Managing the influences and risks of Industry 4.0

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During the last centuries, the industrial sector has faced significant changes; it has undergone several revolutions. Currently, men are saying we are at the dawn of the fourth revolution, which is marked by using cyber-physical systems and the Internet of Things. This possible new revolution is marked as Industry 4.0 (I4.0). Currently, I4.0 is becoming a top priority for many research centres, universities, and companies. However, impacts are not clear.
This study is concerned with identifying current Industry 4.0 applications within firms, even as future states and risks in order to explore the possible state of industry 4.0. To learn about the subject and to know what is in ''the field'' of industry 4.0 a desk-research will be performed. When literature is acquired and researched, a survey will be constructed while following concepts of acquired theories. This survey aims at receiving data from twelve companies in a qualitative way. Thereafter data will be processed in order to provide a view of current and future states even as risk regarding I4.0.
Following this research there could be said companies are taken Industry 4.0 in mind and see a future in this phenomenon, however, there is also a hyped part in it. Companies are working towards a more digitized environment in which processes are automated, monitored real-time and self-configured. Companies are getting more transparent by the use of more data which is acquired, analysed and used to make decisions. Industry 4.0 also enables more flexibility which supports mass-customization. Besides this more data will be shared throughout the supply chain which will optimize transparency and Supply Chain performances. Important in this process is to take risks into account. On both side, cyber and physical, risks occur and companies are getting more vulnerable. Risk assessment while using risk models should create awareness of risks.

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1. INTRODUCTION

1.1 Industry 4.0

During the last centuries, the industrial sector has faced significant changes; it has undergone several revolutions. At the beginning of the 1700's the steam engine was invented. This technique became only useful when subsequent innovations made it possible to apply these techniques. The technical development of the steam engine and the ability to use these techniques within realistic settings changed the operations in a fundamental way. This technological development was the beginning of the first industrial revolution. This industrial revolution made it possible to make use of mechanization within industrial companies. This revolution followed by the second industrial revolution which is based on electricity making it possible to scale up to mass production and the third revolution of digitalization while using Electronics and IT. Currently, men are saying we are at the dawn of the fourth revolution, which is marked by using cyber-physical systems and the Internet of Things. (Jazdi, 2014)

This possible new revolution is marked as Industry 4.0 (I4.0) it indicates a process that started in Germany with the term 'Industrie 4.0'. I4.0 takes the automation of manufacturing processes in companies to a whole new level, due to the integration of the Internet of Things (IoT) and mass production technologies, which simplifies the use of Cyber-Physical Systems.

Currently, I4.0 is becoming a top priority for many research centres, universities, and companies. However the meaning of the term is made rather blurry and vague than clear (Bauernhansl, Ten Hompel, & Vogel-Heuser, 2014). The term is mainly discussed in Germany since the German government announced it as a key initiative of the high-tech strategy(Kagermann, Helbig, Hellinger, & Wahlster, 2013). Outside Germany, this topic is less known, but similar ideas exist under different terms, such as Smart Industries or Advanced Manufacturing.

With I4.0 entire companies change and business processes change. I4.0 takes care of the digitalization of a company and will lead to a renewal of products and services. The impact of I4.0 is not clear, and in contrast to the previous industrial revolution, the current revolution is predicted in front rather than observed after (Drath & Horch, 2014). That is why it is not sure what this phenomenon will bring for manufacturing companies among other things. However, researchers expect I4.0 will have significant influences on businesses and economic. Besides that, a change in operational performances is expected even as changes in products, services, and business models. (Kagermann, Wahlster, & Helbig, 2013).

This affects the company a lot in different ways. In most industries is I4.0 a rather new thing, many manufacturing industries are still finding out a way to implement the I4.0 in their company in an efficient way. In this process, it brings many risks into the company in a way of how to implement it without making too many changes and keeping stakeholders satisfied. Companies need to find a way of implementing I4.0 without making too many changes and taking too many risks, along with influences outside the company and which difficulties it will bring for the business.

Even with the uncertainty of I4.0; key enablers are identified. These key enablers could also be seen as a distinction between the third and fourth industrial revolution. The first enabler is the Internet of Things. Internet of Things refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence (Xia, Yang, Wang, & Vinel, 2012). Besides the Internet of Things, I4.0 consists of the use of cyber-physical systems in manufacturing companies. Cyber-Physical Systems (CPS) is defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities (Baheti & Gill, 2011).The Integration of Internet of Things and Cyber-Physical Systems in operations will lead to smart factories which drive I4.0.

Within this case study, there will be made use of an exploratory view to give an impression of the current and future influences and extent of I4.0 to identify what I4.0 will bring in manufacturing companies in the future and so, how operations of manufacturing companies are affected by I4.0. This description leads us to the central research question: ***''In which way will industry 4.0 influence the operations of manufacturing companies without taking too many risks for the company itself? '***'. To investigate what I4.0 will bring. First, the term will be conceptualized and operationalized to acquire a common understanding throughout this study. After that, there will be investigated to which extent I4.0 is currently implemented in manufacturing companies and in which ways I4.0 influences the businesses and what risks it brings. After identifying the current scope and influences of I4.0, future goals and desires will be determined, even as expected impacts on manufacturing companies. Relating all these parts and finding out how companies can get a better view of a most efficient way of integrating I4.0 will be examined in the case study.

1.2 Problem Statement

The impact of I4.0 is not clear, and in contrast to the previous industrial revolution, the current revolution is predicted in front rather than observed after (Drath & Horch, 2014). That is why it is not sure what this phenomenon will bring for manufacturing companies among other things. However, researchers expect I4.0 will have significant influences on organizations and economic. Besides that, a change in operational performances is expected even as changes in products, services and business models (Kagermann, Wahlster, & Helbig, 2013). Also taken risks into account with for example; Reluctance of employees, investment costs, and changing strategy. This demands a lot from a company to take on. To manage all these influences and risks, a company needs to make choices of what they implement first and what later. To make priorities is important but also hard to do, because only investing in parts of the future keeps other parts behind in line and ideas of a future state of a company.

1.3 Research Question

Description above gives a clear Research Question as described as, *In which way will industry 4.0 influence the operations of manufacturing companies without taking too many risks for the company itself?*

1.1.1 Sub Research Questions

What is industry 4.0?

- To get a better idea of what Industry 4.0 exactly is and get a better understanding of the risks, the basics needed to be learned and understood. By finding a good idea of Industry 4.0 it is easier to get through with the case study.

To which extent is industry 4.0 currently implemented in production companies?

- to see if the company already has knowledge of I4.0

What is the desired future state of production companies regarding industry 4.0?

- What do companies expect from I4.0, and what does the company desire from I4.0

Why would a company make use of Industry 4.0?

- Companies want to know what the benefits are for them to implement industry 4.0 after taking all the risks necessary for implementing Industry 4.0.

What is the current cyber-physical level within companies?

- Because the cyber-physical level is an enabler for I4.0.

What type of risks do you need to take into account as a Company when implementing Industry 4.0?

- To find all the risks, it is good for future companies to see what they should take into account when they will use I4.0. Finding the best way is the main study for this investigation.

2. LITERATURE

2.1 Theory

This study is concerned with identifying current I4.0 applications within firms, even as future states and risks in order to explore the possible state of I4.0.

I4.0 has characteristics in which it distinguishes itself from the third industrial revolution. I4.0 has a cyber-physical aspect and consists of making use of the internet of things within industrial practices.

Cyber-Physical Systems (CPS) could be defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities (Baheti & Gill, 2011). The Integration of Internet of Things and Cyber-Physical Systems in operations will lead to smart factories which drive I4.0. This study will identify the Cyber-Physical aspect of I4.0 while using the 5-level Cyber-Physical Systems structure proposed by (Lee, Bagheri, & Kao, 2015)This model identifies 5 levels of Cyber-Physical Systems uses and will be used to categorize different companies within these levels. As the driver of I4.0, the cyber-physical aspect could be seen as an important part. This model gives a clear overview in which state companies are at the moment and which cyber-physical aspects could be implemented or improved in order to provide a better foundation for I4.0. The model consists of 5 stages: the smart connection level, data-to-information level, cyber level, cognition level and configuration level. This model could be found below:

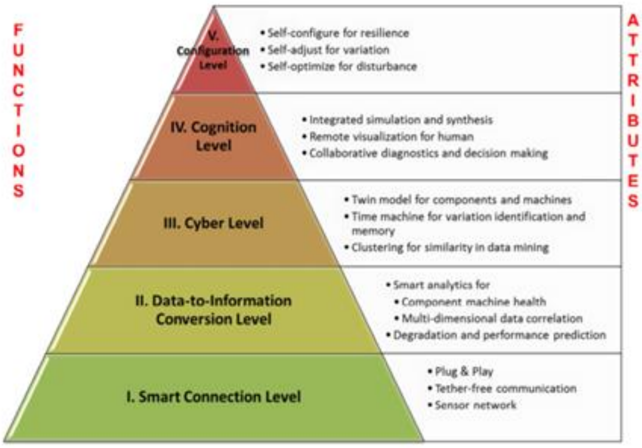

Fig. 1. 5C architecture for implementation of Cyber-Physical System.

When the cyber-physical level of companies are determined the study will focus on identifying I4.0 applications throughout the company and supply chain.

To identify I4.0 in the company the Digital Compass of McKinsey and the Readiness model of the IMPULS foundation of the German Engineering Federation (VDMA) will be used. These models give a proper view to which extent I4.0 is implemented within companies and could help companies to provide a structure for companies to implement Industry 4.0. The McKinsey model consists of 8 value drivers and 26 Industry levels which could be seen as practical applications. In this case, we will use the model to identify Industry 4.0 levers within companies to investigate in which areas I4.0 is implemented. This model is implemented as Appendix A (Baur & Wee, 2015).
The I4.0 Readiness Model could help companies to find out if they are prepared of I4.0 and where improvements could take place. It identifies six level from level zero till level five. The foundation of the model consists of six key dimensions respectively: strategy and organization, smart factory, smart operations, smart products, data-driven services, and employees. Within each level, requirements are set which needs to be fulfilled in order to reach the next level. This model is implemented as Appendix B.

The discussed models of McKinsey and the IMPULS foundation of the German Engineering Federation provides a clear overview of necessities of I4.0 and practical applications. However, within this models, the Supply Chain part is very limited. A potential new industrial revolution will also provide the potential of the Supply Chain. Therefore there will be created a new model which includes both models, McKinsey as well as the IMPULS model, and a Supply Chain part to provide a more extensive overview of the implementation of I4.0 within the company and throughout its Supply Chain.

The new model could help to identify I4.0 within companies and their supply chains and to implement I4.0. I4.0 is a relatively new phenomena and market standards are not set. It is also unknown what it will bring for the future. That is why a flexible model will be created. The core of the model will consist of the readiness model factors. This will provide a foundation for the identification of I4.0. Not all stages logically follow up the preceding stage. That is why the extent to which a factor is implemented will be assessed. For example, a smart product does not necessarily have to come from a smart factory. So, some factors are more applicable to certain companies than other. That is why this model will identify I4.0 and could help companies to implement I4.0 via a contingency approach. The main factors of the model will be complemented by requirements of the IMPULS model and drivers and levers according to the McKinsey model which provide more in-depth applications of I4.0. The latter factors are principles which are yet mainly used for identifying I4.0 but could change over time since standards are not set and I4.0 is in its beginning. Throughout the time these factors might be changed while the core of the model is rather stable and more applicable in longer terms. The model is expanded with a scoring model which is provided in Appendix C. Via this way companies could assess to which extent I4.0 is implemented. In case all aspects within a factor are present, a score of 100% per cent could be assigned. At the end, the percentages could be used as a benchmark and eventual room for improvement could be found. In case applications are present and used within daily operations it receives a V in the scoring list, in case the specific application is not present or is not actively implemented in the process it receives an X. The number of V's are divided by the total number of applications within the driver and multiplied by 100. The numbers could be seen as part of 100%. Currently no distinction is made within applications, it is marked as implemented or not implemented. Future studies could conceptualize and operationalize applications further in order to provide a more nuanced view. Because of the scarce resource time, this is not done yet.

As mentioned the supply chain part is rather limited, therefore a proper foundation of supply chain aspects needs to be implemented. These aspects will be derived from the eight key elements proposed by Schrauff & Berttram (2016), respectively a partner and principle of PWC. These authors propose the evolution of traditional supply chains toward a connected, smart, and highly efficient supply chain ecosystem based on these factors (How digitization makes the supply chain more efficient, agile-, and customer-focused; S. Schrauf, P. Berttram; 2016; p.6). The supply chain part within the executed models could be read the same as other drivers. A total score consists of several applications which are derived from a scoring model. The applications considering a digitized supply chain is provided in Appendix F.

While constructing a model the three models discussed before are taken in mind. This led to the following model. In order to make things more clear first a representation of the model will be provided below:

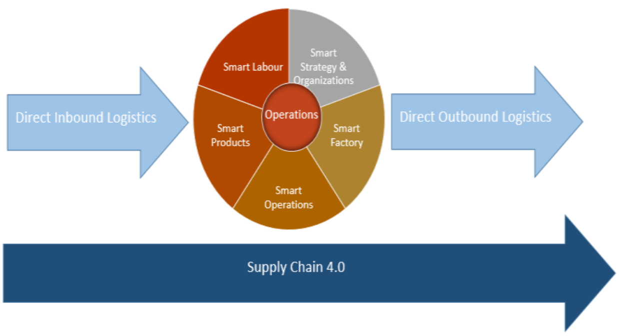

Figure 2: Industry 4.0 Identification Model.

It is very important to analyse risks and react well to them.

The 5 steps of managing risks and how to act on them.

1. *Identify Risks*: determine the risks of a new investment in e.g. new machine or new software. What risks does it bring into the company?
2. *Risk Assess & Analyze*: Make an assessment of the risk and examine what kind of risk it will be and how much it can impact the company. If there are more risks, they should be identified based on priority, to see which one is more important to handle first.
3. *Plan Action*: Base on the analysis a plan of how to reduce the risk or eliminate the risk.
4. *Implement*: The actual plan is taken into action, the primary objective of the program should be performed and carried out in a safe and efficient way
5. *Measure, Control, and Monitor*: Measure if there is any change required? There needs to be a full controllable risk after taken all the steps.

Figure 3. 5 steps of risk management.

3. RESEARCH METHODS

First, a desk-research will be conducted for several reasons. To learn about the subject and to know what is in ''the field'' of I4.0 desk-research will be performed. This will also be used to set a definition of Industry 4.0 and its drivers. Theory acquired of desk research will be applied in order to construct questions which will be used in case studies.
Physical literature as books and online databases as Google Scholar, Scopus, and Web of Science will be consulted to acquire relevant knowledge. There will be mainly searched for terms as 'Industry 4.0' and 'Industrie 4.0'. However, as discussed I4.0 is mainly a familiar term in Germany in which the latter searching term is the German variant. So, also other terms which are used for similar settings should not be neglected. Besides the general term of I4.0, there will also be searched for other terms regarding operations and Internet of Things and Cyber-Physical Systems which are main drivers of I4.0.
When literature is acquired and researched, a survey will be constructed while following concepts of acquired theories. This survey aims at receiving data from companies in a qualitative way. The qualitative aspects will refer to current states and

desired future states of I4.0 even as what companies' representatives will think of I4.0.
For this study, a sample size of 12 will be used. A sample size of 12 allows the investigators to investigate companies within several industries and companies with different sizes and structure. This gives us enough samples to make a good and thorough statement.
When the survey is constructed, it will be used for several mini case studies in which companies will be compared with each other to identify the current and future state of I4.0. Therefore, a case study approach will be used. Several manufacturing companies will be visited and the qualitative data and quantitative data will be collected by conducting the interviews.
While working with questionnaires for companies, dependency could act as a limitation or complication. First, the right companies have to be found which are willing to cooperate. I4.0 is a relatively new concept and companies might not want to share all the necessary information since it is part of their strategy in order to keep competitive in the market. Trying to make clear agreements with the company prevents biases and withholding of information from the company. Besides that, I4.0 is a relatively new subject and is not clearly defined in concepts and future statuses are unclear. That is why an explorative research is chosen. This study will explore the current and future status of I4.0 and the influences on manufacturing companies' operations.

4. DATA COLLECTION & ANALYSIS

4.1 Industry 4.0 according to literature

At this moment we are at the beginning of the fourth industrial revolution, also called Industry 4.0 (I4.0) or Smart Industry. I4.0 is a strategy that has to be aligned with the current strategy of the company to fully adapt to the new industrial revolution. I4.0 is defined in different ways according to literature as for example; 'Industry 4.0 focuses on the establishment of intelligent products and production processes. In future manufacturing, factories have to cope with the need of rapid product development, flexible production as well as complex environments (Brettel, Friederichsen, Keller, & Rosenberg, 2014). Another definition; 'Industry 4.0 describes the organisation of production processes based on technology and devices autonomously communicating with each other along the value chain: a model of the 'smart' factory of the future where computer-driven systems monitor physical processes, create a virtual copy of the physical world and make decentralised decisions based on self-organisation mechanisms' (Smit, Kreutzer, Moeller, & Carlberg, 2016). But as it is summarized by the German prime minister Angela Merkel: 'It is a way of dealing quickly with the fusion of the online world and the world of industrial production'
The main features of I4.0 are described as (Schlaepfer, Koch, & Merkhofer, 2015):

- Vertical networking of smart production systems: This is the use of cyber-physical systems to react fast to changes and faults of machinery, this allows companies to produce customer specific products.
- Horizontal integration: Horizontal integration enables transparency within companies and a high level of flexibility, this causes a better global optimisation and competitiveness. With the transparency, there is a higher chance of new models, because there is a lot of cooperation and ideas between the stakeholders.
- Through-engineering: Taking the product through the entire value chain to not only optimize production processes but also make a smart end product. This optimizes the product life cycle.
- Acceleration through exponential technologies: This allows individual solutions per product, a lot of cost savings and flexible work, 3D printing is one of the prime examples for this, because it allows new product solutions and development methods.

As it is widely described by many people and organizations, I4.0 has some core elements along the supply chain of a company (The Quintessence, Industry Agents, 2015, p.6-7):

- Suppliers: Networking from company to a supplier and production systems gives an opportunity to analyse alternative suppliers and capacities of others in real time.
- Supply Chain: The supply chain responds dynamically to demands and mistakes within the supply chain, machines can adapt to mistakes and will try to deal with the fault from earlier on.
- Raw Materials: Resources will be dealt with, in an efficient way. Information of waste will be saved directly to use later on. This simplifies the process of the re-use of raw materials.
- Product: The making of intelligent products is a must and the products know all about their own capabilities to make themselves as efficient as possible in the process.
- Machines: Intelligent machines adapt to different jobs and environments, to catch up with the demand of customers.
- Manual Labour: Employees are supported by the data stored by the machines which they can use, also their work is optimized by Augmented reality and the low-cost automation of their work processes.
- Robot: Robots are key in the process and adapt quickly to changes and highly flexible workers
- Warehouse: The warehouse has intelligent inventory holders to send information about what the company needs for their processes and keep the warehouse up to date with storage of products.
- End-User Customer: Customers giving details about how they are going to use the products delivered by the company to optimize the processes within the company to adapt more to the demand of the customer.

By combining the core elements and features with each other there is a massive increase in competitiveness, because the flexibility and agility are a lot higher. By having a flexible workforce and a rapid adjustment to the environment, risks are reduced. With I4.0 the chances to change the supply chain are higher than ever, changing individual segments are easier to optimize production processes. All the data stored in an early age before I4.0 there is now an ability to actually do something with the information they stored and to use this information in the supply chain optimization.

4.1.1 Industry 4.0 according to companies

According to 12 interviewed companies, I4.0 could be seen as increasing steps in automation and mechanisation of processes. It builds upon existing automation and mechanisation but it will be more advanced. I4.0 is often not seen as a revolution but more as an evolution of the 3rd industrial revolution. It takes incremental steps to build further upon the digitization of companies.
I4.0 should be investigated and implemented in companies' processes in order to sustain market positions since competition is high. The software is very important in this process to store all the data and make decisions.
I4.0 allows lower batch-sizes, lower throughput-times, lower conversion times and more flexible production with more predictability. It will make it possible to run the company

unmanned. Overall it is seen as a term to boost the industry. Because it is getting widely known around the world, no one wants to keep behind their competitors and will follow the I4.0 route. If a company does not implement I4.0 it is often seen as a misstep in their strategy to not follow this strategy.

In general, it is easier to implement I4.0 for small companies because they do not have to make huge changes in their company in comparison to big enterprises, smaller companies only have a lack of resources to commit to the big changes. Most of the small companies already have the strategy for the implementation of I4.0 but are waiting for the bigger companies to set out the market concepts. Bigger companies need a lot longer for I4.0 because they have a larger factory, more employees and more steps of hierarchy. Before the big company can change, it needs to go through all the steps. So, in conclusion, the small companies already have a plan but are waiting for the market leaders who need more time to fully implement I4.0 in a precise and in an efficient way.

4.2. Cyber-physical level

‘’Recent advances in manufacturing industry has paved way for a systematic deployment of Cyber-Physical Systems (CPS), within which information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space.’’ (Lee, Bagheri, & Kao, 2014, p17) The integration of Cyber-Physical systems within factories is an enabler of I4.0. The 5C-level architecture of James Lee et. al (2014) proposes a structure for cyber-physical systems. Therefore this model will be used in order to identify current cyber-physical levels.

Level 0

Three companies mentioned having low levels regarding cyber-physical applications. One of these companies is an engineering company which applies applications within current electrical systems. They were using old-fashioned techniques. For this company, a cyber-physical level was not applicable. Another company was not yet working automated, the customized low-volume aspect did not trigger the company yet to automate most processes. This did not enable higher cyber-physical levels. This also was the case for the third company which did not enable cyber-physical processes. However, this company wanted to automate more processes and take the cyber-physical level in mind.

Smart Connection Level

All other companies meet the demand of the smart connection level. This level demands to acquire reliable data from machines and components.

Data-to-Information Conversion Level

The data-to-information conversion level requires acquiring meaningful information from the data which is acquired at the smart connection level. Three companies mentioned being active in this level. One of these companies was already translating data to useful information but did reach the next level since they did not send it to a central data point yet. The next stage they wanted to reach is connecting their data to central hubs and represent all decentralized data in central overviews. The other two companies fulfilled the first stage by acquiring data, but are exploring how to translate this data into useful information. One of these companies is working on a concrete project on translating data into useful information. The other company invested in a new machine which allowed the cognition level but was working on the implementation.

Cyber-Level

The cyber level considers a central information hub within the architecture. Data is sent from decentralized machines/ components to this central point. The six companies which fulfilled the cyber-level mentioned are all situated in the cognition or configuration level, none of the companies is ‘’stuck’’ or situated in the cyber-level.

Cognition level

The cognition level enables a deeper understanding of the provided information. This level proposes having decent representations of the acquired information in such a way it supports right decision making of expert users. Five companies mentioned being in this phase. All these companies acquire data, transform it into information, send it to a database and present it in a proper way on a real-time basis. Two of these companies are working towards a self-configured factory by sending data back from databases to machines. Some machines are already able to adjust themselves to data and some practical applications in this aspect already exist within these companies. Another company which is situated in the cognition level did choose to do not implement self-configuring installations on purpose. The company is against self-adapting systems since the company wants to know what is happening in the process and why things are going well or wrong in order to improve the process.

Configuration level

The last level in the 5c-level architecture is the configuration level. In the configuration level data is sent back from the cyberspace to the machines which could make machines self-adaptive. One company was able to reach this level. This company, which has its roots in Germany, manufactures machines installation which enables the self-configuration level and the company possesses smart-factories itself. Within the company, the assembly line connects people, machines, and products. All operations are monitored and automated processes could be self-configured by acquired data. The data and information are shown on interactive communication platform. This interactive system is able to collect, process and visualize relevant data in a real-time manner. The interactive software could diagnose and optimize operations and detect failures. Besides this, the platform could be easily connected with several digital systems and allows third-party applications.

4.3 Industry 4.0 within companies

During the research 12 companies were visited to collect data regarding I4.0. Within this study, I4.0 applications were identified within these companies. The respondents had to identify I4.0 according to the Identification model which is constructed from The Industry Readiness Level Model created by the IMPULS Foundation of the German Engineering Federation (2015), the Digital Compass of McKinsey (2015) and the Supply Chain 4.0 factors proposed by S. Schrauf and P. Berttram (2016). This part will discuss these applications of Industry 4.0 within companies even as the desired future state and the reason why companies started or will start implementing I4.0 or why not. Executed scoring models could be found in Appendix E.

4.3.1 Current Industry 4.0 applications

This part will discuss the current state of I4.0 within companies. As mentioned in the introduction 12 companies were visited to identify I4.0 applications. These applications are structured via the new model which is built upon the three mentioned models. The new model consists of several drivers. These drivers are direct inbound logistics, companies’ internal operations, direct outbound logistics, and supply chain 4.0. The internal operations consist of the following factors: smart factory, smart operations, smart products and smart labour. The goal is to explore to which extent the drivers and factors are implemented throughout the company and supply chain. This will be discussed in this part. An overview of the applications and the number of implementations is provided in Appendix D. This overview shows how many companies, with a total of the twelve companies surveyed, implemented the I4.0 applications. Furthermore, executed models which provide an overview of the extent of I4.0 applications per company could be found in Appendix G and H.

4.3.1.1 Direct Inbound Logistics

Direct inbound logistics consists of several factors which are integrated planning/ execution, logistics visibility, and autonomous logistics. With integrated planning and execution in direct inbound logistics, a connection and execution with direct suppliers are meant. This survey showed 11 companies were integrating planning and execution with direct suppliers. However, within most companies, not all suppliers did have an interface with the companies. Most of the times companies only had a tight line with key suppliers. The next factor logistic could also be seen as a popular factor. Also, eleven companies did mention this aspect. However, the extent of logistics of visibility was sometimes limited to a track and trace service of the delivering company for some parts. Only two companies also mentioned the visibility of parts within their own process, so visibility is most of the times limited by transport between companies. The last aspect, autonomous logistics, was not mentioned. This could be the case for several reasons. Technology regarding this topic needs to be improved even as regulations within countries which should be adjusted.

4.3.1.2 Operations

Smart Strategy & Organizations

The first driver of the internal operations is smart strategy & organizations. This will be the start of the implementation of I4.0 applications. This driver consists of strategy, investments and innovations management. To fulfill these factors I4.0 should be actively implemented within companies' strategy and investments must be made regarding I4.0. Innovations management should be seen as an existing innovative environment within the company. Seven companies mentioned having I4.0 implemented in the strategy. This varied from having vague guidelines of I4.0 implemented in strategy till fully developed strategies. Interesting is that 8 companies were investing in I4.0 applications while only seven companies implemented I4.0 in their strategy. A common statement we identified was that companies are willing to innovate within their company, whether it was an I4.0 application or not. Almost all companies mentioned having an innovative climate and are willing to innovate within their company. Therefore several actions are taken parallel to operations. Only one company did not actively participate regarding innovations management. The respondent explained that the company was applying old-fashioned techniques and knowledge on existing machine installations. He mentioned this as a competitive advantage since less and less companies were focussing on this aspect. In general, most companies did implement I4.0 in their strategy and invested in applications. Most companies also did have an innovative climate.

Smart Factory

This part will discuss till which extent the factories are ''smart''. The smart factory driver considers partly the IT structure of the factory and applications within the company itself as inventories, internal logistic and resource and process usage. This part excludes the internal core operations. Starting with the IT part, smart companies make use of digital modeling and gather data and provide data so it could be used by decision makers. Data collection and usage is an important step in digitized companies. All companies mentioned having IT-systems present within the company which is almost indispensable these days for companies. The extent to which IT is implemented however is heavily variable among these companies. Some companies implemented IT systems throughout the entire operation while some companies mainly used it as a connection to the external world and for administration purposes. Eight companies mentioned using data which is generated. However, only four companies were able to gather this in a real-time perspective. Digital modeling was often mentioned. Production companies did have advantages regarding time, money and quality to implement these programs. CAD-CAM software was often mentioned as development software in order to develop and produce components and products. Regarding inventories 3D printing and batch size decisions by data is less used. Only 3 companies made use of 3D printing to print sub-components for products and only 2 companies used data to determine batch sizes. The resources and processes within factories were also less mentioned. Two companies monitored their use of electricity and tried to optimize this while using data. Also, two companies made use of intelligent lots, which improves the internal logistics visibility. Real-time yield optimization was four times mentioned. These four companies monitored their operations real-time in order to determine the costs of operations. AGV's were not mentioned within this research. As for, eight companies mentioned the automation of processes. Not all processes within the companies were fully automated but in general, companies wanted to automate as much as possible within their operations. This part discussed the extent to which companies are smart. Generally, companies implemented IT systems, used data till certain extents and made use of digital modeling. So most companies are involved in the IT part. However, besides automation, fewer companies do have I4.0 applications.

Smart Operations

Smart Operations consider flexible and qualitative operations. The IT part of smart operations consists of the levers cloud usage, IT security, and information sharing. Working in the cloud could provide highly available data. Most companies mentioned using cloud usage (ten companies), and two companies were not (yet) working in the cloud. One of the latter is working on a pilot regarding cloud-computing. For this company, the technology should first prove itself as useful before it will be implemented. All companies did make use of IT-security. The IT-security within the companies was adjusted to the sizes and data-sensitivity of the companies. This varied from simple anti-virus applications to professional departments including more than 1000 employees. This aspect was very important according to the respondents. More IT within companies and more systems connected to IT makes them more vulnerable to attacks. Information sharing was mentioned seven times. Information sharing enables a transparent information transfer throughout the company and supply chain, so operations could be optimized. Most companies saw this as an opportunity but some companies were hesitant to share information more openly throughout the organization or supply chain. The next aspect of smart operations is asset utilization. Within this aspect, there could be said most companies made use of routing flexibility (9) and machine flexibility (8). This means machines could be used in a flexible way and multiple routes could be taken regarding production. Most companies used these applications but it was not always done fully digital. Five companies had also the ability to monitor and control their operations remotely. Fewer companies (2) are able to predict maintenance within their processes. This was mostly due to machines which did not have this specification. However, companies were working on this aspect. Besides this, also augmented reality for maintenance repair and operations was less popular (2). According to companies, this was still too innovative to implement in own operations. The last aspect of smart operations considers quality management. This aspect was more popular among companies. Nine companies monitored quality digitally, seven companies had a form of advanced process control and eight companies used statistics in the process to control manufactured products or components. Most companies mentioned a focus on the quality aspect of their produced goods and are willing to invest in this.

Smart Products

The smart product driver shows the extent to which companies make smart products. This works kind of the same as in factories. In order to have a smart product, the product should provide data and have the possibility of a connection with IT-based systems. Other factors are data analyses of the generated data and self-diagnose function with the possibility of predictive maintenance. As for, a completely smart product could also adjust itself by using feedback from the data which is sent to IT-systems. This factor is not always applicable for companies. During the study, four companies were visited which produced rather static products or components and one company was an engineering company which did not produce smart products and did not apply smart products. The other seven companies mentioned having products which were able to produce data and have a connection to IT. Several companies mentioned focussing on their offered products first before implementing I4.0 themselves. These companies wanted to make sure their products were ready to connect to IT-systems, so their customers could use the products in a smart way. Other companies were also focusing on own operations and were supplying smart products. The products varied from switchboards, trucks, satellite systems, hydraulic/ electrical presses, machine installations to radar systems. So all these products from surveyed companies could be connected to IT in some way and generate data. Not all products were able to analyse the data themselves (5) and to provide a self-diagnose(5). Only one company produced products which are also self-adaptable by feedback send back by IT-systems. The latter could be seen as the final step in creating smart products. So, in general, all companies which produced products which are no static are working on the digitization of their products. However, the extent to which these products are smart differs.

Smart Labour

The last step regarding internal operations is smart labour. Implementing Industry 4.0 within processes leads to a change in work processes of employees. Smart labour addresses the required skills and knowledge, but also human-robot collaboration. Besides this human aspect, smart labour will also address whether the performances are monitored if remote control/ monitoring is present and whether knowledge is automated. Five companies already have employees which do have the right skill set in order to fulfill requirements of I4.0 workplaces. Seven companies were acquiring new employees which are better compatible with I4.0 applications and were taking this into account. Only one company already made use of human-robot collaboration in the form of co-bots (collaborative robots). Eight companies monitored performances of their employees in order to measure quality. As last three companies were working on the automation of knowledge work. So this does not only include repetitive work but the knowledge aspect within processes.

Direct Outbound Logistics

Direct outbound logistics considers the connection with direct customers. Four aspects are considered which are service/ after sales, time to market, supply/ demand match and a supply chain part. This supply chain part only considers the integrated planning/ execution part, logistics visibility part and autonomous B2C Logistics part. Regarding service and aftersales, the virtually guided self-service is only offered by one company. Four companies are offering remote maintenance and also four companies provide products which could predict maintenance. However, the privacy issue of customers was mentioned. The companies do have the possibilities to remotely use their products at customers but only apply this in case the customer wants to. Considering time to market eleven companies mentioned using a form co-creation with customers. However, none of the companies did mention open innovation. Looking at supply and demand match, five companies used data to create value for customers. This is relatively low since eleven companies did mention using customer co-creation and putting an emphasis on value for customers. Four companies used data in order to predict demand. As for, the connection to customers and traceability were often mentioned, nine and twelve times respectively. Companies used interfaces with customers and used shared planning in order to adapt their operations to demand. Even as with the inbound logistics, autonomous logistics was not mentioned for several reasons.

Supply Chain 4.0

The digitized Supply Chain is divided into seven parts: integrated planning/ execution, logistics visibility, autonomous logistics, smart procurement, smart warehousing, efficient spare parts management and advanced analytics. Within this parts logistics visibility was most mentioned as an aspect of a digitized supply chain. Depending on the company this differs from simple traceability of transported goods to fully traceable products/ components throughout the supply chains. Also, some companies mentioned the importance of backward traceability regarding quality management. Some companies were required to be able to trace the products back in order to detect failures. Only three companies were involved in a system in which products were traceable by multiple participants of the supply chain. Regarding integrated planning/ execution six companies mentioned having real-time data sharing throughout supply chain participants and seven companies mentioned having connected systems. In most cases, companies provided interfaces or portals which allow connectivity with suppliers and customers. All companies mentioned having digitized procurement, however, only two companies were conducting smart procurement. In these two companies, components were ordered automatically when minimum levels were reached. Furthermore, lean principles as Kanban was still popular as order method. However, this was not always done automatically. Different companies were involved in collaboration programs regarding procurement. In most cases, procurement systems were connected and forecasting was shared. Most of the companies were working on a form of procurement innovation. Smart-warehousing involves real-time inventories, internal autonomous transport, and internal transport optimization. Five companies mentioned having real-time inventories monitoring systems. This was not always done via sensors but also transaction based or inventory administratively based. In all of this 5 cases inventories were expressed in ERP systems. Internal autonomous transport was only executed in one company. This was done via rails and not yet via agv's, so certain tracks or rails were present. Seven companies are improving internal transport. The locations of several machines or workstations were considered in order to optimize this process even as implementing autonomous transport as agv's. Only one company was focusing on efficient spare parts management. This company was predicting maintenance of machines and had the possibility of printing 3d spare parts. Fully autonomous logistics was not applied within the twelve companies. This techniques is currently under construction and is faded in test phases. One company which provides trucks was able to run its products for 20% autonomously. As last five companies are using advanced analytics for demand production and supply chain optimization within the supply chain, five companies are using advanced analytics for supply chain prescription and one company used advanced analytics for decision support systems in the supply chain. More in-depth descriptions of digitized supply chain applications per company could be found in the company cases provided in the Appendix I.

The cross case comparison table identifies the most important Industry 4.0 factors of every company interviewed. These factors are based on performances regarding to I4.0 and reveals the strong disciplines of the companies. The cross-case comparison table enables to seek or construct an idea/explanation why one case is different from the others. The analysis makes it possible to compare companies from different settings.

Companies	Direct inbound logistics	Smart strategy & Organizations	Smart Factory	Smart Operations
A				
B				
C	Logistics Visibility, it always needs to be known where products are and to be precise to make products just in time.			Information sharing, when information is available, the data stored is shared with the customer. How far the product is, within the process. 'Smart' product data within the trucks is provided to customers to see if there are any failures.
D				Routing Flexibility, when an order is received, immediately there is connected which route needs to be followed for the most efficient planning and schedule
E			Digital Modelling of products is one of the key factors, in the past this was all done by hand	
F			Automated Processes, highly flexible machines are able to repeat older processes and don't need to be installed for this process.	IT security is improved after being hacked, the complete system is changed and the security is done by someone from windows within his network. Machine Flexibility, the flexibility is high of machines, robots can make products with high precision and flexibility
G		Innovation Management is highly integrated because of the German roots and the self-awareness of I4.0 and they need to keep a leading role of I4.0	Data Usage, use of data is highly available, machines are self-configured with data. Automated Processes are used by the available data, the data is stored and directly used for the machines	Machine Flexibility is high, because of the use of data within the machine data is immediately transmitted to the machine to adapt to a product.
H		Investments are mostly aimed at I4.0 to create a better workflow and be more efficient, they just build a new facility to make this possible	Real time yield, based on what the customer needs there is use of price elasticity within the products	Remote monitoring/control machines are remotely on distance
I			3D printing is used to make products and already identify problems within millimetres.	Augmented Reality for MRO is adapted to find failures very fast within products and prevent these by repairing

J	Integrated planning, all stakeholders are involved to get an optimized supply chain, they look into the most efficient way of a suitable course of action		Digital Modelling for customers to see if the planned product is correct and to make it easier for employees to see what they should produce	Cloud Usage, IT security, Information Sharing, Digital Quality Management,
K		Investments are very high for the I4.0 market to compete with competitors.		IT security is very high due to the products they make for big companies, everything needs to be safe and is linked as one of the safest digital environments
L	Logistics Visibility customers are able to see what happens with the product when they order it, this is a key initiator			

Companies	**Smart Products**	**Smart Labour**	**Direct outbound logistics**	**Digitized Supply Chain**
A	Company A provides a product that is a solution to take over a machine or process by virtualisation with fully independent knowledge.	Digital performance aspect, The company can make digitized models to enable the features to get a better picture of the project.	Customer co-creation is a strong point for Company A, every order they get is specifically made with the customer to experience the best possible collaboration.	
B			Customer Co-creation, together with the customer, Company B is able to produce customer specific products.	
C	Self-Diagnose, Company C is able to let products they produce to diagnose themselves by having a support system to let products follow each other closely to get an optimized and safe environment			Connection of systems is highly integrated within company's C's network
D			data-driven demand prediction, coupled systems to base on data which products are necessary for new elements of machines.	Real time data sharing within the company and systems are well connected
E				
F		Employee Skill Set because only 3 people were working in the company at the moment we were there, so the skill set should be extended for possible failures.		Smart procurement, stocks are supplied automatically
G	Adaptable via Data which they provide to customers, products can make decisions based on data.	human robot collaboration, is possible by an interactive system which shows the movements of the operator to react on them and enables a connection between cyber- and physical world		
H				Integrated planning is highly sufficient, because of the flow of products, they do not need much time to get to the next line of production
I				Traceability, through the supply chain and products

				are back traceable which is important to production
J			customer co-creation with the ability to walk through a digital model of the concrete models, the customer can immediately make changes where necessary.,	Integrated planning, because of the collaboration with stakeholders, the flow of working is highly efficient
K		Remote monitoring/control is highly used and the company receives data from the sensors and systems to use this now for transmitting it to the machines and make it a safer workplace		
L			customer co-creation, together with the customer it is possible to make a digitized model to see what is wished for the customer and what the possibilities are.	

4.3.2 Desired state Industry 4.0

This part will discuss the desired future state of companies regarding I4.0. Besides a view on I4.0 in general, the companies were also asked to provide a future view regarding their own operations.

Strategy

Seven companies did implement I4.0 within their strategy and eight companies were investing in applications. Three multinationals, of which two have its roots in Germany, have a dedicated strategy and view on I4.0. The other companies are following an innovation strategy in which I4.0 plays a part. Besides I4.0 applications also lean-manufacturing was still implemented in some strategies even as agile manufacturing. One company's innovation strategy emphasized lean manufacturing and did not yet included I4.0 but will implement applications in case they have proven its reliability and performance. Two other companies also did not implement it within its strategy but are searching for applications to improve processes. So, in general, most companies are exploring I4.0 and its application while seven companies did implement I4.0 within their strategy.

Concrete Applications

During the research, companies were asked which concrete applications they wanted to implement within the short term. This helps to provide structure and a view of I4.0 in the short term. Besides one engineering/ consulting company every company wanted to implement new applications in the short term. About five companies mentioned increasing automation within its processes in the short term. This does not necessarily be an I4.0 application but it could enable I4.0. The actual connection of the machine park with IT-systems was mentioned three times. Regarding automation, one company which is active in the steel editing industry is considering applying AGV's within its process. Furthermore, one two companies are working on their machine park so it will predict failures. Another aspect in which companies are currently investing is the acquisition of data and the actual use of this data. Six companies are currently willing to gather more data out of the process and five companies are working on monitoring this data real-time. During the research, several companies mentioned the loss of data: data was acquired but was not used. The current level of data gathering and analysis could be found in the Cyber-Physical part of this report. As fo, a popular topic of interest regarding concrete applications in the short term addresses the connectivity with suppliers, customers and throughout the suppliers. Three companies were actively working on connecting systems with suppliers and customers in order to optimize the amount of flow throughout the supply chain. One company also mentioned using data in order to find a better match between supply and demand regarding products. this could be seen as a form of data driven design to value. As last companies mentioned the improvement of the quality and value to its customers. This was already present in most companies but there is still an emphasis on improving quality performances. So, companies are currently focussing on automation, connecting to it-systems, connectivity throughout the supply chain and quality management.

4.3.3 Why Industry 4.0?

In order to determine a possible future for I4.0, companies were asked why they did or did not implement I4.0. First, there will be discussed why companies started implementing I4.0, thereafter reasons will be given why some companies did not actively start implementing I4.0.

Why companies started

Companies started for several reasons. Seven companies provided reasons why they are actively started with I4.0. A shared opinion throughout these companies was the innovative aspect of I4.0 in order to sustain a competitive position. One company mentioned stagnation as decline, another mentioned surviving in a competitive environment. Another company mentioned they did not really ‘’start’’ implementing I4.0 but saw it as an incremental innovation which builds upon existing technologies. This was more like a continuous process of improving processes. Besides continuous innovation, one company explored the world and saw several opportunities which could improve processes. This company mentioned making a difference when making operations smarter. Regarding opportunities, one company mentioned business opportunities as a reason to start with I4.0. When implementing I4.0 business opportunities could be identified and offered to customers. So, besides own operations, the company recognized businesses opportunities for customers in order to improve future profitability. The opportunity of I4.0 itself is also mentioned. Companies expect improvements in performance factors. Several companies mentioned it as a necessary step in order to keep work in western regions. As for, one company with departments in Germany mentioned the great expected potential and wanted to take initiative in this area.

Why companies did not start
Five companies provided reasons why they did not actively start entering the world of I4.0. One company mentioned having other priorities due to limited resources and size. They were thinking about I4.0 applications on a smaller scale but other priorities exist. Another small company keeps working on the old-fashioned way since this is their current competitive advantage. Besides this, one company did not implement it because of a lack of strategic direction. In this case, more structure regarding I4.0 strategy is necessary in order to implement applications. As for, one company did not implement I4.0 because they only want to implement the proven technology. Since I4.0 is in its beginning most applications should be further developed before it has proven its reliability. The latter company has still a strong focus on lean manufacturing and I4.0 is not yet on the agenda.

4.4 Risks of Industry 4.0

I4.0 improves a lot within the company according to, the flexibility of work, speed, cost reduction, higher quality, and dependability, but I4.0 also has some risks to take into account before the implementation of I4.0 and during the process when I4.0 is integrated within the company.
Risks for I4.0 are (as we see it) divided in a physical and IT part. The physical part of the risks contains risks as stated as an investment/capital part and employee part. IT part is aimed at the cyber security and privacy of customers. (Geissbauer, Vedso, & Schrauf, 2016)

4.4.1 Physical

To implement I4.0 it requires a huge investment. To take in a new technology that is expensive to integrate and buy, such a decision has to be made on a CEO level. What risks does it take along while investing in I4.0, does it withhold other investments and running projects, or does the company get money issues regarding their high investments, reputation problems, and their expense might even hurt their market share in the future. I4.0 implementation requires a smooth set up and the risk of a production stop must be avoided.
Based on early speculations on the employment level with the adoption of I4.0 worldwide, it is necessary for employees to learn differently or a new set of skills. I4.0 might help to let production run faster but this has a risk to take away jobs from employees. To let these employees keep their job they need to invest time in studying and practicing the skills to be able to maintain their job. Employees might also not accept the change, they might feel it as a threat and want to stay in their old habits. It is very important to involve employees in the change to convince them of the new way of working.

4.4.2 IT

Privacy is not only the problem of the customer but also from the producer, how does a producer handle all the data stored from customers, what do they do with the information from a customer about what he or she did on a particular website. To a customer this might look like a threat to their privacy, companies need to be as transparent as possible to reduce risks of distrust and take a customer completely along in their process of what happens with the stored data they provided.
IT security is the most challenging risk of implementing I4.0. The online integration of a company makes room for security breaches and opportunities for hackers to steal sensitive data, which is later on sold back to the company for a lot of money. This data refers to the confidential information of customers, suppliers and even personal data from employees. Not only costs this a lot of money it also hurts the reputation of the company, that is why a company needs to invest in their cyber security for an optimized security control and prevention of Data Breaches.

5. CONCLUSION

In this study, we wanted to explore in which way I4.0 is developing and what it will bring to industries. therefore we investigated what I4.0 is according to literature and companies, to which extent I4.0 is currently implemented, which desires companies have regarding I4.0, why I4.0 should be implemented or why not according to companies, what the cyber-physical level is within several companies and which risks are involved regarding I4.0.

What is industry 4.0?
I4.0 is the fourth industrial revolution, it is originated from a project in Germany from the high-tech sector where they say 'Industrie 4.0'. I4.0 has to be aligned with the current strategy to get the maximum and most efficient workflow.
As discussed in the paper, we have the main features of I4.0 and the core elements, these elements and features combined will make a flexible, agile and dependable supply chain. Together with increasing competitiveness and reduction of risks, because the production process is optimized with robots which are more precise than humans.

To which extent is industry 4.0 currently implemented within manufacturing companies?
During the research I4.0, a wide extent of I4.0 applications was identified divided under the drivers inbound/ outbound logistics, smart factory, smart operations, smart products, smart labour and supply chain 4.0. Most companies did already have I4.0 applications. The kind of applications were rather diversified. However, some application were available in almost all companies such as integrated planning & logistics, logistics visibility, innovations management, IT security and customer co-creation. However, there was still a difference to which extends applications were applied. The least popular applications were batch size estimation, smart energy, intelligent lots, agv's, self-configuring products, virtually guided self-service, open innovations and autonomous b2c logistics. Furthermore, other applications were divided among companies. So, most companies did have applications but could not be seen as 100% smart. One company scored high on I4.0 applications and five companies could not fully be identified as smart but came close.

What is the desired future state of production companies regarding industry 4.0?
Seven companies did implement I4.0 within their strategy and eight companies were investing in applications. Three multinationals, of which two have its roots in Germany, have a dedicated strategy and view on I4.0. Besides these three companies, there was noticed that companies were exploring this topic in order to identify opportunities. These companies wanted to create more structure regarding this topic. In the long term only these three companies have a concrete desired future state in which factories are highly automated, transparent, self-adaptable and connected by IT. Furthermore, in the short term,

most popular applications are a higher extent of automation, connecting physical components/ machines with IT, connecting systems with suppliers/ customers, a higher extent of data acquisition and usage and failure prediction.

Why would a company make use of Industry 4.0?
Several reasons were given why companies should and should not ''start'' making use of I4.0.
The main reason to start implementing I4.0 applications is to sustain in a competitive environment. Companies increase chances of sustaining while innovating in a responsible way. I4.0 could help with this aspect. Furthermore, companies mentioned new business opportunities brought by I4.0 and improvements in performance factors.
Besides reasons for the implementation of I4.0 applications, companies who did not actively start provided reasons why. Some companies did not start because of a lack of resources. I4.0 applications could be expensive and could take time before successfully implemented. Another reason is the innovative aspect. Industry 4.0 could be sometimes too innovate and not all technologies are fully proven yet. So, costs and risks could be identified as a main reason to not implement applications yet.

What is the current cyber-physical level within companies?
The cyber-physical systems could be seen as enablers of I4.0 and so is interesting to investigate. The proper acquisition, usage, representation of big data is an important aspect and should be treated carefully while applying I4.0. Regarding the cyber-physical level three companies mentioned having low levels regarding cyber-physical applications, three companies mentioned being active in the data-to-information conversion level, five companies mentioned being in the cognition phase and one company was able to reach the configuration level. While being in a higher cyber-physical level, companies are better able to manage data and are closer to the smart factory level. So, one company already could be marked as a smart factory in which operations could adapt it selves and five companies have applications to enable a deeper understanding of the provided information.

What type of risks do you need to take into account as a Company when implementing Industry 4.0?
As a company, it is important to, whenever you are making a change in the company you need to take into account the risks it will bring with it. With I4.0 there are some risks according to a 'physical' and 'IT' part. This contains employment and capital on the physical part, with cyber security and privacy on the IT part. These are the main risks which need to be taken into account when implementing I4.0, because when these risks are not considered as a threat there is a huge chance of failure.

In which way will industry 4.0 influence the operations of manufacturing companies without taking too many risks for the company itself?
Following this research there could be said companies are taken I4.0 in mind and see a future in this phenomenon, however, there is also a hyped part in it. Companies are working towards a more digitized environment in which processes are automated, monitored real-time and self-configured. Companies are getting more transparent by the use of more data which is acquired, analysed and used to make decisions. I4.0 also enables more flexibility which supports mass-customization. Besides this more data will be shared throughout the supply chain which will optimize transparency and Supply Chain performances. Important in this process is to take risks into account. On both side, cyber and physical, risks occur and companies are getting more vulnerable. Risk assessment while using risk models should create awareness of risks.

6. RECOMMENDATIONS

The study pointed out most companies did see a future in I4.0. Because of the hyped-character of I4.0 it was also seen as a buzzword, but the companies did definitely see possibilities in smart factories. The companies which did implement I4.0 saw an increase in performances based on speed, dependability, quality, flexibility and costs. The opportunities which could be brought by I4.0 are worth studying. Companies need to innovate in order to remain competitive and I4.0 offers possibilities to increase companies' performances. However, companies should not just implement applications only because they think so. Implementing I4.0 applications should be carefully considered in companies' innovation strategy. Every company is different and should be treated as such, therefore there must be investigated which application fits best within the specific organization. This paper proposes the following steps for implementing I4.0 applications:

1. We first suggest to create a proper view of current operations. Companies should understand where they currently stand. For the I4.0 part, companies could follow the I4.0 identification model to identify applications and use the cyber-physical model to identify cyber-physical levels.
2. The second step will be creating a strategy regarding I4.0. Companies should determine which value will be provided and which future setting fits best in the short-, medium- and long-term.
3. In order to create a fit with strategy, a roadmap should be created. The roadmap should create a fit between company and applications. First, the foundation should be taken in mind. It is important to have a cyber-environment and physical applications which are connected. Therefore the cyber-physical model could be used even as the I4.0 identification model for IT applications. Thereafter companies could use the I4.0 identification model to choose further applications. Important is to see the bigger picture of Supply Chain 4.0, Direct Inbound/ Outbound Logistics and Operations, rather than only internal operations.
4. While creating a roadmap, risk should be taken in mind. The risk model implemented in this study could help as a basis in order to manage risks.
5. While a roadmap is set, and risks are assessed, the implementation could start by using pilots in order to prove technologies.
6. When pilots are successful, companies could start implementing the actual technology.
7. After the implementation, the process should be managed and monitored.

7. CONTRIBUTION

This study will contribute to the topic of I4.0 by exploring what Industry will possibly bring in the future. It will give more insights into the current extents and influences of I4.0 in manufacturing companies even as the future desired states and possible influences. There will be elaborated on findings to create a view on this topic. Theoretically, this study could act as a base of understanding where we are and where we will be including influences on manufacturing companies. In the beginning of transitions, many variables are unclear and unidentified. As mentioned before, this study will identify current and future extents and influences of I4.0. This will create a more identified view of I4.0 in current and future settings. As times goes by, future investigations could build upon this research to create a more specific view regarding influences and extents of I4.0 in manufacturing companies. In a practical way, companies could identify their level of I4.0 applications and use the study as a benchmark with own operations. Companies might or might not feel a need to get more engaged in this topic.

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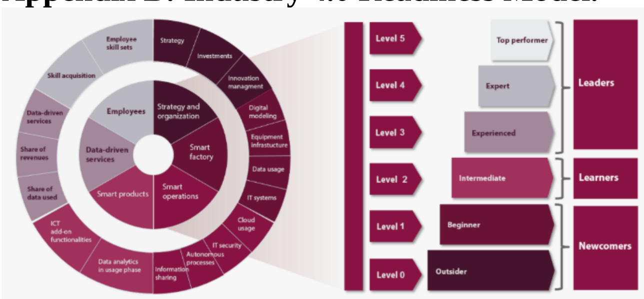
9. APPENDIX

Appendix A: McKinsey Digital Compass.

Appendix B: Industry 4.0 Readiness Model.



Industry 4.0 Readiness Model

Appendix C: Industry 4.0 scoring model.

	Direct Inbound Logistics		Score
	Integrated Planning/Exec.		
	Logistics Visibility		
	Autonomous Logistics		
Total Score			
	Smart Strategy & Organizations		Score
	Strategy		
	Investments		
	Innovations Management		
Total Score			

	Smart Factory	Score
1. IT	Digital Modeling	
	Data Usage	
	IT Systems	
2. Inventories	3D Printing	
	Batch Size	
3. Resource/Process	Smart Energy	
	Intelligent Lots	
	Real Time Yield	
	AGV's	
	Automated Processes	
Total Score		

	Smart Operations	Score
1. Smart IT	Cloud Usage	
	IT Security	
	Information Sharing	
2. Asset	Routing Flexibility	
Utilization	Machine Flexibility	
	Remote Monitoring/Control	
	Prediction Maintenance	
	Augmented Reality for MRO	
3. Quality	Digital Quality Mng.	
Management	Advanced Process Control	
	Statistical Process Control	
Total Score		

	Smart Products	Score
	Data Generations	
	Data Analytics	
	Self-diagnose	
	Connection to IT	
	Adaptable via data	
Total Score		

	Smart Labour	Score
1. Human Labor	Employee Skill Set	
	Skill Acquisition	
	Human-Robot Collab.	
2. IT Aspect	Remote Monitoring/Control	
	Digital Performance Aspect	
	Knowledge Automation	
Total Score		

	Direct Outbound Logistics	Score
1. Service/	Virtually Guided Self-Service	
Aftersales	Remote Maintenance	
	Predictive Maintenance	
2. Time to Market	Customer cocreation	
	Open Innovation	
3. Supply/ Demand	Data-driven design to value	
Match	Data-driven demand prediction	
4. Supply Chain	Integrated Planning & Exec.	
	Logistics Visibility	
	Autonomous B2C Logistics	
Total Score		

Appendix D: I4.0 applications within companies.

	Direct Inbound Logistics	V	X
	Integrated Planning/Exec.	11	1
	Logistics Visibility	11	1
	Autonomous Logistics	0	12
Total Score			

	Smart Strategy & Organizations	V	X
	Strategy	7	5
	Investments	8	4
	Innovations Management	11	1
Total Score			

	Smart Factory	V	X
1. IT	Digital Modeling	11	1
	Data Usage	8	4
	IT Systems	12	0
2. Inventories	3D Printing	3	9
	Batch Size	2	10
3. Resource/Process	Smart Energy	2	10
	Intelligent Lots	2	10
	Real Time Yield	4	8
	AGV's	0	12
	Automated Processes	8	4
Total Score			

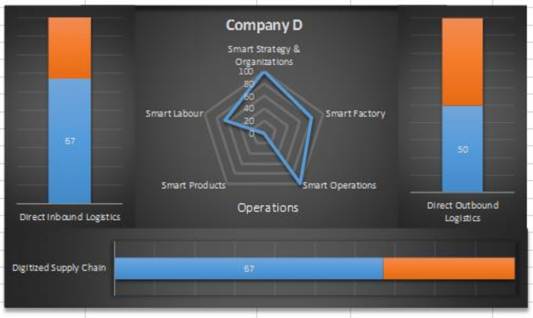
	Smart Operations	V	X
1. Smart IT	Cloud Usage	10	2
	IT Security	12	0
	Information Sharing	7	5
2. Asset	Routing Flexibility	9	3
Utilization	Machine Flexibility	8	4
	Remote Monitoring/Control	5	7
	Prediction Maintenance	2	10
	Augmented Reality for MRO	2	10
3. Quality	Digital Quality Mng.	9	3
Management	Advanced Process Control	7	5
	Statistical Process Control	8	4
Total Score			

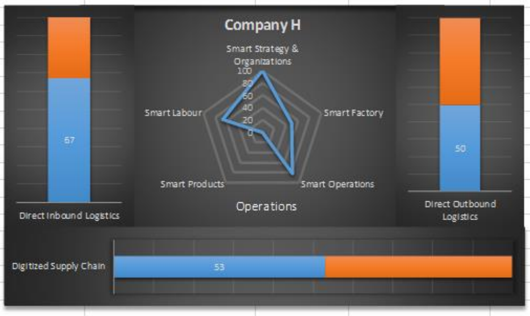
	Smart Products	V	X
	Data Generations	7	5
	Data Analytics	5	7
	Self-diagnose	5	7
	Connection to IT	7	5
	Adaptable via data	1	11
Total Score			

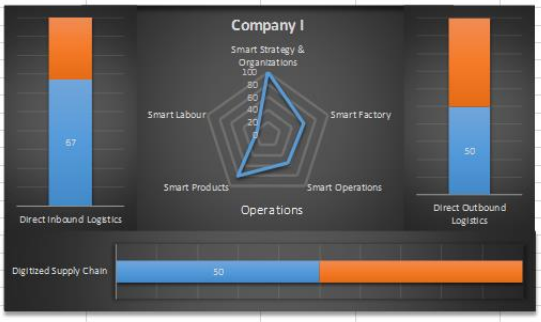
	Smart Labour	V	X
1. Human Labor	Employee Skill Set	5	7
	Skill Acquisition	7	5
	Human-Robot Collab.	2	10
2. IT Aspect	Remote Monitoring/Control	5	7
	Digital Performance Aspect	8	4
	Knowledge Automation	3	9

	Direct Outbound Logistics	V	X
1. Service/	Virtually Guided Self-Service	1	11
Aftersales	Remote Maintenance	4	8
	Predictive Maintenance	4	8
2. Time to Market	Customer cocreation	11	1
	Open Innovation	0	12
3. Supply/ Demand	Data-driven design to value	5	7
Match	Data-driven demand prediction	4	8
4. Supply Chain	Integrated Planning & Exec.	9	3
	Logistics Visibility	12	0
	Autonomous B2C Logistics	0	12

Appendix E: Executed Models I4.0 Applications per Company







Appendix F: Scoring Model Digitized Supply Chain

Digitized Supply Chain
Integrated planning/ Execution
Real-time data sharing
Connection of Systems
Score
Logistics Visibility SC.
Traceable throughout SC
Connected system traceability
Score
Procurement 4.0
Digitized Procurement
Smart Procurement
Real-time data for procurement
Procurement SC Collaboration
Procurement Innovation
Score
Smart Warehousing
Real-Time Inventories
Internal Autonomous Transport
Internal Transport Optimization
Score
Efficient Spare Parts Mang.
Digitizid Sparepart Management
Score
Autonoumous Logistics
Autonomous Ext. Logistics
Score
Advanced Analytics
Demand Prediction SC
Supply Chain Optimization
Supply Chain Prescription
Decision Support System SC
Score
Overall Score (x of 100)

Appendix G: Digitized Supply Chain company scores

Digitized Supply Chain												
Integrated planning/ Execution	A	B	C	D	E	F	G	H	I	J	K	L
Real-time data sharing	X	X	V	V	X	X	V	V	X	V	V	X
Connection of Systems	X	X	V	V	X	X	V	V	V	X	V	V
Score	0,00	0,00	1,00	1,00	0,00	0,00	1,00	1,00	0,50	0,50	1,00	0,50
Logistics Visibility SC.												
Traceable throughout SC	V	V	V	V	V	V	V	V	V	V	V	V
Connected system traceability	X	X	X	X	X	X	X	X	V	X	X	X
Score	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	1,00	0,50	0,50	0,50
Procurement 4.0												
Digitized Procurement	V	V	V	V	V	V	V	V	V	V	V	V
Smart Procurement	X	X	X	X	X	V	V	X	X	X	X	X
Real-time data for procurement	X	X	V	V	X	V	V	V	X	X	V	X
Procurement SC Collaboration	X	X	V	V	V	V	V	V	X	V	V	V
Procurement Innovation	X	X	V	V	V	V	V	V	X	V	V	V
Score	0,20	0,20	0,80	0,80	0,60	1,00	1,00	0,80	0,20	0,60	0,80	0,60
Smart Warehousing												
Real-Time Inventories	X	X	V	V	X	V	V	V	X	X	V	X
Internal Autonomous Transport	X	X	V	X	X	X	X	X	X	X	X	X
Internal Transport Optimization	X	X	V	V	V	V	X	V	V	X	V	X
Score	0,00	0,00	1,00	0,67	0,33	0,67	0,33	0,67	0,33	0,00	0,67	0,00
Efficient Spare Parts Mang.												
Digitizid Sparepart Management	X	X	X	V	X	X	X	X	X	X	X	X
Score	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Autonoumous Logistics												
Autonomous Ext. Logistics	X	X	X	X	X	X	X	X	X	X	X	X
Score	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Advanced Analytics												
Demand Prediction SC	X	X	V	V	X	X	V	V	X	X	V	X
Supply Chain Optimization	X	X	V	V	X	X	V	V	X	X	V	X
Supply Chain Prescription	X	X	V	V	X	V	X	V	X	X	V	X
Decision Support System SC	X	X	X	X	X	X	X	X	X	X	V	X
Score	0,00	0,00	0,75	0,75	0,00	0,25	0,50	0,75	0,00	0,00	1,00	0,00
Overall Score (x of 100)	10	10	57,86	67	20,4	34,6	47,6	53,1	29	22,9	57	22,9

V = (partly) present. X = Not Present. Blank Spaces = Not present/not applicable.

Appendix H Executed I4.0 application scoring model per company.

	Direct Inbound Logistics	A	B	C	D	E	F	G	H	I	J	K	L
	Integrated Planning/Exec.	X	X	V	V	V	V	V	V	V	V	V	V
	Logistics Visibility	V	V	V	V	V	V	V	V	V	X	V	V
	Autonomous Logistics	X	X	X	X	X	X	X	X	X	X	X	X
Total Score		0,33	0,33	0,67	0,67	0,67	0,67	0,67	0,67	0,67	0,33	0,67	0,67
	Smart Strategy & Organizations												
	Strategy	X	X	X	V	X	V	V	V	V	V	V	X
	Investments	X	X	V	V	X	V	V	V	V	V	V	X
	Innovations Management	V	X	V	V	V	V	V	V	V	V	V	V
Total Score		0,33	0,00	0,67	1,00	0,33	1,00	1,00	1,00	1,00	1,00	1,00	0,33
	Smart Factory												
1. IT	Digital Modeling	V	X	V	V	V	V	V	V	V	V	V	V
	Data Usage	V	X	V	V	X	V	V	V	V	V	V	X
	IT Systems	V	V	V	V	V	V	V	V	V	V	V	V
2. Inventories	3D Printing	X	X	X	V	X	X	X	X	V	X	V	X
	Batch Size	X	X	X	V	X	X	V	X	X	X	X	X
3. Resource/Process	Smart Energy	X	X	X	X	X	X	X	X	V	X	X	V
	Intelligent Lots	X	X	X	V	X	V	V	X	X	X	X	X
	Real Time Yield	X	X	V	V	X	X	V	V	X	V	V	X
	AGV's	X	X	X	X	X	X	X	X	X	X	X	X
	Automated Processes	X	X	V	V	X	V	V	V	V	X	V	V
Total Score		0,30	0,10	0,50	0,80	0,20	0,50	0,70	0,50	0,60	0,40	0,60	0,40
	Smart Operations												
1. Smart IT	Cloud Usage	V	V	X	V	X	V	V	V	V	V	V	V
	IT Security	V	V	V	V	V	V	V	V	V	V	V	V
	Information Sharing	X	X	V	V	X	V	V	V	V	V	X	X
2. Asset	Routing Flexibility	X	X	V	V	V	V	V	V	V	X	V	V
Utilization	Machine Flexibility	X	X	V	V	V	V	V	V	V	X	V	X
	Remote Monitoring/Control	X	X	X	V	X	V	V	V	X	X	V	X
	Prediction Maintenance	X	X	X	V	X	X	V	X	X	X	X	X
	Augmented Reality for MRO	X	X	X	V	X	X	X	X	V	X	X	X
3. Quality	Digital Quality Mng.	V	X	V	V	X	V	V	V	X	V	V	V
Management	Advanced Process Control	V	X	V	V	X	X	V	V	X	X	V	V
	Statistical Process Control	V	X	V	V	X	V	V	V	X	X	V	V
Total Score		0,45	0,18	0,63	1,00	0,27	0,72	0,91	0,82	0,55	0,36	0,72	0,55
	Smart Products												
	Data Generations	V		V		V		V		V		V	V
	Data Analytics	V		X		V		V		V		V	X
	Self-diagnose	V		V		V		V		V		V	X
	Connection to IT	V		V		V		V		V		V	V
	Adaptable via data	X		X		X		V		X		X	X
Total Score		0,80	0,00	0,60	0,00	0,80	0,00	1,00	0,00	0,80	0,00	0,80	0,40

	Smart Labour												
1. Human Labor	Employee Skill Set	X		X	V	V	V	V	X	X	X	V	X
	Skill Acquisition	X		X	V	V	V	V	V	V	X	V	X
	Human-Robot Collab.	X		V	X	X	X	V	X	X	X	X	X
2. IT Aspect	Remote Monitoring/Control	X		X	V	X	V	V	V	X	X	V	X
	Digital Performance Aspect	V		V	V	X	V	V	V	X	X	V	V
	Knowledge Automation	X		X	X	X	X	V	V	X	X	V	X
Total Score		0,17	0,00	0,33	0,67	0,33	0,67	1,00	0,67	0,17	0,00	0,83	0,17
	Direct Outbound Logistics												
1. Service/	Virtually Guided Self-Service	X	X	X	X	X	X	V	X	X	X	X	X
Aftersales	Remote Maintenance	X	X	X	X	V	X	V	X	V	X	V	X
	Predictive Maintenance	X	X	X	X	V	X	V	X	V	X	V	X
2. Time to Market	Customer cocreation	V	V	X	V	V	V	V	V	V	V	V	V
	Open Innovation	X	X	X	X	X	X	X	X	X	X	X	X
3. Supply/ Demand	Data-driven design to value	X	X	V	V	X	X	V	V	X	V	X	X
Match	Data-driven demand prediction	X	X	X	V	X	V	V	V	X	X	X	X
4. Supply Chain	Integrated Planning & Exec.	X	X	V	V	X	V	V	V	V	V	V	X
	Logistics Visibility	V	V	V	V	V	V	V	V	V	V	V	V
	Autonomous B2C Logistics	X	X	X	X	X	X	X	X	X	X	X	X
Total Score		0,20	0,20	0,30	0,50	0,40	0,40	0,80	0,50	0,50	0,40	0,50	0,20

V = (partly) present. X = Not Present. Blank spaces = Not present/not applicable

Appendix I : Company Cases

Within this part, the twelve companies will briefly be discussed in small company cases. A table including I4.0 applications per company could be found in the text.

Company Case A

Company A is active in the Electronic Industry. The company is specialized in Industrial Automation, machine- and process control and electrical engineering, motion control and ICT. Furthermore, they are specialized in creating software, hardware, and implementation of control cabinets.

According to the respondent Industry 4.0 is currently in its ''cowboy-phase''. It is unclear what industry 4.0 will bring to the market and no standards are set. Industry 4.0 might face a bubble which might burst just as happened with the Internet. People will keep investing till the bubble might burst. It will also bring risks for the company since more IT is involved. Further, it is used as a buzzword, a lot of people are talking about Industry 4.0 but will not recognize practical implementations which are actual applications of Industry 4.0. Industry 4.0 could bring something to the industry. However, for now it is unclear what it will bring until market standards are set. So, Industry 4.0 is yet a broad definition and the industry should set a standard to actually define this term.

Within the company self, the cyber-physical level would be rather low, the production is mainly customized and installed by hand. Regarding product, the company offers solutions which could be considered higher in the cyber-physical model. For a customer, they were working on a district heating. Within this process, the heat was lost somewhere. To identify leaks they implemented sensors in the system to generate data and coupled this to a central database. Thereafter the data could be analysed while using dashboards. Furthermore, the company provides a product which makes it possible to connect the controlling system to the internet so machines and processes could be remotely controlled. This is a practical application for customers regarding Industry 4.0.

As mentioned the company implements customized products within industrial installations, it is currently hard to implement Industry 4.0 in own production processes. However, it would be possible to automate and connect procurement throughout the supply chain. So the company self is not yet ready to implement Industry 4.0. Regarding applications, quality management is most applicable, furthermore specific products enables Industry 4.0 applications. Furthermore, the company features computer systems which enable a digital environment. However, these systems are not directly connected to production processes. Most noticeable I4.0 application of company A is within its products. The company produces products which allow machine installations to become smart and controlled on distance. Besides this, customer co-creation is a strong point for Company A, most orders are customer specific and created in co-collaboration of the customer in order to experience the best possible end-product/ service.

Company A did not yet start with Industry 4.0 since they want to explore in which way Industry 4.0 will be developed and which market standards will be set within the Industry. But they will make sure the company will be flexible enough to make sure it will be ready for Industry 4.0.

Regarding the future, the company will wait till Industry 4.0 is more defined and market standards are set. In that case, they will make sure the company is ready to implement Industry 4.0. In short term, they want to connect systems with suppliers and customers.

Digitized Supply Chain
Considering the digitized Supply Chain, there could be said only a few applications exist till certain extents. While ordering or delivering products components, traceability exists to a certain degree. Furthermore, procurement is done digitally but not in a smart way. IT systems exist and the company wants to wait for standards before implementing I4.0. So, the company wants to remain flexible and to make sure they are ready for I4.0 when standards are set, also regarding the digitized Supply Chain.

Company Case B

Company B is optimizing processes throughout the whole industry, depending on what the customer has in-house. The company is not directly involved in I4.0 but mainly involved in old-fashioned techniques. The core competence is cooling cabinets, no matter which circumstances. The marketing part is an important factor. The website is managed in-house and we are following the sale funnel and the 4p's principle of marketing. Furthermore, the company offers besides products complete solutions and services instead of products online.
I4.0 is used as a buzzword. The industry is suffering decreases and I4.0 is used as a buzzword to boost the Industry. However, the company thinks it will definitely bring something extra to the industry.
Company B is not working on any related I4.0 machines or implementations, so the readiness model or Cyber-Physical model do not need to be identified within the company. Company B is not interested in a future state with I4.0, so there does not need to be any identification of I4.0 in the future**.** Company B is able to improve rather old-fashioned machine installations. In collaboration with customers, desired states are reached in order to optimize processes. This could be identified as strength. However, this has less to do with I4.0 applications.

Digitized Supply Chain

This company does not use or implement I4.0 applications. Regarding the digitized supply chain, there are also only a few applications. Some inbound and outbound logistics are visible via track-and-trace and procurement is done digitally.

Company Case C

Company C is a multi-national active in the automotive sector. The visited plant is established in order to produce trucks which are built in a modular way.

Industry 4.0 is a buzzword from Germany to give the industrial sector an impulse. Industry 4.0 should only be implemented when Industry 4.0 is implemented properly. However, it will bring something in the future. This company is not an innovator regarding new technology, technology should be proven before it will be implemented within the process. Stability is more important than following trends. For the future, there is expected production systems will be connected and performances will be increased. However, digitization or Industry 3.0 should be implemented well before Industry 4.0 applications could be implemented.

Regarding the cyber-physical model, the company will score a 4 on the 1 -5 scale. Data is acquired by sensors, transformed to useful information and send to multiple databases. However, these databases are rather decentralized. Data could also be provided by dashboards and other programs. Then trends are being investigated and intervention will take place in case needed. The company is against self-adapting systems since the company wants to know what is happening in the process and why things are going well or wrong in order to improve the process. The company is following the Poka Yoke principle which is a term used in lean industry and is based on designing a production process in such a way, that failures will be almost impossible to occur.

Currently, there is still the main focus on lean production and I4.0, in general, is not part of the strategy. However, when techniques are 100 percent proven, the company will identify what it could bring for the company and might implement applications.

Although there is no focus on I4.0, digitized aspects exist which enables applications. Organization and operations planning even as the visibility of products/ components are very important in order to create products in a lean way. Digital systems exist throughout the whole process. This is mostly done while following lean principles and principles of the 3rd Industrial revolution. Automation exists but systems are not connected to a central cloud and machines are not self-aware. The operations consist of a long chain of decentralized clusters in which every cluster has 5 minutes to complete its stage. So, the digital aspect is extensively available even as production processes and monitoring. However, a connection to one central cloud is missing even as the self-awareness and self-adaptability. The connection flows in one direction, the physical aspect does not receive feedback from the cyber world in an automated way. Regarding the products, the company is innovating regarding smart trucks. Data could already be sent to cyber-systems in case customers want to. The next step is the autonomous aspect. Currently, the trucks are able to run for 20% autonomous. A system is in development in which trucks could cruise automatically in a chain. Strengths of the company lie within the visibility of products throughout the organization. This company is a big logistic company in which products and components should always be visible in order to produce without waste of time.

The main reason the company could not be marked as an innovator or early follower is that techniques should prove its reliability in order to implement techniques within the process. The biggest fear while implementing new technologies is a production stop. Therefore, there is always a backup plan in case new implementations do not work. Besides this, techniques are only implemented in case it has proven its reliability.

Taking the future in mind the company has a strategy regarding innovation. If techniques exist which is proven and if these techniques will increase company's performances it will get a chance to be implemented. Currently, the company is testing cloud systems. In case this works the company could go to the next step in which systems could be integrated into and connected to this cloud system.

Digitized Supply Chain
Company C is a big logistic organization which is following lean principles. The company is part of an environment in which direct suppliers and other facilities of the organizations are connected. So, within this network data and information is shared in several ways as connected ERP systems. Within this network, components are also traceable in order to produce without a waste of time. Traceability stops when products are finished and transported to other facilities because of security reasons. Traceability is limited to own facility, there is no overall system involving all players of the supply chain. The procurement is done digitally. The company provides a tool for customers to configure products. After configuration, the requirements are analysed and parts are reserved and/ or ordered. The digital procurement is digitized but not executed in a smart way. Human labour still plays an important part. However, according to the company's innovation philosophy, all processes should be increased even as procurement processes. When the stock is within the internal organization everything is monitored real-time. Autonomously internal transport exists till certain extents. Agv's are not yet applied but autonomous transport via rails etc. is used. Besides internal transport, the company provides products which run for about 20% autonomously. However, external transport is not done autonomously yet.

Company Case D

The company operates in the Aviation industry. This plant is specialized in supplying certified air systems and high-speed rotating components as sub-components for the aviation industry. The company is involved in procurement processes. In case the company gets the order, it supplies sub-components for airplanes for the duration of the contract. The company is working as a single-source supplier.
Based on the Cyber-Physical level, the company is scaled in the Cognition level, almost the configuration level. Data is already collected, analysed and presented in several systems. On the work-floor itself, dashboards are present which provide data regarding productivity etc. Data is also sent back to the machines self in case tolerances are exceeding. The company is working on self-configuring machines.

The readiness level of the company could be assigned to level 4/5.
I4.0 is integrated into the strategy, the factory and operations are adapted to I4.0 and are generating data which is analysed and also presented on the production floor. Repetitive actions which could be automated are automated and new innovations which will increase automation will be implemented. Regarding the products, there could be said I4.0 is not applicable on the product since these are rather static. It is also important to match employees with I4.0 applications. It is important to think about which jobs are necessary in order to fulfill a factory with I4.0 practices and you cannot implement I4.0 successfully in case employees will not adapt to it. The automation is increasing and these processes are becoming more complicated so the educational level will also play an important part.
According to the McKinsey Digital Compass, the company has identified that the machines are flexible, they make use of sensors which could predict maintenance. Furthermore, they are working on augmented reality and machines are working very flexible and work on more dimensions. The company keeps track of the system via remote monitoring and a control dashboard, there is a performance management active and because of this, it is possible to get a real-time business case optimization. 3D printing is available for the company, but the company keeps the use of additive manufacturing such as cold spraying rather than 3D printing.

Company D has strengths regarding integration and connection of IT systems even as the acquisition and representation of data. As described further in the digitized supply chain part of the company, this company has highly integrated systems regarding demand, forecast etc. Orders are automatically processed in the ERP systems and routes are automatically determined. Besides this, company D acquires data extensively and represent this within concerned areas. As example, production performances as productivity and downtime are represented real-time on screens within the production area.

Influences of I4.0 are not necessarily taken from other companies. The company did not automatically ‘’start’’ with I4.0. Within the company it is seen as a continuous process of improving operations. The company must innovate and follow innovative breakthroughs in order to sustain its position. The risks of implementing I4.0 for the company are that the technologies do not work, the company is an early innovator so the techniques brought with I4.0 comes without manual and the technicians need to find their own solutions. Company D takes care of a backup plan every time a failure might happen.
The effects that I4.0 has on the company until now is that the continuous change in the production process led to decreasing costs and increases in quality, speed, dependability, and flexibility. The company was able to ‘’win’’ procurements for airplane components, this mainly due to these increases in performance factors.
In the eyes of the company, I4.0 could be seen as increasing steps in automation and mechanisation of processes. It builds upon existing automation and mechanisation but it will be more advanced. I4.0 should be investigated and implemented in companies' processes in order to sustain market positions since competition is high. The expectations of I4.0 will lead to a higher degree of automation. Companies will follow innovations regarding the industry in order to survive. Data will be highly accessible and properly presented. I4.0 finally enables unmanned production.
Because the company is active in the aviation sector and should meet many requirements which are set by the industry according to IT security. The IT part is handled by an experienced company and is always kept up-to-date and reliable. Furthermore, IT is more and more implemented throughout the company and Supply Chain. Data is acquired and analysed.

Company J is active in the aviation sector and should meet many requirements which are set by the industry. The IT part is handled by an experienced company and is always kept up-to-date and reliable. Furthermore, IT is more and more implemented throughout the company and Supply Chain. Data is acquired and analysed.

Digitized Supply Chain
Company D has a connection with several mostly direct and bigger suppliers and customers. Systems are connected regarding forecast, sales planning, production planning, financial data, open orders etc.. Every session consists of a connection of several databases. The company has an internal programmer which programmed these sessions. Most databases are distracted from the ERP-system, but other connections exist from other databases as PLM-systems. Regarding traceability components are traceable internally, an overall system including all supply chain members does not exist. Suppliers' input is processed in ERP-systems even as customers' input. In order to provide visibility, several databases are connected as described above. Procurement is also done digitally but not rather ‘’smart’’. Procurement uses the connection of databases also as described above. The ERP-system is the central system in which logistical and purchasing orders are processed. Data which is processed could be connected to several systems. For a selected group of suppliers, a Supplier Performance System exists which is processed per term. KPI's consists of Quality, Delivery, and Costs. Recently the stock locations are centralized and order picks activities are redistributed. Stocks are monitored real-time and processed in the ERP system. Internal and external transportation is not done autonomously. The control of spare parts is executed the same as existing production. 3D-printing activities are started, not only for spare parts but also for serial production applications. However, several tests and researches should be conducted before implementing 3d-printed products within the end-product. Finally, the company does make use of advanced data analytics regarding demand production. Contracts and commitments are set based on these predictions. There is also a demand prediction regarding spare parts. Based on several factors as for make/ buy, complexity, throughput time, costs, communication etc. projects could start throughout the supply chain.

Company Case E

The company manufactures machines for the sheet metal industry, it is specialized in developing and constructing press brakes and shears for thin and thick sheet metal. The company manufactures hydraulic press brakes as well electronic press brakes. The latter is innovative within its industry and invented by the company.

The company does see a future in connectivity of physical systems to the cyber world and is they are focussing on how own products are ready for customers in order to allow I4.0 principles. So the company sees I4.0 as an opportunity to deliver higher value for customers in form of I4.0 ready products. They mentioned I4.0 will help us in the future, however, the definition is broad. Current operations within the factory are following lean principles rather than I4.0 principles. However, they are working on innovations while taking this in mind. The use of data will enable more connectivity throughout the process. I4.0 will build upon existing techniques and it will be a combination between disruptive and incremental innovation.

Current machines could acquire data and eventually trade this data to new information. However, currently this data is not analysed. The company is working on the implementation of a new machine in which we have a focus on this aspect. This machine should acquire data, analyse data, send data to a database and present data. This machine could be assigned to the cognition level. However, currently cyber-physical levels are rather low.

Regarding Industry readiness, the company does not enable high levels. IT systems are in place but are currently under construction. There will be innovated regarding IT systems and the actual use of data within processes. Besides this, modeling is done digitally, however there is no digital connection to the actual production process. Routes and machines within the process could operate flexible but are not smart in a sense machines automatically follow the preceding digital process. Regarding hiring new employees, the company involves employees while implementing new processes and while acquiring employees the digitized aspect is taken in mind. Furthermore, the company provides products which are ready for I4.0. Our machines are gathering data which can be used by our customer. The machines are able to diagnose themselves and predict maintenance. The machines also enable IT-connection so customers could connect the machines to their ERP systems. The company is working together with own software engineers and a Swedish company which develops software. The machines are ready to present KPI's, however only software has to be written. This specific machine also has a robotic arm inside which automatically adjust the machine with the right tools. This Automatic Tool Changer can decrease conversion times. Regarding I4.0 applications, most interesting within the company is providing these smart products. The company puts more emphasis on offering smart products rather than producing in a smart way.

The company is not active in implementing I4.0 applications since they are relatively small and other priorities exist. However, I4.0 applications are taking in mind and will be implemented on a small scale. The company is not an early innovator, most techniques are already proven. While implementing applications the company might face criticism of employees when implementing new techniques. This will be reduced by involving employees when implementing new technologies: new technologies are introduced and implemented carefully together with employees.

Currently there is no concrete strategy regarding I4.0, however applications will be implemented. As mentioned on a short term there is a focus on improving IT systems and the actual use of data. Furthermore, there is an acquisition regarding a new production machine which creates useful information, sends data to internal servers and decides upon this information.

Digitized Supply Chain
Throughout the company, less data is acquired and monitored real-time digitally. This is also expressed in lower levels of a digitized supply chain. Even as in many cases, parts and products are traceable to certain extents. Inbound logistics could be traced and outbound logistics depends on the distribution company. The company does provide information when products are finished so external distributors and clients are kept up-to-date. Procurement is just digitally but not smart. The company is increasing IT systems and connections with suppliers in order to optimize the process. Inventories are not monitored real-time and internal and external transport is not done autonomously. However, the company is improving internal transport and processes. In order to improve internal transport, lean applications are applied for the production of small presses. Within this improvement, inbound and outbound logistics are taken into consideration. The company also want to implement this for the production of the bigger presses. They are continuously improving internal transportation.

Company Case F

Company F is active in the steel industry. The company is specialized in manufacturing block cutters, supplying edited steel, and supplying and editing pipe grinders/notchers. Block cutters are produced in a lean way and sold. For editing steel, they work together with customers to acquire requirements. Thereafter pieces will be engineered.
I4.0 is different for every industry. The software is very important in this process. In the company's opinion, I4.0 considers smart producing. I4.0 allows lower batch-sizes, lower throughput-times, lower conversion times and more flexible production. It will make it

possible to run the company unmanned. It is also a term to boost the industry. I4.0 will make things easier. All products and processes will be connected in the future. I4.0 will come with new jobs, but people will not be ready for these jobs. So, companies have to educate people themselves.
Within the company, we acquire data and send it to databases. Employees are able to improve processes via real-time monitoring of information acquired by data. This leads to a cognition level
The readiness level of the company is around Level 4–5. Educating people is a learning and growth process, employees will get orders from managers. It is very important as a company to steer the people in the right direction and make use of the right tools which could do the job. The new machines should be supplied by employees. Currently, we are working on automation of our company to become an automatic production plant.
For the McKinsey model, the company makes use of rapid experimentation and simulation by designing via CAD programs. The company makes use of co-creation together with customers. Stocks are monitored real-time and our suppliers know what we need. So partly systems are connected in order to optimize supply, also using a welding robot which picks the right tools and products via RFID and starts welding. Most remarkable within this company was the willingness and motivation to innovate. Already three employees were able to operate most part of the production process because of highly automated processes and smart way of doing side-activities. The director mentioned seeing I4.0 as an opportunity to put the focus on core activities and reducing side-activities which are not directly used to create value.

25 years ago the company was already working on making processes smarter. Making your production smarter could make a difference. When the company began innovating, people did not understand this. 25 years ago we already wanted products which were not on the market then. Employees might not accept changes, they might feel it as a threat. This will create a gap between employee and employer. In case employees do not want implement changes they have to find jobs which will better fit. Another risk is implementing technologies which do not work. This is, however, a learning process. Making mistakes could be seen as a learning experience. Besides this in the case of employees leaving because of change, this could be used as an opportunity to acquire new human resource which will fit better. In general, I4.0 enables a better focus on our core business. Throughout the year we noticed a positive relation regarding company performances.
The company does not have yet a concrete strategy regarding I4.0. They want to expand their facility for better logistics and flow. We notice processes will be more efficient and implementing software could save human labour and time. This makes it possible to invest more in employees which offer direct value to their products rather than paying for jobs which indirectly contributes to the process.

Digitized supply chain
Company F provides standardized products and unit-one products. Data sharing throughout the supply chain is not yet implemented but the company is working on shared systems. Regarding traceability incoming products could be track & traced till a certain extent. When products are produced and delivered, products are back traceable per batch. Procurement is done digitally and real-time while using the KanBan system. Currently, the company is implementing KanBan systems throughout the overall process as order system. In this case the system is connected to the cyber-environment of the company and shared with suppliers. Together with selected suppliers, there is a collaboration regarding procurement. Order amounts are analysed through time and right amounts are generated and supplemented in KanBan. Besides this bottlenecks are identified and solved where possible. Within the central warehouse, inventories are monitored real-time. This is connected to ERP systems and the inventories of finished products are presented on the web shop. Internal transportation is not done autonomously but the company is interested in this topic. Also, external autonomous transport is not applied. Efficient spare-part management is not used within the company. Looking at advanced data-analytics throughout the supply chain, data is not used throughout the supply chain in order to predict demand, optimize the supply chain and make decisions. However, the company is collaborating with supply chain partners and advanced analytics are used in order to prescribe an optimized the supply chain.

Company Case G

Company G is active in the drive engineering and controlling technology sector. On the basis, they supply components and systems and could execute bigger projects concerning automated machinery lines.

The company sees I4.0 as the connection between physical machines and the cyber-world. I4.0 is broader than factories only, it is situated in the complete Supply Chain. It is also a buzzword in which a lot of things are included which are actually not related to I4.0. I4.0 is very important, more value could be to customers and it will change business models. It is a lever to offer value to customers in a different way. The company is following a dual strategy and will be a supplier of smart products and it has the possibility of trying products in over 275 companies.

Regarding cyber-physical levels, the company is situated on the highest level which concerns self-configuring installations. Within the company, the assembly line connects people, machines, and products. All operations are monitored and automated processes could be self-configured by acquired data. The data and information are shown on interactive communication platform. This interactive system is able to collect, process and visualize relevant data in a real-time manner. The interactive software could diagnose and optimize operations and detect failures. Besides this, the platform could be easily connected with several digital systems and allows third-party applications.

The company has its origins in Germany and has a head-start regarding I4.0. It is implemented within company’s strategy and the factory and operations are designed as such. As German manufacturer of machinery lines, the company feels to take initiatives regarding this subject. Within the plant in the Netherlands, quality is an important factor. The company does also have lots of applications in asset utilization. Machines are automated and designed in a flexible way regarding routing and production. The next step is improving self-predictiveness of machines. Within the Netherlands, there is always a high value connected to asset utilization even as the after-sales aspect. As mentioned the company is providing components for automated machines lines even as the lines self. The company can provide endless options regarding automation and self-configuration. An interactive system is invented which shows the required operator tasks and which could follow movements of the operator. This enables human/ machine collaboration and enables a connection between the cyber and physical world.

The company has German roots and has a leading role regarding I4.0. For the company I4.0 has to raise about 1 billion and 1 billion could be saved. Furthermore, the company has a social background within Germany, therefore I the company should be very innovative. Everything in this process forms a risk, mainly the employees. The biggest trap concerns implementing I4.0 too fast. People have to get used at I4.0. Therefore the company is working on a smooth implementation by coaching employees and support them within this process. It is important to show them the advantages of I4.0. You have to support employees throughout the process.

Regarding the future, the company has implemented I4.0 within its strategy. The company wants to save 1 billion and earn 1 billion with I4.0. Furthermore, there are plans regarding software. The next step is improving and creating self-learning production processes. In the short term, current installations will be improved even as the supply chain by using big data in marketing to respond to needs.

Digitized Supply Chain
Company G's suppliers consist mainly of other facilities involved within the same organization. Within this network, systems are connected regarding data and information. For customers, a portal is created in which they could directly order products or subcomponents. These orders are directly transferred to company's planning. Within the network of the organization and the supply of customers, products could be traced while transported. An overall system involving players throughout the supply chain lacks. Procurement is done digitally and stock is automatically ordered when minimum levels are reached. This process is partly controlled by humans but could be considered smart. To maintain this, inventories are monitored real-time. Autonomous transport internally is not applicable and external autonomous transport is not executed. Finally, the supply chain does make use of advanced data analytics regarding demand prediction and supply chain optimization. This is mostly executed throughout the internal organization in which the organization itself fulfills parts of the supply chain.

Company Case H
Company H is active in the sheet editing of the aluminum industry. The firm is at most busy with the aluminum profiles in different sizes specifically made for the customer.
I4.0 is the connection and optimization of processes by applying ICT. The company expects a higher degree of automation and a higher output, with the same amount of employees. Via this way, the manufacturing industry could stay in The Netherlands. A lot of sectors are disappearing so the manufacturing industry is very important.
Level 4. for the cyber-physical level, data is measured, analysed and presented real-time. The process could be monitored and optimized by using data. Real-time information is used in order to identify costs of production and there will be decided whether the company will make this component next time or not. Level 5 is not reached yet.
For the Readiness level, they are definitely with level 2 but have certain parts of level 3 and 4 such as measuring and default adjustments and simulations of production processes connected to product costs but are not that far yet. Investments of this company are highly pointed towards I4.0 the company wants to keep up with the competition and are deeply investing in the technology of I4.0.

For the McKinsey model, the company uses the remote monitoring and control: machines remotely on distance. this is one of the efficient ways to deal with problems when there is no one available and production needs to continue. The digital performance management, actions are registered. All repetitive work is or will be automated. Inventory management will come later this year. Advanced process control and digital quality management are already integrated into the process. Time to market parts are mostly involved with the early supplier involvement and rapid experimentation.

While implementing I4.0 thinking in a different way is necessary. This different way of thinking is hard. A solution to this is to involve employees, they might have other ideas and help the company with their problems. Company H also has to keep standards high, so they cannot afford lower standards, otherwise, customers will leave the company. This has positive effects on performance factors, such as quality, flexibility, and speed.
Company H has implemented improvements regarding I4.0 in our strategy. They want to implement many more applications internal and throughout the supply chain, also making processes more transparent to customers and suppliers and provide them an overview of real-time statuses. The company wants to improve the machine park and make use of agv's for internal transport. They expect an improvement in operation factors, but also want advantages for our customers.

Digitized supply chain
Company H acquires and transfers data to the digital world. This production data is digitally available which allows higher extents of a digitized supply chain. Systems are connected with suppliers and customers in order to provide needs and requirements more transparent. The real-time data is also used for digitized procurement, however, no traces of smart procurement were noticed. The supply chain is working on improvements regarding better interfaces and sharing of information throughout the supply chain. Internal transport is not done automatically, however, the company is exploring the possibilities regarding agv's. An interesting application within the company is the real-time-yield optimization and real-time supply chain optimization. Processes are continuously monitored and fluctuating prices are maintained per product depending on data of individual processes. This real-time data is also used in order to provide transparency throughout the supply chain and in order to improve overall performances.

Company Case I

Company I is involved in the oil and gas industry. Basic activities are engineering, production, and testing of gas turbine driven compressors for the oil and gas industry. The company is a global player within this sector.

The company sees I4.0 as a completely digitized environment around companies. It will provide more predictability by using data. For the future, fewer non-conformities are expected even as an increase in throughput time and improvements control. Besides this I4.0 will enable a better prediction regarding maintenance and avoidance of double data generation.

The cyber-physical level in which the company is situated is the data-to-information conversion level. In decentralized units of the factory data is acquired and translated into useful information. However, a centralized connection and proper central representation for decision making is missing. This will be the next level for the company. The products offered allows higher cyber-physical levels. These products consist of sensors which acquire data in order to provide useful information. This information could be sent to centralized databases which represent this information to decision makers.

Company I implemented Industry 4.0 within its strategy and investments are made. Besides this the company makes use of IT-systems and the acquisition of data in order to translate this into useful information. The company has to transform information to 1 tier. The cyber-security is mentioned as next level: an ICT team of about 1000 employees is located in Germany. Currently, the company is working towards a smart factory by connecting physical aspects to the cyber-world.

Within the company, several applications could be identified. The energy consumption within the factory and consumption is managed in a smart way. The company is working on digital performance management and real-time monitoring of processes via ERP. These aspects are currently in an exploring phase. Modeling is all done digitally and the company is working towards a configure to order system in order to increase time-to-market performances. Furthermore, the company is exploring I4.0 applications as in situation 3D printing and using augmented reality for MRO. As mentioned the company provides products which could monitor processes and have a connection to IT. Some products could also be remotely used and maintained on distance. Strengths regarding I4.0 application of this company lies within 3D modeling and 3D printing. While acquiring data from oil & gas installations errors could be detected and represented within 3D software programs. Software programs helped the company through times to improve processes and decrease costs. Regarding 3D printing, this company is able to produce entire sub-components which could be implemented in delivered products.

Company I is implementing I4.0 applications in order to improve processes since stagnation means decline. However, the implementation takes place very slowly because of the bureaucratic structure of the company. The company sees also risks in IT security, implementation and also resistance from the management team. Management is expecting certain numbers which cannot be reached with a certain degree of certainty on the short-term when implementing new applications. Besides this employees might feel threatened and might not want to accept change. Involving employees in the process should allow a better implementation of I4.0. Also, managers should be convinced of the possible advantages of I4.0 in order to implement this.

Regarding future perspectives, I4.0 strategies are flowing from higher management to local management levels. However, because of the size of the company, bureaucratic structure, and conservative managers, this implementation is going slowly. But the company is working on interconnectivity: machines will be connected to the network, and data could be acquired. The company is able to acquire a complete model of three machines which could also be simulated automatically. This will be connected to engineering. In the short term they want a better predictability of machines which produces standard products.

Regarding the supply chain, every signal is received digitally, CAD/CAM systems are translated to paper. Currently, the company is working on the digitization of 3d models. Besides this traceability throughout the supply chain will be improved. Currently, operations have to deal with a lot of paperwork which should be transferred to the product. The product and its components should be able to be traced back.

Digitized Supply Chain
In company I, data is not shared real-time but data is monitored in SAP ERP system. This ERP system is till certain extent connected throughout the Supply Chain by SAP. This connection is provided via their PDM system. Besides this, their SAP system is provided within internal drives. Some systems are already connected but this could be increased. The SAP system also has the ability to represent traced products/ components. Via these systems and protocols, certain locations are known. Traceability and back-traceability is a requirement of suppliers. Procurement is done digitally, but not by using real-time data or using smart procurement methods. Human labour is still an important aspect. Furthermore, supplier collaboration is limited and innovation on this aspect is minimal. The stock is monitored via SAP, however, this is not real-time but rather transaction based. Internal, as well as external transport, is not executed autonomously, however, the company is always working on optimizing internal logistics by decreasing distances and improving other logistical processes. Digital Spare Part Management is not executed. Storage and distribution of spare parts are based on request since products are very specific (engineer-to-order). Predictive maintenance indicators are under construction. The company makes use of 3D printing for certain parts, but this technique lacks maturity in order to produce spare parts. This is seen as a future state. Advanced data analytics is not done real-time. Demand prediction, supply chain prescription and decision

support systems regarding the supply chain are not executed. The company is working on supply chain optimization but this is done by after-calculations.

Company Case J

Company J does work in the construction industry. Supplier of Prefab concrete elements. Engineering, production, and supply of concrete. The director is mainly responsible, underneath the director the project-, commercial- and production manager are situated. The sales department receives requests and prepares quotes. Thereafter the job is going to the work-preparation department where 3D models are created. After the engineering phase, the project is going to production. They manage everything via their customized ERP system. The ERP system is implemented throughout the organization, the planning is monitored, the organisation has real time stock management.
Company J sees I4.0 as an incremental process including several developments. Big data will be applied to identify trends. The company expects that it will boost the industry to a new level.

Several applications exist within this company. Currently, this takes place mainly in the administration and works preparation sector. First, engineering work was done by hand. Currently, the company makes use of digital modeling, which saved lots of time. Within the production process, there is no automation and no automatically real-time data acquisition. Currently, the company implemented I4.0 within its strategy and is willing to make investments. Data generation is the next step in this innovation process. Digital modeling of products should be shared throughout the whole process digitally.
According to the Cyber-Physical level, it is not really applicable because they do not use machines.
As a company, they are in a level 3 transition phase. They want to go to the top-performers. A lot of work is done by hand, change is needed by adding more machines with more data and using this data for more control of the machines. The company has no examples for the McKinsey Digital Compass.
Company J wanted to sustain, it went well but they wanted to go faster. In particular, employees are a risk. People are not always convinced to implement new technologies. Another risk is the IT systems, but this is completely outsourced, so company J does not have to worry about that. The implementation has to be rethought till the smallest details. A company has to create, support and involve people in the process.
The strategy knows a lean, agile and IT-driven aspect. These processes will be implemented. Their product is not really their future business, it is more the complete experience around it. The customer gets a look in how the company produces the product and how long this will take. Acquiring data from production, digital performance management and real-time yield optimization are discussed for the future to optimize the performance factors. Investments should be aimed at improving these performance factors.

Digitized Supply Chain
Company J supplies static products and data of the process is currently yet not acquired digitally. So data is not real-time shared throughout the supply chain regarding the process. The company is willing to improve make the process more digitized in order to monitor and share processes and data. The ERP system of the company in which data is processed is connected to suppliers and customers in order to share orders and communicate with suppliers and customers.

Company Case K

Company K is active in the Security and defence sector. Core competencies are developing, producing and installing radar systems. The company offers a certain product portfolio in which aspects could be customized.

Currently, company K is exploring I4.0 in general but they also identify it as a buzzword: some processes were already available before it was labeled as I4.0. Following the respondent, I4.0 consists of automation, additive manufacturing, real-time monitoring, big data analysis, virtual reality, remote control, new materials, digital continuity, cyber-security and others. The company identifies I4.0 as necessary phenomenon in order to innovate and keep competitive. It is also expected to bring business opportunities in form of software applications and cyber security.

Regarding cyber-physical level, this facility will reach the cognition level. Data is acquired, analysed, provided and send to databases. The next level will be self-configuring machines. In order to reach this level more investments regarding increased automation is needed. This stage is currently under construction.

Currently, the company is in its beginning phase regarding the transition from the third to fourth industrial revolution. Not all employees are ready yet. The company, therefore, is partly smart factory, since a lot of automatization is available and machines are digitized. Regarding applications, the focus is on flexible and optimizing processes by making use of real-time yield, routing flexibility, machine flexibility and remote monitoring & control. Besides this performance management is monitored real-time in a digital way, the company makes use of advanced and statistical process control and maintenance is predicted digitally To make all of this possible there is a digital environment needed which is safe and Company K has one of the safest environments known, this is because of the products they make. These are for airplanes and automotive companies. There are also parts which are printed in 3D. The products provided are high-tech and could be considered smart due to remote monitoring and continuous availability of the data provided by the company, remote controlling is highly integrated. However, due to security issues customers might want bounded connections since sensitive information of radars should not be easily available for other parties.

The company has a certain future perspective regarding I4.0. Besides IT connection, process control, increase of automation etc. it will also bring business opportunities in a broad sense. It could increase profitability but also chances for existing or new products. The industry is included in the medium term planning and several studies are conducted at the moment. In the short term E-PLM, Product lifecycle management and secured data sharing will be implemented. There is also an interest in the use of robots or co-bots. For now, it was too early for the company to say something about implementations and risks. Project teams will work on this aspect.

Digitized Supply Chain

Even as company C, Company K has an extensive internal environment in which facilities are connected. Within this environment planning and execution is integrated via PLM and ERP in which data could be derived from centralized systems within facilities of the organization. Besides this, the company provides PLM interfaces via secured portals to suppliers. ERP systems do not possess interface because of low batches and security levels. Via Smart Industry initiatives tests are performed to share and connect internal information. Regarding traceability, specific components are traceable throughout the supply chain because of military aspects via PLM and ERP. There is, however, no overall system including all supply chain participants. Procurement is done digitally via needs derived from ERP systems but they are not executed in a smart way. Currently, there is also not such a focus on improving procurement. There is rather a focus on improving collaboration and shared processes as forecasting. However, a collaboration is present including main suppliers. Inventories are monitored in a real-time way and connected to the ERP system. Internal and external autonomous transportation is not available, but internal logistics is optimized via supply chain optimization. Regarding data analytics, the supply chain is optimizing demand prediction via collaborative projects and while using advanced data analytics, supply chain optimization is present via data-analytics even as supply chain prescription and a supply chain decision support system are present in the form of Business Intelligent Systems.

Company Case L

The company's sector is the hydraulic management, aerospace, automotive low motive and high motive, and safety lights in the UK. Company L has the capability to completely engineer and manufacture, low voltage and switch gear. They make custom solutions for every customer.
I4.0 according to Company L is the connectivity between man and machine, mainly machine, using the intelligence of machine to man and labour. First build up intelligence around your factory, buying machines which are capable of getting data and later on connecting them. Company L sees it as an Evolution vs Revolution 4.0. It is build up from up the third revolution, so it is more an evolution. To apply I4.0, skill sets of employees need to be adapted. Substantial increase of efficiency and a higher output to deliver more to the market.

The company has a project which is going on now according to Cyber-Physical level.. It is a homemade developed tool and they are now implementing it. At this moment, the company is connecting, on a very low level. There is one area in which they see connectivity and conversion, the company is not yet on the cyber level.

Readiness level = Zero. Company L has bits of different levels. they have cloud usage, share information, cyber security. Very little smart products. In terms of data-driven services; neglectable, smart factory; very behind → outdated. This park is not able to generate any data and data is not used. In terms of strategy, we do not really specify that
we want to be I4.0. The company strives for excellence manufacturing. Maybe it becomes a requirement because of competition. It is not yet known how they see it from the strategic levels. You need to have a roadmap and then execute. For the McKinsey model, the only applications the company uses are: Asset Utilization, Quality and Supply-demand match and customer co-creation are one of the applications which are highly valued within the company to create a connection with the customer.. It is furthermore not fully implemented.

The reason for not implementing I4.0 yet is the lack of strategic direction within the company. The only implementation is single improvements on a small scale. A lot of risks are considered in the process of company L, such as Business continuity risk, loss of efficiency, poor change management, and lack of capabilities to cope with new processes/tools/systems. The effects are not yet known, due to not implementing of I4.0 already.

Company L does not have any clear strategic plans according to I4.0, the expectations in the process are that Quality must improve. Dependability and cost are order winners for the company and their first focus. Speed and flexibility are the drivers of their vision for operational excellence.

Digitized Supply Chain

As mentioned the company is currently working on projects regarding cyber-physical applications. Currently, data from the process is not automatically acquired in a digital way but work is in progress. Processed data is partly shared throughout the supply chain via ERP systems and distribution is visible by the sending and receiving party. The procurement part is done digitally but not executed in a smart way. The company, however, is improving this process and collaborating with direct suppliers.

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