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The manufacturing industry transition from traditional manufacturing to a smart factory: Role of 3rd party service providers.

By
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Abstract

This thesis explores the role of 3rd party service providers in the transition from traditional manufacturing to *smart factory*. The research investigates the challenges and opportunities associated with a *digital transformation* by reviewing the concept of a *smart factory* and collecting data through literature reviews and interviews with companies from the manufacturing industry. The analysis reveals that successful *digital transformation* in the manufacturing industry involves not only the adoption of digital technologies but also organizational changes. Today's manufacturing industry faces challenges related to development, integration with existing infrastructure, resource allocation, strategic planning, and organization-wide commitment. It becomes evident that 3rd party service providers, such as Capgemini, can play a crucial role in supporting companies throughout their *digital transformation* journey and filling the resource gap, by providing valuable technology and organizational insights, and expertise. However, the research has identified that Capgemini's current service levels are between limited and moderate in terms of coverage at some key areas towards an end-to-end service towards a *digital transformation*. The thesis proposes a *digital transformation best practices framework*, developed based on the conducted research and analysis, which guides 3rd party service providers to identify areas that lead to a successful *digital transformation* from traditional manufacturing to a *smart factory*.

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Henrik Matias Olufsen
Stavanger, 30.06.23

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3IR – The third industrial revolution (Industry 3.0)
4IR – The fourth industrial revolution (Industry 4.0)
AGV – Autonomous guided vehicles
AI – Artificial intelligence
AR – Augmented reality
B2B – Business to business
B2C – Business to customer
CAD – Computer-Aided Design
CNC – Computer Numeric Control
CPS – Cyber-physical systems
ERP – Enterprise resource planning
ESG – Environmental, social, and governance
GAN – GKN Aerospace Norway
HSE – Health, safety, and environment
IA – Industry agility
IIoT – Industrial Internet of Things
INSEE – The National Institute of Statistics and Economic Studies
IoT – Internet of Things
IT-Network – Information technology network
MES – Manufacturing execution system
ML – Machine learning
MVP – Minimum viable product
OEE – Overall equipment effectiveness
OT-Network – Operational technology network
POC – Proof of concept
ROI – Return on investment
SCADA – Supervisory Control and Data Acquisition
SMLC – Smart Manufacturing Leadership Coalition
VR – Virtual reality

1 INTRODUCTION

The manufacturing industry has long been trying to utilize digital technologies to improve their production facilities but are meeting challenges regarding the integration of technology into the workplace. Despite the existence of the 4th industrial revolution for a decade, companies are now recognizing the technological potential of this next phase in *digitalization* and want to take part [1]. This has been an increasing matter due to the dynamic environment, which is constantly influenced by evolving regulations, customer demands, and market fluctuations, which has led to many companies needing to reimagine manufacturing operations to withstand these disruptions better [2].

The manufacturing industry is currently undergoing a significant transformation driven by digital technologies and the concept of smart manufacturing. Companies face challenges transitioning from traditional manufacturing to a digitally enabled manufacturing environment. This transition, known as *digital transformation*, is not only about introducing new technology into the manufacturing process, but it goes beyond technological advancement and requires a holistic approach with a comprehensive understanding of the organizational and strategic aspects involved.

With these challenges, many companies are struggling to adopt digital technologies, where questions arise regarding how the transition from traditional manufacturing to a *smart factory* can be successfully accomplished and in what ways can 3rd party service providers contribute to the success.

1.1 BACKGROUND OF RESEARCH TOPIC

The manufacturing industry has been adopting Industry 4.0 for many years, and more companies slowly realize the potential digital technology has and how it can significantly affect their business. Terms like "lean" and "agile" has gradually become more popular as companies try to handle disruption better and want to be more resilient. Events like material shortages, energy crises, and a global pandemic are just a few recent events that have forced companies to think differently [2].

However, although *digitalization* has the potential to improve businesses, many companies struggle with implementing new technologies, which might be due to a lack of resources and expertise needed to adopt digital tools effectively. As a result, there is a need for research that explores the factors that influence successful digital adoption in the manufacturing industry and the role 3rd party service providers can play in facilitating this process.

1.2 RESEARCH GAPS, SCOPE, AND OBJECTIVES

There is a lot of research regarding *digital transformation* and recommendations on how to do it successfully, but those are very general and only create a baseline for every industry [3] [4]. Very little analysis is regarding a *digital transformation* from a 3rd party perspective. Where do other 3rd party service providers "fit" in such transformation, and how can they play as a strategic partner?

This thesis is written in collaboration with the IT consulting firm Capgemini, who works with clients in all industries. Due to the growing demand for *digitalization* in the manufacturing industry, Capgemini wants to know more about their position as a 3rd party service provider within the *digitalization* of the manufacturing industry. Where do 3rd party service providers fit in a *digital transformation*? How can they help their clients adopt digital technologies and assist in a successful transition from traditional manufacturing to a *smart factory*?

The scope of the thesis is the role of 3rd party service providers within a *digital transformation* in the manufacturing industry. The thesis scope is divided into three objectives. The first objective is to review the *smart factory* concept. The second objective will be to collect data for the analysis, and the third objective will be to answer the thesis research question, which is how 3rd party service providers can help companies with a *digital transformation* and to give my recommendations for Capgemini as to where they belong in the *digital transformation* landscape.

1.3 METHODOLOGY

The methodology used in this thesis involves a combination of relevant literature reviews and interviews to explore the topic of *digital transformation* in the manufacturing industry. The approach was to use published articles and reports as primary sources to gain an understanding of the topic and develop a theoretical framework. In addition to the literature reviews, interviews were conducted with companies in the manufacturing industry. The purpose of the interviews was to gain insight into their approach toward *digitalization* and the challenges they faced and to have real-world *digitalization* examples to supplement the research found online. Due to the varying degree of *digitalization* within each company, a semi-structured interview approach was used to ensure that the questions asked were open-ended, allowing for the exploration of various aspects of the topic and that ensured questions would fit every company. The analysis will be delivered on two different levels. Level one will be an analysis based on case studies to create building blocks of a *smart factory* to structure interview questions, and level two will be an analysis based on the interviews. A framework to support the 3rd party service provider's role in a *digital transformation* is created based on the collected data and analysis to complete the third objective.

1.4 LIMITATIONS

The current research for this thesis has some limitations that need to be acknowledged. There has not been provided any access to manufacturing data, which has made it difficult to obtain a complete picture of the manufacturing process and may have limited the accuracy. The same goes for manufacturing plant setups, which could have provided valuable insights into the research problem. Another limitation is the interviews, which were a part of the data collection. There has been a relatively low number of response rate from companies regarding interviews. Even though this has been compensated for with extensive literature reviews, it may have limited the depth of the data collected. Time limitations have also determined the scope of this research, which has shaped the thesis to be limited to the manufacturing industry instead of separate sections for each sector (e.g., healthcare, retail, automobile, Oil & Gas). The interviews were only conducted with Norwegian companies, who may have different digital perspectives and advancements from other countries, which also includes limitations. These limitations should be considered when interpreting the findings and conclusions of this research.

1.5 THESIS STRUCTURE

The thesis is structured in 9 different chapters that are ordered logically, each progressively contributing to completing the objectives. Chapter 2 – Capgemini provides knowledge about Capgemini as a company with their roles and services. Chapter 3 – Theoretical background provides the foundational knowledge for understanding the relevant terms and concepts. Chapter 4 – Review of smart factory concept is research regarding the concept of *smart factory*, with definitions, benefits, and value chain, along with literature reviews regarding *digital transformation*. Chapter 5 – Data collection and further analysis look at case studies regarding *digital transformations* to create *smart factory* building blocks, which creates the basis for interview questions to be conducted with companies from the manufacturing industry. Chapter 6 – Analysis combines analysis of literature reviews and conducted interviews that the results and findings conclude upon. Chapter 7 – Results presents findings with a *digital transformation best practices framework*, along with the role of 3rd party service providers in a *digital transformation* and my recommendations to Capgemini. Chapter 8 – Discussion provides an overview of the thesis, discusses the implications in a broad context, presents knowledge gained throughout the research period, and challenges and further research suggestions. Chapter 9 – Conclusion gives an abstract overview of the main findings of the research, with its purpose and the practical value of this thesis.

2 CAPGEMINI

Capgemini is a global consulting company and a leader in partnering with companies to transform and manage their businesses by harnessing the power of technology [5]. Developed in 1961 by Serge Kampf, Capgemini has throughout forty years, expanded to over fifty countries. With a revenue of twenty-two billion euro and with a clientele most notably consisting of 85% of Forbes Global 2000 [5], Capgemini has made a remarkable impact on the marked of *digital transformation*.

Capgemini assists their client in envisioning their future and encourages them to make bold choices by reimagining, elevating, and optimizing, creating a customized and personalized plan for each client. They imagine and build experiences, products, and businesses that disrupt the status quo, win hearts, and realize the future [6], giving technology the human touch the world needs [7]. Capgemini has recognized not only the importance of *digitalization* but also its importance on socio-economic issues through their ESG (Environmental, social, and governance) policy [8], which not only focuses on their own environmental goals but their clients as well, especially Capgemini's role in helping them reach their client's set goals. This is also reflected in Capgemini's 11^{th} consecutive year, where they are on the list of the world's most ethical companies by Ethisphere Institute [9]. Capgemini continues to challenge the status quo and is constantly pursuing new beneficial approaches for the company and the environment, with a team of brave dreamers and curious rebels [10] with deep industry experience as their base.

2.1.1 Roles

Capgemini works with leading technology companies [11], and their role is to help them deliver exceptional personalized experiences to their customers, harness the potential of data, and optimize the operation of their systems and processes. 95% of Capgemini's revenue is derived from long-term partners, suggesting that Capgemini's role is important to their clients, which creates relationships instead of short-term projects [12].

2.1.2 Services

Capgemini strives for change and transformation through the use of *cloud*, data, *artificial intelligence*, connectivity, software, digital engineering, and platforms, which are technologies they work with as an IT consultant firm. Capgemini focuses on three areas dedicated to digitalizing key management areas at the core of businesses: Customer first, intelligent industry, and enterprise management. This is supported by two technological pillars essential to all forms of *digital transformation* – Data and *cloud*, focusing on the fundamentals of *cybersecurity* and sustainable development [13].

Figure 1 shows what services Capgemini offers.

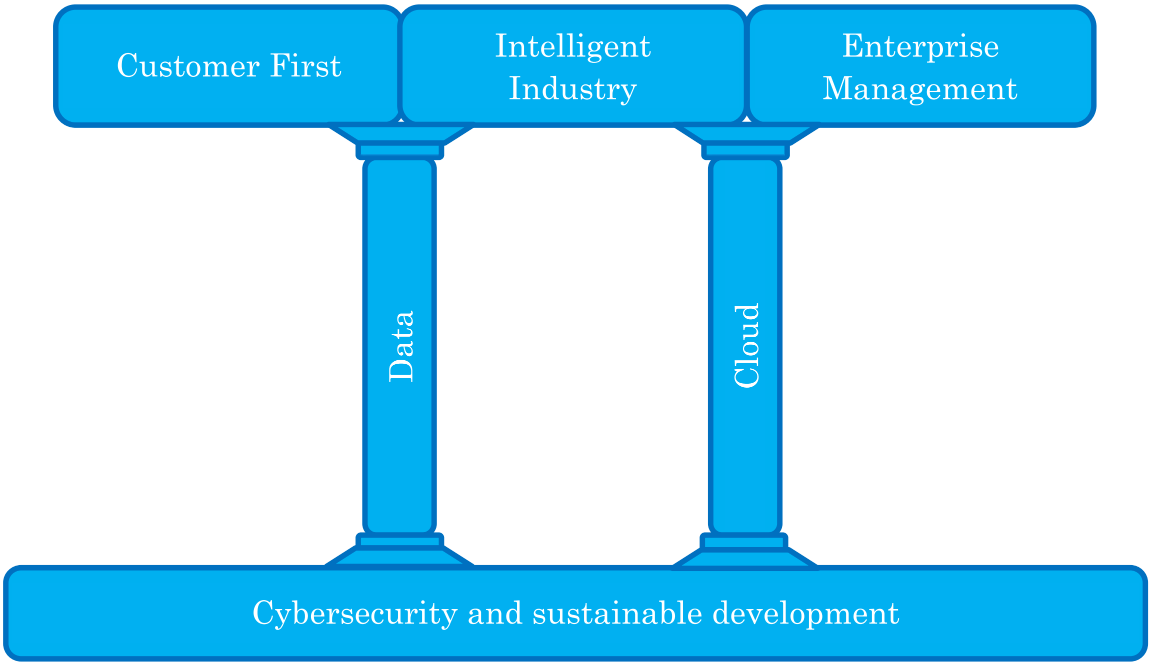

Figure 1 - Services Capgemini offers.

- **Cloud**
  Capgemini delivers *cloud* services for customers interested in enterprise management to modernize and streamline operations and industries like the manufacturing industry to streamline supply chain and manufacturing processes [14].
- **Customer First**
  With a "customer first" mindset, Capgemini offers partnerships to support businesses through continuous business reinvention and focus on customer experience [15].
- **Cybersecurity**
  With *digitalization* comes the need for *cybersecurity*, as connectivity brings the risk of unwanted threats. Capgemini offers *cybersecurity* services where they define a roadmap of where their customer is today and where they want to be tomorrow. They provide services that protect businesses, data, systems, and users [16].
- **Data and artificial intelligence (AI)**
  Capgemini offers *AI*-driven data services, allowing their customers to use their data more efficiently and to use *AI* technology to respond faster to mission-critical decisions with speed, precision, and confidence [17].
- **Enterprise management**
  Capgemini leverages digital business models to transform finance functions, HR services, supply chains, and customer interactions to support organizational needs [18].

- **Intelligent industry**
  With the rise of Industry 4.0 and advanced technology, Capgemini helps clients identify new business models, tackle challenges, and navigate complex ecosystems while integrating intelligence into products, operations, and services. With a focus on human-centered design and breakthrough innovation, Capgemini enables end-to-end transformation, driving enhanced connectivity, efficiency, cost reduction, and revenue stream through servitization models [19].
- **Sustainability**
  With Capgemini's strong ESG policy and a framework for a sustainable journey towards net zero, Capgemini helps customers to adopt a net zero mindset into business models. They also help their customers design sustainable operations, products, and services and enable businesses to monitor and report the journey, generating insights to continuously adapt and adjust the individual sustainable strategy [20].

Capgemini serves as a partner throughout the whole lifecycle, offering services from the start of the design phase to maintenance and decommissioning. When a customer proposes a problem, Capgemini draws from their "toolbox" of industry experts and connections to deliver the necessities. For example, suppose a customer in the manufacturing industry needs to upgrade their maintenance systems. In that case, Capgemini gathers the right expertise to help transform and migrate the old system – database, documents, and platforms over to a new application. Then they can further expand to help with networking and data management and fully utilize the data for predictions or prognostics. Along with the specific services, Capgemini focuses on customer experience and sustainable development that can prove valuable as they contribute to a *digital transformation*.

3 THEORETICAL BACKGROUND

This chapter describes relevant theoretical concepts that will be a part of the first objective. Each section in this chapter has terms to form an understanding and knowledge to support the research topic.

3.1 MANUFACTURING INDUSTRY

The thesis scope is limited to the manufacturing industry, and it is therefore necessary to define and describe what it encompasses. The term manufacturing industry is defined by INSEE as: "*Manufacturing industries are industries transforming goods, that is, mainly manufacturing industries in their own right, but they also concern the repair and installation of industrial equipment and subcontracting operations for third parties*" [21, p. 1]. The manufacturing industry often relies on assembly lines and machinery with large-scale production and has been around since the first industrial revolution [22], but it has drastically changed as technology has become more advanced and available. Since then, digital manufacturing, advanced manufacturing, and intelligent manufacturing have emerged as a description of manufacturing using digital technologies. Advanced manufacturing combines science, engineering, and information technologies to improve existing or create entirely new materials, products, or processes [23]. Even though there are many descriptions of the manufacturing industry, the definition of the manufacturing industry has remained the same. For the context of this thesis, the manufacturing industry refers to- and implies a significant material transformation in a factory environment. Figure 2 shows the process of manufacturing. The cycle starts with raw materials or production parts and then moves to the manufacturing process/operations. Then, parts are delivered, and utilized by the customer, before the part is disposed of or recycled.

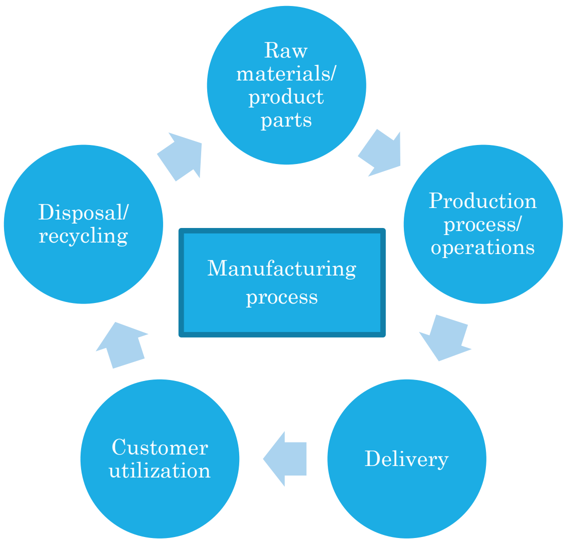

Figure 2 - Manufacturing process/life cycle.

3.2 Traditional factory

A traditional factory is where processes are isolated from one another, where automated processes are separated, and a human workforce is used to handle transitions from one phase to the next. Traditional factories lack connectivity between machines and business processes, which forces manufacturing workers to analyze datasets and produce reports to identify problems and potential areas for improvement. Manufacturing applications are also detached and cannot be used to monitor and control automated processes [24].

Such traditional factory lacks adequate functionality, scalability, sophisticated manufacturing, and well-coordinated connectivity with demand and supply diagnosability. The consequences of sticking with traditional manufacturing on a large scale can lead to factory closures, reduced production and demand, short-time work, and disrupted supply chains. In traditional manufacturing, reusing the same system is not possible, and maintenance costs for old equipment are prone to recurring breakdowns [25].

This does not mean that every stage of a traditional manufacturing process contains manual milling machines and lots of human labor. Traditional factories have automation, robotics, and CNC machines [26], but the description of "traditional" lies in the lack of digital technologies incorporated into the processes, since technology brings productivity, efficiency, and reliability to another level.

3.3 Drivers of intelligent manufacturing and smart factory

3.3.1 Digital domain

Digitization, *digitalization*, and *digital transformation* are terms in the digital domain and can easily be associated with each other as being different words for the same concept. However, these terms are fundamentally different, focusing on distinct aspects within the digital domain.

Figure 3 shows the relationship between the three domains, where *digitization* is a component of *digitalization*, which is a part of a *digital transformation*. One cannot initiate *digitalization* measures before the particular part is *digitized*. The same goes for a *digital transformation*, where you must have parts *digitized*, and *digitalization* efforts must be done before you can undergo a *digital transformation*.

Figure 3 - Digital domains.

Digitization

Digitization is the process of converting analog signals into digital formats [27]. This enables the decoupling of form, function, and access and is essential for developing technological systems. By *digitizing* information, it can be more easily processed, stored, and transmitted, increasing productivity and reducing cost.

An everyday example is how *digitization* has revolutionized the way we access books. In a physical book, form, function, and access are tightly coupled since the text cannot be separated from the pages, and access is restricted to specific channels such as libraries or bookstores. However, with d*igitization*, the same book can be transformed into new digital formats, including e-books and audiobooks, which can easily be downloaded and accessed on tablets, smartphones, and other devices. *Digitization* has enabled the creation of new functionalities, such as digitally searchable and automatically generated summaries, which is not possible in physical books. The same is for music, documents, videos, pictures, and maps. With *digitization*, they can be converted from physical mediums into digital formats, greatly increasing their applications [28]. By identifying analog data streams and converting them into digital formats, businesses can reduce costs [29], increase transparency [30], traceability [31], and improve productivity [32].

It is important to note that the workflow and processes of using the data stays the same. It only changes the format in which the data is stored, processed, and accessed. For example, instead of reading a report from a paper, it can now be read from a monitor. Still, the underlying processes of analyzing, interpreting, and utilizing the data remain the same.

Digitalization

Unlike *digitization*, which only involves the conversion of analog to digital signals, *digitalization* uses digital technologies to change a business model and provide new revenue and value-producing opportunities [33], which is the fundamental difference. *Digitalization* goes beyond data conversion and requires fundamental changes in how the business operates and how data is analyzed, interpreted, and utilized.

Going back to the relatable book example, *digitalization* has enabled a shift from product retail to product access, as customers can now access books digitally instead of through physical products. This changes the business model and has significant implications for writers and distributors, as it directly affects their compensation and how they operate within the industry [34]. *Digitalization* also creates new opportunities for businesses to integrate data from different sources and develop new services and products [35]. Technologies like: *artificial intelligence*, ma*chine learning*, *cloud technology*, and the *Internet of Things (IoT)* can allow businesses to analyze and interpret data in new ways and create personalized data-driven experiences for their customers. Not only is this increasing revenue and profitability [36], but it can improve customer satisfaction by as much as 1.6 times in some cases [37].

Digital transformation

Digital transformation is defined and interpreted in multiple ways, and it can be challenging to fully understand the complete picture. Some describe *digital transformation* as an approach [38] where organizations change their business models based on technology to drive customer satisfaction. Others describe *digital transformation* as a process [39] where the company transforms their products and processes. The book about *Digital transformation* by Lindsay Herbert [40], previously a leader in *digital transformation* at IBM [41] [42], describes *digital transformation* as a process of change that occurs at two different levels of the company. The first level involves implementing new technology into the organization's operations, and the second level involves behavioral and cultural changes to make the organization more resilient.

Since *digital transformation* is more than just about removing paperwork and automating processes though *digitizing* and *digitalization* efforts, but a complete change across all business functions, it's important to understand that *digital transformation* is driven by the recognition that digital technology impacts not only internal operations but also external innovation networks and the overall culture of the organization [4]. Such transformation should start small and, over time, streamline business processes, enhance customer experience, and create new revenue streams [43].

3.3.2 Industry 4.0

Industry 4.0, also known as the fourth industrial revolution (4IR), is the next phase in the *digitalization* of the manufacturing industry [44]. Industry 3.0 (3IR) was about computer technology, electronic systems, and automating processes and operations. 4IR differs from 3IR, where the manufacturing facilities utilize flexible equipment and machinery with network connectivity across the whole value chain [45], transforming how businesses manufacture, improve, and distribute their products.

Figure 4 [45] shows the difference between the hierarchy levels from Industry 3.0 to Industry 4.0, which illustrates the big change, where in 4IR, all assets and processes are connected from top to bottom.

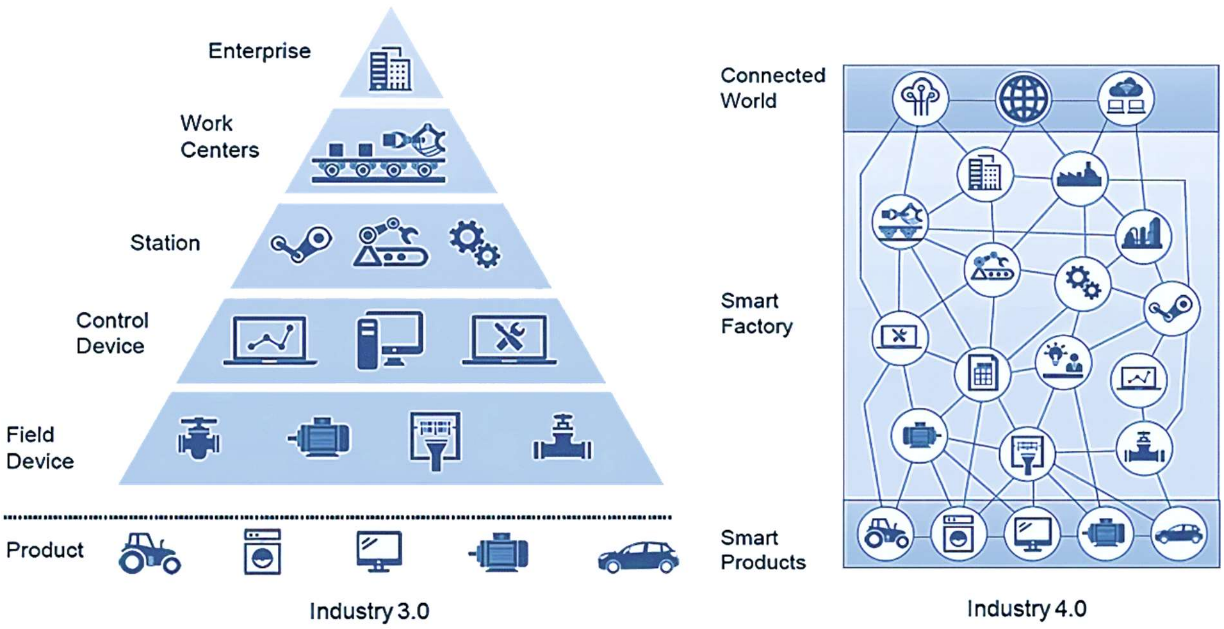

Figure 4 - Interaction between hierarchies Levels in Industry 3.0 and Industry 4.0. [45]

Technology has brought forward this new industrial revolution, as new and advanced technologies enable the ability to collect and share data. The new technology that is the foundation of Industry 4.0 can be categorized into four main categories [44], see Table 1.

Connectivity, data, and computational power: • Cloud technology • The Internet • Blockchain • Sensor	**Analytics and intelligence:** • Advanced analytics • Machine learning • Artificial intelligence
Human-machine interactions: • Virtual reality (VR) • Augmented reality (AR) • Robotics and automation • Autonomous guided vehicles (AGV)	**Advanced engineering:** • Additive manufacturing (3D printing) • Renewable energy • Nanoparticles

Table 1 - Overview of the four main categories of Industry 4.0. [44]

This technology is what brings visibility and insights together by combining data from production with operational data from enterprise resource planning (ERP) systems, supply chains, and customer service systems. It enables increased automation, better maintenance methods, optimization, and improved responsiveness of internal processes. Using *IoT* devices leads to higher productivity and improved quality within manufacturing, where one can replace manual inspection with *artificial intelligence*, and robotics can replace manual labor [46].

Upstream, operations, and downstream activities are all areas that can benefit from Industry 4.0. However, according to the article published by McKinsey & Company, applying these types of technologies is only half of the job [44], which is exactly how Lindsay Herbert described a *digital transformation* in section 3.3.1.

Internet of Things (IoT) / Industrial Internet of Things (IIoT)

The Internet of Things enables Industry 4.0, providing the data necessary for analytics and optimizations essential to Industry 4.0. *IoT* refers to the network of physical assets equipped with sensors, and actuators, allowing the collection and exchange of data and communication over the internet. *IoT* is the term that refers to the connectivity of everyday devices, making them “smarter”. *IIoT*, on the other hand, is aimed toward the industrial side of *IoT*, focusing on industrial applications such as smart manufacturing, power plants, oil & gas, etc. [47]

IoT sensors and devices can monitor and control manufacturing processes like machine performance, product quality, and energy consumption. The data from such processes can be analyzed in real-time to identify patterns and detect anomalies, which can be used to reduce downtime, optimize the manufacturing process, and improve maintenance routines.

Artificial intelligence (AI)

Artificial intelligence was defined by John McCarthy in 2004 as "*It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.*" [48, p. 2].

It is a technology that enables computers to perform advanced tasks that earlier would require human intelligence to complete. It allows computers to reason, learn and act in ways that usually require human intelligence.

Within *AI*, there are several subgroups that focus on specific areas of research and development [49]. *Machine learning*, *deep learning*, *robotics*, and *computer vision* are just a few of the branches used. *Machine learning* involves using algorithms to analyze and learn from data [50]. *Deep learning* involves using neural networks (Involving a third layer, which is between inputs and outputs, consisting of algorithms) to learn and recognize patterns in specific datasets [50]. Robotics involves the development of intelligent machines that can perform tasks autonomously, and computer vision teaches machines to interpret visual data.

In the manufacturing industry, *AI* can be used at an operational level to predict and forecast equipment failure, analyze market demands to adjust production, and eliminate repetitive tasks. This enables the production to be faster and more accurate, reduces human errors, and increases asset availability. At an organizational level, *AI* can optimize and enhance *cybersecurity*, ERP systems, and employee training. [49]

Augmented reality (AR)

Augmented reality is a technology that overlays digital information and virtual objects onto the real world. It is done in real-time and requires a device such as a smartphone, tablet, or smart glasses to display digital content on top of the physical environment [51].

Industrial use cases for AR technology:

- **Equipment data:** Maintenance workers can equip smart glasses to display schematics or user manuals of factory equipment to perform maintenance work more easily.
- **Navigation:** It can display graphical indicators on top of pipes and instruments to show the exact location of the wanted tag number and help with navigation to where the faulty equipment is located in the factory.
- **Tools and measurements:** AR can be used to measure distances by placing 3D points within the user's environment.
- **Employee training:** By integrating AR into the workplace, employees can gain professional skills and learn faster with enhanced educational learning through different AR modules [52].

Figure 5 [53] shows how AR can be used in maintenance tasks. Smart-tablet is used to visually show the technician where different valves and connections are to increase productivity, efficiency, and uncertainty.

Figure 5 - Illustration of AR usage in maintenance task. [53]

Virtual reality (VR)

Virtual reality differs from augmented reality, where the whole environment is virtual/digital. VR technology simulates a user's physical presence in a computer-generated environment viewed through monitors or smart glasses. A computer program can track the movement with motion sensors attached to the device, allowing users to move around in the virtual space [54].

Industrial use cases for VR technology:

- **Maintenance and repair**: Maintenance technicians can use VR to diagnose and troubleshoot in a safe and controlled environment.
- **Collaboration and remote work**: With VR, remote teams can be brought together in a virtual environment to collaborate on projects.
- **Design and prototyping**: 3D models of products and prototypes can be generated, viewed, and tested with VR. This can lower the overall costs of new products by reducing development time, saving resources, and lower costs.
- **Employee training**: VR can also be used for employee training, where real-world scenarios can be generated and used as an immersive and interactive environment to practice different skills. This is especially beneficial when working in high-risk environments, where VR will allow for a risk-free training environment.

Figure 6 [55] shows an example where VR can be used in the manufacturing industry as a tool to monitor and test assembly lines in a safe environment.

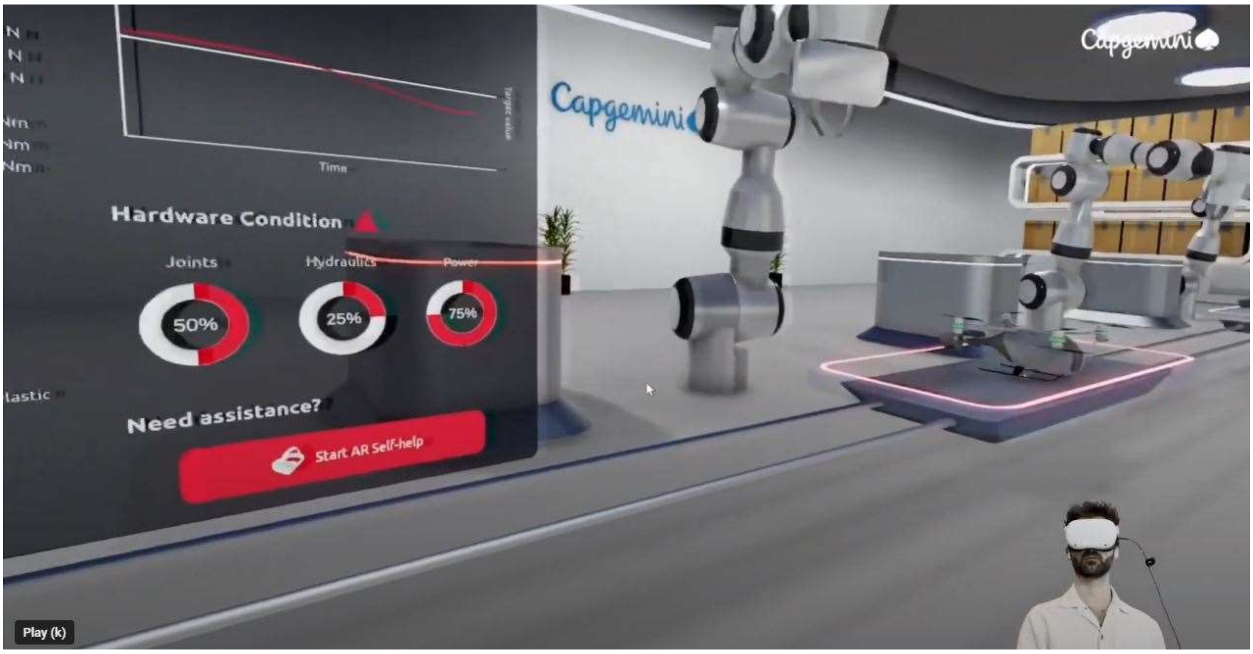

Figure 6 - Illustration of VR in the manufacturing industry. [55]

Cloud technology

Cloud technology is a virtual storage space that exists on the internet, where users can store software, applications, and files and access it remotely, anywhere there is an internet connection, meaning there are no physical location restrictions [56]. Unlike previous storage methods, *cloud technology* offers an option that doesn't compromise capacity, meaning there is no need to upgrade any hardware. This makes *cloud technology* a much better storage solution and more affordable. Scalability is also a factor, as bandwidth and the amount of space can easily be adjusted to individual needs.

Cloud-based *IoT* solutions are essential in the transformation of a traditional manufacturing to a *smart factory*, as it is revolutionizing how data is managed. Since data plays a significant role in intelligent manufacturing, integrating *cloud technology* with *IIoT* allows for the gathering, storing, and processing of production data in large volumes to improve overall production. Supply chain management, inventory management, sales and marketing, product development, and customer service are also elevated with *cloud technology* [57]. With the remote capabilities of *cloud technology*, the organization is also much more connected.

Cyber-physical systems (CPS)

Cyber-physical systems are systems that integrate physical and digital components to create intelligent, connected systems that interact with the physical world [58]. Combinations of physical systems like machines, robots, and vehicles, with digital systems like sensors, controllers, and communication networks, work together to bring significant operational, social, and environmental benefits.

Within the manufacturing industry, *CPS* helps with production reliability by automating processes, providing secure and energy-optimized facilities, and increasing efficiency by monitoring equipment.

Figure 7 [59] shows a concept map designed by professors at the University of California - Berkeley and Ph.D. candidates from various universities to represent the different domains [59] visually. It illustrates the grasp of *CPS*, where *CPS* can be applied, what it enables, and the requirements.

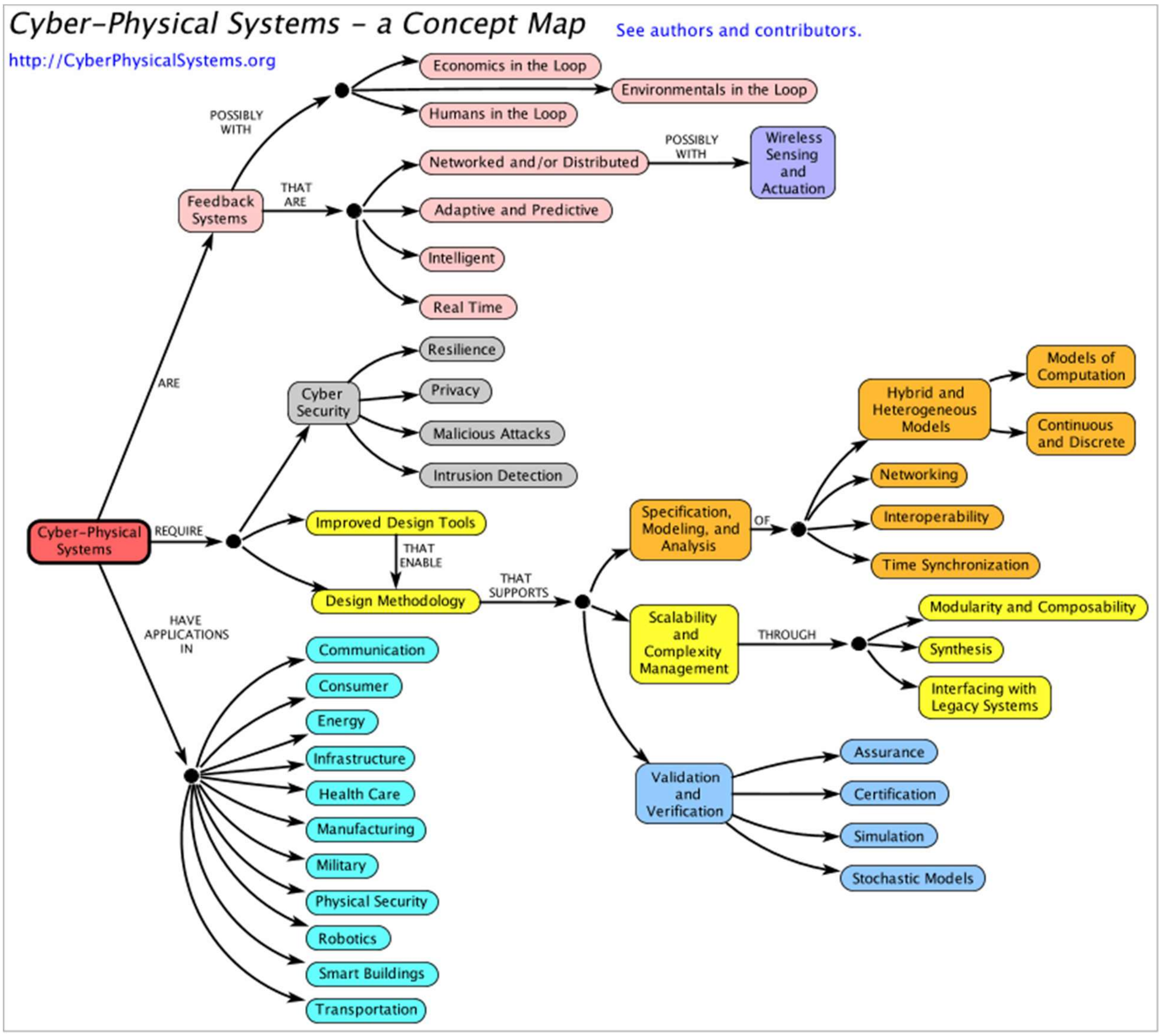

Figure 7 - A concept map of CPS. [59]

4 REVIEW OF SMART FACTORY CONCEPT

The concept of a *smart factory* dates back to 2006, when the term smart manufacturing was first introduced at a National Science Foundation workshop [60]. Smart manufacturing focused on highly connected and information-driven manufacturing. Later in 2011, Industry 4.0 was introduced at the Hannover Messe in Germany [61] along with a published paper from The Smart Manufacturing Leadership Coalition (SMLC), which created a framework for a proposed path forward for smart manufacturing together with a group of over fifty industry leaders [62]. Since then, smart manufacturing, smart plant, and *smart factory* have been used to describe various concepts around technology integration into the manufacturing landscape.

4.1 SMART FACTORY DEFINITION

The definition of a *smart factory* varies, as many interpret the concept differently. Table 2 show different smart factory definitions.

Company	**Definition**
Gartner, the world's leading research and advisory company	*"The smart factory is a concept used to describe the application of different combinations of modern technologies to create a hyperflexible, self-adapting manufacturing capability. Smart factories are an opportunity to create new forms of efficiency and flexibility by connecting different processes, information streams, and stakeholders (frontline workers, planners, etc.) in a streamlined fashion. Smart factory initiatives might also be referred to as "digital factory" or "intelligent factory."* [63, p. 1]
TWI-Global, one of the world's foremost independent research and technology organizations	*"A smart factory is a digitised manufacturing facility that uses connected devices, machinery and production systems to continuously collect and share data. This data is then used to inform decisions to improve processes as well as address any issues that may arise."* [64, p. 1]
SAP, a German multinational software company	*"Smart factory is a cyber-physical system that uses advanced technologies such as artificial intelligence (AI) and machine learning to analyze data, drive automated processes, and learn as it goes."* [65, p. 1]

Table 2 - Smart factory definitions

Gartner defines a *smart factory* as a factory that uses technology to streamline processes, information streams, and stakeholders to become more efficient, flexible, and self-adapting.

TWI-Global defines a *smart factory* as a manufacturing facility that connects devices, machinery, and systems to collect and share data, to then use the data to improve processes and address issues. SAP defines *Smart factory* as a CPS that uses advanced technology to analyze data, automate processes, and self-adapt. All three definitions share the idea of a manufacturing facility that uses technology to improve operations by utilizing collected and shared data. TWI-Global and SAP only include technology in the definition by saying that connected machinery, data collection, and *AI* makes a *smart factory*. But what about the human aspect? Only Gartner includes people (Stakeholders). "smart" means that someone or something can learn and understand things easily [66]. You could say that self-adapting systems can be called smart, but without streamlined processes regarding human and organizational aspects, there are a lot of missed opportunities. Table 3 clarifies the distinctions between the three definitions, showing how each compared definition aligns with different smart factory dimensions.

Aspect	**Gartner definition**	**TW-Global definition**	**SAP definition**
Main concept	Application of modern technologies	Digitized manufacturing facility	Cyber-physical system
Technologies used	Combination of modern technologies	Connected devices, machinery, and production systems	Advanced technologies such as Artificial intelligence and machine learning
Manufacturing approach	Hyperflexible, self-adapting	Continuous data collection and sharing	Data analysis, automated processes, and learning
Efficiency	Create new forms of efficiency and flexibility	Improve processes and address issues	Drive automated processes
Connectivity	Connect processes, information streams, stakeholders	Collect and share data	Analyze data
Human/organization	Connect stakeholders to other processes.	-	-

Table 3 - Differences in smart factory definitions.

4.2 DIFFERENCE BETWEEN TRADITIONAL AND SMART MANUFACTURING

With a better understanding of the *smart factory* concept, the differences between traditional manufacturing and smart manufacturing can be compared. The two manufacturing processes are vastly different, and Table 4 [25] shows a clear line between the two manufacturing processes. There are the traditional methods, with little to no technological intervention, inefficient processes, and wrong organizational culture on one side, and fully streamlined smart manufacturing, where technology, processes, and organizational aspects work together on the other side.

Traditional manufacturing	**Smart manufacturing**
A stand-alone, manual, isolated process with separate systems that are not capable of automated monitoring and control.	A dependent, strongly related, and closely linked system that continuously communicates and collaborates is backed by automation, monitoring, and control capabilities.
Humans are in charge of machine operation and control.	Machines and robots interact with, without, or with little human intervention.
There is no plan to develop an action through equipment that learns from processes; therefore, gathering, evaluating, and updating information is carried out manually.	It is possible to collect, analyze, update, and develop an action that learns from data-driven processes.
The manufacturing line is fixed, and the system must be shut down before any reconfiguration occurs.	The production line is dynamic and can be maintained without being disconnected from the power supply.
The production process is centrally managed.	Decentralized production processes.
A less productive, flexible, sustainable system. Enterprise competitiveness suffers as a result of wasteful resource utilization.	More competitiveness is achieved by increased productivity, flexibility, sustainability, and efficient resource usage.
A considerable number of inexperienced operators are engaged. As a result, the factory's production line has increased labor costs.	At a lower cost to the manufacturing, a workforce skilled in developing and operating intelligent devices is brought on board.
There is a lack of self-optimization and reconfiguration of production systems to learn and respond to shifting demand patterns.	Self-optimization and reconfiguration, production systems that learn and adjust to changing demand patterns, are available.

Table 4 - Traditional manufacturing vs. Smart manufacturing [25]

4.3 BENEFITS OF A SMART FACTORY

The benefits of a *smart factory* are clear. A *smart factory* is a manufacturing facility with Industry 4.0 and the right organizational culture to enhance production. With highly automated and interconnected networks of machines that use real-time data and analytics to optimize production processes, smart factories are a lot better suited to respond to changes in market demands than traditional factories. Since a *smart factory* is a *cyber-physical system* that utilizes *IoT* and *AI* technology, product quality is be improved, waste and downtime can be reduced by as much as 30-50% [67], and throughput increased by as much as 10-30% in some cases [67]. Using automated processes with robots and computer-aided machines is not unique to smart factories. Traditional factories also have such systems, but the difference is that every process in a *smart factory* is digitally connected to form an ecosystem. The system learns from data sets, events, and forecast trends and adjusts the workflow of assembly lines accordingly. *Smart factory* undergoes continuous improvement to self-correct and self-optimized [65]. A *smart factory* is where processes are streamlined with one another, where automated processes are connected, and automated machinery is used to handle transitions from one phase to the next. Smart factories have connectivity between machines and business processes, where computers analyze datasets and produce reports that identify problems and potential areas for improvement. A *smart factory* has functionality, scalability, sophisticated manufacturing, and well-coordinated connectivity with demand and supply diagnostics [25]. This is where the real benefit and difference from a traditional manufacturing facility lie.

To categorize areas that a *smart factory* enhances, we can see how productivity and efficiency, sustainability and safety, and product quality and customer experience gain benefits.

- **Productivity and efficiency**
  Within a *smart factory*, automation, data-driven analytics, and demand forecasting allows for better productivity, capacity utilization, and production output. Digital tools and insights also help workers to streamline their efforts toward the operation. A study [68] done by Deloitte reflects this, as their findings about *smart factory* initiatives reported, on average, 10-12 percent gains in these areas.
- **Sustainability and safety**
  Due to customers' growing demand for sustainable products [69], smart factories can make it easier to identify and implement opportunities for more green, safe, and socially responsible manufacturing practices [65]. Technology also enables better tacking and quality control of goods and raw materials. The safety of factory workers is also increased with automation and robotics. According to a report from the International Society of Automation [70], three out of the five leading causes of workplace injuries can be prevented with automated devices.

- **Product quality and customer experience**
  In traditional manufacturing, communication with suppliers and ensuring that guidelines are followed can be challenging [71]. But with increased visibility and connectivity, smart factories communicate across the whole value chain, enabling faster and better improvements across all operations. This allows for faster response to shifting trends, leading to improved competitiveness in the market and better customer relations [65].

Figure 8 [67] shows the potential value of adopting Industry 4.0.

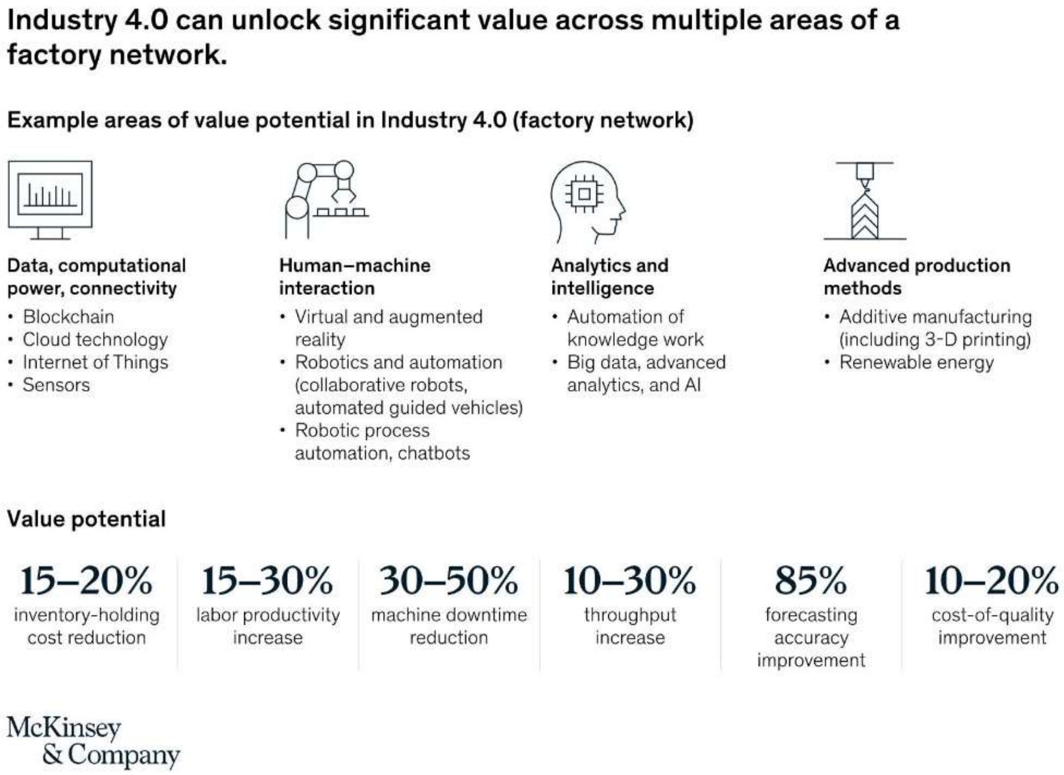

Figure 8 - Value potential of smart factory and Industry 4.0. [67]

4.4 Value chain

The value chain refers to different activities and processes companies are involved in when creating a product or service. The value chain consists of multiple stages, capturing many aspects of the product or service lifecycle [72]. The Porter value chain is a fundamental framework for understanding and optimizing a company's internal activities. The value chain framework breaks down a company's operations into two activities, enabling organizations to identify the components needed to succeed. Figure 9 [73] shows the components of Porter's value chain model with the two activities.

Figure 9 - Porter's value chain model. [73]

In the manufacturing industry, we can break down the components as follows:

4.4.1 Porters value chain - Primary activities

Inbound logistics

Since the manufacturing industry produces products, they need raw materials. Inbound logistics is about managing the supply chain from sourcing, transporting, and storing raw materials.

Operations

Operations activity represents the core manufacturing process. This is where the raw materials are transformed into finished products. Operations such as machining, assembly, quality control, and product scheduling are all activities in this component.

Outbound logistics
Order processing, packaging, warehousing, and transportation are all important activities that encompass outbound logistics to ensure that the finished product is distributed.

Marketing & Sales
Marketing and sales involve promoting manufactured products, identifying customer needs, and generating demand to increase sales and revenue. This activity is needed for companies targeting B2B (Business to Business) and B2C (Business to customers) sales.

Service
Manufacturing companies must offer service policies for their products to stay competitive. This includes post-sale support warranty management, repairs, and maintenance services.

4.4.2 Porters value chain - Support activities

Firm infrastructure
Firm infrastructure includes manufacturing facilities, equipment, IT systems, and organizational structure.

Human resource management
Human resource management encompasses all activities revolving around employees. It is not only the people who work but activities regarding recruitment, training, performance management, welfare, and development plans.

Technology development
Staying competitive needs a constant focus on research, development, and innovation to enhance manufacturing capabilities. Technology development activity involves research and development, technology acquisition, and process improvement.

Procurement
Procurement includes activities such as selecting suppliers, ordering raw materials, negotiating pricing, and contract management.

Evolution of Porters value chain

Porter's value chain framework is a great tool for categorizing business activities to identify areas for cost reduction, differentiation, and competitive advantage. But as the business landscape continues to evolve, there is a need to revisit and expand upon this traditional view. The reasons are that Porter's value chain focuses primarily on internal activities and efficiency improvements within a single organization. In today's globalized and interconnected world, the value chain has become more complex [74] and extends beyond individual companies. The modern value chain encompasses much more, as it extends to multiple stakeholders, suppliers, partners, and customers on a global scale. This shift is driven by the increased specialization and outsourcing of various activities to different geographical locations to take advantage of cost efficiencies and expertise. Over the last twenty years, the global outsourcing market has grown by more than double [75], and the main reasons are cost reduction and flexibility [76]. Along with a more globalized market, the value chain evolution is tied to technology advancement, as real-time information flow, data-driven decision-making, *IoT,* and *Cloud technology* have enabled companies to gather and analyze data throughout the whole value chain.

4.4.3 Industrial agility (IA)

Industrial agility is a term that describes a company's ability to embrace flexibility, adaptability, and readiness for change or to meet stochastic industrial demands [77]. *Industrial agility* offers a new perspective on the traditional value chain, going beyond internal operations and considering the broader ecosystem in which companies operate. The traditional value chain can be enhanced to accommodate the changing dynamics of the modern manufacturing industry by examining the inbound and outbound activities of the value chain and the processes that connect them.

Information flow

Connecting processes with inbound and outbound activities, there is upstream agility that focuses on managing strategic relationships with suppliers and services. This enables companies to adapt and stay flexible to handle risks and opportunities related to technical or supply interruptions. Downstream agility focuses on meeting customer demands and dynamically responding to market changes by being customer-driven, providing customer-centric products and services, and adapting to changing market requirements. Lastly, cross-functional agility supports the other streams by integrating the various functions within the organization. Communication, collaboration, and decision-making must all be seamlessly integrated to ensure that the different departments work together toward common goals and respond to industrial uncertainties. This achieves overall adaptability and readiness and is strengthened by creating a culture that embraces innovation, learning, and continuous improvement.

Dataflow of a smart factory

To achieve *IA* within the value chain, it is essential to consider the role of dataflow. The dataflow of a *smart factory* can be viewed to understand how the availability of real-time data, analytics, and connectivity across various stages enhances decision-making and operational efficiency to enable a robust and agile value chain. The dataflow contains a continuous feedback-loop and involves monitoring, optimizing, and adjusting production based on external and internal inputs. With this flexibility and adaptability, *IA* can be achieved.

Figure 10 summarizes and visualizes the technological aspect of a *smart factory* and how the data flows from data collection to the analysis step and then to data usage [65].

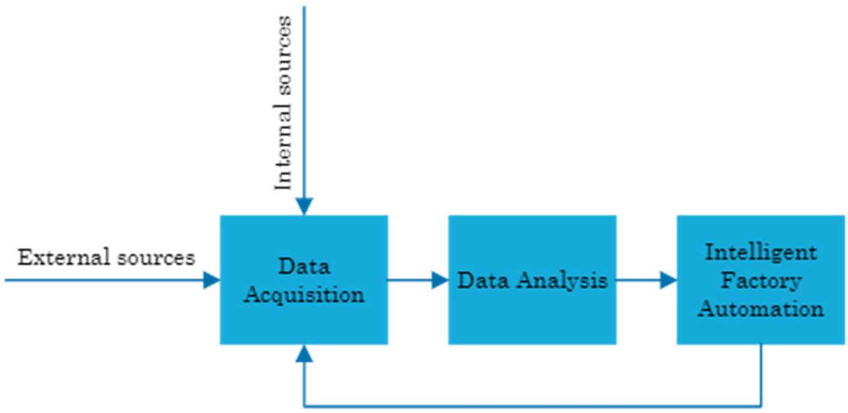

Figure 10 - The three steps of dataflow within a smart factory.

1. **Data acquisition**
   The first step in the technological aspects of a smart factory is when information from internal and external sources is gathered with the help of technology like *AI*, modern databases, *IoT* devices, and other connected systems.
2. **Data analysis**
   Once the data is acquired, information on performance, market trends, logistics, and other potentially relevant sources is analyzed. *Machine learning*, advanced analytics, and data management solutions will use this data to warn when machines need repair or maintenance. Market and operational data can be analyzed to find opportunities and risks. Operational and organizational workflow can be optimized, and data can be compared and analyzed for supply chain forecasting.

3. **Intelligent factory automation**
   The final step is where the acquired and analyzed data is used. This data is sent to the machines and devices within the system and is constantly used in real-time. The operation data is fed back into the system under a continuous data loop. This is where smart workflows and processes are monitored continuously, optimized, and adjusted. Machines will automatically change production rates if there is a sudden change in market needs. If there is a delay in raw material, buffers can be used to compensate for any disruption.

The three steps highlight how modern technology is used in a *smart factory* environment to make *IA* happen. The dataflow has a critical role in directly enhancing upstream and downstream agility. The dataflow extends beyond the company's internal operations to various stakeholders, including suppliers, partners, and customers. Figure 10 shows only the general principle of dataflow internally, but it can be extended further from the internal and external sources enabled via other Industry 4.0 technologies.

4.4.4 3rd party service providers in the manufacturing value chain

Looking at the different Porter value chain activities, 3rd party service providers fit mostly with the support activities. Even though 3rd party service providers could assist in the primary activities, they have a more prominent role in the support activities. By partnering with 3rd party service providers, companies can get support in certain value chain activities.

Firm infrastructure

3rd party service providers can support the infrastructure needs of a *smart factory* by offering services to support the operational needed to upkeep facilities, equipment, IT systems, and organizational structure. They can provide technical expertise, software solutions, and consulting services to optimize the factory's infrastructure and related support systems.

Human resource management

Regarding human resource management, 3rd party service providers can provide recruitment services based on specific needs the manufacturing company seeks. This can be coupled with training and employee follow-up. Manufacturing companies might lack adequate resources or expertise needed to uphold a strong workforce, where 3rd party service providers can supply tailored training programs specific to the manufacturing industry.

Technology development

This support activity is slightly connected to the firm infrastructure activity, as many of the services that 3rd party services providers can help with regarding firm infrastructure overlap with technology development activities. Many solutions that help companies support their infrastructure will also add to the company's technological developments. A few examples where 3rd service providers contribute to technology development are offering software development, data analytics, and *IoT* implementation services. They can also help develop and customize technology solutions that align with the *smart factory* needs.

Procurement

Within Procurement, 3rd party service providers can assist with their access to a broad network of suppliers or specialized knowledge in specific industries, which would allow them to assist with sourcing, negotiating contracts, and managing relationships with different suppliers

4.4.5 3rd party service providers as Industry Agility enablers

From Porter's value chain perspective, 3rd party service providers have a more prominent role in support activities. But looking at the value chain from an *industry agility* perspective, 3rd party service providers fit throughout the whole value chain, and their services will enable companies to be better prepared and to handle disruption. In upstream agility activities, 3rd party service providers can leverage their specialized expertise and connections to provide industry practices and technologies, allowing companies to allocate resources elsewhere. Regarding resources, 3rd party service providers allow for more flexible resource allocation. Instead of maintaining a large in-house team for every business function, 3rd party service providers can be used, allowing the companies to scale their operations up and down based on demands, to better respond to market fluctuations. 3rd party service providers can also be leveraged for risk mitigation. Supplier delays can cause problems for manufacturing companies that rely on a single supplier for raw materials. When a delay occurs, the manufacturer is left waiting for the supplier. If 3rd party service providers were responsible for inbound logistics, these providers could leverage their connections to source the same raw materials from one of their other suppliers. Same with risks in unexpected maintenance issues, which can cause production delays. The manufacturer would notice problems with their machines after completing an operation, then call for assistance and wait for troubleshooting and fixes. But by connecting 3rd party service providers to equipment data that reports any deviations during operations, 3rd party service providers can preemptively work on solutions.

4.5 SUCCESSFUL DIGITAL TRANSFORMATIONS: FACTORS, TECHNOLOGIES, AND PITFALLS.

As discussed in section 3.3 about *smart factory* drivers, *digitization*, *digitalization,* and *digital transformation* are important steps to becoming a *smart factory*. Since *digital transformation* happens at two levels, this section reviews published research on factors that leads to a successful *digital transformation*.

4.5.1 Digital transformation strategy

Since *digital transformation* goes beyond *digitalization* and is a strategic business transformation that requires both technology and organizational change, a digital transformation strategy is vital for success. Less than 30% [78] [79] [80] of companies succeed in a *digital transformation*, indicating that companies lack the knowledge on how to transform their business and how to avoid common pitfalls.

Digital transformation success factors

McKinsey & Company's study [78] on key factors in successful *digital transformation* highlights twenty-one factors to success, falling into five categories.

- **Having the right, digital-savvy leaders in place**
  Transformation success is more likely when organizations have leaders familiar with digital technologies and dedicated leaders for the change effort. Engaging a leader to support the transformation showed 1,6 times more likely to report a successful *digital transformation*.
- **Building capabilities for the workforce of the future**
  Developing talent and skills throughout the organization, redefining roles, and engaging integrators and technology innovation managers. McKinsey & Co. survey reported a 1,5 times likely success when individuals' roles were redefined to align with the company's transformation goals.
- **Empowering people to work in new ways**
  Cultural and behavioral changes, such as calculated risk-taking, collaboration, and customer focus, are supported by establishing new practices, involving employees in *digitization* ideas, and encouraging challenging of old ways of work. The survey reported a 1,4 times likely success if employees had a say on where *digitalization* could and should be adopted.
- **Giving day-to-day tools a digital upgrade**
  Digitizing tools, implementing self-serve technologies, and modifying procedures with new technologies. The survey showed great success when changes involved using digital tools a new organizational norm. Another key factor what adopting digital tools to make information more accessible across the whole organization, which in reported cases leads to a 2,0 times increase in success.

- **Communicating frequently via traditional and digital methods.** A factor to success is clear communication of the change story to employees. A change story that helps employees understand where the organization is headed, why the change takes place, and its importance.

Figure 11 [78] shows the result from a McKinsey & Co survey that indicates how companies should make the technology-supported changes that different successful digital transformations from the rest.

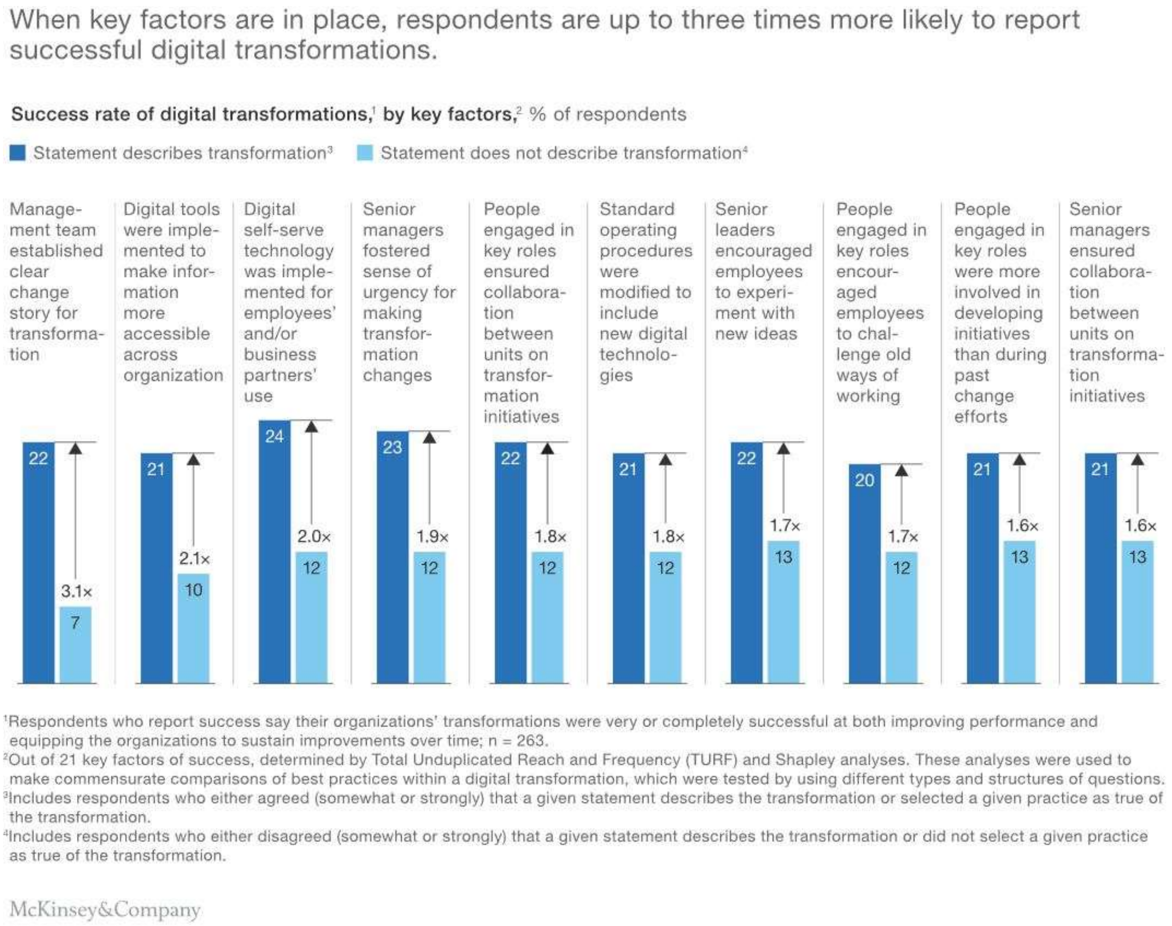

Figure 11 - McKinsey & Co survey results on key factors for a successful digital transformation. [78]

Forbes published an article [81] in Jan. 2023 on Rick Kelly's six tips to help ensure a successful *digital transformation*, where he shares six key success factors he has gathered from his experience in the *digital transformation* scene.

- **Start with a strategy and outcome-focused approach.**
  First, a strategic plan that encompasses short-term and long-term objectives must be created. The focus must be on the company's desired outcome, align with how people work, and prioritize security and compliance to ensure successful long-term results like scalability and resilience.
- **Choose the right talent for the outcome in mind.**
  Create a team that consists of members with experience in the relevant domains. Along with specific skillsets, build the team with overlapping domain experience.
- **Create an adoption plan.**
  Successful transformation requires user adoption and integration into daily workflows. This requires the involvement of stakeholders to provide input to avoid resistance and ensure a smooth launch.
- **Address obsolete processes and policies.**
  Identify and address existing processes and policies that might hinder the benefits of *digital transformation*. Implement new systems in incremental releases to gradually transition to the desired end-state.
- **Ensure complete alignment across the organization.**
  Create an understanding from all levels of the organization regarding the changes, and communicate the phased approach and long-term commitment required for successful transformation.
- **Operate with an agile and resilient mindset.**
  Agile methodology throughout the transformation is key to success. Have regular and iterative releases to gather feedback to ensure the projects stay on track and deliver the intended value.

Both McKinsey & Co and Rick K. capture the same success factors that other research [82] [83] [84] [85] suggests regarding a *digital transformation*. However, most of these factors are pointed toward organizational measures and creating a backbone for a successful transformation. Since a *digital transformation* also includes technology integration and advancements, implementation strategies regarding technology should be included. A report [86] by AcaTech suggests following an Industry 4.0 development framework to help implement technological measures.

Industry 4.0 development stages

Acatech has developed an Industry 4.0 development path, which supports the strategic implementation of Industry 4.0 to succeed in a *digital transformation*. Figure 12 [86] shows a suggested development path designed by Acatech and the different intelligence levels a factory can achieve.

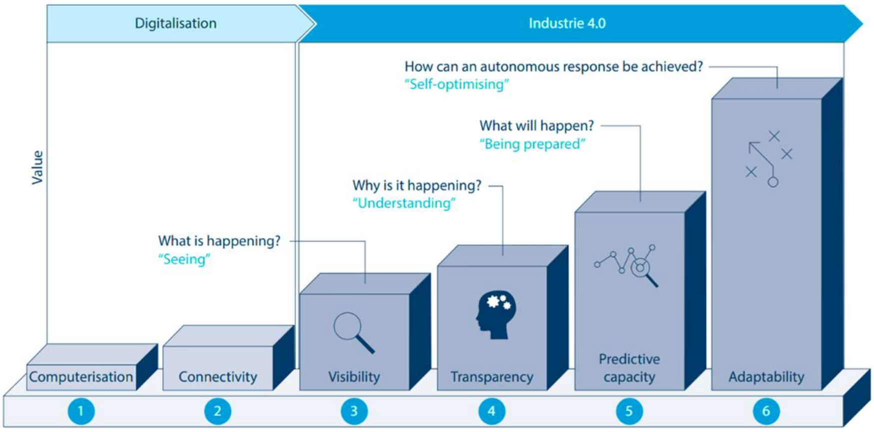

Figure 12 - Stages in the Industry 4.0 development path. [86]

By using such development path as a framework for a *digital transformation*, companies can identify on what level they are on and which Industry 4.0 capabilities they still need to develop. A tool that gives companies a step-by-step approach to how such transformation should be tackled is vital since *digitalization* initiatives that are rushed, without a well-thought-out process or performance infrastructure, often lead to failure [87]. With such plan, the entire organization can visualize the journey and plan towards the next step to ensure the transition from the *digital transformation* is successful.

Technologies that lead to success

Regarding technology, McKinsey & Co.'s survey [78] captured different technologies and how organizations deploying more technologies than others had more successful digital transformations. Cloud-based services, mobile internet technologies, *IoT*, and design thinking were the different technologies that showed significant benefits. Figure 13 [78] shows the results.

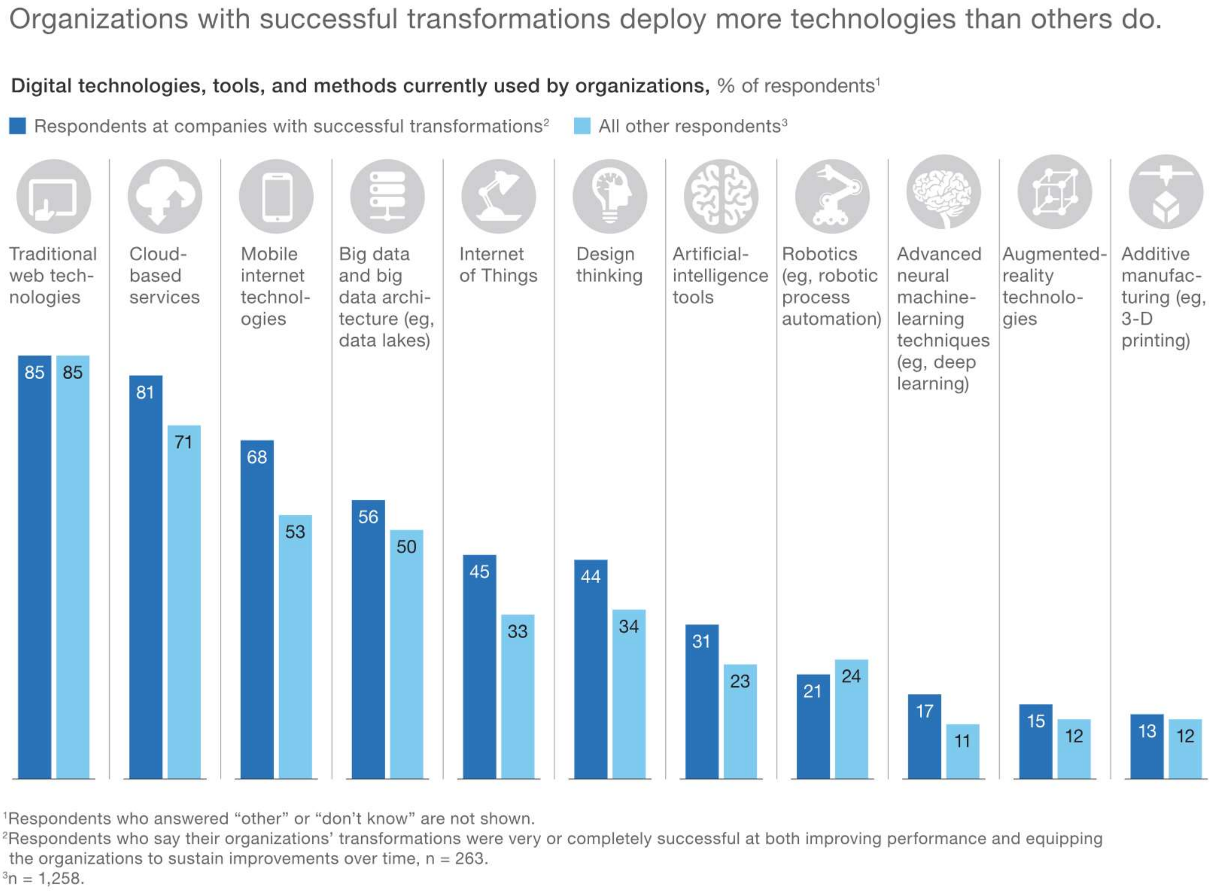

Figure 13 - Technologies that lead to a successful digital transformation. [78]

4.5.2 Digital transformation pitfalls

Common pitfalls in *digital transformation* contribute to the low success rate. Jon Garcia, founder of McKinsey's RTS unit and senior partner and leader in McKinsey's transformation practice, mentions three common pitfalls [88] companies fall into when trying to *digitalize*. The first is failure to set fact-based, high aspirations. Company leaders rely on consensus rather than data-driven decision-making and must set fact-based targets to succeed. The second is a lack of communication about why the company must make such changes. A *digital transformation* requires the whole organization to be on board, and leaders must provide all their employees with a compelling reason explaining why they should do things differently. According to Jon G., the third cause for transformation failure is poor execution, where managers focus on activities surrounding the transformation rather than the desired outcome.

Sandra Parker, who has more than ten years of experience in the IT-sphere and works on accelerating businesses through *digital transformation*, lists her four biggest *digital transformation* mistakes [89], which are:

- Adopting technology for the sake of technology
- Considering *digital transformation*, a one-time thing
- Collecting data and failing to use it
- Underestimating the importance of cultural change in a *digital transformation*

US-based IT consulting firm Vertis also address the same pitfalls [90] as Jon Garcia and Sandra Parker. Unclear goals, ignoring data, and internal resistance are the same pitfalls that Vertis mentions as to why companies fail regarding their transformation journey. In addition, Vertis highlights a few others. Lack of IT skills is one pitfall, where the lack of the right skillset can significantly hinder the *digital transformation* journey, as such transformation require expertise in skillsets many may not be aware of and can even jeopardize operations. Another pitfall is when companies set unrealistic deadlines. A *digital transformation* isn't a one-time setup but a continuous process that requires interim goals rather than a concrete deadline.

IT company Accenture conducted a survey where more than 1350 global senior executives from key industrial sectors participated. The survey aimed to find reasons why *digital transformations* fail, and in the final report [80], they concluded with the same pitfalls and challenges as Jon G., Sandra P., and Vertis.

4.6 SMART FACTORY MATURITY LEVELS

Smart factory maturity levels refer to the stages of development and implementation of smart technologies and processes within a manufacturing facility. These levels typically present the progression from traditional manufacturing practices to highly advanced and digitally integrated smart factories. While the specific categorizations may vary, a commonly used model for *smart factory* maturity levels includes the following stages, as seen in Table 5 [91].

Maturity level	**People** **Cultivate digital people**	**Process** **Introduce agile processes**	**Technology** **Configure modular technology**
Level 4. Smart, predictable manufacturing	Create a culture of continuous smart factory innovation. Create specialized roles and responsibilities geared toward predictable production.	Develop processes for integrating data visualization into decision-making. Create proactive processes for forecasting and planning future production.	Create systems to monitor and visualize critical operational analytics. Integrate digital system insights from external partners to enable supply chain predictability.
Level 3. Real-time process analytics and optimization	Organize sense-making sessions with suppliers, users, and other stakeholders. Recruit data analysts and data scientists to optimize production.	Use insight analysis and data interpretation to streamline operational processes. Create processes for evaluating optimization opportunities.	Implement systems for real-time performance analysis. Implement simulation systems to test, prototype, and optimize the digital factory.
Level 2. Structured data gathering and sharing	Educate people to develop the ability to exploit connected data systems. Revise production staff roles to proactively coordinate digital insights and knowledge sharing.	Create specialized insight-mining processes to support information gathering across departments. Build cross-functional digitalization networks to facilitate knowledge sharing.	Increase the accuracy of data collection from technology. Create automated processes for data mining and sharing across functions.
Level 1. Connected technologies	Create an inclusive culture for implementation by involving workforce in vision development. Recruit people with digitalization competencies.	Formalize hybrid smart factory implementation processes. Create process for involving external actors in development of connected platform.	Apply a digital lens to map existing and new technologies. Connect existing technological applications to create data flow.

Table 5 - Smart factory maturity levels. [91]

5 DATA COLLECTION AND FURTHER ANALYSIS

In Chapter 4, the *smart factory* concept was described, defined, and compared with more traditional manufacturing. This chapter aims to provide a more detailed classification of the various attributes of a *smart factory*, breaking it down into building blocks based on case analysis and reviews of relevant literature. The goal is to give a comprehensive breakdown of the structure of a *smart factory* and to give a better understanding of the different parts a *smart factory* consists of.

In addition to the general breakdown and classification, the building blocks will be used in the interviews in Chapter 5.3. When a *smart factory* has been divided into smaller blocks, interview questions can be designed to focus on each separate part of a *smart factory*. This makes the questions better organized.

The goal of the building blocks is also to deliver a more comprehensive recommendation on how 3rd party service providers can assist in a *digital transformation*. By segmenting *smart factory* this way, recommendations can be created to directly target specific blocks and better specify the role of 3rd party service providers in a *digital transformation*.

5.1 CASE STUDY

To develop the building blocks, case studies of different *smart factory* initiatives and *digitalization* efforts have been done to analyze what measures different companies have taken to improve their production.

5.1.1 Stabburet case

The facts about this case are based on an industrial case presented by a Norwegian engineering magazine: Teknisk Ukeblad [92].

In 2017, a Norwegian food company called Stabburet decided to upgrade one of their factories that produces canned liver paste due to a combination of old manufacturing processes from the 50s and a 10-15% increase in sales in 2015 and 2016. The company achieved numerous gains, increasing the production capacity from 4000 to 7500 tons per year, reducing manual stations from sixteen to only three, and almost halving the sickness absence. During Stabburet's transition from traditional manufacturing to a *smart factory*, Stabburet had help from external partners to replace their manual production processes with automation, increasing their number of robots from one to 18. Along the two new production lines, they installed machines connected via an overarching system, where every machine communicated with each other to ensure a smooth production flow. They also ensured that the entire system was based on one shared platform.

During the upgrade, challenges with the aluminum cans emerged. In the canning industry, magnets are usually used when robots move cans from one process to the next. But due to the aluminum cans, they had to install specific suction and vacuum equipment to ensure the cans were moved properly in difficult environments with moisture and the need for gentle movement. Human-machine interfaces were also installed to operate the production remotely. With this *digital transformation*, Stabburet made changes in their departments regarding how they separated employees. Previously, they had a technical department and shop floor operators, but this was changed into a single group of technical operators. Automated production and the merged department allowed for the development of an internal apprenticeship program, allowing technical operators to perform simple maintenance themselves. Stabburet's new factory, with its increased automation, also allowed them to host external apprenticeship programs in the automation field, which was impossible before.

Stabburet case analysis

From this Stabburet case, we can see how their new production lines can be divided into four different building blocks, each emphasizing the important characteristics of a *smart factory*. We see the addition of <u>automation and robotics</u>, where the article mentions that they increased their robot count from one to eighteen, reducing their manual stations from sixteen down to only three. This implies increased productivity, efficiency, and quality, reduced costs, and increased HSE. The gathered statistics reflected this, almost doubling the production capacity from 4000 to 7500 tons per year and almost halving the employee's sickness absence. These are also expected improvements when automating production, as automation and robots perform tasks with much higher precision, improving work quality and increasing safety [93].

<u>Connectivity and communication</u> and <u>IoT and sensors</u> building blocks can be created based on their decision on shared platforms, connected machinery, and new equipment, which contribute to the increased production capacity of the production lines. These are also measures that can be tied to the reliability and scalability of the production lines. By utilizing a shared platform for all of the new equipment, system reliability is increased, and with the importance of scalability for further factory development, *digitalization* measures that Stabburet used will contribute to lower costs associated with additional upgrades.

Organizational measures were done, which highlights one of the key principles of *digital transformation* mentioned in section 3.3.1, which emphasizes the importance of organizational contribution and cultural change. Previously siloed departments were merged, and employees were cross-trained to perform tasks to further increase productivity in the factory. This empowerment of operators to take on more responsibility will most likely lead to increased long-term profitability and can lead to increased job satisfaction and engagement due to the fostering of a greater sense of ownership and responsibility among employees. [94]

5.1.2 Takeda case

The facts about this case are based on an industrial case presented by Triple-S [95], who was a part of Takeda's *digitalization* efforts:

Takeda is a global pharmaceutical company with a factory in Asker, Norway. They produce calcium tablets with flavor and vitamin additives. Takeda has a strong foundation in lean practices and a culture among operators and management who work in a structured manner towards daily improvement. In addition to organizational engagement, the factory already has a big presence of automation. In 2019, Takeda started their next step toward a *digital transformation*. Takeda started the initial phase by creating a digital version of the *digital transformation* within the leader groups in the factory. This was done to get an overview, to ensure that the right *digitalization* measures were done, and to make sure all the leaders were on the same page and understood the importance of this new initiative. Then they focused on establishing an operational technology network (OT-network) to collect data from machines and production equipment. This data would allow Takeda to analyze and identify causes and correlations for irregularities in their production. This would also allow for predictive maintenance and *AI* technology in the future.

At Takeda Globally, there has been a big focus on automation, meaning that many initiatives are started from a central organization. This has allowed for funds to support Takeda Asker's local measures and has opened for collaboration with other factories. In addition to their collaboration and experience sharing, Takeda is also performing pilot tests with new technology to test small scale before expanding to other factories.

Cybersecurity was also a priority when building an OT-network and securing their existing IT-network. Penetration tests were performed to map Takeda's vulnerability and to give valuable information during the design of their new connectivity infrastructure.

Takeda case analysis

Based on the article regarding Takeda's *digitalization* initiatives, we can divide their efforts into five building blocks. They already had a highly automated factory which would be categorized as Automation and Robotics block. They have organizational measures already imbedded in their culture, but also the addition of pilot tests during technology-related projects. With the addition of an OT-network, connectivity and communication have been added to the production. This allows Takeda to collect data from machines, production lines, and equipment. Not only does that enables data collection, but it allows for interconnected machinery to increase productivity. With Takeda's new way of collecting production data, Takeda sees their future in predictive maintenance, and Artificial intelligence and machine learning. Due to *AI* and *ML's* big presence in enabling *smart factory*, this would make its own building block. With the addition of new networks, Takeda performed penetration tests to enhance their cybersecurity. Ensuring robust *cybersecurity* measures is essential in a *smart factory* environment. Protecting sensitive data, intellectual property, and maintaining the integrity of production processes are more important than ever in a technological world where anybody can perform cyberattacks anywhere in the world [96].

5.2 DEFINITION OF SMART FACTORY BUILDING BLOCKS

Combined with the case studies and the drivers of intelligent manufacturing, a *smart factory* can be classified into six building blocks. Figure 14 shows the six building blocks of a *smart factory*.

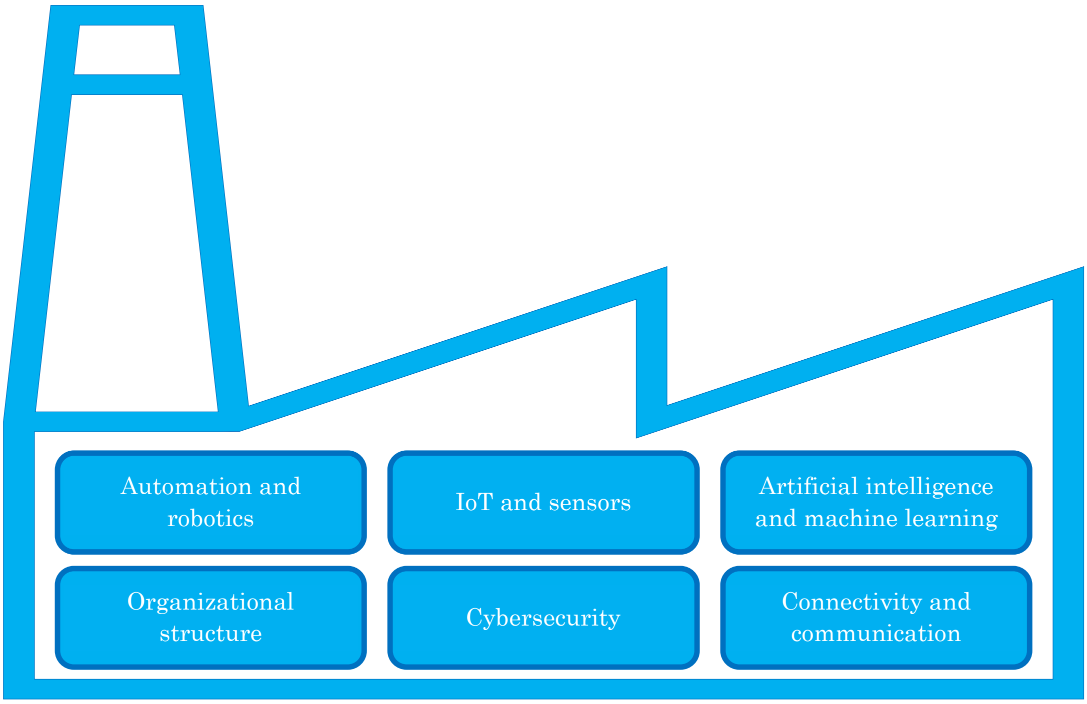

Figure 14 - The six building blocks of a smart factory.

5.2.1 Automation and robotics

Automation and robotics is a key building block of a *smart factory*, as it revolutionizes how products are manufactured. By integrating automated systems into the production, companies can achieve higher productivity, improve accuracy, and quality. Automated production streamlines workflow and enables seamless coordination between the different stages of production, while robots can perform repetitive tasks with precision and speed.

5.2.2 Connectivity and communication

Connectivity and communication form the backbone of a *smart factory*, allowing for seamless data exchange and real-time collaboration. Production equipment can perform independently, but through interconnected systems, machines, and equipment can gather and share information across the factory floor, enabling increased productivity, coordination, and efficiency. Connectivity infrastructure allows for organizational aspects to be streamlined, forming an ecosystem that interacts with the whole value chain.

5.2.3 IoT and sensors

In between automation and connectivity lies *IoT* and sensors. They are the devices that capture and transmit the data in the manufacturing environment. Automation is enabled through *IoT* and sensors, which communicate and exchange data through communication networks. In traditional manufacturing, sensors are used to monitor single equipment and to ensure a specific machine operates. But with the addition of *IoT* and interconnected systems, the collected data can be used to gain valuable insights into the processes, identify inefficiencies, and proactively address issues to improve overall operational efficiency.

5.2.4 Artificial intelligence and machine learning

Artificial intelligence and *machine learning* enable smart factories to analyze large volumes of data, extract patterns, and make intelligent decisions more accurately. With *AI* technology, human resources can be allocated to other aspects of the manufacturing where the human factor has a better use. Computer power has a more reliable and faster way of identifying anomalies, predicting maintenance needs, optimizing production schedules, and performing decision-making based on statistical data. *Machine learning* models can learn from historical data and adapt to dynamic conditions, continuously improving process efficiency and quality control. The reason *AL* and *ML* is their own building block instead of a shared block with automation and robotics is that this technology is vastly different. Even though *AL* and *ML* are a way of automating data analysis processes, they require a different approach and another focus area to apply this technology to the manufacturing process.

5.2.5 Organizational structure

Management structure, workflow, culture, and internal processes are organizational aspects that are as important as technology in a *smart factory*. A strong focus on the organization is necessary to foster collaboration, agility, and continuous improvement. This involves aligning teams, standardized processes, and technology to optimize operations and achieve objectives. Embracing lean manufacturing principles, agile methodologies, and cross-trained teams enables companies to respond quickly to market demands, reduce waste, and enhance overall flexibility. An organized *smart factory* culture encourages employees to embrace change, innovation, and lifelong learning, fostering an environment of continuous improvement and competitiveness.

5.2.6 Cybersecurity

With an increased presence of technology and connectivity, robust *cybersecurity* measures are crucial. Due to the highly data-driven factories, the protection of critical manufacturing systems, intellectual property, and sensitive data must be taken seriously as a part of a *digital transformation*. Especially in high-reliability organizations where unauthorized access could tamper or disrupt processes that would lead to catastrophic consequences. Implementing secure network architectures, encryption protocols, access controls, and continuous monitoring helps mitigate the risk of cyber threats. Regular security assessments, training programs, and incident response plans are all ways to maintain a secure and resilient *smart factory* ecosystem.

5.3 Interviews

Complementing the literature reviews, interviews were conducted with companies from the manufacturing industry. The goal was to gain insights into industry cases, to get valuable data on how the industry experiences *digitalization*, and what views they had regarding the technology and uncertainties in the digital landscape.

5.3.1 GKN Aerospace Engine Systems Norway

GKN Aerospace Norway (GAN) manufactures complex components for jet engines and gas turbines for the world's largest aircraft manufacturers [97] and has a manufacturing facility in Kongsberg, Norway. The interview [98] with GAN was held with two employees with involvement in GAN's initiatives regarding *digitalization* and streamlining of production processes.

Lean initiatives

Earlier, GAN had some trials of implementing lean principles to their products without much success, but in 2020 the owner of GAN, Melrose, requested a Lean program to be applied to the Kongsberg factory. Lean philosophy, where reduction of lead-time and waste at its core, was initiated to deliver better results in terms of quality, increase safety, better KPIs of the production, and secure the future of deliveries. To assist in the Lean-production transition, GAN had help from a consultant firm to teach GAN about lean and to put lean practices to use. Single-piece flow and 5s standards were a few of the tools introduced. As one of the interviewees described, the initial help was a good "trigger" to get the right processes in play, to further work on perfecting the techniques internally at GAN's own pace.

Digitalization measures

GAN has had several *digitalization* measures done in the past, mainly regarding product and production visibility. Tools to control where certain products are at what time, production time, and product costs. GAN has also newly worked on increasing production visibility on the shop floor. Earlier, they had manual whiteboards with production information, but have now installed monitors that show machine states, e.g., Finished producing, working, alarms. This was done to increase the visibility for the workshop operators and leaders walking by.

During such *digitalization* initiatives, GAN is actively working with the operators in very early phases to improve the proposed solutions. Hence, they get hands-on experience with newly developed solutions and routines. This is so the actual users of the final product can pass on previous knowledge and understanding of the work, give feedback, and suggest changes.

Challenges

GAN has encountered challenges related to work processes and workload changes. Workers who have had the same workday for years have suddenly had to change their work habits to accommodate the new routines. Workload has also changed for many due to streamlining specific production processes. Even though the reasons for the change have been made clear, the changes have not been to the liking of everyone.

Thoughts on digitalization and a digital transformation

GAN views *digitalization* as an essential step towards improving their production and has many ideas on how digital technology can improve production phases. They emphasize the importance of a clear objective when initiating changes, the involvement of relevant stakeholders, and clear measurement parameters to visualize the effect.

Regarding the assistance of 3rd party services, they see the value and their use in cases where special competence is needed, like how they previously hired help during their lean initiatives. 3rd party assistance can be great, but GAN emphasizes that it is essential that external service clearly shows that they can improve results with their help.

5.3.2 Aker Solutions

Aker Solutions has multiple facilities across Norway and delivers integrated solutions, products, and services to the global energy industry, enabling low-carbon oil and gas production and developing renewable solutions to meet future energy needs. [99] The interview [100] was held with the Warehouse & industrial production senior manager at Aker Solutions Tranby. The manufacturing facility at Tranby produces equipment related to heavy industries, e.g., Oil & Gas, wind power, and hydropower.

Digitalization measures

Aker Solutions has multiple *digitalization* projects that they currently work on. The biggest project is to get an OT-network in place. They have an IT-network, but due to security concerns, sensors from the production should be connected to an OT-network. The plan is to connect this OT-network to their existing ERP system to collect data from machines and processes to analyze and find ways to increase production efficiency. An immense amount of data can be gathered from tools and sensors, which is desired to help reduce maintenance and production costs. Data like energy consumption and CO_2 footprint are also desired, as environmental, Social, and Governance (ESG) data is often a customer request and will support the industry's green shift. Another *digitalization* project Aker Solution is working on is a digital work order. Today, data from their ERP system is mostly on paper and needs to be *digitized*. This paper-less initiative has started, where they first need to locate sources that generate paper and how they can be *digitized*. This digital work order system is already in use on Aker Solution's other industry branches but needs to be customized for the manufacturing industry.

Organization

During customization phases and projects directly impacting operators, Aker Solutions involves the operators who these systems are intended for to get valuable feedback on which features will be needed and to suit existing work processes.

Challenges

Some challenges mentioned regarding the ongoing *digitalization* efforts were the need for OT-network competence. They have IT-network competence but are shot on network architects and employees with OT-network competence. This will be a priority in the future, as they will hire relevant personnel to work in the IT department or potentially create a new department.

5.3.3 Nortura

Nortura is one of Norway's largest food producers, with 26 production facilities across Norway. They receive raw materials from thousands of farmers nationwide and process and pack the food produced [101]. This interview [102] was held with the leader of a newly established team working on Nortura's several future strategies regarding *digitalization*.

Strategic technology investment

One of Nortura's major investments is smart technology, which revolves around profitability and technology-driven production. This investment is centered around leveraging technology to lower costs and strengthen their competitive position in the market. Nortura doesn't simply pursue technology for technology's sake. They prioritize value-driven initiatives, ensuring that any new technological solutions they adopt provide a clear value-proposition and long-term benefits.

Nortura has identified several key focus categories. These include animal welfare, quality, safety, Health, Safety, and Environment (HSE), lean practices for continuous improvement, and fostering the right industrial culture. Within these areas, Nortura directs their technological investments toward lean methodologies, industrial IT, smart technology applications, and expanding automation and robotics capabilities.

By integrating smart technology into their production, Nortura aims to optimize efficiency, streamline processes, and enhance overall productivity. Their investment strategy is driven by carefully evaluating each technology's potential value, ensuring that it aligns with their future goals.

Implementation strategy

Nortura has a comprehensive implementation strategy that contains a complete development process plan from start to finish. The methodology they use consists of an analysis of available technology and Nortura's business needs. Then they follow a six-step process with a Mapping stage – Proof of concept (POC)/pilot projects – Master plan – Investments – Implementation – Results. This process starts with the mapping stage of possible solutions and needs before they enter a POC stage. At the POC stage, they test the concept with laboratory tests or small-scale pilot projects. In the POC stage, they "think big, act small," where solutions are tested and adjusted. If the POC succeeds, they create a minimum viable product (MVP) that enables Nortura to "scale fast." When a MVP is created, the master plan stage is initiated, where the solution is developed. The development is usually set on a three-five year horizon before investments and implementations are made, with results recorded.

Dedicated development team

Nortura believes a key component of a successful *digital transformation* is a dedicated team consisting of experienced personnel, where the combination of their individual expertise helps to build factories of the future. Nortura has assembled a team with expertise in multiple areas, including business advisors who have some knowledge of technology but an expert in finding business opportunities, identifying their possibilities, and clarifying the potential benefits. They have industrial IT architects who know how to build Industry 4.0 platforms, project managers with experience implementing plans, and technicians who handle automation and robotics.

Digitalization measures

Nortura has newly started using autonomous mobile robots and autonomous lift trucks. This is to secure production flow and replace the human workforce.

Overall equipment effectiveness (OEE) measurements have also been installed. This solution is currently under the POC stage, where they track OEE on a few production lines. Measures of availability, performance, and quality show how productive the planned production is, and with that data, they can find the causes of different production losses. With the OEE data, Nortura can apply lean principles to test their effects on the OEE scale to pinpoint what procedure changes drive line efficiency. With current tests running on a small scale, Nortura can later expand the system with the best solution for other production lines and facilities.

Nortura have built an OT-network with an IoT-edge solution that collects data from their manufacturing execution system (MES), SCADA system, and equipment sensors. Database and *cloud* solutions are used to store data, and the data is used to visualize production, as well as for predictive analysis and digital twins. A part of the digital twin they are working on is related to energy consumption, where they can plan production processes and initiate specific processes when the energy cost is at its lowest.

Future projects

Related to maintenance, Nortura is planning to use *AI* and *ML* to drive maintenance. Today, 60-70% is preventive maintenance, while the rest is corrective maintenance. They are in the early stages of development, but the goal is to use *AI* and *ML* to drive equipment failure modes.

To integrate solutions to existing production faster, Nortura has a goal related to system architecture, where scalability and flexibility are prioritized, making the job of expanding to new assets faster.

Future projects are to generate more data and to gain better insights. Real-time data from equipment, production lines, and machines will be used to drive continuous improvement within the production.

Challenges

Even with an established team with expertise in relevant fields, Nortura still seeks additional expertise. Mainly in the areas of connectivity from sensors to end devices, the building of network architecture, and data visualization. Nortura also emphasizes the quality of new employees who have "will and skill" and are motivated to work with the company and identify their needs.

Nortura has also faced challenges with collaboration with 3rd party service providers. While Nortura relies on internal resources for most projects, they have external help regarding programming and implementing specific IT solutions. The problem has been the considerable time Nortura has had to teach the 3rd party service providers what skills they require. They require individuals with knowledge of data visualization, coding in an agile team environment, and people who have experience in full-stack development and architecture. Nortura also highlighted the problem of diving early on into this technological landscape, as specialists in this field are particularly difficult to find. Many individuals have core consulting skills, but individuals with expertise in IoT-edge/connectivity, Azure data explorer, and digital twins are very limited.

Organization

One important step that Nortura values is involving all stakeholders during development. They have defined smaller agile sprints with functionality demonstrations to ensure that the users can influence the final product to their needs. This ensures the finished solution is successful, optimal, brings value, and reduces unnecessary development costs.

Failed POC

An example of one of Nortura's failed POC is related to predictive maintenance. The POC was put on hold after eight-nine months of work due to the unsuccessful development of the intended architecture. The failure was due to the wrong resources working on the project and the lack of strict management. The team members lacked prior experience working on such projects and were unfamiliar with the systems involved. Contributing to that were the additional problems regarding establishing data streams for the *AI* and *ML* algorithms.

5.3.4 Hennig-Olsen Is AS

Hennig-Olsen Is AS is the Nordic region's oldest ice cream producer and has been producing ice cream since 1924. Their yearly production is 32 million liters of ice cream, and they have a factory located in Kristiansand [103]. The interview [104] was held with their technical manager.

Digitalization measures

Hennig-Olsen Is AS has implemented multiple *digitalization* measures in their production. They have a MES system to gather production data, an ERP system, and they have built a network infrastructure related to customer orders and order processing. Related directly to the production, they have a combination of standalone machines and connected machines, where they have prioritized the most important machines first, which are equipped with more advanced systems. Hennig-Olsen Is AS uses *ML* for prognostics and production plans to balance supply with demand along production lines. Along these lines, they have built their own *ML* vision system to monitor production, which ensures the right product matches the package and the right lid is used with the right box. The same system also ensures that each production pallet has the right product type and the correct product count. Robots have also been installed to sort boxes in the freezer, and they are also equipped with vision systems to monitor that each box has a lid.

Hennig-Olsen Is AS has also installed many sensors on all their compressors. These compressors produce the cold temperature needed in their freezers, and they use this data for predictive maintenance to prevent total collapse.

Implementation strategy

Hennig-Olsen Is AS has a structured process for implementing anything new to their production. Their technical team works on improvements, and their strategy is to start working towards solutions when they have an exact problem. They start on a small scale, and when they have a MVP, they scale that solution.

Organization

Hennig-Olsen Is AS's methodology regarding continuous improvement, and general improvement work is to gather and include the whole organization, especially shop-floor operators. Key partners are involved when processes change, and they all work together to find a reason to change and what is the best way to go forward. An example is when they, in 2014-2015, started working with lean principles. They eventually made their own program. Instead of looking for places to implement lean, they changed to more data-driven changes, identified problems, and then utilized a lean toolbox to improve.

Challenges

The challenge Hennig-Olsen Is AS face is using the collected production data. They have systems that gather all equipment data, but very little is used. They store the data to be used later, but they do not have any dedicated system to actively utilize this data for its potential. This is due to the allocation of resources for the job and the competence needed. They also have some puzzles they can't figure out. Sometimes they get the wrong mixing ratio, where the issue is still unknown, resulting in a backlog that will be handled later.

Sustainability

Regarding sustainability, Hennig-Olsen Is AS has been working actively to reduce waste. This has mainly been from a cost-effective perspective, as the price they charge for one box of ice cream is the same if it contains 1000 grams or 1075 grams. Since they produce millions of liters annually, reducing just a few grams from each box would greatly increase their profitability. Before they installed more precise weights and dispensing systems, they usually overfilled the ice cream boxes to guarantee at least 1000 grams in each box since that was what they advertised for, which then ended up as minimum regulatory requirements. This change also affected their batch blending mixes. With more precise equipment, they ended up with the right blend amount, resulting in fewer bad batches being discarded.

3rd party involvement

Since Hennig-Olsen Is AS has their own technical team with automation technicians, mechanics, electricians, and process engineers, they do most of the upgrades internally. They do still rely on external help regarding error correction and bug fixing. Equipment providers are also often present to replace old equipment and perform improvements on the production lines. They also had 3rd party involvement during the 2014-2015 lean project, where they got help implementing learn principles and the general methodology behind lean.

5.3.5 Heidelberg Materials, Kjøpsvik Cement factory

Kjøpsvik cement factory is the world's northernmost cement factory, producing cement for Norway and export. The factory has been through several modernizations and rebuilds, and the interview was held with their process technician and department manager. [105]

Digitalization measures

Kjøpsvik cement factory has mostly focused on *digitizing*. They have added unique QR codes to machines that maintenance workers scan on their phones to add work orders and reports digitally. The same is done for trucks and wheel loaders, which now have a digital pre-trip inspection checklist, so the user can easily perform the inspection and even add pictures of defects. They have also done some *digitalization* measures, where a reporting system is connected to the production equipment. This system automatically fills out production data on the reports and allows supervisors to view reports from the web. With this system, they can also work remotely from home. All of their instrumentation is connected to a centralized control room, stored in a database, and used for production. They have some automated processes, but many sequences are still manual. Regarding future upgrades, the department manager believes much of the production will stay manual, as they require personnel on-site and believe many of their processes do not have any automated solution.

Cybersecurity

Today, most IT-related tasks are operated centrally from Germany, but Kjøpsvik did have some problems with security breaches earlier when they had their own IT department. When Heidelberg Materials decided to have a centralized IT department, they had some challenges in the deployment phase, but everything works as intended today.

Challenges

After the newly added digital reporting tools, problems regarding Wi-Fi connections have emerged. Since most of the production happens outside and among concrete constructions, they have issues with internet connectivity. They have added access points to improve the coverage but still have problems. Kjøpsvik Cement also has challenges regarding the use of new systems. Workers are used to having one way of working and are suddenly required to use a new system, meaning they constantly must learn new skills. Some systems are also very slow, decreasing productivity since workers must wait for the systems to load. Earlier, some reporting jobs were done in minutes but are now taking longer due to technical issues.

Since Heidelberg Materials own Kjøpsvik Cement, they must also follow their standards. When the headquarter in Germany send out demands for new standardized systems, they tend to send out one system for all their factories. The latest example of this is with their new scheduling system. Since Kjøpsvik Cement produces in bulk and not smaller cement packages, challenges occurred with a standardized scheduling system. With this new system, the planning horizon is much smaller, meaning the new system cannot be used. They are working on tailoring the system, but for now, Kjøpsvik Cement uses the reliable excel sheet they are used to. As an endnote to many challenges regarding the digital landscape, the department manager stated that much of it is due to a lack of resources. They had their own IT department earlier, but now everything is centralized in Germany. They have some IT responsibilities, but much of the work is still undone due to production priorities.

Organization

Regarding organizational aspects connected to Kjøpsvik Cement's *digitalization* efforts, they do have some processes where they include operators in the digital changes, but many of the technologies they have added are demands from the headquarters in Germany. This means there are limited ways in which they can include workers during testing and implementation to influence the result. They also have meetings with workgroups and operators to discuss ideas for potential production improvements. With these ideas, they have connections to the headquarters in Germany that have helped in some cases, but they also end up using Google web-search for some problems.

5.3.6 Nobia Norway AS

Nobia is Europe's largest kitchen specialist, with operations through the entire value chain, from design to installation of new kitchens. Nobia designs, manufactures, sells, and distributes kitchens through more than 15 brands in seven European countries [106]. In Norway, Nobia has a factory with 177 employees located in Sigdal. This interview [107] was held with their technical manager.

Digitalization measures

Nobia Norway produces 850 kitchen cabinets daily, distributed over three production lines. They have one production line for the main production and two secondary lines dedicated to producing low volume. The latest *digitalization* measures Nobia Norway has done are new digital reporting tools and automated systems for the production lines. To meet new external demands, Nobia had to upgrade their drawer production. They accomplished this by implementing a new automated system that removed 1,5 full-time positions and eliminated manual labor, enabling Nobia Norway to meet the new demands. In addition to the automated production systems, Nobia Norway made significant *digitalization* efforts in their reporting processes. They successfully *digitalized* their reporting systems with a deviation management system, allowing employees to digitally document any deviations instead of relying on paper notes.

Along with the deviation management system, they integrated their safety inspections into the same system. Previously, safety inspections involved the use of paper notes, emails, and action logs, but with the new changes, safety inspections have been incorporated into the same deviation management system, creating a common platform for both types of reporting. This new platform streamlines the process, making it easier for employees to conduct safety inspections, report any issues, and track the necessary actions.

Cybersecurity

Nobia Norway does not have a complex data-driven production, but their IT department is focused on security regarding their ERP system and the few connected machines on the shop floor.

3rd party involvement

Nobia Norway relies on external help for most of their *digitalization* efforts. They have had multiple 3rd party service providers inspect their factory to see how they can assist in their needs, since they do not have the internal expertise to do complex installations. They have partnered with a company that assists in automation and robot installations and are industry experts in expanding production lines.

Implementation strategy

Since Nobia Norway primarily work with 3rd party service providers on more significant *digitalization* projects, most of their strategies regarding *digitalization* are connected to their partner and how they work. But when it comes to Nobia Norway's strategy regarding manufacturing changes, they have a project team that works on product implementation, product integration, technical solutions, and quality control.

Organization

Nobia is a global company, and many organizational decisions are made centrally. This centralization affects the *digitalization* progress of Nobia Norway, as many investments are deprioritized in favor of other more profitable projects. One of the main reasons for this lower priority is the demands set by Nobia International regarding the return on investment (ROI). The ROI window is so short, that Nobia Norway finds it difficult to justify the necessary investments.

Nobia Norway has an IT department of six employees that work on their ERP system, line upgrades, and development, but they rely on external assistance for most of their *digitalization* projects. Regarding employee engagement, they involve the stakeholders in the relevant *digitalization* projects, which is something that they have learned from earlier unsuccessful adoptions. Earlier, Nobia Norway installed new automated equipment, but due to a lack of employee inclusion, they ended up with lots of problems.

Challenges

Nobia Norway operates on a made-to-order basis rather than producing items for stock. This has opposed several challenges regarding the *digitalization* of the production lines. Challenges with the installation of the new automated drawer machine were due to poor planning and communication. The machine installation was originally scheduled for February 2023, with a planned two-day stop of the production line. But when the installation day arrived, the necessary preparations were not in place, leading to almost half a year's delay, as Nobia Norway recently managed to finalize the installation. Regarding made-to-order production, the technical manager suspects the practice dates from an earlier lean project that remains, as the production today could produce with smaller buffers. Within the project team, several processes are functioning effectively, thanks to the implementation of certain digital tools. However, they still face challenges related to scattered information. They have a backlog of tasks and projects requiring follow-up, but the relevant information is scattered across emails, servers, and physical papers, where they see the need for a project management tool.

Nobia Norway is currently facing challenges with sick absences due to the physical demands of all the manual operations. This absence halts production and puts pressure on Nobia Norway from regulatory authorities regarding ergonomic concerns. To address this issue, the management is actively working on implementing measures such as rotating workstations and developing a multi-skilled workforce, which aims to prevent some of the problems until many of the most demanding tasks are automated.

Lastly, communication issues between management and operators are problems Nobia Norway has today, which has led to a low score on communication and continuous improvement in employee feedback conversations.

Future digitalization projects

Nobia Norway is currently in the early stages of automating the cabinet painting process as part of their future *digitalization* projects. Today, an automated machine paints one side of the kitchen panel before an operator manually turns the panel to be painted on the other side. Another future project is regarding pallet packaging. Nobia Norway wastes 44 days of labor a year on manual packaging that a robot could do. Otherwise, Nobia Norway has many "low-hanging fruits," which are small yet efficient *digitalization* measures that are relatively easy to implement. But due to many years of inadequate organizational structure and a lack of the right employees in the technical department, they are currently working on many years of backlog.

6 ANALYSIS

This chapter is for analyzing the collected data, to find the role of 3rd party service providers in a *digital transformation*, and then connect Capgemini with the findings and give recommendations as to what role Capgemini serves in a *digital transformation* in the manufacturing industry.

6.1 INTERVIEWS AND LITERATURE ANALYSIS

By analyzing the interviews, areas the manufacturing industry is currently working on, and commonalities between the different companies can be connected to the classifications of a *smart factory*. Bringing up the six building blocks of a *smart factory*, it is easier to find what areas might get less attention than others. Even though Automation and robotics, IoT and sensors, and connectivity and communication are important building blocks and Industry 4.0 essentials, they were not the focus of the interviews. Every interviewee mentioned some level of automation and usage of *IoT* devices, and was working on connectivity and communication, but the extent and advancement were not within the scope, as the limited interview-time would draw too much away from other, more important data that would contribute more towards the research objective. Figure 15 shows the percentage of companies that included automation and robotics in their production.

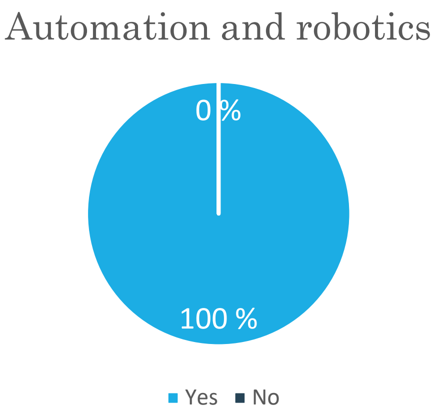

Figure 15 - Inclusion of automation and robotics in the companies interviewed.

Figure 16 shows the percentage of companies that used *IoT* and sensors.

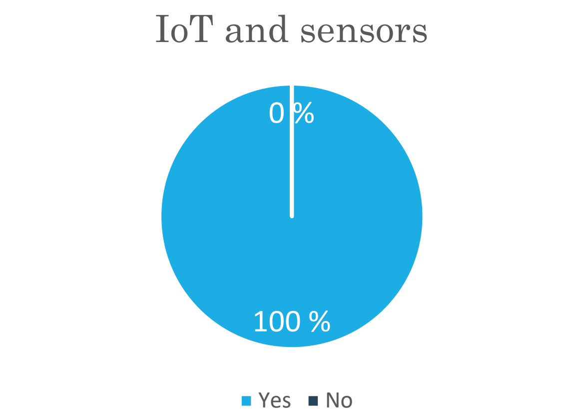

Figure 16 - Inclusion of IoT and Sensors.

Figure 17 shows the percentage of the companies with connectivity and communication focused *digitalization* initiatives.

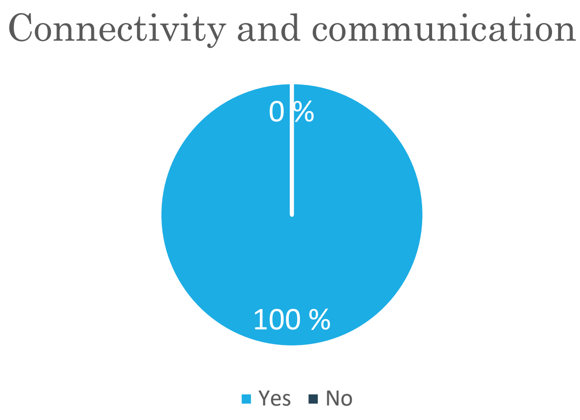

Figure 17 - Inclusion of Connectivity and communication.

Results from the other three building blocks show more variety, with the most noticeable difference in utilizing *AL* and *ML*. There could be multiple factors behind this reason. One could argue that *AI* and *ML* technologies are relatively advanced compared to many of the other digital technologies, and that the companies focused more on less demanding technologies that still contributed to increasing the productivity and efficiency of production. Another could be the expertise available within the organization and the lack of understanding of the potential. Figure 18 shows the percentage of companies utilizing *artificial intelligence* and *machine learning* in production.

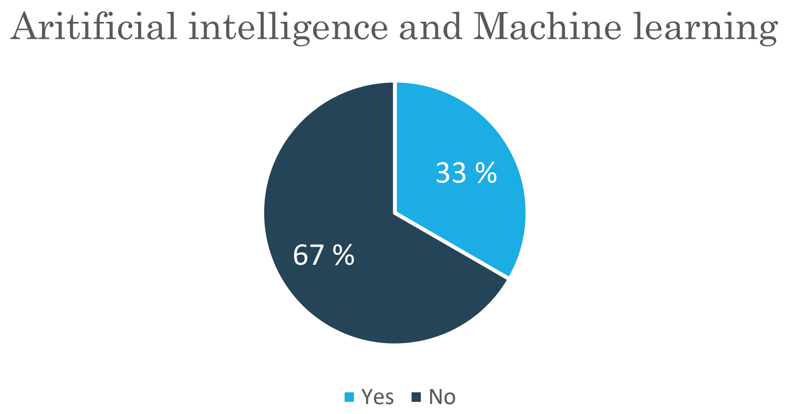

Figure 18 - Inclusion of Artificial Intelligence and Machine Learning.

Cybersecurity also showed some differences. This does not mean that the companies do not find it important, but it could indicate that it's not their main priority. It would be wrong to assume that *cybersecurity* isn't an important measure for companies. However, this would explain the differences in the findings in addition to it not being the main driving factor in the *digitalization* journey. Figure 19 shows the percentage of companies focused on *cybersecurity*.

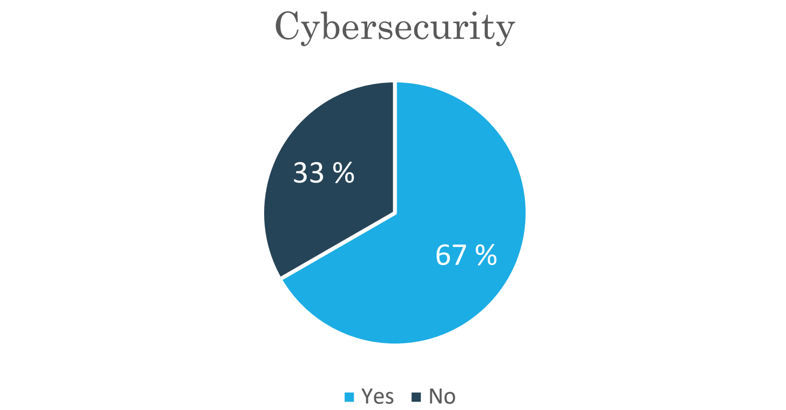

Figure 19 - Inclusion of Cybersecurity.

100% of the companies had an organizational structure related to *digitalization* measures. Since organizational structure involves many crucial areas that are important for a successful *digital transformation*, there is a need to divide this block into smaller sub-sections. Figure 20 shows the percentage of how many companies had the inclusion of organizational structure.

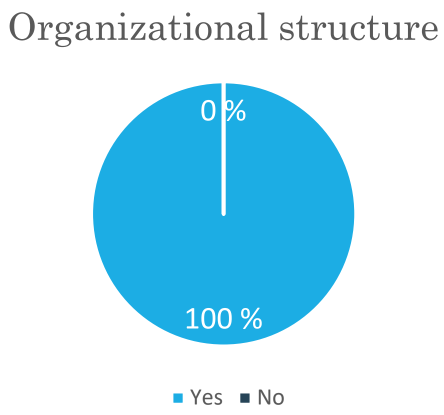

Figure 20 - Inclusion of Organizational structure.

By connecting *digital transformation* success factors and common pitfalls with organizational structure, the organizational structure block can be further divided into six sub-sections contributing to a successful transformation. Figure 21 is a hierarchical illustration of the different sub-sections in the organizational structure.

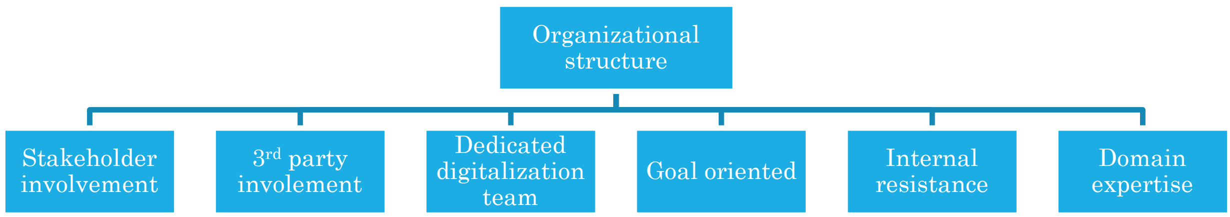

Figure 21 - Sub-sections of organizational structure.

100% of companies interviewed had some level of stakeholder involvement in their *digitalization* efforts, indicating that most companies adopt this process well. One interesting finding that shows the importance of stakeholder involvement, was Nobia's unsuccessful adoption of a new system due to employee exclusion. Figure 22 shows the percentage of companies with stakeholder involvement.

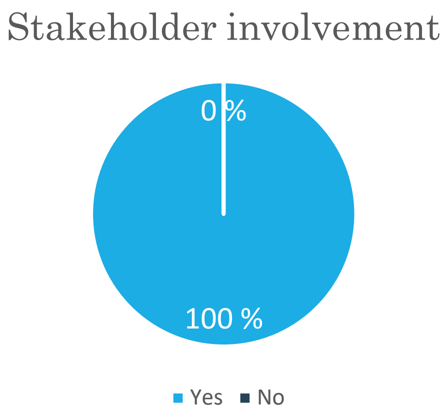

Figure 22 - Inclusion of Stakeholder involvement.

The involvement of 3rd party service providers is very prominent. 83% of companies interviewed had interacted with 3rd party service providers during changes to the manufacturing operations. Some had external assistance for one specific task, while others have 3rd party service providers as long-term partners. This shows how important 3rd party service providers are and that companies find value in their services. Figure 23 shows the percentage of how many companies had 3rd party service providers involved in various *digitalization* efforts.

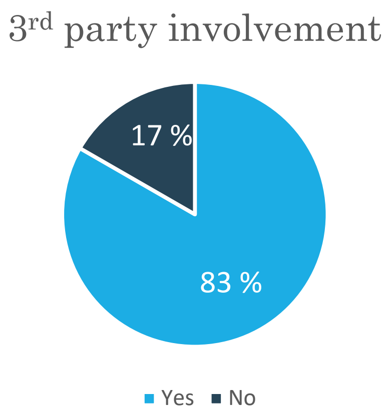

Figure 23 - Inclusion of 3rd party involvement

One success factor is having a dedicated *digitalization* team of technology-familiar leaders, leaders for change efforts, and a workforce with individual domain expertise. Out of the companies interviewed, only 50% had dedicated teams for *digitalization*. Factors influencing the findings can be connected with the company size, as bigger companies might have more resources to introduce a new *digitalization* department, while others rely on individual employees with IT experience to drive *digitalization* efforts. Figure 24 shows the percentage of how many had dedicated *digitalization* teams.

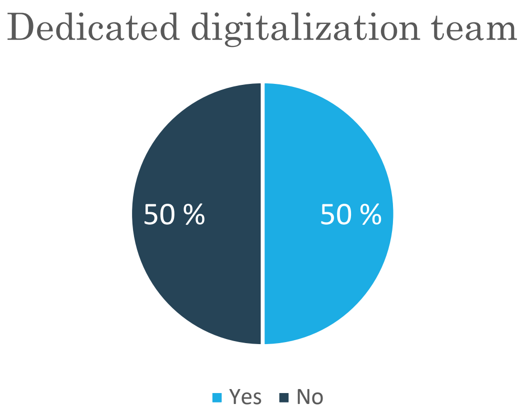

Figure 24 - Inclusion of a dedicated digitalization team.

Goal-oriented transformation with clear objectives is important for a successful transformation. 67% had a clear goal in mind. This might indicate that some fall into the common pitfall of introducing technology for technology's sake, lacking a clear vision and knowledge of what possibilities lie within the *digitalization* domain, or forgetting to *address obsolete processes and policies*. One clear case of introducing technology for the technology's sake, and without the right understanding, is the Heidelberg Materials example, where the centralized unit initiated new systems without the knowledge of the manufacturing process. Figure 25 shows the percentage of how many of the companies had clear goals.

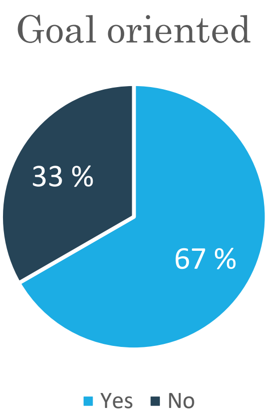

Figure 25 - Inclusion of goal-oriented digitalization efforts.

Internal resistance was quite prominent, which is understandable, as employees are forced to adapt to new technologies or new ways of working. This comes down to the management *empowering people to work in new ways* and *clear communication of the change story* to secure organization-wide commitment. Another factor can be the absence of agile methodology, with no soft-launches or ways for the employee to adjust to new methods. Figure 26 shows the percentage of how many had internal resistance to *digitalization* efforts.

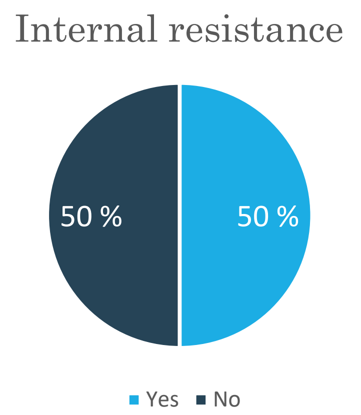

Figure 26 - Inclusion of internal resistance to digitalization efforts.

The last sub-section for organizational structure is domain expertise. 83% explicitly mentioned that they lacked expertise in the digital domain. Some hired 3rd party service providers to introduce the companies to new concepts, while others depended on external assistance. Even with Nortura's comprehensive implementation strategy and dedicated team with a wide range of expertise, they still face challenges, as individuals with the right IT competencies are hard to come by. Figure 27 shows the percentage of how many companies mentioned a lack of experience in the digital domain.

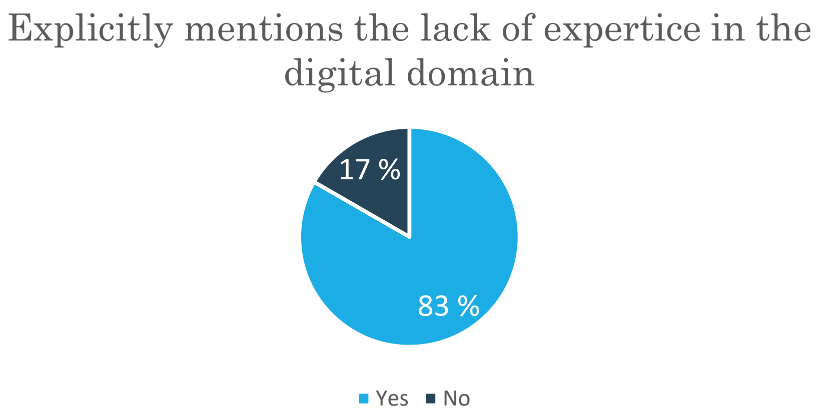

Figure 27 - Inclusion of interviewees who explicitly mentioned lack of expertise.

In addition to the *smart factory* building blocks, *digitalization* supported by sustainability-focused initiatives and motivation were only 50%. Even though the companies were not directly questioned regarding sustainability, the companies that did mention their reasoning behind some of their *digitalization* efforts as environmental-driven motives could be argued to have a higher sustainability focus than others. This could be due to the same reasons as *AI* and *ML* adoption, where the need for more streamlined processes is rated higher than working directly to increase sustainable manufacturing above what is already required. Figure 28 shows how the percentage of companies that had sustainability as a driver for *digitalization*.

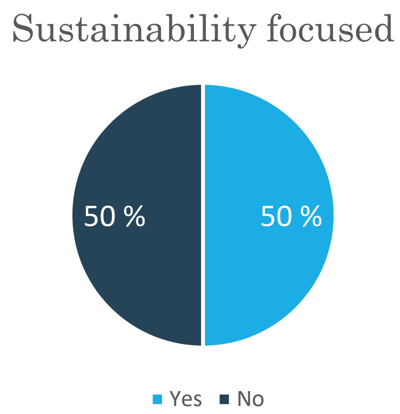

Figure 28 - Inclusion of sustainability-driven digitalization initiatives.

Other important findings from the interviews

The interviews showed that many companies followed key success factors and best practices. Everyone involved stakeholders, GAN and Hennig-Olsen Is AS emphasized the importance of data-driven decision-making, and Nortura had created a dedicated team focusing on value-driven initiatives with a clear goal. However, the companies faced many mistakes and challenges, which we can learn from. While challenges are inherent to *digital transformations*, incorporating *digital transformation* success factors can significantly mitigate and effectively address these issues.

Nobia Norway had difficulties receiving investment from Nobia International due to the low ROI window on the funded projects. This can be down to the wrong priorities or problems related to visibility. McKinsey & Co reported a high success rate regarding *day-to-day tools a digital upgrades*. Nobia Norway has had *digitalization* done for reporting systems that go under this category. However, many may forget all the small yet efficient ways of streamlining daily activities that can contribute to increasing profitability. Identifying smaller improvement areas first can, over a period, lead to a bigger budget for the more complex projects. Nobia Norway has a problem with sick absences due to manual labor. This is the exact reason why Nobia Norway needs more automation. Their management is working on cross-training and rotating workstations, which would most likely result in a short/mid-term solution, as the heavy manual labor will still be present. GAN emphasized the importance of a clear objective when initiating changes and having clear measurement parameters to visualize the efforts, supported by the literature. This is where Nobia Norway might have the opportunity to create an action plan with clear reasoning with visualized numbers to show that the investments are justified with long-term gains. This could be an opportunity to seek guidance from 3rd party service providers to create an overview of the whole picture and to assist in creating an action plan.

Out of the six interviews, it was clear that two had much more advanced technology incorporated into their manufacturing than the others. From what was extracted from the interviews, they had a much more sophisticated structure behind their *digitalization* efforts and followed many of the success factors, which clearly contributed and showed in terms of complex Industry 4.0 integration. There could be many factors to which company size could contribute, which was mentioned earlier. It could be influenced by *having the right, digital-savvy leaders in place* who push the organization to make space for such a team. It could also be a factor of siloed departments, where smaller groups discuss organization-wide changes without *building capabilities for the workforce of the future.* There are so many talented operators out there who could contribute, but are left out due to the wrong organizational culture. Even though some mention workgroups and meetings where production improvements could be made, there is a need for an industry-wide understanding of the small yet effective measures that can transform traditional manufacturing and work towards becoming a *smart factory*.

7 RESULT

This chapter presents the results, with a connection between theoretical background, *smart factory* concept, and data collection from case studies and interviews. The result chapter is divided into four parts. First, a review of the *smart factory* definitions from chapter 4.1, which challenges the differences and where a new thesis definition is created based on the research done. Then, a developed framework is presented, including elements vital for a successful *digital transformation*. The third section presents the third objective of this thesis, where the role of 3rd party service providers is presented, and lastly, the fourth section presents my recommendations to Capgemini.

7.1 REVIEWING SMART FACTORY DEFINITION

Reviewing section 4.1 *smart factory* definitions, it is clear how the *smart factory* concept can have different viewpoints. However, after researching the *digital transformation* domain, analyzed industrial cases, and conducted interviews from the manufacturing industry, it has become clear that a *smart factory* is much more than just a traditional factory with digital technologies. To fully become a *smart factory*, humans, and machines must work together to form a fully connected ecosystem alongside an organizational culture that fosters innovation, continuous improvement, and change management. Leadership with digital knowledge must be established, and a connection between top-level stakeholders and the bottom-level workforce must be connected to fully utilize the manufacturing possibilities.

Table 6 shows my definition of a *smart factory* based on conducted research.

Company	**Definition**
Thesis definition of a smart factory:	*"A smart factory is an advanced manufacturing facility that leverages technology, data integration, and stakeholder collaboration to enhance operational efficiency, flexibility, and adaptability. It encompasses connected machinery, data analytics, and organizational culture driven by clear leadership and a strategic approach. A smart factory fosters continuous improvement to optimize processes and drive innovation, creating a sustainable manufacturing environment."*

Table 6 - Definition of a smart factory, version 2.

Adding thesis definition to Table 3 from section 4.1 to see the different viewpoints. Table 7 shows the three definitions in comparison to my thesis definition.

Aspect	**Gartner definition**	**TW-Global definition**	**SAP definition**	**Thesis definition**
Main concept	Application of modern technologies	Digitized manufacturing facility	Cyber-physical system	Advanced manufacturing facility
Technologies used	Combination of modern technologies	Connected devices, machinery, and production systems	Advanced technologies such as Artificial intelligence and machine learning	Technology, data integration, connected machinery, data analytics.
Manufacturing approach	Hyperflexible, self-adapting	Continuous data collection and sharing	Data analysis, automated processes, and learning	Continuous improvement, process optimization, innovation
Efficiency	Create new forms of efficiency and flexibility	Improve processes and address issues	Drive automated processes	Enhances operational efficiency, flexibility, and adaptability
Connectivity	Connect processes, information streams, stakeholders	Collect and share data	Analyze data	Data integration, stakeholder collaboration
Human/ organization	Connect stakeholders to other processes.	-	-	Stakeholder collaboration, organizational culture, clear leadership, and strategic approach.

Table 7 - Differences in smart factory definitions, version 2.

7.2 Framework for digital transformation best practices

A framework is developed based on the research conducted to find 3rd party service provider's role in a *digital transformation*. The *digital transformation best practices framework* serves as a guideline on practices that lead to a successful *digital transformation*.

The framework is based on the following research:

- *Smart factory* concepts highlight that a *smart factory* combines technology and organizational aspects, which requires a *digital transformation*.
- *Digital transformation*, which is a comprehensive change across all business functions, requires a strategic approach to ensure success.
- Case studies and interviews, where key points were found as a result, where challenges in organizational structure, clear goals, and IT expertise were among the most prominent challenges.

The *digital transformation best practices framework* considers the common mistakes and challenges related to *digital transformations* and ties the success factors of a *digital transformation* with the thesis research findings. Figure 29 shows the six categories of best practices that lead to a successful *digital transformation*.

Figure 29 - Digital transformation best practices

Breaking down the six categories includes the following elements, which consist of the key takeaways from the data collected, which are the importance of strategic planning, talent selection, user adoption, process adaptation, organizational alignment, and an agile mindset which is seen in Figure 30.

Leadership

- Ensure management engagement and commitment throughout the digital transformation journey.
- Secure leaders with a strong technology background and a clear vision for the transformation.

People and culture

- Build digital capabilities across the organization.
- Redefine roles and responsibilities to align with transformation goals.
- Foster a culture of innovation, collaboration, and continuous learning to drive digital adoption.
- Involve employees and empower them to contribute ideas and insights.

Strategy and planning

- Define a strategy that encompasses both short-term and long-term objectives.
- Outcome-focused approach.
- Align the transformation with business objectives.

Technology and tools

- Start small by selecting pilot projects or use cases that demonstrate the value achieved.
- Digitize communication platforms to ensure visibility and accessibility of information across the organization.
- Establish clear metrics to measure success and progress

Communication and execution

- Clear communication of the change story about the why, what and how of the digital transformation to all stakeholders.
- Agile and iterative approaches to keep projects on track and deliver intended value.
- Regular communication across the organization to ensure alignment and understanding.

Collaboration

- Collaborate with external partners and industry experts to access specific skills, technologies, and knowledge to accelerate innovation.
- Regularly review and evaluate the collaboration efforts to ensure the services deliver the intended value and to adjust the partnership as needed.

Figure 30 - Digital transformation best practices framework.

7.3 Role of 3rd party service providers in a transition from traditional manufacturing to a smart factory

From the research, it has become clear that 3rd party service providers play a crucial role in transitioning from traditional manufacturing to a *smart factory*. The findings highlight the close connection between the success or failure of *digital transformation* initiatives and why only 30% of companies achieve successful transformation. Since a *digital transformation* is such a complex journey that requires changes throughout the whole value chain, there is no doubt that companies need external assistance to have a successful transition and to achieve industrial agility. This aligns with the best practices outlined in Figure 29, which emphasizes key categories that lead to a successful transformation. Analysis from industrial case studies shows how 3rd party service providers were present in both cases to aid in the transformation. Stabburet and Takeda emphasized how important 3rd party service providers were in their *digitalization* initiatives, as many of the processes involved in such restructuring were too complex to handle internally. The same is reflected in the interviews conducted. 83% had 3rd party involvement in their *digitalization* projects and emphasized the lack of internal expertise in many of the processes involved. Even the companies with more sophisticated structures and implementation strategies had 3rd party service providers involved. This is why collaboration is a part of the framework in Figure 30. Collaboration is such an important part of the best practices, as it delivers value to companies seeking guidance, expertise, partnership, or industrial agility.

Reflecting more on the *digital transformation best practice framework*, many of the categories are related to organizational measures. This brings the role of 3rd party service providers closer to organizational management due to the adequate level of organization-wide commitment and communication that was missing. 100% had automation, sensors, and connectivity, but the percentage dropped substantially when moving close to organizational aspects. The majority of companies with 3rd party involvement used their services only towards increasing digital capabilities, which is why the *digital transformation best practices framework* is developed. To have a tool that can be used by companies internally and 3rd party service providers to see what practices are followed and which areas need more focus. Since the findings show that organizational aspects are as important but that many forget that part of the transformation, the framework works to highlight that leadership, people, culture, communication, and strategy are as important as technological progress.

7.4 CAPGEMINI AS A PARTNER

Chapter 2 describes Capgemini as a company, their role, and their services. To complete objective three, we need to plug Capgemini into the *digital transformation best practices framework* to find their role in the *digital transformation* of the manufacturing industry. Capgemini is a customer-centric partner that leverages data and *cloud technology* in a secure and sustainable way to support intelligent industries and enterprise management. Every company interviewed had <u>Automation and robotics</u>, <u>IoT and sensors</u>, and <u>Connectivity and communications</u>. The extent of the three building blocks is less known due to the width of these technologies and their variety. But we can draw some conclusions from the challenges the companies encountered. Many faced challenges regarding development, integration with existing infrastructure, and resource allocation. We also see where Nortura fell down a common pitfall, as they spent eight-nine months on a POC that failed due to a lack of the right skills. This leads to the importance of strategic planning and *choosing the right talent for the outcome in mind*. This is where Capgemini can come in. They add the IT expertise that the companies are lacking, are they are a reliable partner who fills in the needed resources, allowing the company to focus their own resources on other operations.

Further, the analysis showed us that *AI* and *ML*, and *cybersecurity* are not a high priority. A few factors that could be the leading cause were pointed out, which is what Capgemini can support. Capgemini delivers *AI* and *ML* and *Cybersecurity* services where they can bring more awareness about the technologies and bring up potential use case areas and applications where these technologies can help the companies stay competitive. Every company involved stakeholders during *digitalization* initiatives, which can be assumed to be industry standard. But other lackluster areas of organizational structure were related to *internal resistance* and *dedicated teams*. This is caused by the lack of knowledge about *digital transformation*, as many companies do not know how to approach it. This is an area that Capgemini does not directly offer, as this goes beyond the technological aspect and is more related to human factors and business management. This is where I believe Capgemini can become a competitive player in the *digital transformation* scene, if Capgemini can deliver services across the whole *digital transformation best practice framework*. Since Capgemini strives to be a long-term partner, it would be a good opportunity for them to provide organization-wide services as a package for their customers to rely on one partner for every aspect of the *digital transformation*.

Table 8 shows the service levels Capgemini delivers in the *digital transformation best practices framework.*

Best practices framework categories	**Limited**	**Moderate**	**Extensive**
Leadership		x	
People and culture	x		
Strategy and planning			x
Technology and tools			x
Communication and execution		x	
Collaboration			x

Table 8 - Capgemini within the digital transformation best practices framework.

With Table 8, Capgemini can see what areas they need to improve to become an end-to-end player in the *digital transformation* scene. Reviewing the successful technologies from Figure 13, *cloud technology*, design thinking, and *IoT*/connectivity are among the most used technologies that lead to success. This is right in Capgemini's area of expertise, which means that within the *digital transformation best practices framework*, they offer extensive service towards Strategy and planning and Technology and tools. Capgemini also has a customer-first approach, providing extensive service within Collaboration. However, based on the services that Capgemini provides, they fall below regarding Leadership, People and culture, and Communication and execution, since they don't engage in these services to a full extent.

Reviewing the elements of Table 8, Capgemini delivers limited services toward People and culture. This is due to the extent of organizational aspects associated with this practice, where digital capabilities across the organization must be built, roles and responsibilities of the employees must be aligned with the goals, and employees must be empowered to contribute. Out of Capgemini's services, they do not have any clear service parameters that address this part of their partnership. The reason Capgemini's service level is moderate for Leadership, and Communication and execution are the same reasons as People and culture service level. Management engagement and commitment, change story, and organization-wide communication are among the services under organizational aspects. But what brings Capgemini one level up is due to their technical background and role as technology leaders in *digitalization* projects, where during their partnership, Capgemini ensures a clear vision for the transformation. As well for agile and iterative approaches to their projects, where they make sure the adoption of digital technologies are successful. Regarding Capgemini's extensive services, there is no doubt they deliver extensive services within Strategy and planning, Technology and tools, and Collaboration. These categories revolve much more around technology aspects, digital technology integration, and goal-oriented strategies.

My recommendations to Capgemini are for them to focus on areas of technology awareness, advertise their *IoT* and connectivity expertise, and provide a service that addresses the difficult technological and organizational aspects behind a *digital transformation*. Research shows clear evidence that the manufacturing industry is struggling with complex technology integration and the right organizational structure for *digitalization*. Since Capgemini reaches extensive service levels across multiple categories in the *digital transformation best practices framework,* they are already in a strong position to have a prominent role in enabling companies to transform their traditional manufacturing. However, due to their limited and moderate service levels towards crucial practices, there could be a beneficial strategy to reevaluate their service portfolio, to provide comprehensive support for organizational aspects, which would tie up loose ends and complete the whole framework. If Capgemini can show their commitment and expertise through the entire best practices framework, they will become a stronger player in the *digital transformation* landscape.

Otherwise, if Capgemini wants to stay a pure technology-focused consultant firm, their role is prominent in the framework. Their role is to leverage their IT expertise to ensure that the best practices are followed so companies do not fall into the pitfalls of unclear *digitalization* goals, inadequate planning, and wrong resource allocation. If Capgemini also can clearly show the benefits and visualize the reasoning behind a given *digitalization* initiative, it could, in turn, provide a stronger fact-based reason for companies to gain more investments toward such *digital transformation*, which would create even more opportunities for Capgemini to extend their partnerships and strengthen their position as a trusted partner.

8 DISCUSSION

This study aimed to explore the role of 3rd party service providers in transitioning from traditional manufacturing to a *smart factory*. By reviewing the concept of a *smart factory* and collecting data through literature reviews and interviews with companies in the manufacturing industry, insights into challenges and opportunities associated with such transformation have been acquired.

The analysis revealed that the manufacturing industry's *digital transformation* involves much more than just digital technologies, but also organizational changes. The organizational aspects are just as vital to a successful transformation, and the findings suggest that companies face challenges related to development, integration with existing infrastructure, and resource allocation. As well as the importance of goal-oriented, strategic planning, and talent selection for a successful *digitalization* initiative was highlighted.

It became evident that 3rd party service providers can play a crucial role in supporting companies during their *digital transformation* journey, and that Capgemini offers valuable experience in IT and fills the resource gap that companies may encounter. However, Capgemini does not directly provide services linked to human and business management challenges. However, if they were to acquire adequate resources to offer additional services, their commitment to being a long-term partner would position them to provide organization-wide services that would encompass the entire *digital transformation best practices framework*. By addressing technological and organizational aspects, Capgemini can establish themselves as a competitive player in the *digital transformation* landscape.

8.1 KNOWLEDGE GAINED

This research has provided valuable insights into the role of 3rd party service providers in the manufacturing industry's *digital transformation*. It has found where manufacturing companies face challenges in the digital domain and in what areas 3rd party service providers can utilize their strengths to help companies with a successful *digital transformation*.

This research has filled a gap in understanding the role of 3rd party service providers in the transition from traditional manufacturing to a *smart factory*, with the development of a *digital transformation best practice framework* as a tool to support the *digital transformation* journey.

8.2 CHALLENGES

Most of the challenges encountered during this thesis research were primarily associated with the interview process. One of the main limitations was the relatively low number of conducted interviews, which may have influenced the outcome. Despite extensive efforts, including reaching out to dozens of manufacturing companies, only ~20% answered, and only ~5% had the ability to participate in the interviews. Another challenge was the time constraints, as most companies could only allocate 30 minutes, which proved insufficient to fully capture their extensive *digitalization* projects, challenges, and implementation strategies.

8.3 FURTHER RESEARCH SUGGESTIONS

There are plenty of angles where this research could be carried out further. The thesis scope is limited to the manufacturing industry, and further sector-specific research could be carried out e.g., healthcare, retail, education, oil & gas. More research can also be done on how 3rd party service providers enable industrial agility. Research on the practical use of the *digital transformation best practices framework* would also be an interesting topic, to find connections between the theoretical framework and real transformation projects.

9 CONCLUSION

This study examined the role of 3rd party service providers in the transition from traditional manufacturing to a *smart factory*. The analysis of literature reviews and interviews with manufacturing companies provided valuable insights into the challenges and opportunities associated with *digital transformation*. The findings demonstrated that a *digital transformation* in the manufacturing industry encompasses adopting digital technologies and organizational change. The aspect of organizational change proved to be a significant factor leading companies to unsuccessful adoptions, as the focus of the companies turned out to be more technology-based, and the importance of the right organizational culture to support the transformation was practiced to a lesser extent. The research also highlights the significant role that 3rd party service providers, such as Capgemini, can play in supporting companies during their *digital transformation* journey. Capgemini's expertise in IT and ability to fill the resource gaps can be an important factor in overcoming the challenges companies face today. However, it was recognized that Capgemini does not directly address human and business management aspects, which is equally important. This is where the developed *digital transformation best practices framework* can come to use, as it serves as a guideline for practices that lead to a successful transition from traditional manufacturing to a *smart factory*.

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Appendix A: Interview questions

Background and goals:

- What digitalization measures have you taken recently?
- Why did you initiate exactly that measure?

Implementation and challenges:

- What was you implementation strategy for the digitalization measures?
- Did you face any challenges during the digital transformation?

Employee involvement:

- How did you involve the stakeholders in the digitalization efforts?
- Have you received any complaints or improvement suggestions from the daily users of the system regarding what they would like to see differently?

Involvement of 3rd party service providers:

- Did you receive assistance from any 3rd party service providers in determining the solution/installation and other related aspects?
- Did the involvement of 3rd party service providers bring a different perspective to the problem or suggest a better way to solve it?
- Do you foresee a need for further assistance from 3rd party service providers in future developments?
- Would you prefer internal expertise, or do you feel the need to seek external help?

Current production challenges:

- Do you have any challenges in production today that you would like to improve but are unsure how to address?

Cybersecurity:

- How do you address cybersecurity?

Note:

- Not all questions were asked due to time constraints.
- Due to a semi-structured interview, specific/custom questions were asked that related to the discussed topic, and is not included as a part of appendix A.