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Case study about industry 4.0 in the internal supply chain of a defense company: are we ready for industry 4.0?

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Abstract

This thesis aims to aid with the challenges the internal supply chain in the defense industry face regarding the implementation of industry 4.0. The literature indicates that hindering factors could occur in the categories Organization, Employee, External Context and Characteristics of the Innovation. This qualitative research made use of eight semi-structured interviews and a peer-session. The transcripts were analyzed by open-coding, axial-coding and selective-coding. Overall, most hindering factors occur in the category Organization and second in the category Employee. The category External Context do not contain that many factors and the influence on the implementation of industry 4.0 is almost nil. The peer session resulted in a top 3 hindering factors: lack of strategy, lack of multidisciplinary team, lack of skills and knowledge. This study offers theoretical and practical implications for the internal supply chain regarding the hindering factors on the implementation of industry 4.0.

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1 Industry 4.0 could change the defense sector, despite its absence in in the literature

Today, the industry is facing various economic, social, and technological challenges. Think of increasing competition, new technologies (Ghadge, Er Kara, Marilou, & Goswami, 2020), personalized products and services and a shorter product life cycle (Oztemel & Gursev, 2020). A subject that is therefore receiving increasing attention is industry 4.0 (da Costa, dos Santos, Schaefer, Baierle, & Nara, 2019; Kamble, Gunasekaran, & Gawankar, 2018; Oztemel & Gursev, 2020). There is however no unanimously agreed definition of industry 4.0. It can broadly be described as the integration between production, information, and communication flows (Disengage, Benitez, Ayala, & Frank, 2018; Kamble et al., 2018), where supply chains are connected and production systems are increasingly intelligent, autonomous, and automated (Schumacher, Erol, & Sihn, 2016). So, industry 4.0 will transform supply chains and production. In addition, improved products, and quality, faster processes and organizational performance are desired outcomes of industry 4.0 (Ahuett-Garza & Kurfess, 2018; da Costa et al., 2019; Kamble et al., 2018; Oztemel & Gursev, 2020).

The number of companies considering and/or implementing industry 4.0 is growing (Hoyer, Gunawan, & Reaiche, 2020). There are several reviews in the literature on the implementation of industry 4.0. The literature highlights the factors that affect implementation. According to Müller, Kiel, & Voigt (2018), research shows that industry 4.0 is more difficult to implement in industries where companies with a low degree of standardized processes, flexible but less automated production equipment and resource limitations operate. There is a need for research on the implementation of industry 4.0 in these type of companies, to get insight in factors that are hindering the implementation of industry 4.0 (da Costa et al., 2019; Hoyer et al., 2020).

An industry in which interest in industry 4.0 is growing is the defense sector. Yet, there is little literature and knowledge about industry 4.0 in the defense sector. This makes it hard to implement. The defense sector is characterized by high tech products, complex processes and customer specific products and services (Ferreri, 2003; Lineberger, Hussain, Hanley, Rutgers, & Sniderman, 2019). These characteristics result in no or little standardization. More research is done in industries such as for instance the automotive industry because of the more standardized process and products and more automated machines (Bibby & Dehe, 2018; J. M. Müller et al., 2018). These characteristics fit with implementing and using industry 4.0 technologies. Although the defense sector possesses these characteristics to a lesser extent, according to R. S. Lineberger et al. (2019), 84 percent of the executives in the defense sector consider new digital technologies but only 25 percent

is currently using these technologies. R. S. Lineberger et al. (2019) mention that this percentage could be the result of "defense companies being slow in adopting broader digital transformation initiatives that span the entire enterprise" (p. 2). Limiting the digital strategy to just a part of the company increases the risk of being left behind in today's digital world.

As mentioned, industry 4.0 will transform supply chains and production. Developments around industry 4.0 also do not go unnoticed in the internal supply chain. The internal supply chain can be defined as "the chain of activities or functions within company that results in providing a product to the customer" (Basnet, 2013, p.153). The challenges facing the industry also have an impact on the internal supply chain. To respond to the complexity, dynamics and competition of the market, digitalization is important (Ghadge et al., 2020). This shift, towards digitalization, is important for companies to survive in the complex and highly competitive market. It also ensures long-term growth and success (Büyüközkan & Göçer, 2018; Ghadge et al., 2020).

The defense industry, especially the internal supply chain, is curious about what is hindering the implementation of industry 4.0. Therefore, the aim of this research is to provide insight into the hindering factors to take steps towards the implementation of industry 4.0. The aim of this research led to the following research question:

How does the context influence the hindering factors and how can the most important hindering factors be solved so that the internal supply chain of defense company can implement industry 4.0?

This thesis aims to aid with the challenges the internal supply chain in the defense industry face regarding the implementation of industry 4.0. On one hand, this thesis contributes to the literature by identifying the current situation of the defense industry with specific characteristics regarding industry 4.0. Current literature focuses more on industries where processes and products are more standardized in contrast to the defense company in this research (Bibby & Dehe, 2018; Ferreri, 2003). On the other hand, this thesis investigates which factors hinder the implementation of industry 4.0 which contributes to the literature. Most scientific literature, including Bibby & Dehe (2018) and J. M. Müller et al. (2018), show that the automotive industry, for example, is further along in terms of industry 4.0. This research shows by means of a single case study which factors are perceived as hindering in a different type of industry.

Besides the theoretical contributions, this thesis also contributes to practice. The practical contribution of this study is to provide management positions in the internal supply chain of complex industries a framework that show in which different broader dimensions the hindering factors occur, what these factors are and which have the most impact. This thesis also includes practical

recommendations to the most important factors. By providing these insights, it could help executives in the defense industry to not only consider implementing new digital technologies but also using them (Lineberger et al., 2019). The recommendations could serve as a first step.

The thesis is structured as follows: it starts with the theoretical framework, in which the defense industry, industry 4.0 and hindering factors are described and defined. Afterwards, the research model is defined. After the theoretical framework, the applied research methods and the case company are described. Fourth, the collected data is presented. The discussion section interprets the results. Lastly, limitations and future research are highlighted, and a conclusion is drawn.

2 Theoretical Framework

First the defense industry and different supply chain strategies will be described in section 2.1 and 2.2. In the next section 2.3 and 2.4, a description of the different industrial phases with the focus on industry 4.0 and its related technologies. Afterwards, different maturity and readiness models are assessed as input for the research model in section 2.5. Based on this model, the hindering factors were identified (section 2.6). Lastly the complete research model is visualized in section 2.7.

2.1 Parts of the defense industry are characterized by low volume and high complexity

The Dutch defense and security market contain large, medium-sized, and small companies but also knowledge institutions and start-ups. In 2018 the large, medium-sized, and small companies had a turnover of 4,5 billion euros (Ministerie van Defensie, 2018). The defense market could be considered as a relative closed market, the most important purchaser is the government. This results in orders being spent primarily in the home country (Ministerie van Defensie, 2018). When a government decided to outsource the order, they expect offsets. Offsets can be defined as follows: “offsets ensure an economic/industrial return on the investment market” (European Comission, 2016). The characteristics of the market do not contribute to level playing field. Level playing field refers to a situation (market), “where everyone has a fair and equal chance of succeeding” (Oxford, n.d.). The European Union is committed to creating a better level playing field, which led to a more open, competitive, and efficient market. The benefits for the suppliers are lower costs, optimize production capacity and achieve economies of scale to make European products competitive on the global market (European Comission, 2016).

The companies within the defense sector produce high tech products. A product can be considered high tech when the company spends a lot of money on research and development (R&D)

(Ferreri, 2003). In the defense sector the R&D process can be described as complex. For new products the R&D and commercialization can take several years (Lineberger et al., 2019). Besides, Ferreri (2003) assumes that the product has a high content of technology. Because technology is constantly innovating, parts of the product are becoming obsolete. The products and services are also customer specific (Prilytskaya, Murukina, & Podoliak, 2020). Products that are constantly innovating and customer specific result in no or little standardization and asks for a flexible manufacturing process and supply chain.

As mentioned, the defense industry is characterized by high-tech products, with low volume and high complexity due to customer specific products. This could have an influence on the difficulty of implementation because industry 4.0 is mostly implemented in industries with high volume, high degree of standardization and automated machines (Bibby & Dehe, 2018; J. M. Müller et al., 2018). So, the industry characteristics could have an influence on the factors that are perceived as hindering.

2.2 Supply chain strategies: Make to order/Design to Order fits the internal supply chain in the defense industry

This chapter shortly describes the internal supply chain. After this, the different supply chain strategies are mentioned which are also applicable to the internal supply chain.

2.2.1 The internal supply chain

The internal supply chain is defined as "the chain of activities or functions within a company that results in providing a product to the customer" (Basnet, 2013, p.153). Within a company this is the integration of the holistic performance of activities across different departments. This means that every department should work with each other (Basnet, 2013). According to Germain & Iyer (2006) this holistic performance and a well-integrated supply chain, results in excellent customer service and company performance.

2.2.2 Supply chain strategies

Stavrulaki & Davis, (2010) distinguishes four types of supply chain strategies: Build to Stock (BTS), Assemble to Order (ATO), Make to Order (MTO) and Design to Order (DTO). For each strategy the product and production process characteristics and supply chain strategy will be briefly explained.

2.2.3 Build to stock

In Build to Stock (BTS) the customers purchase the product by a retailer. They have a choice in different types of a certain product but has no individual inputs.

The products are standardized and produced in high volume and with low profit margins. The forecast is accurate because of the stable demand. An example of a product category are groceries, with the appropriate historical data the prediction of the demand can be done properly. The product is mostly direct available to the customer (Stavrulaki & Davis, 2010). Due to the low profit margins the production process focuses on cost efficiency for either the product design and process. This can be accomplished by continuous processes or high-volume assembly lines. These are often highly automated. Another characteristic of the BTO supply chain is the minimum contact of the manufacturer with the end customer. The customer often has contact with the retailer of the products (Stavrulaki & Davis, 2010). Lean can be seen as the strategy of minimizing waste and improve manufacturing, so doing more with less (Christopher, 2000). This strategy is in line with the characteristics of BTS. As mentioned BTS knows standardized products, stable demand and focuses on cost efficiency.

2.2.4 Assemble to Order

In contrast to BTO, the Assemble to Order (ATO) supply chain offers some options according to the products to their customers. The customer can modify the product by some standardized options to customize their product (Stavrulaki & Davis, 2010).

ATO supply chains consists of higher priced and more customized products. Forecasting of the demand is not done at product level but at component level. In this way the supply chain generates a more accurate forecast (Stavrulaki & Davis, 2010). Because ATO works with more customized products, the production process is not designed for continuous production. In contrast with BTS, the final assembly of the product starts after the order is received. Therefore, ATO uses a modular approach. This means that the "standardized components are produced in batch sizes and then assembled to meet individual customer orders" (Stavrulaki & Davis, 2010, p137). To meet the customer, demand the process needs to be flexible, cost efficient and on time. The customer contact runs the same as with BTS, between the customer and the retailer. Due to the flexibility, cost efficiency and the on-time delivery of the supply chain, the best suited strategy is a combination between lean and agile. Christopher (2000) defines an agile supply chain "as the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety" (p.38). The combination is often called the 'leagile' supply chain (Stavrulaki & Davis, 2010).

2.2.5 Make to Order

Make to Order (MTO) goes further than ATO with product customization. The customer can build the product partly uniquely without standardized options, but the end design remains the same (Stavrulaki & Davis, 2010).

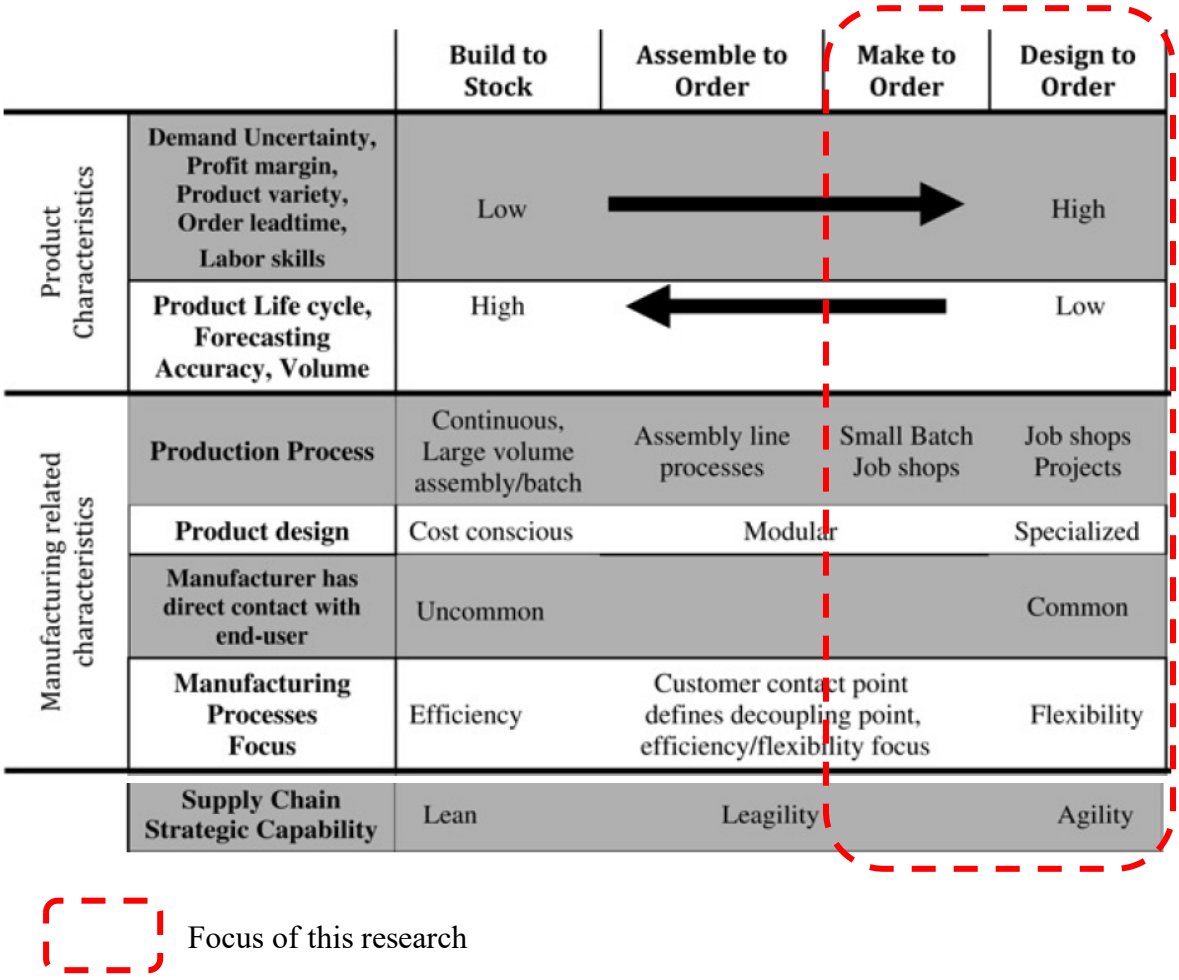
Products within the MTO supply chain are low volume and with high margin. They are expensive and designed to meet the customer needs, although the end design is fixed (Stavrulaki & Davis, 2010). As mentioned, the customer has some influence on the product. As with ATO, MTO uses the same modular approach to meet the requirements of standardized components and specially produced elements. There exists a combination between automated processes and labor work. To predict the demand, the forecast is based on raw materials. Because customers can add special elements, the lead times are longer according to ATO (Stavrulaki & Davis, 2010). The focus of MTO supply chains in not primarily on cost efficiency but more on flexibility due to the higher degree of customization. Like ATO, the strategy is between lean and agile but with more characteristics of agile supply chains.

2.2.6 Design to Order

The final supply chain strategy is Design to Order (DTO), characterized by the ability to completely customize the whole product. The customer does not have to consider standardized options or components, they have the greatest amount of input in the finished products (Stavrulaki & Davis, 2010).

The products of DTO are characterized by low volume, high variability, and high price. Because of these huge variability, forecasting is difficult due to the market situation at the moment of ordering. Second, some components may be produced especially for the customer which requires more time (Stavrulaki & Davis, 2010). The process needs to be flexible to meet the customer requirements, also known as project processes. “Flexibility is accomplished through the use of computerized machine tools that can adjust to a wide range of seized and thickness of sheet metal, and through the use of highly skilled workers in fabrication and assembly operations” (Stavrulaki & Davis, 2010, p.142). Another characteristic is that there are none or little finished goods in inventory (Stavrulaki & Davis, 2010). DTO supply chains need to operate in uncertain environments and be able to be flexible and deliver high quality. The agile supply chain strategy is the priority of DTO to achieve this (Stavrulaki & Davis, 2010).

Figure 1 Supply Chain Characteristics (Stavrulaki & Davis, 2010, p.135)



An overview of the supply chain strategies is given in Figure 1. This research focuses on companies in the defense industry that have a make to order or design to order strategy (visualized in the red box). As mentioned, the products are of relatively high variety due to customer specific wishes. Besides, the products are produced mainly in low volumes. Because of the high-tech products and the variety, the product design can be seen as specialized. Together, this results in a manufacturing process and supply strategy that are both flexible (Ferreri, 2003; Lineberger et al., 2019).

2.3 Industrial revolutions

About three hundred years ago, the agricultural industry changed to the mechanic industry with help of steam power, which later changed to an industry of mass production with help of electrical energy. These revolutions respectively are also known as the first and second industry or industry 1.0 and industry 2.0. These stages were followed by the third revolution (industry 3.0), the digital transformation. In this stage the computer and the internet appeared in different areas including

manufacturing. Later the internet was also used as communication tool. The current revolution, called industry 4.0, was introduced by Germany (Fonseca, 2018; Hou, Cheng, Wang, Xue, & Chaudhry, 2020; Murat M. Gunal, 2019) "characterized by the emergence of technologies based on the use of large volumes of information" (da Costa et al., 2019). This obtained information drive further actions (Rao & Prasad, 2018). The changes in the industrial revolutions are shown in Figure 2.

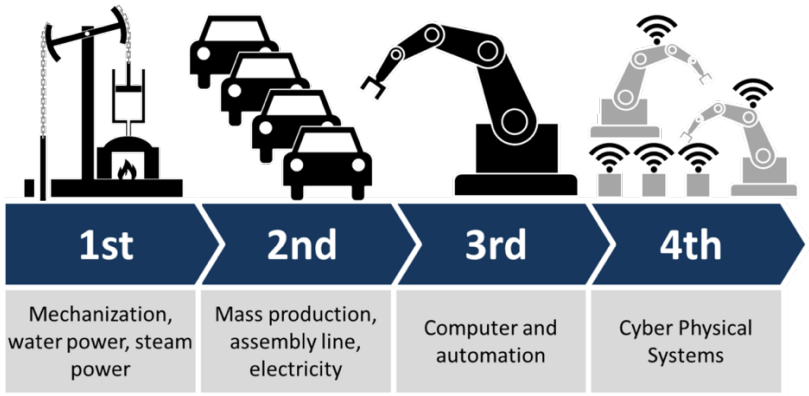


Figure 2 From 1st to 4th industrial revolution (Roser, 2015, p.1)

2.3.1 Industry 1.0: agriculture changes to mechanic industry

According to Turner (2021) a combination of technological changes, innovation and improvements in several industries led to a transformation of the economy, especially in Britain. This is also known as the first industrial revolution at the end of the eighteenth century (Oztemel & Gursev, 2020). It changes the agricultural industry to the mechanic industry (Rojko, 2017), which means that water and steam powered machines were developed to substitute human power (Rao & Prasad, 2018). This mechanization brought about the standardization of processes and systems (division of labor), which made it possible to develop a larger scale industry (Rojko, 2017; Turner, 2021). Not only did various industries change during the first revolution, but society did also as well. People moved to the towns to work in factories rather than on the land and the population and national income per head increased (Turner, 2021). These changes took place because there was a great need for an improved quality of life (Rojko, 2017).

2.3.2 Industry 2.0: mass production and division of labor

After the first industrial revolution, due to electrification and the division of labor the second industrial revolution occurred (Oztemel & Gursev, 2020). This resulted in electrically driven production, characterized by mass production and assembly lines (Rojko, 2017). The division of labor

increased the productivity by dividing the total job in several simplified tasks so that each worker would complete a part of the job (Rao & Prasad, 2018). Alongside steam power and iron, electricity and steal appeared. This period is characterized by various inventions such as light bulbs, automobiles and photography and film (Turner, 2021). Besides, also more managerial programs developed which has an effect on the efficiency, effectiveness, and quality of manufacturing (Rao & Prasad, 2018). During this industrial revolution the focus was on "increased quality and productivity with optimization of labor" (Rao & Prasad, 2018).

2.3.3 Industry 3.0: digitalization and automation

Around 1970 the third industrial revolution, also known as the digital revolution, occurred (Oztemel & Gursev, 2020). Therefore, a shift is taking place from mechanical and analogue technology to digitalization. According to Turner (2021) the digital revolution can be described as "the coming together of various enabling technologies created 'informatization 'with the miniaturization of electronics and the integration of telecommunications and computing" (p.103). Informatization or information technology can be defined as the "inter-mix of computers and communications, and the increasing use of electronics both in industrial processes and commerce" (Khan, 1987, p.115). Some key drivers of industry 3.0 are circuit boards, microelectronics, telecommunication, and further automation of manufacturing (Rao & Prasad, 2018; Rojko, 2017).

An important development is taking place regarding the computer, not only within companies but also for personal use (Turner, 2021). The tasks that can be performed by computers within companies result in a cost and time reduction. This results in automated routines. Especially in the manufacturing industry this results in flexible production, in which different products are manufactured on flexible lines served by machines (Rojko, 2017).

In this period, the globalization of markets, products and research and development occurs through the easy and cheap transmission of data (Khan, 1987). The sharing of data, but also of products, leads to an increasing need for international standardization. It must be possible to link a component from a certain manufacturer to that of another manufacturer. This is also important when it comes to robotization. The goal is to have their own information flow so that they can respond to in-efficiency (Khan, 1987).

2.3.4 Industry 4.0: digital manufacturing with devices connected to the internet

Industry 4.0 is a revolution in, mainly, the manufacturing industry. According to Dalenogare et al., (2018) industry 4.0 "brings an integration between manufacturing operations and information and communication technologies." This means a swift from dominant machine manufacturing to digital manufacturing, (Kamble et al., 2018; Oztemel & Gursev, 2020). The outcome of these interactions are large amounts of data, the storage of these data and transform it to useful information are main elements of industry 4.0 (Ahuett-Garza & Kurfess, 2018).

2.3.5 From industry 3.0 to industry 4.0

As mentioned, industry 3.0 is about the shift from analogue to digitalization and robotization. This is characterized by human-machine interface, digitalization, and automation (Roser, 2015). In industry 4.0 machines/devices communicate with each other without the intervention of humans, also called machine-to-machine communication (Oztemel & Gursev, 2020). This is possible due to Cyber-Physical Systems (CPS), which is the basis of intelligently connected production systems (Rao & Prasad, 2018). In contrast to industry 3.0, machines are autonomous and able to make decisions without the help of humans. Weenink (2022) visualized the change from industry 3.0 to industry 4.0 in Figure 3.

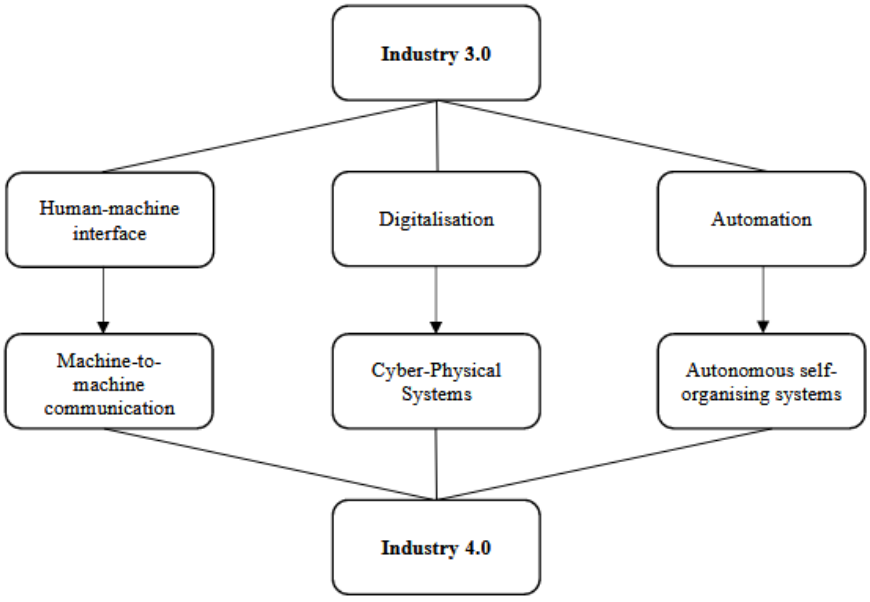


Figure 3 From industry 3.0 to industry 4.0 (Weenink, 2022, p.20)

2.4 Technologies within industry 4.0

As mentioned, the information technology of Industry 4.0 is based on CPS. CPS is the basis of intelligently connected production systems (Rao & Prasad, 2018) and facilitates communication between machines but also between machines and people (Oztemel & Gursev, 2020). CPS enables easier access to information, preventive maintenance, timely decision-making, and process optimization (Oztemel & Gursev, 2020). Oztemel & Gursev (2020) describes that CPS consists of several phases. The first includes the use of various technologies, such as RFID tags for unique identification. The next is sensors and 'actuators' with limited functions. The third and final phase involves the use of data, specifically the storage and analysis of data. CPS therefore consists of different technologies (sensors and actuators) and is designed to be compatible with networks (data). According to Kamble et al. (2018), CPS "makes the whole factory adaptable" (p. 408).

Another important part of Industry 4.0 is the Internet of Things (IoT). It connects physical devices equipped with electronics, software, and sensors for the purpose of collecting and exchanging data (Kamble et al., 2018; Oztemel & Gursev, 2020; Rao & Prasad, 2018), which leads to big data (Ahuett-Garza & Kurfess, 2018). “IoT facilitate real-time data collection and information sharing” (Moosavi, Bakhshi, & Martek, 2021, p.3). In addition to connecting physical devices to the Internet, IoT also allows machines and people to work together. Together, this increases productivity, efficiency, and reliability(Kamble et al., 2018).

In addition to CPS and IOT, cloud computing is also a key component of Industry 4.0. Cloud computing is the infrastructure that supports the interconnection of industry 4.0. Think of servers, storage space or a database on the internet (da Costa et al., 2019; Kamble et al., 2018). This system helps to handle Big Data. Cloud computing has different advantages, it reduces costs and provides an infrastructure, it protects data and makes it possible to access the data at any time (Oztemel & Gursev, 2020).

Industry 4.0 generates Big Data, which is described as a large, complex data set generated from different sources (Moosavi et al., 2021). By analyzing and visualizing this data, patterns are discovered that are used for making decisions (Moosavi et al., 2021). Analyzing usually does not succeed with traditional analysis methods (da Costa et al., 2019), for this cloud computing can provide a solution (Oztemel & Gursev, 2020).

2.5 Readiness and maturity models regarding industry 4.0

To determine the readiness and maturity in terms of industry 4.0, different models can be used. Maturity is defined as "the state of being completely grown" (Oxford, n.d.-a). Usually, maturity models are used to measure the maturity of the organization regarding a concept, in this case industry 4.0 (Schumacher et al., 2016). On the other hand, the goal of readiness models is to capture the starting point before the maturity level can be determined (Schumacher et al., 2016).

There exist various models in the area of readiness and maturity. One of the readiness models is the PWC-model. This model provides insight in the current situation of the organization and offers advice on the next steps to be taken (Bibby & Dehe, 2018). PWC uses five overarching categories, mentioned in Table 1, and a 1-5 Likert scale for each category (Geissbauer, Schrauf, Koch, & Kuge, 2014). An advantage of this model is that it is applicable in various industries. However, this results in more general information (Bibby & Dehe, 2018).

A second readiness model, the IMPULS model, consists of six categories, using a 1 to 5 Likers scale. According to Bibby & Dehe (2018) the focus is on manufacturing and engineering, which results in more attention towards technology aspects of industry 4.0. Besides, the model is scientifically well established, and its structure and results are transparently (Bibby & Dehe, 2018).

Thirdly, maturity models can also be used to assess how advanced an organization is in terms of industry 4.0. The Acatech Maturity Index helps organizations to transform companies into learning organizations (Schuh, Anderl, Dumitrescu, & Krüger, 2017). The Acatech index assesses the organization form three different perspectives. As mentioned, the maturity index builds on readiness models. Organizations will therefore already need to have a clear staring point with which they can determine the maturity of the organization (Schumacher et al., 2016).

Table 1 Categories in various readiness/maturity models

Model	***PWC-model***	***IMPULS-model***	***Acatech Maturity Index***
Category	Business models, product & service portfolio	Strategy and organization	Technological
	Market & customer access	Employees	Organizational
	Value chain, processes, and systems	Data-driven services	Culture
	Compliance, legal, risk, security & tax	Smart factory	
	Organization & culture	Smart operations	
		Smart products	

As mentioned, this research focuses on factors that hinders the implementation of industry 4.0. Although all the three models are using different categories to assess the readiness or maturity, the categories of the IMPULS model fits best to the purpose of this research. First, the categories of the PWC-model are too broad defined and focusing partly on some external subjects. Besides, the factors are difficult to apply to the context of the internal supply chain. The Acatech Maturity Index is focusing more on internal subjects but is missing some depth. The overall categories are not defined in subjects to assess the overall categories. The IMPULS model considers both soft and hard factors related to industry 4.0, which provides a total overview. Second, the Acatech Maturity Index does not use the Likert scale to assess the organization on different categories, resulting in conclusions based on reasoning. Both the PWC-model and IMPULS-model use the Likert scale which results in besides reasoning also in a conclusion based on numbers. However, the PWC-model lack some sub-categories to clearly assess the overarching category. This is something the IMPULS-model has clearly defined. Lastly, according to Bibby & Dehe (2018) the IMPULS-model is scientifically well-established in contrast to PWC and Acatech Maturity Index. Therefore, the IMPULS-model will be used to determine the hindering factors. In the next section the model is described in detail.

2.5.1 IMPULS Model fits the best in this research

In 2016 the industry 4.0 readiness model was conducted by the IMPULS foundation of the German Engineering Federation (VDMA) (Bibby & Dehe, 2018; Lichtblau, Stich, & Goericke, 2015). The IMPULS model provides insight and improvements on the preparations for industry 4.0. The readiness model contains six key dimensions; strategy and organization, employees, data-driven services, smart factory, smart operations, and smart products, for detailed description see Table 2. The first step in the IMPULS-model is to look at the six dimensions and determine which dimension is applicable for the organization (Grufman & Lyons, 2020). The focus of this research is on the factors: strategy and organization and employees (red box Table 2). It is important that these dimensions be considered first because this is at the front end of implementing an innovation (Kotter, 1997). The other factors, in this case the transition to data-driven services, smart factory, smart operations, and smart products are considered in more general.

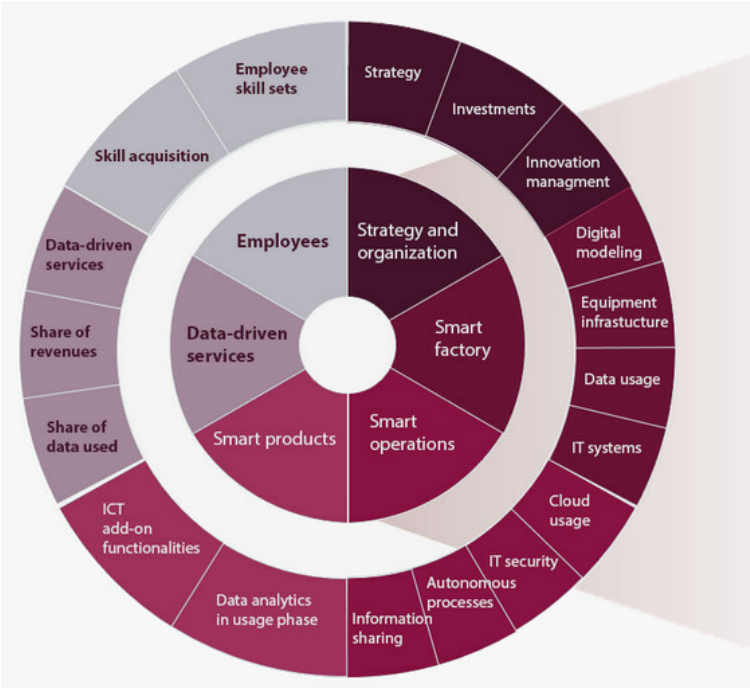
Table 2 Detailed description of IMPULS dimensions based on Bibby & Dehe (2018).

Dimension	Description
Strategy and organization	Not only products and processes could be improved by industry 4.0 but also entirely new business models could be developed. Within this dimension the model examines the openness toward and the cultural interaction with industry 4.0.
Employees	Employees are important in the digital transformation and the most affected in this transformation. Employees should be prepared for these changes.
Data-driven services	The after-sales will be based more on data (analysis). The products which are equipped with ICT collect and send data to deliver better service based on data.
Smart factory	Smart factory can be seen as an environment in which production and logistic systems organize themselves. These systems result in huge amount of data which should be processed, analyzed, and integrated.
Smart operations	Smart operations support the smart factory. The technical requirements to realize the self-organizing environment in the production and logistics are known as smart operations.
Smart products	Smart products are an important aspect of the smart industry. Physical products equipped with ICT to collect data are considered as smart products. When products collect data and communicate with the systems, real-time improvements can be implemented.

Focus of this research

After determining the relevant dimensions, these dimensions can be assessed by subjects related to the dimensions. These subjects are shown in Figure 4, in the most outer circle. As mentioned, these subjects are measured with a 1 to 5 Likert scale which provide a score. According to Lichtblau et al. (2015) the decision of how many points is given for each dimension can be determined via a survey, where top managers or business experts are asked questions about industry 4.0. The outcome reflects the level that an organization is at in terms of industry 4.0 (Lichtblau et al., 2015).

Figure 4 Industry 4.0 readiness model (Lichtblau et al., 2015)

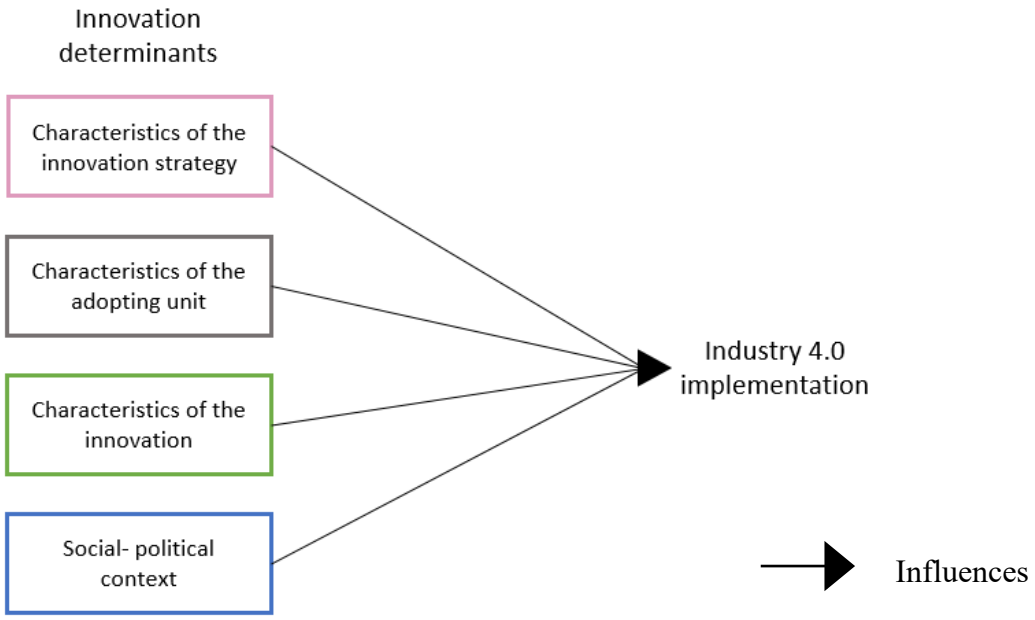


2.5.2 Innovation determinants

When an organization decides to implement industry 4.0, this can be seen as an innovation with an associated process. This process is unique to each situation. According to Paulussen (1994) the innovation process involves dissemination, adoption, implementation, and continuation. This process is considered more general since this research focuses only on the hindering factors.

This innovation process can be influenced by different factors. Derived from the theory, Paulussen (1994) distinguished four categories of hindering factors. These factors are characteristics of the innovation strategy, characteristics of the adopting unit, characteristics of the innovation, social- political context (Figure 5). This theory can be supported by more practical research. According to Krottje (2021), challenges arise around three pillars: technology, organization, and human.

Figure 5 Determinants of implementation (*Paulussen, 1994, p.50)*

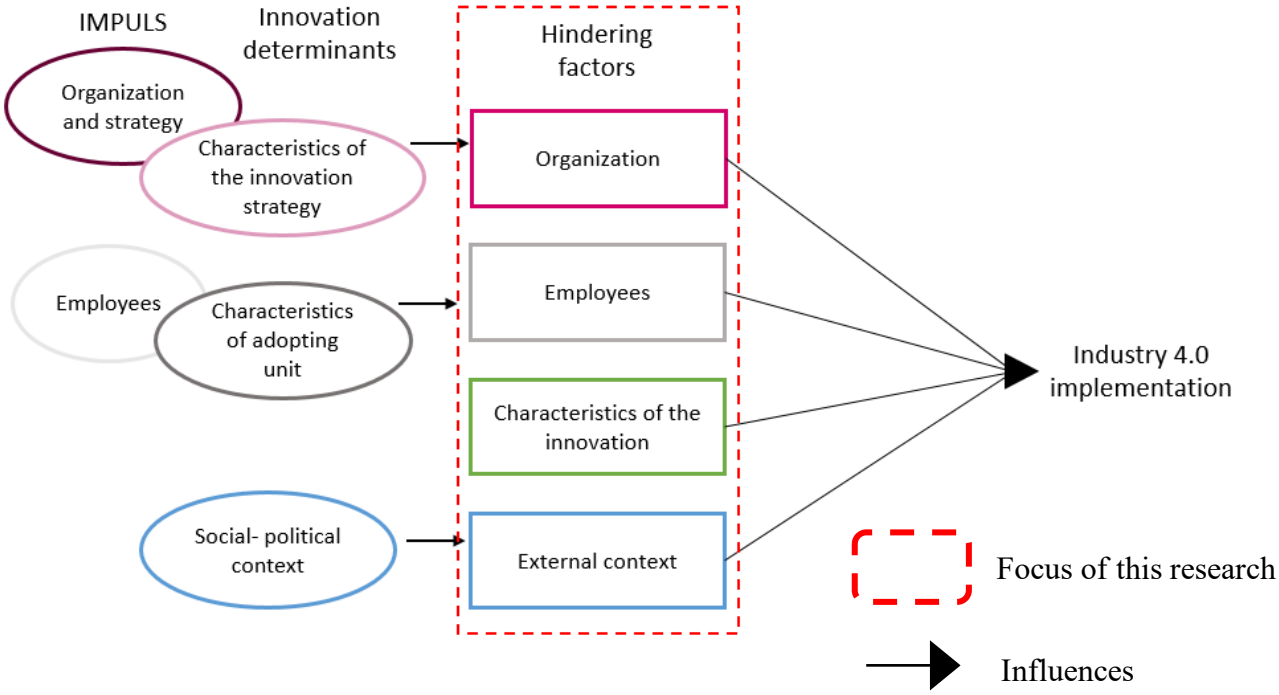


The first characteristic refers to the strategy to actual implement the innovation. Second, the characteristics of the adopting unit are important to consider because this leads to an innovation being implemented or not. The innovation should fit the potential users. The characteristic of the innovation refers to characteristics that could have an influence on the innovation process. The last characteristic refers to social political factors refer to policies, legislations, or any pressure outside the organization (Paulussen, 1994).

2.5.3 Combining IMPULS-model and Innovation determinants

Both the IMPULS-model and the innovation determinants define factors that are important to consider for industry 4.0 in general and specific when implementing industry 4.0. This research aims to give insight in the factors that hinder the implementation of industry 4.0 so both are combined. The combination is visualized in Figure 6 . This thesis focuses on the hindering factors, which is the scope of this research framed in red. This is also the reason why the innovation process is simplified in "Industry 4.0 implementation".

Figure 6 Combination of IMPULS-model and innovation determinants



The categories of the hindering factors on the implementation of industry 4.0 are Organization, Employees, Characteristics of the innovation and Social-political context. The category Organization is derived from Organization and strategy in the IMPULS-model and Characteristics of the innovation strategy in the innovation process. These two dimensions are combined to Organization. Strategy is left out of the category because it is something embedded in the organization. Besides, this thesis focuses on an organization which will provide a broader scope of subjects when only asking about the organizational factors instead of steering towards the organization and its strategy. The second category is Employees. This category also derives from the IMPULS-model and innovation process. In the context of this research, the adopting unit are the employees within the organization. Therefore, the Employees are seen as separate category. The third category, characteristics of the innovation, remains as it is. Industry 4.0 is a complex concept with different aspects, this complexity could have an influence on the implementation process. Therefore, the characteristic of the innovation is taken into account. Lastly, according to Paulussen (1994) the social- political context refers to any pressure outside the organization. Organizations in the defense sector have to deal with influence from for instance the industry, market and government. This results in changing the social- political context to a broader scope, the External context. In this way not only the policies and legislations are considered but also other factors in the external context.

2.6 Hindering factors based on combination of IMPULS-model and innovation process

According to the literature, there are different factors that influence the implementation of industry 4.0. These factors are categorized into: Organization, Employee, Characteristics of the innovation and External context.

2.6.1 Organizational factors

Company characteristics: some company characteristics may have an impact on the implementation of industry 4.0. The sector in which an organization operates in, could have an influence on implementing industry 4.0. Especially repetitive and highly automated production environments are suitable for implementing industry 4.0. Besides, some research also mentions the size of the company as important characteristic. Smaller companies have less resources to adopt industry 4.0 compared to bigger companies. However, according to Hoyer et al. (2020) there are several studies that does not indicate the influence of the company size on industry 4.0.

Financial constraints: industry 4.0 is a relatively new concept with new associated technologies. Financial constraints could influence the implementation of Industry 4.0 (Ghadge et al., 2020). Companies with greater financial resources will see the financial aspect as a lesser obstacle (Čater, Čater, Černe, Koman, & Redek, 2021; J. Müller, Maier, Veile, & Voigt, 2017).

Lack of digital culture: every company has its own culture, which is mainly based on the behavior of its employees (Schuh et al., 2017). If it is not in the culture of a company, and thus in its employees, to take risks, this will hinder industry 4.0. It takes courage to make the technical and organizational changes to reap the benefits of industry 4.0 (McKinsey, 2016). It is important for the implementation that a company incorporates industry 4.0 in its culture. There is then a shift towards the digital culture.

Lack of management support: another aspect that influences the implementation of Industry 4.0 is the knowledge of the subject. Research shows that the lack of in-house expertise affects the implementation of industry 4.0. The more knowledge employees have about industry 4.0, the greater the intention to use its technologies and the greater the chance that this happens (Ghadge et al., 2020). By means of training, the employees' knowledge can be broadened, think of technical skills in the field of production, purchasing and logistics (Deloitte, 2014). These trainings will have to be stimulated from higher management. If this is not the case, it will also hinder implementation.

According to Deloitte (2014) answering the challenges, benefits and how it will be managed is a task of higher management.

Lack of infrastructure: industry 4.0 consists largely of data from which valuable information can be extracted. This sometimes requires completely new IT systems and infrastructures. This applies not only to information but also to any machines that communicate with each other (Deloitte, 2014). This creates information flows between different departments. This requires a infrastructure with "internet connectivity", otherwise it will hinder the initiatives of industry 4.0 (Luthra & Mangla, 2018). Shi et al. (2020) ads that, to integrate industry 4.0 both vertically and horizontally in the company, an important element is the infrastructure. A first step towards the right infrastructure is to see what is already possible with the current systems within a company (Deloitte, 2014).

Poor quality data: according to Santos et al. (2017), data quality is one of the most important requirements. Several machines, sensors and manufacturing systems are interconnected to generate big data. The available data supports companies to put industry 4.0 into practice.

Strategic consideration: the lack of a strategy regarding industry 4.0 leads to misunderstanding and wrong expectations. When employees have different definitions of industry 4.0 and understanding of the technologies and the concepts there are no clear standards for implementing it. This results in different levels of implementation within an organization while it is not clear when the department has sufficiently implemented industry 4.0 even though this department claims it does (Hoyer et al., 2020).

2.6.2 Employee factors

Knowledge and skills: Industry 4.0 brings new opportunities and challenges. Different processes and the way of working will change for employees (Deloitte, 2014). As a result, for instance, production employees will feel that they do not have enough knowledge to make industry 4.0 a success (McKinsey, 2016). There will be a lack of a common vision and goal regarding industry 4.0. If this is not known, the benefits of industry 4.0 will not be recognized (Shi et al., 2020). Therefore, organizations should pay attention to promoting important skills and knowledge that are needed to understand and work with industry 4.0. The use of smart devices, advanced IT systems and automation will increase which will require specific skills. The knowledge about industry 4.0 is not

distributed equally within the organization. According to Hoyer et al. (2020) managers showed a higher degree of knowledge of industry 4.0 compared to the workforce.

Resistance to change: a factor that goes hand in hand with culture is the willingness to change. If most employees do not see advantages, it will be difficult to implement industry 4.0. Schuh et al. (2017) defines five skills that ensure that employees want to go along with the change. The first skill is that making mistakes is allowed. (Schuh et al., 2017) states that making mistakes provides better insight into processes, for example. By dealing with mistakes in the right way, the learning process of employees is triggered, and they will be more open to change. Subsequently, employees will have to be open to innovations. When employees embrace new technologies and implement them in their daily work, this will add value to the company. Third, employees must have the skills to learn and make decisions based on data. If employees see that data is a reliable source for learning and making decisions, they will be more inclined to accept industry 4.0. As mentioned before, industry 4.0 will change work and skills. Employees will have to realize that they need to continuously develop themselves. The knowledge and skills of years ago will not always be useful in the future. Finally, the company will have to show the employees that they also have a say in the change. By letting the employees think along and giving them more responsibility, industry 4.0 will be accepted sooner.

2.6.3 External context

Legal issues: companies are not familiar with the laws and regulations surrounding industry 4.0. As mentioned before, industry 4.0 has to do with data in large numbers. This involves things like data security and privacy (J. Müller et al., 2017). When the step towards industry 4.0 has been made, companies will ask themselves for which purposes the data can be used exactly. This applies both internally, for example the tracking of employee activities, and externally, for example sensitive data from suppliers (Luthra & Mangla, 2018).

Lack of policies and support from the government: government policies and their support are crucial in developing industry 4.0. Governments are unsure on the consequences of industry 4.0. Therefore, governments have not revealed a roadmap for transforming traditional business into smarter (digital) business yet (Luthra & Mangla, 2018).

2.6.4 Characteristics of the innovation

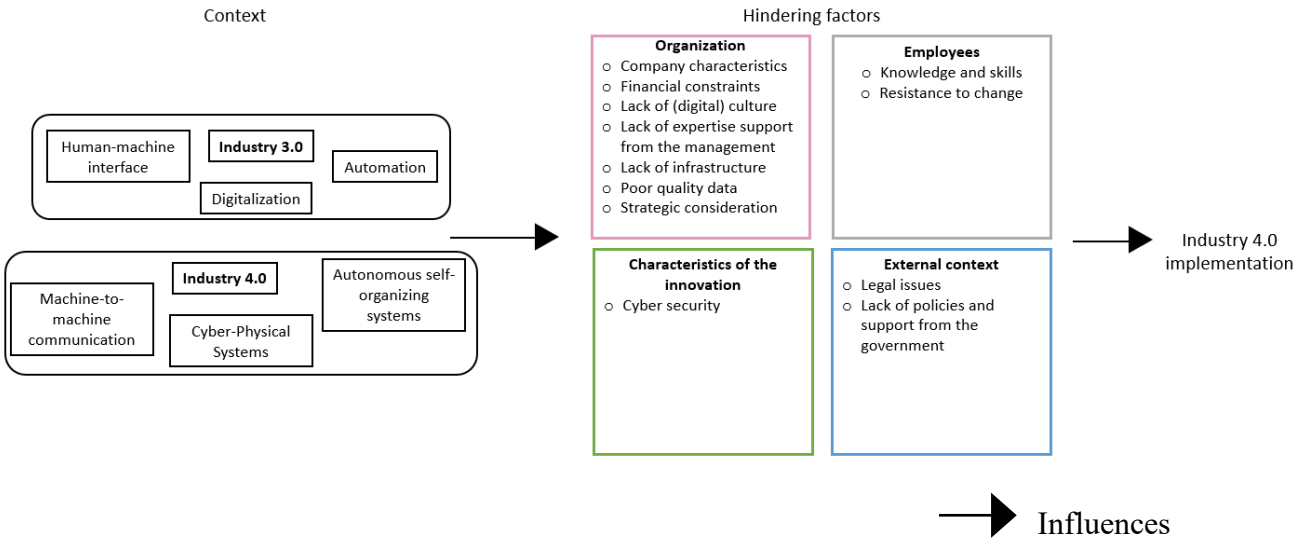
Cyber security: industry 4.0 is all about data. Machines are connected to machines and machines communicate with people. Cybersecurity is therefore an important topic. The

implementation of industry 4.0 (technologies) often involves a third party (McKinsey, 2016). The more parties involved, the more sensitive. After all, if one of these parties is hacked, there may also be access to other parts of the company (Luthra & Mangla, 2018). If the cyber security issues cannot be resolved, the potential benefits will not be fully realized either (Thames & Schaefer, 2017).

2.7 Theoretic model based on different contexts, IMPULS, Innovation determinants and hindering factors

As the objective of this research is to identify what the context is and which factors influence the implementation of industry 4.0 the following model, derived from the literature, was set up. On the left side, the theoretic model shows the context of industry 3.0 and 4.0 (See paragraph 2.3.5). This is included because the context may influence the hindering factors. The hindering factors found in the literature are categorized in the categories based on the IMPULS-model and innovation determinants. The final research model is visualized in Figure 7.

Figure 7 Research model



3 Method

As mentioned, the objective of this research is to identify which factors hinder the implementation of industry 4.0. The following research question is formulated: *How does the context influence the hindering factors and how can the most important hindering factors be solved so that the internal supply chain of defense company can implement industry 4.0?* Because this question is a so called "how" question, this research has a qualitative approach which often uses interviews as data collection method.

3.1 Data gathering: interviews and peer-session

To acquire data, semi-structured interviews and a peer-session is used to answer the research question because of its qualitative nature.

Interviews are the main method used in this research. There are three types of interviews: unstructured, semi-structured, and structured interviews (Eriksson & Kovalainen, 2008). The research question is called a 'how' question, which can be studied best with semi-structured interviews. Semi-structured interviews are somewhat systematic but there is the possibility to vary the order of the questions and ask additional questions. The most challenging about this type of interviewing is to make sure that all the subjects are covered during the interview (Eriksson & Kovalainen, 2008). Interviews can be held individual or in a group. An individual interview is preferred over group interview because in a group it is more difficult to ask targeted follow-up questions to an individual. Besides, the answers of interviewees may be affected by the presence of other interviewees.

In this research, both types of interviews are used. To get an overview of the current situation a group interview was held. With non-probability sampling a first selection was made. To map out the current situation sufficient knowledge about the startup and current situation of industry 4.0 is required. Therefore, out of the possible participants the design engineer, industrial manager, and Product Lifecycle Management (PLM) expert are selected for the interviews about the current situation. This type of interview (group interview) is used to create interaction between the interviewees which results in a more complete view, of the current situation. Besides, two individual interviews are held with the improvement manager and werkcel leader to check whether the current situation mentioned in the group interview is shared within the internal supply chain (Table 3).

Table 3 Interview current situation

Type of interview	Who	Duration
Group interview	Digital Industry Engineer (I6), Industrialization Manager (I1), and PLM Expert (I9)	34:31
Individual interview	Improvement Manager (I5)	42:27
Individual interview	Workcell leader (I10)	12:20

A second series of eight individual interviews will provide input for the hindering factors. Individual interviews are used to prevent biased interviewees and ensure involvement of each participant. Logically, not every person has sufficient knowledge about industry 4.0. Besides, as mentioned it is recommended to ask questions to top managers and/or business experts about industry 4.0 (Lichtblau et al., 2015). Therefore, the research filtered respondents through nonprobability sampling. The interviewees are active in the supply chain and have knowledge about the subject. Most of the respondents have a managing role in the company or, when this is not the case, are business experts. The different positions in the supply chain gave different views from within the supply chain.

Table 4 List of participants individual interviews.

Resp.	Function	Duration
1	Manager Industrial Supply Chain	40:37
2	Industrialization Manager	43:50
3	Industrial Architect	45.33
4	Manager Industrial Engineering	44:27
5	Manager SC Improvement	38:52
6	Digital Industry Engineer	34:50
7	Manager support ABS	20:44
8	Manufacturing Technology Engineer	37:43

Out of the eight interviews, one was conducted in English and seven in Dutch. All interviews where conduction on location at defense company. On average the interviews lasted about 39 minutes, with the shortest interview of 21 minutes and the longest 46 minutes. The interviews were held in June 2022 (Table 4).

3.2 Interview setup

The theoretical model is used as input for the interview setup. The interview starts with a knowledge question. In this way the context is defined. As mentioned, this could influence the hindering factors that are experienced by an employee. After this, open questions are asked. This provide the respondents to have a broad and open answer without being pushed into a direction. After that, each dimension from the theoretical framework are asked about. It may be that the participant is limited to certain topics without having thought about other dimensions. However, also the first question about the dimension was an open question. When it appears that the participant has no response to the open question, an additional question will be asked to verify that there are indeed no hindering factors within the dimension according to the specific respondent.

"Organization" is the first dimension that will be discussed in the interview. According to (Kotter, 1997)**,** the third step in an innovation/change process is to develop a vision and strategy. This is a sub-factor within the organization. Therefore, the organization dimension is examined first. Second the "Employees" because this is related to the organization but on a less general level. After looking to the internal organization, the interview discusses the External Factors. This is done to stay in the context of the organization before discussing other topic that does not relate to the organization. Lastly, the Characteristics of Industry 4.0 are discussed. The interviews end again with a broad open question to examine whether there are more dimensions that hinders the implementation. Second, a ranking question is asked. This is done separately so that every respondent has its own arguments whether the hindering factor is important or not. Besides, the impact and ease of implementation is asked. The outcome of this questions will be used as input for the peer-review session.

When conducting research, validity is essential to consider. Validity describes how well an instrument measures what it is supposed to measure (Andrade, 2018). There exist two types of validity, internal and external validity. Andrade (2018) defines internal validity as "validity examines whether the study design, conduct, and analysis answer the research question without bias" and external validity as "examines whether the findings of a study can be generalized to other contexts". To achieve validity, the interview questions are based on the literature review. To decrease bias, the interviewees are interviewed separately, and the questions were asked in the same order and way.

These questions are chosen to remain as open and independent as possible. To get the most out of the interviews and create awareness about some dimensions, an additional question is asked. This additional question serves not as a check to ensure that certain factors found in the literature will be mentioned but to encourage the participant to think more deeply about different dimensions. In addition to these structured questions, also questions will be asked based on the answers given. These questions are asked for the purpose of clarification, verification and drawing the correct conclusion. The interview questions can be found in appendix I.

The second research method is the peer-session. The interviews result in different hindering factors. Even tough, every respondent had been asked to make a top 5 this could differ among the respondents. To delineate the research and have the respondents on the same side, the peer-session results in a top 3 hindering factors to which a recommendation will be given.

Next to validity, reliability should also be considered. “Reliability describes the consistency with which results are obtained” (Andrade, 2018). To ensure reliability, the number of participants is considered, and the peer-session is used to test whether the interview outcomes are consistent.

3.3 Data analysis: transcribing and coding

The data gathered from the interviews are analyzed. The interviews were recorded and transcribed. After transcribing, the transcript was shared with the interviewee to increase reliability. No software was used because of confidentiality. When the interviewee approved the transcript, this transcript was coded. Locke, Feldman, & Golden-Biddle (2022) define coding as “coding entails the work of scrutinizing, pondering, and organizing collected observations and relating them to theoretically relevant abstract features, possible relationships, and research questions” (p.264). The analysis started with open coding, which breaks apart data and generated codes (Locke et al., 2022). After open coding, axial coding is used to identify characteristics of the sub themes, clarifying similarities and differences between the codes and develop some categories (Locke et al., 2022). The last step is to refer the categories, derived from axial coding to the core category. This step refers to selective coding (Locke et al., 2022). These core categories are based on the theoretical framework. When coding the interview, it is searched for factors that the participant experience as hindering. These factors can dan be classified into the core categories. The code scheme is used to extend or modify the theoretical framework. After transcribing, and coding it was possible to analyze the data and draw a conclusion.

4 Results: the interviewees answers center around the categories Organization and Employee

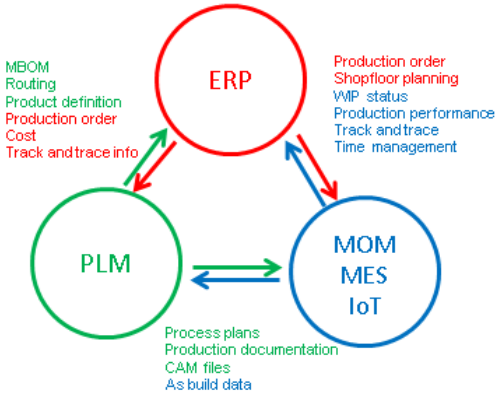
This research focuses on hindering factors of the implementation of industry 4.0 in the defense sector. As mentioned in the theoretical framework, the hindering factors could occur in a different context and categories. In this chapter, the results are described. The structure will be as follows: first, the current situation regarding industry 4.0 is described, then the obtained data about the industry 4.0 context and the hindering factors in the categories Organization, Employee, External context, and Characteristic of the Innovation are described. After open-coding, axial-coding and selective-coding it became clear that the core categories found in the literature cover the mentioned hindering factors.

4.1 Current situation: Focus on taking steps from industry 2.0 to industry 3.0

To describe the current situation, existing available documents were examined: the main input is the problem description and industry 4.0 documents. Besides, three interviews about the current situation are used. The problem description (Appendix II Problem description) shows there exist a gap between the current way of working and the industry 4.0 standard. To overcome this gap, it is important to determine the current situation because different steps could be necessary to become closer towards industry 4.0.

The intranet page dedicated to industry 4.0 mentions that the company answers to the industry 4.0 developments by means of the Digital Transformation. Within the defense company the first step in Digital Transformation is to create the Digital Backbone (Figure 8). The Digital Backbone is seen as the network infrastructure that interconnects different networks and provides a path for the exchange of data. For the supply chain this means the integration between Enterprise Resource Planning (ERP) and Product Lifecycle Management (PLM). The idea behind this is that when the Digital Backbone is in place, it will be the basis for the industry 4.0 projects and tools.

Figure 8 Digital Backbone



During the interview on the current situation, the participants were asked about what the supply chain is currently working on in terms of industry 4.0. Interviewees 2, 6 and 9 mention that at the moment the focus is on building data. Interviewee 9 adds the following: "(…) So also interpreting that data. Building data, interpreting data, and having data driven that's actually what's going on right now". The same question was asked during the interview with interviewee 5. It was mentioned that the industry 4.0 team is fully dedicated to a digital shop floor interface (DSI) and the Digital Backbone. The follow up question was about the industry phases. From their perspective (I. 2, 6, 9), the supply chain of the company is in the transition from industry 2.0 to 3.0. In this context interviewee 9 mention: "The way of managing still partly goes with paper, production is managed on paper, there are many errors, quality issues and these can ultimately be traced back to the quality of data". However, it was also mentioned that placing the department in an industrial phase does not have much value. The interviewee 5 mentions the following: "(…) I just want in six months from now we are a step forward and maybe in two years or so we are a good showroom of industry 4.0".

To conclude, the existing documents and the interviews made clear that the internal supply chain is dedicated to making steps from industry 2.0 to industry 3.0. From their perspective, the Digital Backbone is something that should be in place before industry 4.0 can be implemented.

4.2 Context: data and digitalization as main context

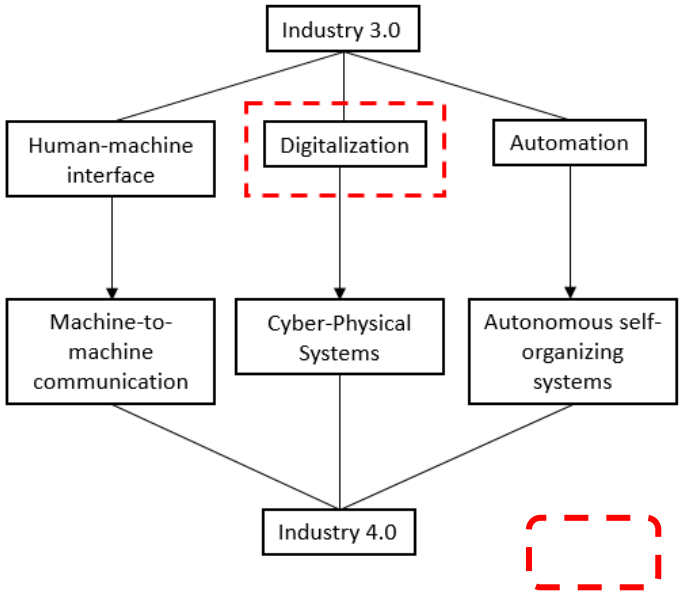
Industry 4.0 knows many definitions. It may be that employees have different definitions of industry 4.0. This could result in different experiences in terms of hindering factors. Therefore, the starting question of the interview was about the definition of industry 4.0 to see whether the factors differ among the definitions given.

The interviews showed that data and/or digitalization is seen as the core element in the definition of industry 4.0 (I. 1, 2, 3, 4, 6, 7). In more detail, the definitions are about using data to make better decisions, do data-driven analysis and be more efficient. The technologies that are mentioned are software systems, IoT, VR, AR, blockchain, robots and mobile devices. Although some technologies are mentioned, because the internal supply chain is doing a lot by hand and paper it is too early to think about industry 4.0 technologies (I. 4). Interviewee 3 supports this by mentioning that trace-ability is something that should be in place first before working with industry 4.0 technologies.

A few also mention (I. 4, 8) in combination with data, automation of process in the sentence of operations that do not necessarily have to be done by people but by machines and/or robots. In this context computers on workplaces or imbedded in tools and cameras are mentioned. Besides, the connection between products and between products and humans are described in the context of automation. Another aspect that is mentioned by interviewee 2 is the inter-connection between humans and machines.

Last, two interviewees (I. 5, 8) mention that they see industry 4.0 as a set of tools to raise the efficiency of the organization or to use for smart production. The technologies linked to data and digitization also apply here with the overarching concept of wireless technologies. It can be concluded that digitalization is the core concept. Most technologies mentioned belong to industry 4.0 but the concepts mentioned are more in line with industry 3.0. The context is shown below in Figure 9.

Figure 9 Context of the interviews



4.3 Hindering factors: the answers center around the categories Organization and Employee

The second subject of the interviews were the hindering factors. Although the definitions of the participants are more focused on industry 3.0, the answers given focus on the future oriented industry 4.0. The interviews reveal that the most hinderance is experienced in terms of Organization and Employee. Besides, when the interviewees were asked about hindering factors in specific departments of the internal supply chain they respond with the same hindering factors when asked about the supply chain in general. Also, the two interviewees that are closely linked to one of the workcells did not mention significant other hindering factors. Therefore, this chapter describes the hindering factors in more general for the internal supply chain. This section is divided by the four categories mentioned in the theoretical framework.

4.3.1 Organization focuses on strategy and resources

During the analysis of the transcripts several theme's according to the organization emerged. Generally, the interviews focused on ten different themes: different departments, definition of I4.0, governance, processes, initiatives, ICT infrastructure, knowledge, nature of the company, resources, and vision and strategy. The factors definition of I4.0, initiatives and knowledge were mentioned less often than the other factors (by less than two people). In the cross table it can be seen that the lack of a definition is something that is mentioned by interviewees that are closely involved with the ABS workcell. Besides, the initiatives are experienced as hindering (I. 3, 5). However, other interviewees mention that this can increase quick wins. Lastly, knowledge is mentioned within the Organization because interviewee 4 believe that the organization should steer towards knowledge of industry 4.0 and that this is not just the responsibility of employees. The detailed description of these factors can be found in the appendix (Appendix III). Generally, the interviewees desire more clearance about the strategy and the availability of resources.

Interviews show that the involvement of different departments are perceived as hindering (I. 1, 2, 3, 8). Industry 4.0 is seen as a subject that includes many different departments such as ICT, production, engineering which all have their own way of working (I. 1, 2). Besides, the need to take steps towards industry 4.0 is not seen by the entire internal supply chain, which makes it no priority for the different departments within the company NL (I. 1, 3). The participants from the internal supply chain experience hinder when many different departments do not have the same priorities according to industry 4.0 and therefore do not actively participate in taking steps towards industry 4.0.

Governance and steering towards I4.0 are mentioned as hindering factors. These two factors are similar, so these are combined into the factor governance. In half of the interviews, topics according to governance are mentioned (I. 2, 3, 4, 5). Interviewee 1 described the hindrance as follows: “(…) I feel there is a lack of ownership”. Interviewee 5 adds to this that a lot of different employees are working on industry 4.0 so it is not clear who is doing what. Another topic that has been mentioned under the heading of governance is top-down. Interviewee 3 mentioned “I think it is not carried top down. (…) It would be better if industry 4.0 is driven from the top and goals are set”. However, not all the interviewees agree on the fact that industry 4.0 should only be driven from the top. It should be a combination of bottom-up and top-down to get the best results (I. 4, 5). Overall, the lack of steering towards industry 4.0 and clearance about the organization of industry 4.0 is experienced as hindering.

Thirdly, the processes within the supply chain are complex, not clear and there is little standardization (I. 1, 2, 4, 6, 7). Interviewee 4 mentioned that the supply chain consists of a few similar processes, but these are all different between the departments. This causes hinder when an industry 4.0 aspect is implemented in a department, but it cannot be replicated one-to-one for other departments. It results in a lot of effort to define the processes before the supply chain can continue with implementing industry 4.0 (I. 2).

In almost every interview the hinderance according to systems, the basics and ICT infrastructure (I. 1, 3, 4, 5, 6, 8). Because these three factors are about the same subject, these are combined into ICT infrastructure. Both interviewee 1 and 5 mention that the systems are not ready for industry 4.0. The second subject in the ICT infrastructure is the basics. According to interviewees 5, 6 and 8 the basics are not in place and the focus is now on making this work. The basics refer to the systems (ERP and PLM), also known as the digital backbone (I. 5, 6). But interviewee 3 described the basics as follows: “I see trace-ability as the basis. Without trace-ability, the data is useless.” Interviewee 4 provides a broader definition that refers to the fact that data management is not in place. A good ICT infrastructure is desired, especially in terms of systems and data.

Besides the ICT infrastructure, resources are also a factor that is often mentioned (I. 2, 3, 4, 5, 6, 8). This is primarily about resources in the sense of the availability of people. There are not enough people involved in industry 4.0 (I. 2, 3, 4, 5, 6, 8). This results in a, proportionally, too small industry 4.0 team (I. 3, 5,). Besides people, financial resources are also mentioned (I. 6, 8). Interviewee 6 describes it as "(...) we have to dare to invest in this." This is meant for both people and financial resources.

Lastly, many factors were mentioned around vision and strategy. Although vision is mentioned less often, vision and strategy are terms that are used interchangeably and with each other. The lack of vision is experienced as hindering. However, interviews show that the company as a company is good at determining what needs to be done to get where they want to go but that it falters with the execution (strategy). Interviewee 4 formulated this as follows: “(…) "We often find it less interesting to implement such an idea, but that is the most important thing in order to take that step structurally".

Especially under the heading of strategy, topics such as roadmap, plan and priorities were mentioned. A few interviewees mention the lack of a roadmap. Although participants are aware that it may have been formulated it is not known to various departments within the supply chain (I. 1, 8). By extension, it is perceived as hindering if there is no plan available. As a result, it is not clear which benefits industry 4.0 could have (I. 1, 8), where to start (I. 6) and which steps should be taken (I. 2, 4). Last, the focus is on day-to-day operations and there is little room for industry 4.0 in the long term (I. 8).

Below the cross-case table can be found (Table 5). This table shows which participants mentioned which factors. It can be seen that most interviewees mention 4 or more hindering factors regarding the Organization. Only interviewee 7 mention two factors. Moreover, the participants within the departments mentioned approximately the same hindering factors. The participants which are closely related to the workcell mentioned different hindering factors among each other.

Table 5 Cross table of hindering factors in the Organization category

	Industrial SC	*Industrial Engineering*			*Improvement*		*Workcell*		
Organization	*I1*	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	***Count***
Different departments	x	x	x					x	4
Governance		x	x	x	x				4
Processes	x	x		x		x	x		5
ICT infrastructure	x	x	x	x	x	x		x	7
Resources	x	x	x	x	x	x		x	7
Strategy & Vision	x	x		x		x		x	5
Definition*							x	x	2
Initiatives*	x				x				2

Knowledge*				x					1
Nature of the company					x	x	x		3

** Detailed description of the factor can be found in the appendix.*

4.3.2 Employee focuses on skills and knowledge

The factors that are mentioned in the context of employee are: integral view, interest, willingness to change, profession, and skills and knowledge. It became clear that there is a need for employees with certain skills and knowledge to take steps towards industry 4.0.

The limited skills and knowledge among employees are most mentioned. Interviews show that the level of skills and knowledge is insufficient within the internal supply chain to make industry 4.0 a success (I. 1, 2, 5, 6, 7). Interviewee 2 mentioned the following: "(…) you have to work multidisciplinary. You need to have knowledge about many different professions but also knowledge about the process, our business process." Interviewee 6 adds to this that there is a lack of skills especially in IT and business. Overall, this kind of skills and knowledge is too limited within the supply chain which hinders the steps towards industry 4.0 (I. 2, 5, 7).

Something that is in extension of the above is the lack of the integral view (I. 3, 4, 6). Missing the integral view is seen as hindering because each process is going to implement topics on its own which does not contribute to that entire internal supply chain (I. 4). It is important that industry 4.0 is approached company wide, which is decisive for success (I. 3,4)

The last three factors mentioned are interest, profession, and willingness to change. These three factors overlap, and it can be concluded that the willingness to change and seek the full breadth of the profession begins with the degree of interest. Besides, willingness to change is mentioned (I. 6, 8) but it is something that is always a factor in any change process, so that is why it is not perceived as hindering. Not seeking the full breadth of the profession and not being familiar with the developments around industry 4.0 in the profession is perceived as a hindrance (I. 4). From here the connection can be made with interest. Again, only interviewee 4 mentions being hindered by the conscious/unconscious disinterest and lack of intrinsic motivation. Interviewee 7 adds: "I don't want to draw any conclusions, but I do think that the willingness and readiness and interest of people who grew up in the computer world is greater than in a large group of older people". Below the cross-table can be found in Table 6. In every interview factors in the context of employee are mentioned. However, there is no clear pattern among the departments.

Table 6 Cross table of hindering factors in the Employee category

	Industrial SC	*Industrial Engineering*			*Improvement*		*Workcell*		
Employee	*I1*	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	***Count***
Skills and knowledge	x	x			x	x	x		5
Integral view			x	x		x			3
Interest				x		x	x	x	4

4.3.3 External context hinder implementation to a lesser extent

The interviews suggest that the factors in the external context hinder implementation to a lesser extent than the other categories. The factors are: defense industry, law and regulations and low competitive market.

The defense industry is characterized by low numbers and high degree of complexity (I. 5). Besides, the supply chain is setting up the basis for the industry, so it is more complicated to try industry 4.0 practices. Interviewee 5 mentioned this as hindering. Next to this, the defense industry is bound by rules of various parties (I. 6). There are rules concerning cloud solutions and working with certain WIFI networks. But interviewee 6 state to this: "(…) There are quite a few possibilities, but it makes it more complicated, it makes it more difficult than with a company that doesn't have to comply with those regulations. But it doesn't make it impossible, I don't believe that". By extension, it was mentioned that for these reasons, security is something that should also be considered (I. 1, 5, 6, 8).

Laws and procedures are also specifically mentioned by interviewee 1. The interviewee experience hinderance by the fact that the speed of the industry is disproportionate to the speed of laws and regulations. The defense company is bound to different laws and regulations concerning for instance security, cloud solutions and publishing information online. But if the industry asks for it, the laws and regulations are usually amended much later where inconvenience is experienced. Interviewee 1 adds: "Anyway, there are regulations that you should take into account but again, at the moment you determine your strategy, this is part of your strategy".

Another single factor mentioned is the perception that the defense industry is not facing high levels of competition. Interviewee 5 mentioned that this hinders to take steps towards industry 4.0. When this perception exists, the need to do things more efficient is not a concern because there exists the thought of not having the market shares taken by a competitor.

The fact that these factors are only mentioned by one or two participants confirms that these factors hinder implementation to a lesser extent. The interviews show that the external context is a place to learn from others. There is a perception that other companies are further along than the company .(I. 4, 6, 8,). The cross table shows that only three interviewees are mentioning hindering factors in the External context (Table 7).

Table 7 Cross table of hindering factors in the External context category

	Industrial SC	*Industrial Engineering*			*Improvement*		*Workcell*		
External context	*I1*	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	***Count***
Defense industry					x	x			2
Law and regulations	x								1
Low competitive market					x				1

4.3.4 Characteristic of the innovation has no influence on the implementation

As with the external context, the characteristics of the innovation also hinder the implementation to a lesser extent. The factor confidential and security is mentioned by two interviewees (I. 1, 8). The interviewees mentioned that if the supply chain decided to see industry 4.0 as a way to collect data and use this to make decisions, then a hindering factor occurs around confidentiality and security. This is due to the open network, use of could networks and so on. Interviewee 8 states: "(…) but if one feature of industry 4.0 is data collection then I only see problems in the area of confidentiality of products and security when it comes to the network". As mentioned in the previous section, the defense industry must take confidentiality and security into account. Although, two interviewees mentioned this in the context of characteristic of the innovation it can also be seen as a characteristic of the defense industry. After all, the defense industry goes hand in hand with confidentiality and security. Therefore, it was decided to classify this factor under the external context as part of the defense industry.

4.4 On average interviewees indicate that formulating a strategy will have the most impact on industry 4.0

The last four questions were centered around the top five most hindering factors, the degree of impact and implementation and the knowledge of industry 4.0.

First it was asked to make a top 5 most hindering factors (see Appendix IV Top 5 hindering factors and impact implementation table). These hindering factors and other factors mentioned during the interview are used as an input for the session. The top 5 is asked during the interview to compare the individual input and the outcome of the session.

Although the position of the factors differs, all interviewees mention factors in terms of vision and strategy. Also, resources (mentioned 5 times) and skills and knowledge (mentioned 4 times) are factors that are mentioned sufficiently. The other factors mentioned clustered around the themes of IT infrastructure and support, different departments, standardization, and nature of the company.

Second, out of the 8 interviews 4 state that the formulation of a vision and/or strategy will have the most impact. The 4 other interviewees can be divided in terms of governance and take care of the basis.

As for the implementation the factors differ. Interviewees 1 and 4 could not identify the factor that is most easy to implement. Interviewee 1 for instance mention: “So you can do it overarching with a long-term strategy. That's difficult but then you can pretty much define quick wins and implement on that easily. (...) So you can do it on different scales”. The interviewee is referring here to the top 3 hindering factors. The other interviewees mention systems, resources, security, and governance as most easy to implement.

Last, it was asked if the participants felt they had enough knowledge to answer the questions. All interviewees mention that they could not give an overall definition of industry 4.0, however, the interviewees feel like they are having sufficient knowledge of the subject. This especially applies when they talk about industry 4.0 in a broader context. Two interviewees (2, 3 and 5) mention that due to their experience in other companies have a good understanding of what is possible regarding industry 4.0. The other interviewees look at it from their role and/or experience within the defense company from which they conclude that in combination with a broad definition they can contribute to the research.

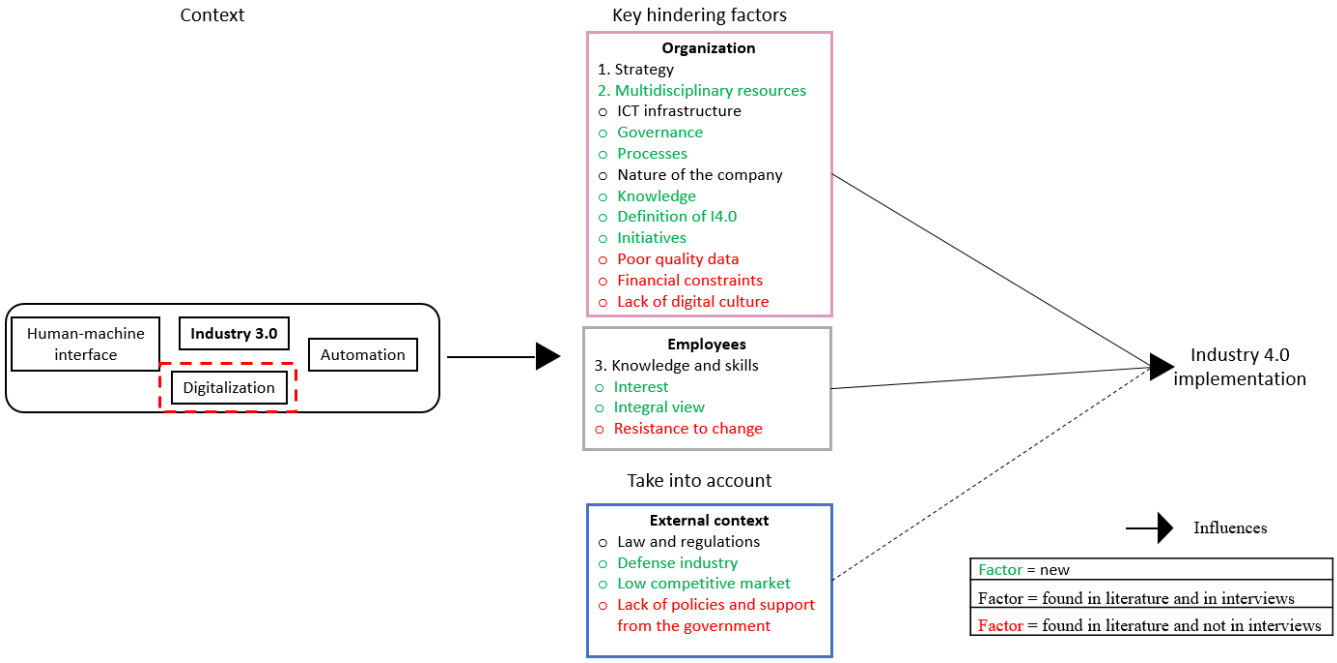
4.5 Final research model: Organization consist of the most hindering factors

Based on the results above, the following research model is derived (Figure 10). As mentioned, the definitions center more around industry 3.0 in terms of digitalization and data. This also aligns with the current situation of the supply chain. Therefore, the model consists of the industry 3.0 context with the emphasis on digitalization. The arrow in the model links the hindering factors mentioned in the industry 3.0 context.

In the middle of the model, the hindering factors are listed. The green factors are not found in the literature but mentioned during the interviews. The red factors are found in the literature but not mentioned during the interviews and the black factors are also found in the literature. The category Organization consists of the most hindering factors, Employee and External context both consists of three factors. The only factor mentioned within the Characteristics of the Innovation is included in the External Context.

The factors are listed by category in order of which interviewees considered them most important (Appendix IV Top 5 hindering factors and impact implementation table). The factors with a number (strategy, multidisciplinary team, and skills and knowledge) were named as the top 3 factors because of the session. In the section before, the second most important factor is called multidisciplinary team. This consist of resources and different departments, therefore these two factors are mentioned as number 2.

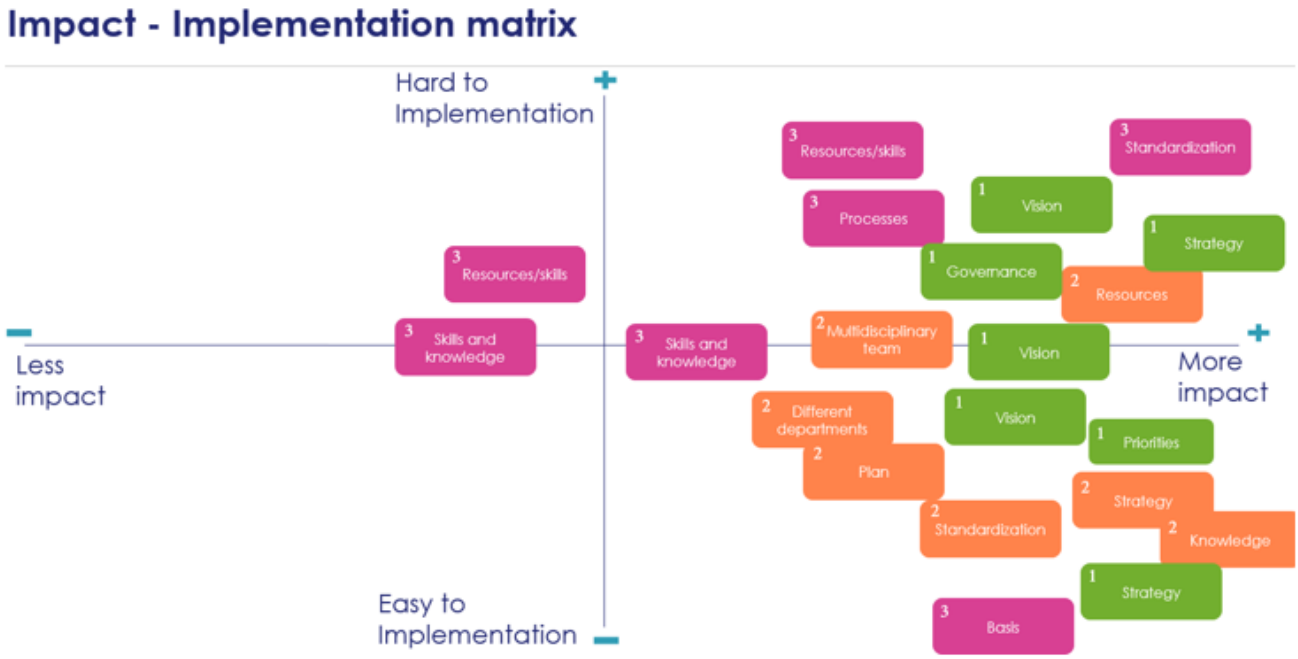
Figure 10 Final research model



4.6 Session: the top three hindering factors are strategy, multidisciplinary resources, and skills & knowledge

After processing and analyzing the interviews, a shared top 3 was determined through a session. The top 5 has been reduced to a top 3 which allows for more detailed recommendations. It was asked to the attendees to make a top 3 and place them in the impact – implementation matrix. The outcome is visualized in Figure 11. The green boxes are the numbers 1, the orange boxes are the numbers 2, and the pink boxes are the numbers 3 of the different attendees. Together, these form the top three hindering factors as can be seen in Figure 11.

Figure 11 Impact - Implementation matrix based on the session



Results in

Nr.	Hindering factor
1.	Strategy
2.	Multidisciplinary teams
3.	Skills and knowledge

The green boxes cluster on the more impact side. The content of the numbers 1 is located around the theme of vision and strategy. This is consistent with the individual interviews where these

topics were also mentioned the most. It was therefore agreed that the number 1 is strategy. This is mainly about the actual execution of the strategy and the governance around it. This was preferred over vision because within the internal supply chain defining the vision is not the main issue.

The factors that are rated as number 2 are visualized in the orange boxes. These factors are also more or less clustered around more impact and easy to implement. However, the themes differ among the numbers 2. Two attendees had strategy and plan as number two, but these are considered as number 1. The other factors, resources, multidisciplinary team, different departments, and standardization are in line with each other. During the session and the interviews, it is stated that industry 4.0 is about many departments in which every department should free up some resources and have more standardization. This results in multidisciplinary resources, which is the number 2.

Lastly, the pink boxes (numbers 3) are more spread around the matrix. However, four attendees mentioned resources and skills and knowledge. During the session it became clear that knowledge and skills are seen as more important than the other factors. Besides, standardization is also categorized within the number 2. The number 3 is therefore skills and knowledge.

To summarize, the lack of a clear strategy and the execution of it, multidisciplinary teams and skills and knowledge are experienced as most hindering to take steps towards industry 4.0. These factors are positioned in the overall categories Organization and Employee.

5 Discussion: To make steps towards industry 4.0, the top 3 hindering factors should be solved

This research aimed to identify the context of this research and the most important hindering factors of the implementation of industry 4.0. On the basis of literature and qualitative data, three broader categories with hindering factors were identified. First the theoretical implications are described. Second, the practical recommendations for the case company are formulated. This section concludes with research limitations and suggestions for further research.

5.1 Theoretical implications

On one hand, this research identifies the current situation of the defense industry with specific characteristics regarding industry 4.0. The case company's internal supply chain is characterized by a make to order and design to order strategy which results in characteristics such as little standardization in product and process, low volume and high product variety. There is a lack of research on the current situation in such companies (Bibby & Dehe, 2018; Ferreri, 2003). This

research found that the current situation is formulated as the transition from industry 2.0 to industry 3.0. According to Bibby & Dehe (2018) and J. M. Müller et al. (2018), industries with more standardized processes and products and more automated machines are better suited for implementing industry 4.0. The characteristics of the defense company could underlie the difficulty in implementing industry 4.0. Besides, the current situation is in line with Lineberger et al. (2019), which mention that defense companies are relatively slow in adopting digital initiatives. This may also contribute to the fact that the defense company is still situated in the transition from industry 2.0 to 3.0. Further research could help to identify which steps should be taken to bring the defense industry closer towards industry 4.0.

Besides the current situation, this research had a focus on the context of the participants to assess whether the definition has an influence on the hindering factors. According to Bibby & Dehe (2018), the lack of a definition could be perceived as hindering for implementing industry 4.0. This is also supported by Culot, Nassimbeni, Orzes, & Sartor2020), which mentioned that there is a shortcoming in the conceptualization of industry 4.0. The case company has a definition but more in line with industry 3.0. However, this has no influence on the hindering factors. The interviews show that, even though the definition is more in line with industry 3.0, the hindering factors are mentioned with a industry 4.0 vision. So, it is assumed that the definition has no direct influence on the hindering factors. Further research could indicate whether the hindering factors differ when the definition is fixed.

On the other hand, this research shows which factors are perceived as hindering in a different type of industry. Different literature indicates which factors hinder the implementation of industry 4.0 (Čater et al., 2021; Ghadge et al., 2020; Hoyer et al., 2020; Luthra & Mangla, 2018; J. M. Müller et al., 2018; Schuh et al., 2017). This research investigated if these factors are also perceived as hindering in a different type of industry.

First, looking at the Organization in more detail there is some overlap with the literature. The hinderance experienced in terms of lack of strategy, lack of ICT infrastructure and nature of the company are supported by the literature. It should be noted that the context of nature of the company differs a bit from the literature. The literature mentions in this context the type of industry and the size of the company (Hoyer et al., 2020). This study shows that these factors are not experienced as hindering but the average age is mentioned in terms of nature of the company, which is in line with the suggestion that some company characteristics have an impact on the implementation of industry 4.0 (Hoyer et al., 2020).

On the other hand, three hindering factors derived from the literature are not mentioned in the interviews. These are: poor quality data, financial constraints, and lack of digital culture. The reason why these hindering factors are not mentioned could be because of the amounts of data available but not knowing how to manage them. This also reflects that there exists some sort of digital culture because it does not indicate that employees do not want to use the data (Schuh et al., 2017). Lastly, the financial constraints could be no issue because of the size of the defense industry and their available financial resources (Čater et al., 2021; J. M. Müller et al., 2018). It would be interesting to perform similar research in a similar or different organization to verify these results.

There are also factors mentioned, that where not found in the literature. Within the case company there exist a lack of strategy. Due to this, it is possible that there is no governance around industry 4.0, no knowledge and no clear definition of industry 4.0 because it is not clear what the organization would like to achieve with industry 4.0. The factors processes and initiatives are also not found in the literature. The fact that the hindering factor process did not emerge from the literature may be due to the industry in which the case company operates. The defense industry is described as complex with little standardization and variation in customer requirements. The complex processes and industry 4.0 require the involvement of different departments which could take a long time. This results in departments taking their own initiatives but there is no overview if these initiatives have a positive effect on the internal supply chain because the overall strategy/vision is missing, this is also mentioned by interviewees located in management functions. The two factors mentioned during the interviews: not enough resources and dealing with different departments are combined into multidisciplinary resources based on the peer session. This is also not found in the literature, which could be due to the lack of strategy and different departments. For the factors that are not found in the literature it can be concluded that the characteristics of the defense industry causes some hindering factors. When these hindering factors occur, other hindering factors that are perceived as hindering occur in turn. Future research is necessary in terms of characteristics of the defense industry and how industry 4.0 can be integrated in complex industries such as defense.

Second, the category Employee consists of one factor that overlaps with the literature: skills and knowledge. It is important to provide and maintain a certain skill level to make industry 4.0 a success (Hoyer et al., 2020).

The factor that is not mentioned during the interviews is willingness to change. There is no specific resistance towards industry 4.0 comparing to other innovation initiatives (Kotter, 1997). This implies that interviewees do not expect more resistance on the implementation of industry 4.0 than

to other innovations/improvements. It is stated that any change process generates resistance, but this is not something that is perceived as hindering.

The two factors derived from the interviews, that are not mentioned in the literature are: interest and integral view. These factors are mentioned by different employees in the organization, which indicates that these factors are experienced by different layers in the organization. The lack of interest could be linked to the average age within the company (nature of the company) and the awareness of the possibilities within a profession. Besides, the combination of the defense industry and industry 4.0 is relatively unknown in the literature, which could have an influence on the degree of interest. This combination result in difficulties when implementing industry 4.0. Besides, the lack of an integral view could be because of the many departments and the complex processes which exist within the defense industry. Future research should focus on the role of the employees in complex organizations which are willing to implement industry 4.0.

Third, the category External Context consists of one factor that was also found in the literature. The factor law and regulations can also be substantiated from the theory. The defense industry is perhaps more than other industries bound by laws and regulations.

The lack of policies and support from the government is found in the literature but not in the interviews. It was mentioned during the interviews that it takes a long time to have several laws and regulations but that this does not indicate that the government is not supportive towards the industry.

Two hindering factors are not found in the literature. The perception that the defense industry has a low level of competition was mentioned. This partly may be because the government is the largest purchaser (Ministerie van Defensie, 2018). This is reflected in the lack of pursuit of efficiency within the internal supply chain (I5). Finally, the defensie industry in the external context. As mentioned the industry is bound by laws and regulations but also by security and confidentiality. Even tough, this was a hindering factor found in the category Characteristic of the Innovation the factor is also in line with the defense industry. Different interviewees mentioned that confidentiality and security is something that characterizes the defense industry (I. 1, 5, 6, 8). Besides, the context was more focused on industry 3.0 which implicates that the category Characteristic of the Innovation was not completely about industry 4.0.

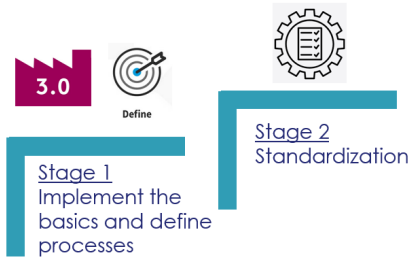
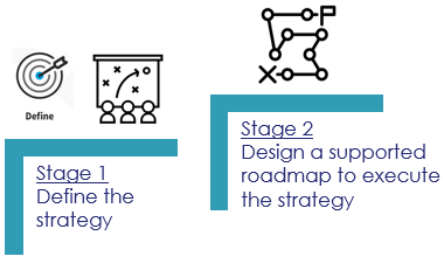
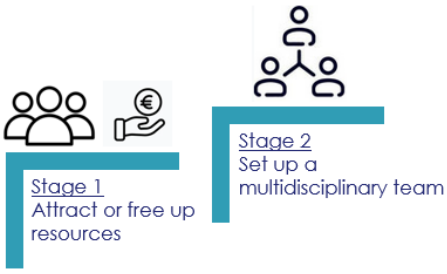
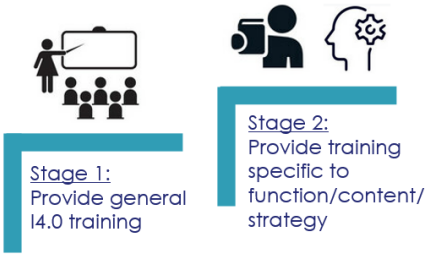
To conclude, the most hindering factors occur within the Organization which is in line with the literature. Besides, the category Employee is seen as important because of the necessary knowledge and skills. It appears that the External context is something to take into account which differs from the literature. This also applies to the Characteristic of the Innovation which has no clear influence at all. As described in Chapter 1, this research contributes to the literature. However, this

research ended up to focus more on industry 3.0 regarding the context with an industry 4.0 view on the hindering factors. Therefore, this study also contributes to the literature about industry 3.0.

5.2 Practical recommendations

This research also provides in some practical recommendations. These will contribute to the literature by providing some general recommendations, so the defense industry has a starting point. Besides, it will provide a guide for managers to indicate and overcome hindering factors. The general recommendations are mentioned in Table 8 and are explained in more detail below.

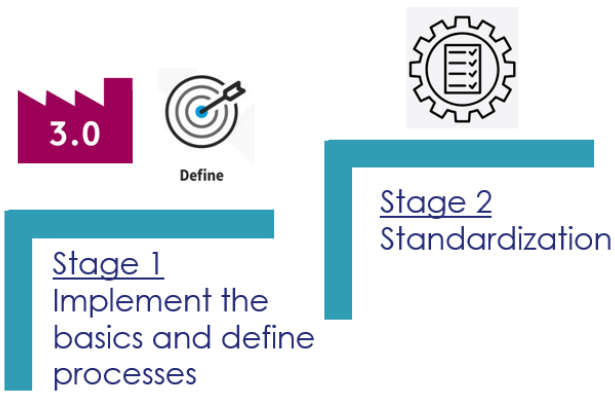
Table 8 Practical recommendations

Provide a basis	
Formulate and execute a strategy	
Design a multidisciplinary team	
Teach certain skills and knowledge	

5.2.1 Provide a basis for industry 4.0

Concerning the implementation of industry 4.0, the challenges could be caused due to the current situation. As mentioned, the internal supply chain is focusing on the Digital Backbone that is the network infrastructure that interconnects different networks (ERP and PLM). This indicates that the focus is on creating informatization which is the inter-mix of computers and communications and the creation of automation (Turner, 2021). It can be stated that the internal supply chain is located in the beginning of industry 3.0. The positioning around the beginning of industry 3.0 requires steps that match this situation. Therefore, it is imperative to develop a basis for industry 4.0 mentioned by interviewee 6 and 7. Once the foundation for the implementation of industry 4.0 is in place, next steps could be taken in terms of data-driven services, smart factory, smart operations, and smart products. It should be noted that a wide scale application of new technologies will be difficult because of the characteristics of the defense sector. These difficulties are likely to arise in terms of little standardization due to high tech and customers specific products (Ferreri, 2003). Therefore, the combination of the basis and standardization is key. The first stage could be to continuing developing the basis and define the current processes within the supply chain. The second stage, when the processes are defined, is to take steps towards supply chain standardization. The implementation of industry 4.0 will benefit of the basis and more standardization, because this allows for implementation of industry 4.0 technologies that fits the internal supply chain. Furthermore, the basics of industry 3.0 and standardization allow for data analysis and data driven decision making. All in all, the basics and standardization are dependent on each other, and these are the first steps, in addition to the main hindering factors, towards the implementation industry 4.0. It can be stated that the focus of the supply chain in Hengelo is now on creating digitalization as a basis for industry 4.0 aspects.

Figure 12 Recommendation on providing a basis for industry 4.0.

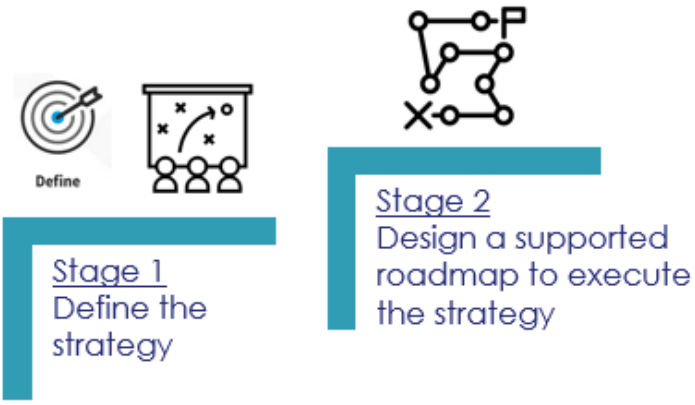


5.2.2 Define and execute a shared strategy

The category Organization centers around defining and executing the strategy and forming multidisciplinary resources. As in the literature, in practice the lack of a strategy is also named as a hindering factor when an innovation needs to be implemented. However, it is added during the interviews that it should not be limited to just formulating a strategy but should actually be executed in order to make the implementation a success. The factor multidisciplinary resources was created by merging the two factors different departments and resources. Neither of these factors emerged from the literature but are perceived as hindering.

According to the session, attendees desire an improvement in terms of strategy and the availability of multidisciplinary resources. For the strategy the first stage could be to define the strategy within the supply chain. To be useful and feasible, it would be appropriate to extend the scope, after the strategy in the supply chain has been determined, to other departments. In this way, other departments will also adopt it and cooperate in this strategy. The second stage could be designing a roadmap to execute the strategy. The roadmap then serves as a more detailed version of the strategy so that it is clear to everyone what and when something is expected in terms of industry 4.0 (Figure 13). This roadmap should consist of smaller steps so that they are executable and contribute to the strategy. Besides, someone should be held accountable for both the execution of the strategy and the roadmap.

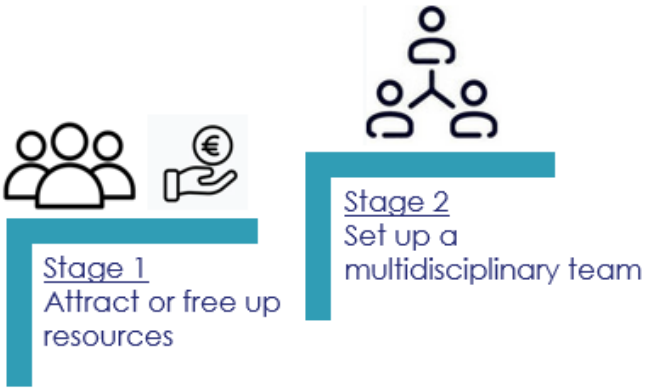
Figure 13 Recommendations on strategy



5.2.3 Set up a multidisciplinary team

The second most hindering factor also belongs to the category organization, which is multidisciplinary resources. The interviews revealed the need for multidisciplinary teams. The stages mentioned in Figure 12 and Figure 13 are localized in the supply chain but once the roadmap is described and it is executed, multidisciplinary resources are needed. Thus, the previous theme relies on the availability of multidisciplinary resources. Therefore, the first stage is to attract or make available resources. In this way, more hours or financial resources can be freed up for the implementation of industry 4.0. A second step is to create a multidisciplinary team (Figure 14). The phase of attracting resources should be spread throughout the company and not only in the supply chain. Industry 4.0 involves different departments, therefore the multidisciplinary team should consists of employees form these different departments. The team members should be full time available to make industry 4.0 a success.

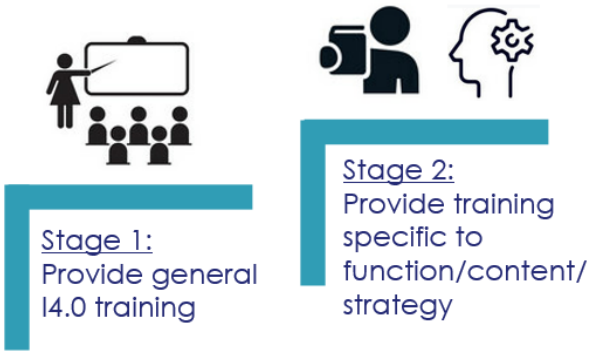
Figure 14 Recommendation on multidisciplinary team



5.2.4 Provide a certain level of skills and knowledge

The lack of skills and knowledge is perceived as hindering. Although a certain level of knowledge is most likely needed to take the first steps towards industry 4.0, a general training can be given in the first phase. In this way, employees become aware of the possibilities of industry 4.0, which can be used during the formulation of the strategy. When there is a clear strategy and roadmap, training can be provided on a more detailed level. The prerequisite is that these trainings are in line with the function and the content of the strategy (Figure 15).

Figure 15 Recommendation on skills and knowledge



In general, it can be stated that the organization and the employees contain the most hindering factors when it comes to the implementation of industry 4.0. In addition, it appears that the defense industry is still in the process of fully implementing industry 3.0. Since this is the beginning towards industry 4.0, it can be said that no revolutionary industry 4.0 developments will take place in the defense sector in the near future. This is especially true for technologies that do not focus on data. This is probably partly due to the unique characteristics of the defense sector such as high complexity and little standardization.

5.3 Limitations and future research

After conducting this research certain limiting factors have to be considered. The first limitation is the scant research on industry 4.0 in the defense industry. Scientific research is even harder to find when it comes to characteristics of the defense industry in combination with industry 4.0.

Second, when conducting qualitative research, the data collection mainly consists of interviews. It could be possible that the interpretation of the given answers differs. Besides, this research is based on a single case study, with eight interviewees, so the generalization regarding the whole defense industry cannot be completely derived from this research. Future research should include more companies and a larger sample size to be able to generalize the results.

Third, this research appeared to focus more on industry 3.0 instead of industry 4.0. Future research should investigate whether the hindering factors are similar when the context is actually about industry 4.0 which factors hinders and facilitates the implementation of industry 4.0.

Lastly, this research was not able to find differences between the internal supply chain departments. This could be due to the fact that the sample size and characteristics of the sample size was too limited. Therefore, future research should investigate whether there are difference in hindering factors between departments and layers in the organization.

6 Conclusion

Conclusively, it can be stated that the defense company with specific characteristics is situated in the transition from industry 2.0 to 3.0. Besides, the context of the participants has no direct influence on the hindering factors. It is essential for companies to understand the difference between industry 3.0 and 4.0 in order to identify which technologies bring value to the business. This research found that most of the hindering factors occur in the category Organization. Next to that, factors also occur in the categories Employee and External Context. However, the categories Organization and Employees contains the factors that have the most impact on the implementation of industry 4.0. These factors are lack of strategy, lack of multidisciplinary team and lack of skills and knowledge. The influence of the factors found in the category External Context are nihil. This category should be taken into account when implementing industry 4.0. Therefore, it can be stated this research contributes to the literature by identifying the current situation and the hindering factors of the implementation of industry 4.0 within a defense company.

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Appendix I Interview questions

Opening question
What is, to your understanding, industry 4.0?
Which technologies are you thinking of in the context of industry 4.0?
What makes it difficult to implement industry 4.0?
Organization
Are there any organizational aspects that hinder implementation of industry 4.0?
Do you feel that the organization is ready to implement industry 4.0? Why yes or no?
Employees
Are there any characteristics of the employees that hinder implementation of industry 4.0?
Do you feel the employees are familiar enough with industry 4.0?
Characteristics of the innovation
Are there some features of industry 4.0 that makes it hard to implement?
Do you feel that there are potential industry 4.0 aspects that would fit the organization? Why yes or no?
External context
Are there any aspects outside the organization that hinders implementing?
According to the products that the organization makes, are there are no external aspects to consider?
Closing question
Are there, after this conversation, more factors that hinder the implementation?
What are in your opinion the top 5 most important factors?
Which factors have the most impact?
Which factors are most easy to be implemented?
Do you feel you had enough knowledge to answer the questions?

Appendix II Problem description

Confidential

Appendix III Description of less mentioned factors

Two participants mention the lack of a clear definition (I. 7, 8). According to the interviewees industry 4.0 is not complex but comprehensive which could make it hard to understand. The lack of an own clear definition within the company or the supply chain makes it difficult to actually make the transition (I. 7).

An aspect that is not mentioned much but could make a difference when the participants agree on this, are the single initiatives. Interviewee 2 and 5 mention that there exist no plan behind local initiatives. It is stated that the local initiatives are not contributing to the bigger picture of industry 4.0. However, interviewee 3 and 7 would like to see more possibilities for local initiatives. In this way, the benefits of industry 4.0 are seen by other employees and eventually adopted.

Knowledge is a factor that is mentioned in the context of organization. However, it is mentioned by just one participant. Due to the fact that the internal supply chain focus a lot on personal development through various courses, the interviewee therefore sees knowledge building as a task of the organization. The fact that this is not currently the case is perceived as hindering.

The nature of the company is mentioned by three participants (I. 5, 6 and 8). Interviewee 5 faces the problem that within the company everything can be reasoned technically but that behavior/culture or rather sociological factors are less easy to deal with. Besides, interviewee 8 experience hinderance when single initiatives are included in the complex processes. It is mentioned that this is something that occurs more often within the defense company "(…) and then it becomes another very difficult complex story". Lastly, the internal maturity is mentioned which also belongs to the nature of the company. Interviewee 8 commented the following about that "Because it can sound very not logical for people to talk about industry 4.0 projects where they see that they don't even have the basis of industry 1.0 or what else".

Appendix IV Top 5 hindering factors and impact implementation table

Nr.	Interview 1	Interview 2	Interview 3	Interview 4
1.	Vision	Plan	Basis	Vision
2.	Strategy	Knowledge	Strategy	Knowledge
3.	Resources	Priorities	Resources	Interest
4.		Systems	Integral view	Data management
5.		Different departments	Support IT	Standardization

Nr.	Interview 5	Interview 6	Interview 7	Interview 8
1.	Strategy/governance	Vision	ICT infrastructure	Nature of the company
2.	Internal maturity	Processes	Knowledge	ICT capacities
3.	Skills	Basis	Strategy	Definition of I4.0
4.	Security	Resources	Resources	Roadmap
5.	Resources	Digital culture values	Hardware infrastructure	Basis

Interviewee	Most impact	Most easy to implement
1	Vision	
2	Plan	Systems
3	Top-down	Resources
4	Vision	
5	Governance	Security
6	Basis	Governance
7	Strategy	Resources
8	Basis	Roadmap