of industry digitalization in general, focus was put on gathering information on digital twins, and its applications among industry stakeholders. The respondents participating within the research were, within the scope of the interview asked to identify and define their view on digital twins, see table 3.

Table 3. Collected definitions concerning digital twins from interview participants. As well as stating what organization they belong to, name, and current position at respective organization.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Respondent</th>
<th>Current position</th>
<th>Digital Twin Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software and Production Company</td>
<td>Jane Doe</td>
<td>Digital Product Manager</td>
<td>“Definition depends on who you are talking with. However, I feel that a Digital twin is a holistic tool that interconnects different software.”</td>
</tr>
<tr>
<td>Delft University</td>
<td>Emilia Ingemarsdotter</td>
<td>PhD Researcher</td>
<td>“A digital twin is for me a form of digital-records of a physical product. With data of that product’s conditions and compositions.”</td>
</tr>
<tr>
<td>Deloitte</td>
<td>Martin Larsson</td>
<td>Partner, Consulting</td>
<td>“A digital representation of a physical reality. Used to simulate and digitally test different applications.”</td>
</tr>
<tr>
<td>Swedish Standards Institute</td>
<td>Mikael Hjalmansson</td>
<td>Project Manager Information Technology</td>
<td>“A virtual computerized representation of an object that you want to control, test and evaluate in different ways. It could be big, small or an entire society.”</td>
</tr>
<tr>
<td>Erhvervshus Sydjylland</td>
<td>Torben Schwartz</td>
<td>Consultant Business Development</td>
<td>“As a system where you make a virtual model of the physical world. Which can be used to virtually test situations, eliminating costly errors.”</td>
</tr>
<tr>
<td>Volvo cars</td>
<td>Anders Carlsson</td>
<td>Technical Expert</td>
<td>“We have alternated between definitions of a digital twin. However, what we mean with digital twins is to be able to prognose how a device looks like virtually. Although, not just run our machines through it but be able to see flows.”</td>
</tr>
<tr>
<td>Sweco Industry AB</td>
<td>Fredrik Björk</td>
<td>Digital Strategy Manager</td>
<td>“Digital twin was for me a clear concept when I started looking into it. However, with time I have realized that a digital twin could be many things. We therefore look at digital twins in different levels. Where the lowest level constitutes a virtual copy of a physical object, without any sensors attached to it. At the highest level the Digital twin is connected to real-time data, enabling e.g. predictive maintenance.”</td>
</tr>
<tr>
<td>Stora Enso</td>
<td>Richard Morén</td>
<td>Technology and Investment Manager</td>
<td>“Personally, I define a digital twin as a direct mirror image of e.g. a control system. Where the digital twin acts as a modelling- and improvement tool.”</td>
</tr>
</tbody>
</table>
4.2.1 Digital twin development and the hype surrounding it

Within industry there are different definitions on what a real working digital twin is (Doe, 2019). For instance, a constructor claims having a digital twin with reference to their CAD drawings. Subsequently, in the case of digital twins there are splits among the involved stakeholders; software developers, consultants, end users, and nonetheless researchers, where researchers are behind what’s happening within industry. Especially during present technology evolutions/revolutions, including the development of the digital twin and splits the idea of what is possible (Doe, 2019). This opinion is shared among industry stakeholders, claiming as well that research is lagging and presently aims at figuring out the basics of working digital twin (Ingemarsdotter, 2019). Concrete examples are needed to enable research on technology surrounding the digital twin and its development in general.

Adding to this dilemma, there are a lot of hype related to the digital twin concept. Hype that is needed surrounding new technology development by building an interest across industry organizations and acting as a fire starter (Doe, 2019). Digital twin will only stop being a buzzword when sufficient tests have been made, showing what is possible and what could be gained from such a tool, as well as having a unified definition among industry stakeholders (Doe, 2019) (Ingemarsdotter, 2019). The perceived hype concerning digital twins are portrayed in figure 11. Respondents have individually plotted how they perceive digital twins in context of their own organization as well as industry in general.

![Figure 11. A Gartner Hype-Cycle based on the project's interview participants, visualizing where digital twin stands as a concept within industry](image-url)
Although, seeing digital twin as one-in-all solution to every operational problem could create issues. Where early in development, the digital twin was believed to incorporate everything from programming, certificate, and CAD to work as a single tool, interactively. For instance, Jane Doe (2019) believes that to have one tool that handles all the above is hard and unnecessary, and claims that focus instead should be put on customer needs, establishing a connection with end users and hear what problems they want to solve and what efficiency they seek. Thereafter a technical solution could be established, meeting customers’ demands. Ingemarsdotter (2019) adds to this thesis, stating that the development of digital twins is heavily dependent on the use-case in question. Hjalmarson (2019) depicts digital twin as one among many hyped concepts within industry. This entails that you cannot by now say “this is a digital twin”, instead put the concept in a context, and look at the actual problems you are aiming to solve (Hjalmarson, 2019).

4.2.2 Use cases of Digital twins within industry

Industry organizations often asks what changes they can make within their operations in order to be more efficient, what can be made more efficient, and what capabilities they currently have from a digitalization standpoint (Schalander, 2019). According to Schalander, and his experience, clients or end users don’t ask what a digital twin is, nor the implementation of such a tool. Furthermore, Schalander explains that from a consultancy perspective, companies that are at the forefront of digitalization will earn tomorrow and companies that don’t follow the trend of digitalization, nonetheless the digital twin implementation, and earns today, will not have a business model for tomorrow.

In accordance with one of the leading software and production company in Sweden, digitalization for machines’ processes, CAD drawings with physical pictures and calculations are used together in order to establish a digital picture of how things work (Doe, 2019). This is already done within production today and stands as the organization’s closed-loop approach. In addition, different perspective among industry stakeholders are apparent. With a consultancy perspective on digital twins or any digital solution, one should not look at the technical aspects initially (Larsson, 2019). Instead focus should be put on the actual business problems/bottlenecks at the end users, to eliminate the possibility of having “a hammer looking for a nail”. Within an organization as end users of digital solutions, the questions lies with what and how problems can be solved, focusing on results based on data, not the implementation of the digital twin tool per se (Carlsson, 2019). An important aspect, stressed by end users is that end users need to be able to implement industry 4.0 applications on existing equipment, due to having large investments on installations (machines and equipment) that have a life expectancy of 10-20 years (Morén, 2019) (Carlsson, 2019).

4.2.3 Digital twin applications

There are a lot of applications that could be enabled using digital twins. One of which is maintenance, where a customer requires that their production machinery is working smoothly (Doe, 2019). Other applications include predictive maintenance, pay per use, and as a tool used for minimizing the time you need to stop production. In addition, Volvo Cars sees
opportunities with present digitalization concerning making operations better, safer, and more efficient (Carlsson, 2019).

As an example of a digital twin use case, a company such as Jane Doe’s could have an end user’s machinery connected to a virtual copy and see how it operates. Thereafter an operator from Jane Doe’s company could simulate and test-run situations such as maintenance virtually, see what works best, being able to schedule maintenance in advance and making the clients operations subsequently more efficient. A challenge is to identify why you need a digital twin, the value of a digital twin within your operation. Ideas on what you should have do not match the output, what you actually get out, practically. From a researcher’s perspective, important parameters of digital twins consists of tracking products’ health, quality, and efficiency over time, especially within the area of maintenance and re-manufacturing (Ingemarsdotter, 2019). For instance, concerning re-manufacturing, when a product is disassembled and different parts are recycled it requires a good track-record on that product’s part specification, how old the parts are, how long-life expectancy they have, its conditions and compositions. In order to enable such capabilities Ingemarsdotter states that a digital twin is needed, with its connection to a product’s parameters.

A concept that further enables the use of digital twins is a PLM-system. For instance, Hjalmarson (2019) views Product Lifecycle Management and digital twins as complements to each other, where having good capabilities within PLM can be applied on a virtual unit (Digital twin) and a physical unit. Other views concerns PLM as a part of the digital twin, in different process steps, incorporating data from a products lifecycle with the digital twin’s real time data processing (Björk, 2019).

Furthermore, a digital twin, as a virtual representation of an object or process, can be implemented and used at different levels with different capabilities and applications (Hjalmarson, 2019). Jane Doe (2019) claims that the highest applicable level of a digital twin is when you connect Artificial Intelligence (AI) in order to take decisions autonomously and implement the decisions directly to an operating machine. On the contrary, from an end user’s perspective, an AI connected digital twin is seen as a predictive tool, whereas suggestions on changes within operation, inevitably is taken by the operator, not autonomously by the digital twin (Morén, 2019).

In order to achieve implementation, concerning digital twins or 3D models, importance lies with making demands on the suppliers, project-planners and others involved in such a project, where requirement specifications and contract attachments that control these processes are correctly managed (Björk, 2019). Consequently, then being able to create a digital twin of e.g. a plant at an aimed at level. As an example, Stora Enso at Fors Mill has found its applications of digital twins by building a simulation-model, the foundation of a digital twin for their control systems on a machine (Morén, 2019). The main application opportunities are aimed at security, cost, and efficiency. However, the big picture for Stora Enso as a whole is about developing new technologies and abilities to be able to develop new business opportunities (Morén, 2019).
4.2.4 Perceived problems

One main perceived problem concerns the integration of data which is to enable the use of the digital twin concept, due to its differences in quality, type, and frequency. Companies that are currently working with digital twins and the new technology it contains, also have problems concerning what they should measure in e.g. their production (Ingemarsson, 2019). Often companies measure more data than they require. Therefore, processes are needed that specify the course of action, limiting the data amount, filtering out unwanted data before its used in context of a digital twin. Björk (2019) believes that there’s currently an immaturity concerning digitalization of industry, where organization aren’t concretizing (Björk, 2019). Instead of looking at hyped concepts one should investigate and analyse bottlenecks within the organization, then apply an efficient solution.

How far companies have come respectively how far behind some are relates to their built infrastructure and network, and how easy it is connecting a concept with a function (Hjalmarsson, 2019). For example, if an organization is working vertically within the different parts of the company the infrastructure inhibits digitalization. Whereas, working horizontally, a position where you work more closely together, promotes the advancements with digital twin and digital solutions in general. Other aspects that inhibits the advancements of digital twins are conflicts between generations and the lack of applicability for every individual/organization/industry sector. Torben Schwartz claims that in order to realize digital twins and digitalization of industry in general, using a start-up model for organizing things is for many companies the way to go. It is impossible if you are a larger company to make that transformation, you have to start small, gets some success, and then scale up afterwards (Schwartz, 2019). As a company example, Volvo Cars is in a transitioning phase regarding digitalization, conducting pilot projects aimed at the information-data problem (Carlsson, 2019). Two main problems are being perceived by Carlsson at Volvo Cars. Firstly, concerning PLC that assists within current factories, which take the operational decisions today, indirectly means that how the system is programmed determines which decisions are made, heavily dependent on the human factor. Instead of having a PLC taking decisions Volvo Cars for instance, are more interested on the actual input data, sensor data, i.e. raw data, and use digital tools to help assist decision making in a proactive or even predictive manner. Carlsson (2019) states that problems then occur, receiving all that raw data without running down Volvo Cars’ networks and processors running the production. Furthermore, the second challenge perceived by Carlsson, is that there are different types of machines with no common information model obstructing the changes Volvo Cars want to make in-line with industry 4.0 applications, subsequently digital twins.

As in digitalization of industry in general, the implementation of tools such as digital twins, competence stands as an important aspect. Clearly digital twin requires competence within the IT domain, but it also requires knowledge of processes, an understanding how the operations work (Carlsson, 2019). A shift in competence is quite clear and finding the right staff with interdisciplinary knowledge is a challenge.
5. Analysis

The analysis chapter aims at declaring stakeholders within the research context, and at concretizing research data, research literature, and theory literature in an analytic manner.

5.1 Stakeholder analysis and mapping

In order to understand what stakeholders that are used within the scope of the research a digital twin use case has been mapped, see figure 12. The basis for the use case derives from the literature review intertwined with the conducted interviews. Regarding digital twins, there are interconnections between both consultancy companies, software companies, and subsequently end users. A typical use case could be initiated where an end user perceives a need for digitalization in-line with the eminent pressure and competitive landscape of industry 4.0 and therefore establishes contact with a consultancy company. The consultancy company thereafter acts and starts examining the end user’s operations after retrieving its organizational data and information. Results deriving from a consultant analysis with basis on the data and information, could constitute of identified bottlenecks within the end user’s facilities, where a possible digital solution could make production more efficient, secure, and proactive. The consultancy company, after defining the case, makes a maturity assessment. This assessment aims at evaluating where the end user stands against industry 4.0 practice. Possible questions contained within the assessment could concern; automation capabilities, connected equipment, educated staff, and infrastructure status in general. Furthermore, in conjunction with the maturity assessment, the consultancy company starts contacting their network of partners e.g. software providers. Depending on the prior assessment, various digital tools, and subsequently different software companies are assessed. After completing these steps, the business case has been mapped.

![Diagram of stakeholder analysis and mapping](image-url)

*Figure 12. Portraying a Digital Twin use case, visualizing the involved stakeholders and their work processes*
However, with regards to the collected empirical data within this research, digital twin is not centered in either steps within the use case. As the concept is immature and connected with industry hype, focus is instead put on the end user’s actual bottlenecks and problems, whereas what technology ends up being used and what the digital solution is called is initially neglected.

The three types of stakeholders depicted within the use case in figure 12, derives from the research methodology with inspiration from reviewed articles. Firstly, the literature review builds a clear picture of what stakeholders that are connected with regards to digitalization challenges in context of smart manufacturing, by exemplifying different cases (Baur & Wee, 2015) (Chen, 2017) (Kusiak, 2017) (Probst, et al., 2019) (Vaidya, et al., 2018). The main described stakeholders concern software companies and production companies. Software developers are described by various authors to be of high importance, having capabilities of industry 4.0 application development. Production companies are described as end users, ultimately using and implementing the solutions created by the developers. However, in order to orchestrate the implementation of digital solutions, company whitepapers strengthen the need for an additional stakeholder, a consultancy company. These consultancy companies, as visualized within figure 12, acts as facilitators of practical implementations of software within e.g. productions companies. The consultant act as the stakeholder that assesses an end user’s perceived problems, capabilities and maturity, subsequently connecting the end user to software developers that could realize digital solutions and solve organizational problems such as efficiency, safety, quality. Furthermore, in highlight of these three individual stakeholders, interviewees within the scope of the research were chosen accordingly, incorporating a mix between consultants, software developers, and end users, which in retrospect gives substance to the general analysis, connecting empirical data, research literature and theory.

The identified stakeholders regarding a digital twin use case, have different roles, dependencies, and requirements to take a use case from idea to practice, see table 4. For instance, a consultancy company incorporated within a digital twin use case needs to have technological knowledge, where examples of such organizations concern Deloitte, Eurostep, and Sweco Industry. Furthermore, a software developer could consist of SAP, GE, Eurostep, and PTC, all having capabilities of providing either IoT platforms or ERP-systems, enabling different digital twin applications depending on what level the digital twin is to be implemented. Lastly, an end user could in the scope of the research and a digital twin use case, consist of companies such as Stora Enso and Volvo Cars, both having production facilities and having needs of industry 4.0 applications to make their production e.g. more secure, efficient, and quality oriented. Eurostep, takes on the role as both consultant and software developer, having both capabilities of providing software solutions, project management, and implementation of digital solutions.
Table 4. Stakeholder mapping, displaying the three different stakeholders connected to a digital twin use case.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Role</th>
<th>Depends on</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultancy company</td>
<td>Assess end user, collaborate with software developer</td>
<td>End user (data/information) and software developer (solution architecture)</td>
<td>End user data, software developer solutions</td>
</tr>
<tr>
<td>Software developer</td>
<td>Supply digital solutions e.g. IoT platform, ERP-systems</td>
<td>Consultancy company</td>
<td>Consultancy company communication</td>
</tr>
<tr>
<td>End user</td>
<td>Provide operational data and perceived problems</td>
<td>Consultancy company and Software developer</td>
<td>Solution to perceived problems</td>
</tr>
</tbody>
</table>

5.2 Is there a convergence to a smarter industry?

Similarities can definitely be seen concerning stakeholders and what’s happening within industry today. There’s a common belief among the interviewed industry stakeholders that the industry is changing, and digitalization, apart from prior machinery automation, is present. Although, depending on the stakeholder; consultant, software developer, and end user, different views on how conducting the change within operations should be carried out. First and foremost, as Björk (2019) from Sweco Industry stated, that digitalization as a digital assistance within industry is not something new. In fact, it has been around the industry in general for about 40-50 years and undergone even bigger revolutions than industry 4.0, as an example, the shift to robotics within manufacturing, having connected devices. For instance, Volvo Cars, described by Carlsson (2019) as being an industry 3.0 company, having most of their equipment connected and computerized, which according to Vaidya, et al. (2018), due to having automated production processes and improved mechanical systems, opts for opportunities, being able to digitizing facilities in-line with industry 4.0.

To get a perspective on industry digitalization change one could look at the private sector, which has already gone through digitalization with similarities to what the industry is going through with revolution 4.0. The private sector is interestingly after its apparent change to a digitized private sector, being digital, which Björk (2019) states, “Digital tools are used without us knowing it, still vastly changing how we go about in our daily lives”, which portrays where the industry will be in the upcoming years, looking at the pace the change is moving with. Nowadays, industry is grasping for new technology, the most hyped concepts available, inevitably so companies can claim to be at the forefront of the digitalization era, which becomes clear when going through IT company whitepapers. A topic which is touched upon from a consultancy perspective, where Larsson (2019) from Deloitte states, when scratching the surface of companies that aim for a more technology intensive operation, there’s an ambiguity, where their “complete solutions” consists of pilot projects, and concepts in the making. In that sense, the industry apart from the private sector, is doing digital, having complex solutions and systems that operate separate, where the data that stands as the key when applying new digital capabilities within e.g. production facilities isn’t used at its full capacity. Baur and Wee (2015) ads to the dilemma of data being the key aspect, that expertise is needed for the added value for data to become a reality, where consultancy companies could help concretizes data, by pool various partners and their digital solutions, realizing manufacturers’ vision of industry 4.0 and its applications. Kusiak (2017), ads to Björk’s thesis, but claims that industry organizations moving to a smarter industry operation, needs to see specificities within the available technology solutions, not what’s hyped or the newest
available tool “that can solve any problem”. To increase the move to a smarter industry and nonetheless, smart manufacturing Zhong, et al. (2017) thesis that standardization of sensors, wireless communication, and system model, integrated within a generic industry framework is needed, which could, in retrospect, enable the industry of moving away from doing digital towards being digital. Apart from the perspectives from industry stakeholders regarding a change towards a smarter industry, researchers are attacking the problem from a different angle, opting for how easy the possibilities of industry digitalization is to grasp but how much harder it is to realize in practice, without becoming abstract or just another hype. Kusiak (2017) belief that manufacturers are oblivious to smart manufacturing practicalities, adds to this thesis, further claiming that research could help fill that gap. Furthermore, filling the gap of manufacturers or end user’s obliviousness to industry 4.0 applications, Baur and Wee (2015) uses, when they assess an organization, a digital compass. The digital compass, depicted in figure 5, acts as a rudimentary model to look at the manufacturer’s drivers, where they want to make their operations more efficient, connecting to digitalization applications, pointing the organization in the right direction. For instance, Stora Enso, within their production, want to focus on quality as their value drivers, could then look at what applications that match, and realize that Statistical process control is a starting point. In addition, having a position as an organization with software development and consultancy capabilities, such as Eurostep, digital solutions could firstly be developed and initially tested inhouse, thereafter deploy to customers, end users. A strategy that has been proven by Jane Doe’s organization. From an end user’s perspective however, a point of departure is to start focusing on expertise within the organization, finding expertise high up in the organization, building on a common vision for the company. In addition, apart from expertise aspects, Baur and Wee (2015) indicates that the foundation for the digitalization of industry, presently has its basis within digital platforms. Platforms that are used to streamline and connect various stakeholders and their data. For instance, such a software PLM platform Eurostep provides. Interestingly, although many researchers opt for the use of an IoT platform, neither Sweco Industry nor their clients have such a platform available. Instead, Sweco and subsequently their clients’ practical digitalization examples consist of traditional MES, connected to various systems (Björk, 2019).

With the change of industry, new business dimensions are also present. According to Schwartz (2019), proceeding the industry 4.0 revolution, where digitalization consisted of implementing traditional IT systems within organizations, only large companies could join the change, due to the high costs and capabilities needed. Nowadays, however, with technology and digital solutions becoming cheaper, SME can also take part of the changing climate within industry. This is directly contradicted by Vaidya, et al. (2018), claiming that large funds are still needed to digitize industry, due to its high complexity and required change in infrastructure, which subsequently removes SME from the equation. Two additional aspects interconnected with operational change, is technology and expertise (Carlsson, 2019) (Larsson, 2019). Expertise, and a shift within competence across organizations, derives from the added service dimension to e.g. manufacturing, where hands-on expertise within production isn’t as valuable as before. The technology shift derives from equipment used in factories are becoming cheaper, and a tendency of having decision making computerized. Baur and Wee (2015) adds to this dilemma and states that these shifts are
changing the landscape of manufacturing to smart manufacturing, in hand also shifting how organizations operate and what business models to use. According to Ingemarsdotter (2019) these shifts have their basis in the new dimension within industry, apart from the prior physical dimension within manufacturing, a digital dimension. This new dimension subsequently leads to the prior mentioned shifts, due to the change in demand within processes and expertise. For instance, an operational strategy example, Bauer and Wee (2019) and Kusiak (2017) states that industry is changing from a Capital Expenditure (CAPEX) to Operational Expenditure (OPEX), where production companies, instead of owning, lease their equipment, and outsource maintenance or even predictive maintenance through digitalization.

5.2.1 Challenges within industry 4.0

The manufacturing industry is in an immature, autonomy implementing phase, where according to Vaidya, et al. (2018) the adaptation of automation within the manufacturing domain requires capabilities development mainly surrounding how the operational data is collected as well as how it is subsequently used. Kusiak adds to this thesis, specifying that the industry is in fact unprepared for the change towards smart manufacturing, where organizations specifically do not know when, what and where in production to effectively measure data, where the interpretation of data is crucial for the advancements within manufacturing. Ingemarsdotter (2019) has the same approach, stating that apart from the challenge of integrating collected data, the main problems lie within the differences in data quality, and frequency. In addition, organizations that although have connected equipment, and are able to measure data, Ingemarsdotter claims that often more data is measured than required. In solving this problem, solutions could derive from having specific operational processes that specify the course of action, by somewhat limiting the data amount so its easier to handle, and have an effective way of filtering unwanted data, to avoid outliers when the data is analysed. Carlsson (2019) at Volvo Cars, as an end user, perceives data handling as a main problem of adapting to industry 4.0. Volvo Cars, with their connected machinery and equipment, generates and collects large amounts of data points, and uses it to control and react on alarms within their operations, a reactive approach. However, Carlsson states that they are not able to create information-density and the data collected is deleted after 8h due to network capacity being low. This thesis from Volvo Cars correlates with Kusiak (2017) statement that, within a manufacturing context, collected data is not properly utilized, which hems the advancements among industry practitioners. Furthermore, Kusiak recognizes these data handling problems due to lack of experience, where organizations believe that data is not analysable due to the amount of data collected. Misinformation also lies within the legalities and that irregular measurements can’t be used, which needs to be communicated throughout the organization, and stems from the shift in competence stated earlier in the analysis. Solutions, apart from a shift in competence within organizations, is to standardize the frequency to collect data, what data that should be analysed, and how long it should be stored to bring a stop to the confusion. Vaidya, et al. (2018) also states an important parameter when analysing the collected data, to take account semantics in data analytics, which, brought forth from the empirical data stands as a fundamental problem.
Further obstacles which can be seen as commonalities both within research literature and the conducted interviews is the lack of software and modelling systems (Kusiak, 2017) (Vaidya, et al., 2018) (Ingemarsdotter, 2019). These systems, when talking about digitalization in context of smart manufacturing, are of high importance due to the creation of value from the collected data. Vaidya et al. also stresses with their research that the system modelling for digitalization should be viewed as a separate part and an individual manufacturing system, in order to see improvements within the area, however, the authors don’t explain how and why in detail, which makes it hard to take a standpoint to their claim. Furthermore, Ingemarsdotter (2019) states that this obstacle also entails a higher focus on the services apart from produced physical products, and when more focus is put towards services closer and longer customer relations become a bi product, where co-creation of services occurs more frequently.

Obstacles experienced by end users, such as Stora Enso and Volvo Cars are perceived as being practical, where much focus is put on their operations, not risking a decrease in production by testing digital applications, reliability is therefore a must when applying new solutions. Further challenges and where there’s an immaturity among end users, concerns applying new digital applications, such as connecting their equipment to an IoT platform, where a common belief among Stora Enso and Volvo Cars is that it’s not possible on their current machinery. However, one could understand their misbelief, where their old equipment, having a life expectancy of 10-20 years needs to configure with solutions developed today. Connected with this immaturity among industry stakeholders, there’s still a standpoint that the digitalization of industry is moving too slow (Morén, 2019), which could be seen as approaching digitalization with a dose of ambiguity. In correlation, from a consultant perspective, viewing the applicability of digital solutions within manufacturing companies as a cultural problem, stating that the technical capabilities are already present (Schwartz, 2019) (Björk, 2019). For instance, when industry 3.0 was present, Volvo Cars tested and applied different automation solutions, such as AGV (Automated Guided Vehicles) within their production facilities. However, due to the limited battery capabilities and software, the AGV implementation wasn’t successful, which nowadays proves to have become a problem when approaching industry 4.0 applications, where workers only remember the downsides of testing new solutions, a cultural problem.

The last obstacle concerns the integration and use of common language through an IoT platform, enabling the benefits of using and analysing data. The problem originates from having various control systems, each having a different platform, where finding a common IoT platform, connecting every e.g. machine is complex. On the contrary, according to Baur and Wee (2015), the problem derives and occurs when data is in fact transferred, stored and its architecture, not the platform per se. However, Probst, et al. study on an actual IoT platform, ThingWorx, provided by PTC, new problems were found connected with the actual use of the platform. Probst, et al. had people testing ThingWorx, what they found was that the interface could change overnight, making it hard to learn and use the platform. In addition, support for the platform was lacking, which could in practical cases within a production facility lead to bottlenecks in production, the fear of end users such as Stora Enso and Volvo Cars.
5.2.2 Adapting digital twins

In connection with the interviews that were carried out throughout the project the respondents were asked to, in their own words, explain their definition of a digital twin. The results from mapping out the different definitions in table 3, shows, not surprisingly a general view of a digital twin as being a virtual representation of a physical entity. Some respondents were more detailed in their definition, referring to the digital twin to act as a modelling and improvement tool (Morén, 2019), or explaining the tool with the use of data, virtually test situations with the aim to eliminate inefficiencies. The two definitions that stood out from the interviewees were Jane Doe’s and Björk, where Doe (2019) firstly declared that it heavily depends on who you’re talking with, for instance, is it an end user, consultant, software developer, or a researcher. Doe continues to define digital twin as a holistic tool, that interconnects various software, an interesting aspect with regards to the findings in the literature, where interconnecting digital twin through object modelling tools are discussed. Björk (2019), explains the digital twin concept from a point of view that correlates with the literature as well, where digital twins, although being a virtual representation of a physical entity, is defined as being applicable in various levels. Due to viewing the tool in various levels, consequently the definitions vary. From the lowest applicable level of a digital twin Björk states that the digital twin is only a virtual copy of a physical object, not connected to real-time data, whereas at the highest level the digital twin is interconnected with real-time data, enabling further capabilities, such as predictive maintenance. What’s interesting is Björk’s definition correlates heavily with two papers on the digital twin concept, where IDC (2018), explains digital twins from lightweight to detailed implemented, and Qi, et al. (2018) views digital twins in different applicable levels within a manufacturing context. Apart from different views in defining the concept of digital twins, Schleich, et al. (2017) states that different views and focus exists among leading companies within the IT sector, from PTC aiming on developing a digital twin improving the cyber-physical linkage, Dassault narrowing their focus to the design phase, Siemens on manufacturing excellence, and GE on monitoring a product’s performance during its usage.

The Gartner hype-cycle was also a method that was used within the project, which helped when figuring out where industry stakeholder claims that digital twins stands as a concept within industry, seen in figure 11. Most interesting aspects depicted in the Gartner model concerns firstly how closely the different organizations declared digital twins. In fact, the majority of stakeholders put both their organization and the industry in general within the Peak of Inflated Expectation section of the graph, meaning that in summary the stakeholders have the same trajectory. However, regarding the end users of digital twins, Volvo Cars and Stora Enso there are big differences. Volvo cars put themselves and their standpoint on digital twins as being within the innovation trigger, having just introduced the concept within their organization, where Stora Enso on the other side of the spectrum, believes that they are situated within the third stage. Morén, the respondent from Stora Enso’s reasoning derives from having conducted pilot projects, driving simulations through one of their milling machines at Fors Mill, which according to Morén stands as the basis for a digital twin concept. Although differences are clear looking at the Gartner model, the differences and similarities could derive from the viewpoint of, applying digital twins in different levels,
which results in organizations viewing the concept in various stages within the Gartner model, once again showing that the concept is hyped, new and in an exploration phase among industry practitioners. However, according to Doe (2019), with every new concept there’s an inevitable hype, and in most cases, it is necessary, acting as a fire starter for the concept to make ground. It will only stop being a hype until practical examples emerge within industry organizations, and thereafter in research (Doe, 2019) (Ingemarsdotter, 2019). On the contrary, Björk (2019) feels that the hype concerning digital twins is only a testimony of immaturity towards digitalization in general, where focus instead should be put on investigating and analysing operational bottlenecks, applying efficient solutions where digital twins could be one of them. In addition, this approach would remove Ingemarsdotter (2019) stated challenges of identifying why a digital twin should be used, what the value actually is concerning digital twins in an operation, and that ideas do not match the practical output. The viewpoint of investigating digital twins as a solution to operational problems as secondary to first looking within an organization, unravelling practical problems, stands as a commonality among industry practitioners (Hjalmarson, 2019) (Schalander, 2019) (Larsson, 2019). However, from a consultancy perspective, during the development of a digital twin solution, collaboration with customers is believed to be an efficient approach. Kusiak (2017) adds to these claims with the thesis that collaboration across industry stakeholders is needed, especially connecting industry practitioners with researchers, where pilot projects together with researchers could speed up the innovation process.

Approaching the development and implementation of a digital twin solution within an end user organization, there are different approaches. Deloitte, when tackling such a challenge starts with conducting a maturity assessment. For instance, regarding Volvo Cars, their machinery and operations are assessed as to if they are connected and computerized, estimating what capabilities are present, possibly looking at what applicable level of a digital twin that could be implemented within the production. Thereafter, after assessing the operation, the operational structure is viewed upon, explained as MES and PLCs interconnection with the company’s ERP system, building a roadmap, where to start and what the output should be. Looking into the current MES and ERP systems at the organization is important, claimed by Olivotti (2018), especially when implementing a digital twin. However, Zhuang, et al. (2018) stresses that PPC systems such as ERP and MES are incapable of processing sensor data, data that is heavily interrelated with a working digital twin. Therefore, Zhuang, et al. states that a data and management storage, separated from the MES and ERP systems are essential, having the purpose of processing sensor data prior being connected to the PPC systems. Botkina, et al. (2018) with research on practically developing a digital twin of a production tool, also found obstacles with the collection of data and the information exchange within the different stages in production. The ISO 13399 standard was used to solve the problem of having different configured data. Zhuang, et al. concerns about information exchange, was subsequently solved by using the information system architecture LISA, enabling the same data format across the production stages. Apart from having issues with information exchange, concerning the data history, PLM is considered among the interviewed stakeholders to be of importance. Hjalmarson (2019), states that PLM indirectly enables the use of a digital twin, acting as a complement, where capabilities within PLM could be applied on virtual units versus physical units. Björk (2019) adds to this statement,
however views PLM as a part of a digital twin, in different processes, incorporating data from PLC and real-time data processing. Using a PLM system in conjunction with a digital twin could also assist when developing a standardized approach to the concept, especially since Eurostep’s PLM software ShareAspace Nova is based on the PLCS standard. Kunath and Winkler (2018) subsequently claims that a standardized approach to digital twins is needed, preventing rudimentary problems initially.

5.2.3 Organizational structure, Strategy, and Innovation Theory

Depicting how a firm adapts and enacts on technology processes and product development Salavou, et al. (2004) stresses the importance of overviewing an organization’s innovation process, which nonetheless becomes important factor when as a consultancy company assess an end user. The assessment could therefore highlight where an end user stands in relation to new concepts such as digital twins, and its possible success rate within the organization. As a software developer their innovation could also depend in orientation. According to Narver and Slater 1990 in Salavou, et al. 2004, it mainly concerns the e.g. software developers market orientation and how well the organization adapts to customer requirements within. As the basis, on the enactment to changes within industry, Decanio, et al. (2000) claims to situate around that specific organization’s structure, where the structure of a firm directly affects its performance and at what speed an innovation e.g. digital twins gets adopted. On the contrary, a lack of structural focus and understanding leads to inefficient adaptation to such innovations. Regarding having standardized processes when tackling the challenges and obstacles of adapting digital twins within an organization, such as data integration and having common modelling systems, it is connected to some extent with Mintzberg (1980) views on organizational structure. Subsequently, working heavily with standardized processes, requires according to Mintzberg a guidance through an organization’s technostructure, resulting in its decision-making being centralized. On the contrary, having less standardized processes, and focus is put on an organization’s operating core, results in an autonomous organization, where a reliance is put on employees’ expertise, giving them the power of taking decisions, a decentralized approach. Furthermore, as Hjalmarsson (2019) stated, how far behind or in front an organization is with regards to the digital twin concept, depends on vertical and horizontal organizational structure. Where working vertically, hems the adaption of the digital twin, and working horizontally, therefore closer together, instead promotes it. This thesis, inclines with Mintzberg (1980) research on vertical versus horizontal structures, claiming that it heavily affects how stakeholders within business work together.

In the case of forming strategies within an organization, Mintzberg (1978) claims that using explicit set of guiding bullet-points only hems the efficiency of that strategy, as well as results in abstract assumptions, which highlights the importance of strategy formation. Therefore, in highlight of the declared stakeholders within this research, should categorize strategies either as deliberate or emergent. The former constitutes an intended strategy, when a consultant could build a clear roadmap for an end user, and the latter insinuates a strategy that emerges from different outsets and capabilities within an organization. A consultant should, with retrospect to Bouncken, et al. (2010) research on the matter, adapt on deliberate strategies regarding solutions that have low uncertainty with regards to an end user, using
road mapping in conjunction with market assessments. On the contrary an emergent strategy, deriving from a solution’s high uncertainty, should be introduced, which according to Bouncken, et al. requires high rates of improvisation and adaptation to exchange of information among industry stakeholders. In addition, as a consultant, when choosing what strategy to pursue in a digital solution use case, importance also lies within what type of innovation the solution is categorized. For instance, a radical digital solution, consisting of a new innovation which revolutionizes a use case, high uncertainty applies, and an emergent strategy should be pursued. However, a digital solution building on incremental steps of improvement on an existing product, one could say that low uncertainty applies, and a deliberate strategy should follow.

In conjunction with Schalander (2019) statement that saturated firms, making profits today, do not innovate and adopt digital solutions such as digital twins, interrelates with Kingston (2013) thesis on creative destruction, whereas these depicted firms, only see the high risk and uncertainty, and relies on their current operations. According to Schumpeter (1942), in Kingston (2013), this directly insinuates the firm to be replaced by new organizations that chose to innovate and adapt to new technological innovations, as well as disruptive innovations, which could be argued as to being too concretized, heavily dependent on the use case at hand. Schiafone and De Falco (2016), on this basis, criticize the concept of creative destruction, meaning that such organizations that rely on old, successful operations, having a robust technological framework, could with continued collaboration among its stakeholders in conjunction with investing in their old technology hem creative destruction. In fact, as Christensen and Bower (1996) adds to this thesis, disruptive innovations, which could consist of the digital twin concept, could fail miserably when derived solely from customer requirements, pointing the innovating organization in the wrong direction. Therefore, staying too close to your customers, is according to Christensen and Bower not always the best trajectory.

Roger (1983) theory of diffusion of innovation could be applied to the concept of a digital twin use case, where an end user/client approaches a consultant with perceived problems, consequently after mapping the use case the consultant recommends digital twins as a solution. Problems could arise, when not taking diffusion in consideration, where the high uncertainty of such an immature solution according to Rogers (1983) only can be adopted at a desired rate if it’s compatible with current practice, have a reasonable degree of complexity related to the end user’s network and infrastructure, and having a high trialability. Furthermore, regarding digital twins, where Rogers stresses the importance of understanding what social system the innovation operates within, whether it’s a consultant engaging with a client/end user, or a company engaging with a supplier or manufacturer, it could affect the adoption rate of the digital twin and therefore its success rate.
6. Results

*The result chapter aims at declaring the two developed strategies based on the research analysis. The strategies have both an emergent and a deliberate structure.*

6.1 Deliberate strategy: IDEF0 Diagram

As stated by Mintzberg (1978), when forming a strategy in a business setting it is important to contemplate on what structure to apply. Intended strategies, depicted in figure 9, constitute strategies that have been used and applied in a similar setting in cases prior to the present e.g. product implementation. In the case of Eurostep adapting digital twins in a customer setting, one possibility, based on literature, and the conducted interviews, is to form an intended, deliberate strategy. Meaning, that the digital twin solution challenge is tackled from a viewpoint where Eurostep recognizes that they have the capabilities and knowledge to develop a digital twin customer solution at a suitable level. Bouncken, et al. (2010), strengthen this strategic viewpoint within their quantitative research on 140 IT organizations, where, if a use-case concerning digital twins is believed by a principal to have low uncertainty, a deliberate strategy should be used. Furthermore, in line with Bouncken, et al. research findings, deliberate strategies should be approached by applying road-mapping and strategic market assessments to reach full potential of the developed use case. Therefore, in conjunction with the interviewed respondents, having the same view on the matter, the first approached strategy within the scope of this research’s results, is a deliberate strategy. In realizing and building on a deliberate strategy, an IDEF0 diagram has been used to map out a strategy, which subsequently could be followed by a Eurostep consultant when approaching a digital twin use-case in a customer setting.

To grasp the logical order in the developed IDEF0 diagrams a node tree has been used, see figure 13. The node tree graphically shows, at the top level, a context diagram, where the general use-case of developing a digital twin customer solution is showcased. The context diagram is subsequently broken down into 4 separate function boxes, A0-A4, where the child diagrams A3 and A4 have been decomposed to understand how to carry out the depicted functions. Furthermore, at the lowest described levels within the node tree, the A3 and A4 diagrams have been decomposed into 3 function boxes in A3, as well as 2 function boxes in A4.
The context diagram, seen in figure 14, acts as the foundation of the formed deliberate strategy. The diagram has the general function to develop a digital twin customer solution, containing two separate inputs; undefined digital solution (I1) and perceived operational problems (I2). Consequently, the function has an output; digital solution implementation package (O1), which is linked to the prior inputs. In order to facilitate and realize the top-level function in the context diagram, certain controls and mechanisms are needed. The two control conditions; Eurostep capabilities (C1) and Customer requirements (C2) are needed to control what is produced by the function. The mechanisms; PLM standard framework (M1), Eurostep consultant (M2), and Customer representation (M3) are all needed as agents to carry out the function of developing a customer solution and therefore, consequently, the desired function outputs.

Figure 13. An IDEF0 Node Tree visualizing the decomposition of the context diagram and its child diagrams

The context diagram, seen in figure 14, acts as the foundation of the formed deliberate strategy. The diagram has the general function to develop a digital twin customer solution, containing two separate inputs; undefined digital solution (I1) and perceived operational problems (I2). Consequently, the function has an output; digital solution implementation package (O1), which is linked to the prior inputs. In order to facilitate and realize the top-level function in the context diagram, certain controls and mechanisms are needed. The two control conditions; Eurostep capabilities (C1) and Customer requirements (C2) are needed to control what is produced by the function. The mechanisms; PLM standard framework (M1), Eurostep consultant (M2), and Customer representation (M3) are all needed as agents to carry out the function of developing a customer solution and therefore, consequently, the desired function outputs.
The decomposition of the developed context diagram, seen in figure 15, depicts the various functions needed to, inevitably, develop a digital solution implementation package and realizing the actual operational problems at the involved customer’s operation. The A0 diagram consists of 4 different functions; evaluation of PPC systems, investigation of operational bottlenecks, maturity assessment, and road mapping. The different function boxes described within the IDEF0 diagram have different controls and mechanisms. In function 1, evaluation of PPC systems, Eurostep’s capabilities controls the function itself, whereas a Eurostep consultant and a customer representation, in collaboration, acts as agents and makes sure that the output from the function is possible. Furthermore, within this function, customer requirements aren’t involved to eliminate influence on the function output; customer operational capabilities. Function 2 within the A0 diagram, consists of carrying out an investigation of the customer’s operational bottlenecks, the actual problems within e.g. a production facility such as; inefficiency due to a certain machine, worker interference, data handling etc. This is an important step when trying to find the applicable digital solution. Controlling the output of the investigation of operational bottlenecks concerns customer requirements, and mechanisms acting as agents to facilitate the function output is, with similarities to function one, a collaboration between the Eurostep consultant and the customer. The customer provides needed intel of the operations, and the consultant carry out the investigation by analyzing customer data in conjunction with the received information.
The function box 3 within diagram A0, having the function of conducting a maturity assessment, has been further decomposed as child diagram A3, see figure 16. The A3 diagram, consists of three functions that are needed when carrying out a customer maturity assessment. In essence, the maturity assessment is done in order to realize the aimed applicable level of a digital twin, which as a minimum should solve the operational bottlenecks perceived in the prior function. Firstly, the Eurostep consultant benchmarks the customer’s maturity in relation to other industry competitors, to the best of abilities. Subsequently, the customer’s facility connectivity is evaluated, meaning that the e.g. production facility at question is looked upon with regards to data collection capabilities such as sensors, network, and data architecture. Furthermore, having the mapped data architecture, the Eurostep consultant, as an agent, assess at what level the digital twin could be applied, in conjunction with the prior obtained knowledge. After assessing the range from lightweight to detailed digital twin level, the aimed applicable digital twin level is finalized. Controlling all the functions contained within the A3 child diagram is the customer’s operational capabilities, as it directly affects the functions’ outputs.
The function box 4 within diagram A0, having the function of developing a customer use case roadmap, has been further decomposed as child diagram A4, see figure 17. The A4 diagram, consists of two functions that are needed when creating a use-case roadmap, to eventually deliver a digital solution implementation package. Firstly, within the first function of the A4 diagram, an analysis is done by the Eurostep consultant in collaboration with the customer representative, on the customer’s PPC systems in conjunction with the realized digital twin applicable level. Secondly, after realizing the aimed system architecture is needed to facilitate the aimed digital twin level, the function of developing a standardized data framework is carried out. The function, assisted with the Eurostep consultant and their PLM standard framework, an implementation package is delivered to be reviewed by the customer. Both function 1 and 2, facilitated within the child diagram A4 is controlled by both customer operational capabilities and customer requirements. Subsequently, function 2 is also controlled by the unraveled operational problems, one of the outputs from the conducted maturity assessment.

Figure 16, IDEF0 child diagram A3, showing the functions needed in order to conduct a maturity assessment
Emergent strategy: Organizational and Innovation theory

Emergent strategies stated by Mintzberg (1978) differentiate from deliberate strategies and are in essence formed through unplanned cases that emerges from different outsets within an organization. In the case of digital twins, as being a hyped concept within industry, as visualized within the charted Gartner hype-cycle in figure 11, it could require in general a certain organizational structure and focus on innovation theory for such a solution to become imbedded as an organizational strategy. Furthermore, as Bouncken, et al. (2010) stated within his research, that in cases of high uncertainty, emergent strategies should be used to achieve market success, where importance lies within the use of improvisation and adaptation to exchange of information among firms. Therefore, within this second part of the research’s results is constituted by a generalization of how one could approach the challenge of digital twin in an industry context. In addition, how digital twins, as a hyped industry concept, could be a part of a business strategy with fewer risks involved, subsequently less financial investments.

As mentioned in the analysis organizational structure heavily affects how an innovation gets adopted and used throughout an organization. This also affect how a principal such as Eurostep is working with, for instance, digital twins. Therefore, to enable an emergent strategy approach regarding digital twins, small groups within the organization, that operates on the basis on idea generation and pilot projects could be introduced. These groups, or divisions, should have strong focus on its base structure, which will affect the efficiency of how digital solutions, such as digital twins, could emerge as a business strategy and product solution within their portfolio, deriving from different outset within these newly established
Mintzberg (1980) mentions two relatable views on the dilemma of organizational structure, in conjunction with innovation adaptation. Firstly, working heavily with standardized processes require guidance within a division or organization’s technostructure, a centralized approach, and secondly less standardized processes focus is put on the operating core, relying on employee’s expertise, a decentralized approach. In the case for Eurostep and the proposed innovation divisions, a mix between the two should be applied, with regards to the reviewed literature and interviews. On one hand, the division must include standardized processes, as the context of product innovation derives from data collection, distribution, and integration, using modelling systems, as well as Eurostep having their PLM platform grounded within the PLCS standard. In addition, the division should opt for a focus on its operating core, resulting in an autonomous organization where expertise is relied on. Furthermore, apart from focusing on the operating core, which in hand opts for decentralization within the division, horizontal organizational structure should be used in conjunction.

The digital twin concept, having been defined as a hyped and high-risk solution, subsequently stands as a disruptive technology innovation, vastly changing how end users operate. As a result, firms only see the high risks and uncertainty, and don’t innovate. Therefore, the proposed divisions should, with regards to operating with radical digital innovations that have high uncertainty, such as digital twins, include high rates of collaboration and information exchange across industry stakeholders. Consequently, creating pilot projects together, in order to split the risk and the initial costs. Furthermore, to reduce the risk of problems, not taking diffusion of innovation in account, especially regarding immature solutions, the solutions should be viewed upon by the division with regards to its compatibility to current practices and architecture, complexity, and trialability. This results in different requirements on different outsets within the division, conducting research regarding these pillars. The division should also, when investigating different solutions, understand the system where the innovation could operate within. For instance, if the digital solution is situated within the manufacturing segment, including Stora Enso and Volvo Cars, or is the solution to be targeted towards suppliers directly. Consequently, the adoption rate of the emerging innovative solutions is affected positively.
7. Conclusion and Implications

This chapter aims at declaring if the research questions have been answered, what has limited the results, ethical implications and how the research topic could be further developed.

7.1 Digital twins within a manufacturing context

Based on a unification between literature, interviewees, and theory, a two-part strategy has been formed, trying to answer the project’s research questions. The former, consists of a deliberate strategy, developed on the basis that in the current state of Eurostep’s operations and capabilities, they could be able to approach customers and provide a digital twin solution at an appropriate level based on current practice and customer expectations. However, in addition, similar companies could use the formed strategy to tackle use cases of digital twins in a customer setting, in a manufacturing context. The created strategy is shown within various IDEF0 diagrams, standing as a point of departure when creating a digital twin use-case, a deliberate strategy. Furthermore, when approaching a hyped industry concept such as digital twins, an emergent strategy could be used as to the high uncertainty involved, thus reducing the risk for a company such as Eurostep when entering the scene. Taking the approach of an emergent strategy, with a focus on organizational structure and innovation studies could result in a realized strategy, emerging from different outsets of an organization.

7.2 Ethical implications

Change towards digitalization and industry 4.0, not only creates benefits for organizations, where operational efficiency, predictive solutions, improved design phases, and cuts in overhead costs could be a by-product, but could as well create organizational problems. The problems could derive from neglecting current employee’s, where their way of doing things are replaced in connection with the inevitable shift in competence and technology within industry. Consequently, the digitalization change, as portrayed by the interviewed end users, is moving slow, where saturated workers don’t believe in the efficiency promises, instead they see drawbacks and replacements as by-products.

Another aspect concerns the data integrity issues, which could be connected on the development and implementations of digital twins. The issue derives from the vast amount of data that the digital twin and digital thread uses, and when the move from having such solutions and data integrated models polluted within actual consumer products integrity issues is a fact. These issues not only create problems for the end users at hand, but consequently adds problems for organizations that uses more advanced digital solutions, having to create protocols, time consuming data integrity standards and processes. The future scope of the digital twin, autonomously taking decisions without supervision, could also create ethical issues, where leaving authority to a computerized tool could take decisions that directly affects employees, production, and the organization.
7.3 Future research and Research implications

Future research on the topic of digital twins could concern narrowing down the scope of the research to one specific industry branch. For instance, oil and gas, automotive, food and beverage, or life science, which could enrich the accuracy of the research, focusing the applications within one segment. Subsequently, narrowing down the scope could be interconnected with focusing on only one of the applicable digital twin levels mentioned in the report, where efforts could be put on production equipment, and how to apply a digital solution such as a digital twin. Furthermore, unraveled from interview participants, future research could incorporate the cultural challenges within organizations implementing digital solutions, whereas it currently is believed, mainly by production companies (end users) to be of high importance. The focus on cultural change could give a deeper understanding on the complexity of not only the digital solution’s technical aspects, but the complexity on how to get current employee’s, factory workers, to comply to the apparent changes within industry.

This research project had a point of departure as a qualitative explorative research, trying to dig deeper on the actual subject on digital twins in context of the industry and smart manufacturing. However, moving ahead, a quantitative study, incorporating a large number of participants from an industry branch, could further enrich and pinpoint relative problems that industry practitioners have at present and future times when implementing digital solutions.

With all projects there are certain implications that arises throughout and after it is conducted. This project’s main limitations firstly concern the lack of practical applications testing, for instance, using Eurostep’s PLM software testing a developed digital twin architecture could have enriched the project’s results. Furthermore, limitations concern interviewing end user stakeholders, where additional information could have impacted the analysis, and prevented the risk of company secrecy, being able to compare a larger number of stakeholders. Lastly, as the research included a rather explorative subject, the gather journal articles were few, which resulted in the lack of practical examples.
References


**Interview participants**


Appendix A – Interview guide

This appendix aims at declaring the interview guide and its associated questions that have been used for the qualitative interviews carried out within this research. Although the questions within this interview guide were used as a basis, leading questions were subjective to each interview participant. This was done in order to get a deeper understanding about the interviewee’s standpoint on a subject in relevance to their respective domain and position at their organizations.

*Questions up for discussion*

1. What is your background; profession, position, years employed/involved projects?

2. What is your experience about the change/digitalization of industry, industry 4.0?
   a) Examples on digitalization, implementation?
   b) What tools/concepts do you find necessary towards an Industry 4.0 landscape?

3. What is your experience with digital twins?
   a) How do you define a Digital twin?
   b) Do you see any issues with today’s definitions of digital twins?

4. What are the ideal applications of a digital twin within your domain?

5. How mature is the applicability of digital twins?
   a) Is it the same maturity within your organization?
      What measures do you take when working towards/preparing for a more digitized industry?
   b) industry?

6. What business strategies are there bringing digital twins from idea to practice?
   a) What strategies could be used?
   b) If you would recommend a framework or concept, what would that be?

7. What problems are there with digital twins/digitalization of industry
   a) What problems can you see within your domain at your organization?

8. What is your opinion on the connection between PLM and digital twins?

9. How would a standard (SIS/ISO) on digital twins change the industry?
   a) Do you believe such a standard is needed?
   b) How would you utilize such a standard working towards a digitized industry?