The Readiness and Obstacles while working towards implementing Industry 4.0

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ABSTRACT,

Since the introduction of Industry 4.0, the concept is under constant development and that process is going more rapidly and more in-depth ever since. Still, there is no uniform definition of Industry 4.0 and its implementation process. Larger companies have been the first movers in exploring and implementing Industry 4.0 into their production processes. Therefore, this research is developed with the aim of exploring and identifying the opportunities and challenges an SME companies faces when implementing the Industry 4.0 ways of working. This research makes use of a case study method and cross-case analysis between three different SMEs built upon a thorough theoretical framework of the existing literature. In the process, different opportunities and challenges are identified for SMEs: How can SMEs develop their readiness in order to successfully implement Industry 4.0 in their business process? The main challenges found during this research, besides from the many ones already mentioned in the existing literature, is the lack of knowledge, which is also reflecting in 'not seeing the benefits'. This research contributes to the existing literature by providing a better understanding of the ways how SMEs can identify and overcome the challenges and how to make use of the opportunities whilst implementing Industry with the ultimate outcome of success.

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Key words:
Industry 4.0, Smart Industry, SMEs, Maturity levels, Maturity types, Multi-dimensional smart industry scan, Focus group session, Case study.

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ABBREVIATIONS

I4.0:	Industry 4.0
SMEs:	Small and medium-sized enterprises
MNEs:	Multinational enterprises
Extended Scan:	Extended Science-Based Multi-Dimensional Scan
SIMS:	Smart Industry Maturity Scan

1. INTRODUCTION

1.1 Situation and Complication

Industry 4.0 is all about automation and further digitalisation of producing companies. Digitalisation and automation of inter-machine communication is what differentiates it from Industry 3.0. Which was focussed on introducing computing and the Internet into the production process, just for single processes or machines, while Industry 4.0 is focussing on end-to-end digitisation of all assets and aspects of the physical way of producing (Geissbauer, Vedso & Schrauf, 2016).

Preparing for, and the readiness to adapt to the Industry 4.0 way of working, takes a lot of time and often needs large financial investments (Nieuwenhuize, 2016). Although there are significant benefits from it, it is mostly the big multinational companies that are implementing and benefitting from Industry 4.0. For small and medium-sized enterprises (SMEs) the sometimes-substantial investments costs are an obstacle in implementing and adapting to Industry 4.0 (Nieuwenhuize, 2016).

The aim of Industry 4.0 is to convert the current production process into data driven smart manufacturing platforms, by enabling regular machines to become self-aware and self-learning. Real time data needs to be available at all times in order for a production process to improve its performance and to support the overall decision-making process within smart factories (Koch, Kuge, Geissbauer, & Schauf, 2014; Vaidya, Ambad, & Bhosle, 2018).

Maturity models play an important role in identifying the current state of an organisation regarding the level of implementation of Industry 4.0 in their digitation process. The purpose of a maturity model is to describe the development of a company and to identify their readiness (Klimko, 2001). Maturity models help to identify the "conditions when the examined objects reach the best (perfect) state for their intended purpose" (Wendler, 2012). Since Smart Manufacturing is about increasing the efficiency within a company, a maturity model helps to get insight in the level of achieved efficiency and identifying their readiness. Ungerer (2018) introduced a multi dimensional smart industry scan as a fully integrated maturity model called the Smart Industry Maturity Scan (SIMS). He later developed an extended version of this scan: Extended Science-based Multi-Dimensional Scan (Extended Scan) for assessing Smart Industry Maturity (Ungerer, 2019).

SMEs are an instrumental and dominating part of manufacturing oriented economies (Schiersch, 2013). The majority of scientific literature however is about elaborating maturity models for the implementation of Industry 4.0, focused on large enterprises. There are only just a few scientific studies that focus on how to support the implementation of Industry 4.0 in SMEs (Mittal, Romero, & Wuest, 2018). A lack of resources is often a problem for SMEs in implementing Industry 4.0 and making Smart Manufacturing part of their core competencies. Mostly, they are not (early) adapters of Industry 4.0 because a lack of resources brings fear of implementing it. For example, fear of investing in the wrong technologies and fear of adopting Smart Manufacturing in the wrong way. The adverse effects of this can be that their larger competitors are getting ahead of them, since larger enterprises have already begun their implementation and journey into the new world of Industry 4.0 (Mittal, Khan, Romero, & Wuest, 2018).

1.2 The objective of the research

The main objective of this bachelor thesis is the mapping of readiness of SMEs in implementing and adapting towards Industry 4.0. In order to focus on a certain market, SME manufacturing companies in the Netherlands shall be the focal issue. This contributes in strengthening the focus, making a more sector specific recommendations, which help making a direct comparison between the companies. Maturity levels will be used to analyse the different companies regarding their readiness with the aim of looking at the readiness and obstacles in this process of implementation.
What is the current status of the readiness of SMEs, especially from semi-automation manufacturing companies in the process of going from industry 3.0 towards implementing Industry 4.0? This research will focus on SMEs because of their often limited (access to) funds for implementing Industry 4.0. The Extended Scan (Ungerer, 2019) and the Multi-Dimensional Scan for assessing Smart Industry Maturity (Ungerer, 2018) will be the basis for this thesis. In order to get a clear insight of the obstacles and opportunities in the process of implementing Industry 4.0 into a company, helping to develop strategic ideas for smoothly introducing and implementing Industry 4.0.

1.3 Research question

This bachelor thesis is going to be written with the aim of answering the following research question:
How can SMEs develop their readiness in order to successfully implement Industry 4.0 in their business process?
In order to answer this research question, this paper will consist of a thorough literature review in order to look at the already defined obstacles and opportunities. The Multi-Dimensional Scan for Assessing Smart Industry Maturity will support this thesis as well as the scientific literature about this topic. It will help to answer the abovementioned research question and will be an important aspect of the methodology, providing empirical evidence. The literature used in this research will be primarily focused on SMEs in the manufacturing industry.

1.4 Academic relevance

The academic relevance of this paper is to provide additional research on the topic of implementing Industry 4.0 in a specific sector. The research done up till now, is mostly focussed on larger enterprises, not on SMEs. Another addition the aim will be the focus on the specific industry if possible. As mentioned before, there are still a lot of open ends in the literature about implementing Industry 4.0 and Smart Manufacturing in SMEs.

Evaluating current levels of maturity regarding the implementation helps to give insights in the readiness and future obstacles and opportunities of implementation. By making use of Ungerer's (2019) Extended Scan, the specific context can be examined and with that the extent of readiness for implementing Industry 4.0. All of this should contribute to a better understanding of implementing Industry 4.0 within SMEs in the manufacturing industry.

1.5 Practical relevance

The practical beneficial side of this academic relevance is the degree of practical insights companies can get by reading this paper.
Because it will give practical insights and tools for companies in order to improve the efficiency of their production process. Current levels of performance will be assessed using the already existing Extended Scan. Assessment is a way of collecting practical data within companies, which in turn generates empirical data for both the mentioned companies as well as for the further development of the existing scan.

2. THEORETICAL FRAMEWORK

In this section, the theoretical background will be discussed and reviewed regarding the field of Industry 4.0, in order to get a clear scientific overview of what Industry 4.0 is. The theoretical framework will consist of an extensive literature review in order to provide a clear and well-argued background for this thesis. This helps in establishing a good basis for the research that is to be conducted via the Extended Scan. With the aim of answering the research question, it is key to understand the main key concepts of this thesis. It starts with identifying and defining the concepts of Industrial revolutions, Industry 4.0, Smart Industry, SMEs, Maturity Levels and the Extended Scan developed by Ungerer (2019).

The focus will be on the Extended Scan dimensions and the importance of a holistic approach in combination with already known scientific research about SMEs developing towards Industry 4.0. The theoretical background will give a more elaborate oversight of previous studies and findings regarding the topic and companies in question, with the aim of identifying the challenges of implementing Industry 4.0.

In the literature, there are several different terms, which are used to refer to the concept of Industry 4.0. The term Industry 4.0 is predominantly used in Europe and originates from Germany. Smart Manufacturing is used predominantly in the USA. Smart Factory is a term that is generally used in Asia and sometimes in Europe as well, originating from Korea (Thoben, Wiesner, & Wuest, 2017). Although there are some minor differences, for this thesis they are used interchangeably, since those differences are not affecting the paper.

2.1 Industry 4.0

Revolution is defined as 'a big change or improvement in the way that something works or looks, or in the way that people do a particular activity' (Cambridge University Press). Revolution is also characterised by abrupt and radical change in existing situations, changing the ways things are done and seen. Looking at moments in time of big and radical changes in the field of production and industry, there are four major critical moments that can be defined as revolutionary.

The first industrial revolution, industry 1.0, saw the introduction of the steam engines that helped to establish a mechanical way of production. The second industrial revolution, industry 2.0, saw the introduction of electricity and the assembly line. This resulted in the possibility of mass production.
The third industrial revolution, industry 3.0, also known as the digital revolution, saw the introduction of semiconductors, mainframe computing, personal computing and the Internet. With these developments, automation of production processes and the Internet contributed to the beginning of the information age (Morsinkhof, 2018; Schwab, 2017), which paved the way for industry 4.0 to take place and develop.

In the literature, there are a lot of definitions of Industry 4.0. There is no *one size fits all* when talking about Industry 4.0. Since it is a topic that is still under development. Many different concepts, ways of usage, and interpretation comes with it.
Since it is still developing and being researched, there are many definitions to cover the concept of Industry 4.0. Morsinkhof (2018) defines industry 4.0 as *"application of the generic concept of cyber-physical systems"*. And Torn (2017) defines it as "*Industry 4.0 relates to the implementations of machines that make decisions autonomously, facilitated by data-driven machine-to-machine communication and cyber-physical systems that concert the analysed and communicated information to action"*. Those cyber-physical systems are integrated into industrial manufacturing with the aim of establishing intelligent, self-regulating and interconnected industrial value creation. Using smart machines, storage systems and production facilities does this. These are all connected via Internet, ensuring the constant flow of real-time data for exchanging information and initiating actions, which are mutually controlled by each other. The effect is automating of the decision-making process (Müller, Buliga, & Voigt, 2018).
According to Kohler and Weisz (2016), Industry 4.0 can be defined as "*a new approach for controlling production processes by providing real-time synchronisation of flows and by enabling the unitary and customised fabrication of products"*.
Since there are so many definitions, it's not possible to just pick one. Despite the differences in the definitions, they are overlapping as well. In short, we can conclude that full automation of all (production) processes within a company via an integrated digital network, through which real-time data flows continuously, in order to ensure the processes from happening without any human interference.

One of the key concepts of Industry 4.0 is implementing automatic autonomously working systems, supported by and through the use of the internet, in the decision-making process of production processes. Using data as a source of information in the machine-to-machine communication.

An article by PriceWaterhouseCoopers points out that the baseline of availability of relevant information via internet as follows: "*the basis for the fourth industrial revolution is the available relevant information in real time by connecting all instances involved in the value chain"* (Koch, Kuge, Geissbauer, & Schrauf (2014). Industry 4.0 is also related to terms as Industrial Internet and Digital Factories when referred to in scientific literature (Artificial Intelligence Journalism: the 4IR and media structuring, 2019).

According to Bryner (2012), O'Donovan et al. (2015) and Qi & Tao (2018) the main objective of Industry 4.0 for the production process is the use of real time data transmission and the subsequent analysis of that data to create a positive and improving effect on all the processes involved in the operations across the factory.

Smart Manufacturing is considered a revolutionary concept, which aims to improve production systems' performance. These improvements are made with the intention of reducing time and costs and increasing the quality, time efficiency, flexibility and the human-machine decision-making capabilities (Mittal et al., 2019).

2.2 SMEs towards Industry 4.0

In this part the position of SMEs towards implementation of Industry 4.0 is discussed. In particular their readiness and obstacles when dealing with their transition towards implementation of Industry 4.0 in their production processes.

In Europe, SMEs account for around 67,1% of the jobs in the private sector, when looking at the industrial segment, this can even be up to 80% (Moeuf et al., 2020). SMEs have been and are still the driving force of economies, especially in industrial segments and manufacturing economies (Schiersch, 2013). Since SMEs are in place as supplier, not only for other SMEs, but for large enterprises as well, they play an important role in the value creation process along the whole (supply) chain (Müller, Buliga, & Voigt, 2018).

For defining an SME, the conditions stated by the European Union Commission (2003) will be persisted. The SME conditions that are taken into account in classifying SMEs are based on turnover, number of employees and their annual balance sheet total. Number of employees may not exceed 250 people. For the turnover this figure is a maximum of €50 million with a balance sheet total of €43 million per year.

According to the European Union Commission (2003), the size of an enterprise is measured by the two following components: staff headcount and turnover or balance sheet total. For this research, we will stick to the definition of the European Union Commission regarding the determination whether the companies meet these conditions. This overview helps to identify whether a can be seen as an SME. They give the following overview regarding SMEs:

Company category	Staff headcount	Turnover	or	Balance sheet total
Medium-sized	< 250	≤ € 50 m		≤ € 43 m
Small	< 50	≤ € 10 m		≤ € 10 m
Micro	< 10	≤ € 2 m		≤ € 2 m

Figure 1: Overview SME conditions (European Union, 2003).

Challenges regarding competitiveness and future viability when looking at implementing Industry 4.0 prevent production companies from implementing Industry 4.0 into their production process, independent of company size. Concluding that a company size is not an influential factor concerning the ability of Industry 4.0 implementation (Müller, Kiel, & Voigt, 2018).

For SMEs, implementing Industry 4.0 in their business and production process can be a value adding system of working.

2.3 Obstacles and opportunities in the implementation process

A study conducted by Wuest, Schmid, Lego & Bowen (2018) with the aim of identifying the main obstacles of implementing smart manufacturing pointed out that the main challenges of implementing smart manufacturing in the manufacturing sector are: lack of economic opportunities, access to capital and cost-related challenges, as a main reason for not or difficult implementation. With an additional conclusion that the smaller the company, the more these challenges play a predominant role, compared to lager companies (Wuest, Schmid, Lego & Bowen, 2018).

As size plays a predominant role in implementing smart manufacturing, the smaller the size of a company, the chances are bigger that they will not be able to successfully implement Industry 4.0. As a result SMEs will be the losing party of this industrial revolution (Sommer, 2015). These mainly financial challenges of implementing Industry 4.0 prevent SMEs from investing the required capital in the new technologies involved in Industry 4.0, which often require huge investments and much needed understanding of the technology and technological resources (Mittal, Khan, Romero, & Wuest, 2018).

According to Mittal, Khan, Romero, & Wuest (2018) the main obstacles for SMEs in implementing Industry 4.0 are the availability of financial resources, the readily availability of technical resources, the inflexibility of the organizational culture, a lack of employee participation and the lack of collaboration strategies and alliances with universities and research institutes. All these concepts are part of what defines an SME when compared to an MNE.

When looking at the obstacles concerned with implementation of Industry 4.0, these concepts can be considered a negative factor in the implementation process.
In other literature, these concepts are reoccurring subjects when discussing Industry 4.0 and SMEs. According to Moeuf et al. (2020) SMEs have specific managerial features that tend to undermine the implementation of Industry 4.0. They identified these relevant features: local management, short-term strategy, lack of expertise, non-functional organisation, limited resources and a lack of methods and procedures.
Digitisation is an important part of the implementation process of Industry 4.0. As a paper by Müller, Buliga, & Voigt (2018) emphasises, digitisation levels of SMEs are more often lower than digitisation levels of MNEs, which can cause an additional obstacle in the implementation process.
When looking at implementation, strategies needed to ensure a good implementation of Industry 4.0 mainly depend on the leader of an SME company. Mostly, the leader is also the owner. So, the quality of the implementation depends highly on the understanding and willingness of this single person (Mittal, Khan, Romero, & Wuest, 2018).

2.4 Maturity Scan

Maturity scans are developed in order to systematically assess the state of development, in this case of a production company. This is done to identifying the status quo in order to outline the starting point of the implementation process. The basis of the term maturity is referring to "state of being complete, perfect or ready'' (Simpson, & Weiner, 1989). In this case, a maturity model is aiming at measuring the maturity of a production company regarding the goal of Industry 4.0 implementation.

As is pointed out by Schumacher, Erol & Sihn (2016) many companies struggle with determining their current level of development, regarding Industry 4.0 implementation. Lacking vision for the future, not being able to identify the necessary steps to undertake in order to smoothly implement the new ways of working. The actionable plan and where to start is lacking and missing in most cases. A maturity models helps to provide the guidance in this process. A maturity model helps in this process, helping a company reaching a higher level of maturity following a step-by-step continuous improvement process (Mettler, 2011).

After an extensive research, Ungerer (2018) developed the Smart Industry Maturity Scan (SIMS) aiming at identifying the maturity of a company. Secondly, Ungerer (2019) continued developing and evolving SIMS, which led to the development of the Extended Scan. Both of them with the goal of being able to assess Smart Industry Maturing. The 15 business aspects he defined as relevant for establishing the maturity level of a company, are Strategy, Employees, Management & Leadership, Organisational Culture & Knowledge, Management, Marketing & Sales, Customer Services, Channels, Institutional Awareness, Inbound Logistics Activities, Outbound Logistics Activities, Products & Services, Production & Process, IT Management, Industry 4.0 Technologies.

3. METMHODOLOGY

3.1 Data collection

This research will help to give an insight of implementing Industry 4.0 and to determine the level of maturity of the selected SMEs companies. In order to answer the research question, this research will consist of three components: extensive literature review, applying the Extended Scan and the interactive workshop. The first basis for this research, the extensive literature review, is described in the previous chapter. This type of research, a form of exploratory research, provides the qualitative data and previous research will underline the theoretical qualitative data. The purpose of explorative research is to focus "*on the discovery of ideas and insights as opposed to collecting statistically accurate data. That is why exploratory research is best suited as [...] it is most commonly used for further defining company issues, areas for potential growth, alternative courses of action, and prioritizing areas that require statistical research*" (FluidSurveys Team, 2014).
Since the method for this research is a case study, conducting an exploratory research is very appropriate and suitable (Bonoma, 1985).

The literature review focuses on the readiness and obstacles of implementing Industry 4.0. The unit of analyses are the selected manufacturing SMEs. Analysing the companies in the form of case studies within the focus group of three companies will provide the practical qualitative data. Qualitative data contributes in understanding the current state of the sectors.

To this qualitative data, quantitative descriptive data will be added with the help of the Extended Scan (Ungerer, 2019) to establish the maturity levels. The combination of qualitative and quantitative data is a way of producing richer and more comprehensive data and understanding of the research topic, which will contribute to answering the research question.

A selected focus group of manufacturing companies will be used for the Extended Scan in combination with workshops. Using focus groups to obtain qualitative data is a frequently used method to gain in-depth understanding of the research objective (O. Nyumba, Wilson, Derrick, & Mukherjee, 2018). This descriptive data will be further used for the collection of additional empirical qualitative data provided by the workshops that will be organised. Ideally, at least 2 and preferably more companies will participate in this research. With each of the companies having at least four experts to fill in the Scan.

3.1.1 The Extended Scan

The scan developed by Ungerer (2019) called the Extended Science-Based Multi-Dimensional Scan for assessing Smart Industry Maturing, is one of the tools to collect the data. For this research, the focus lies on (SPECIFIC SECTOR) in the Netherlands, meeting the previous mentioned conditions of an SME. For each company the current level of Industry 4.0 implementation will be established, using 15 different business aspects.
The Extended Scan makes use of a questionnaire, consisting of 86 ordinal measurement level questions that have been designed in previous research of Ungerer

(2019). These 86 questions are covering the 15 different business aspects, also called dimensions.
Every measurement question is scored from “not at all” (1) till “to a very great extend” (5), on a Likert scale basis. Excluding the measurement questions that cover the 15th dimension; this is a multiple answer option question. The reason for choosing the Likert-scale is mentioned by Luc Ungerer (2019) because it can provide highly reliable ability estimates and provide the validity of the interpretations made from the data through different means. The data can easily be compared and combined with qualitative data-gathering techniques, such as open-ended questions.

This will lead to a determination of a certain level of maturity, also provided by Ungerer (2019). The questionnaire will be distributed and filled out in an online format. By making use of an online questionnaire, the data collected via the questionnaire can be easily analysed and processed into the database. The questions will cover the following 15 dimensions: Strategy Employees, Management & Leadership, Organisational Culture & Knowledge, Management, Marketing & Sales, Customer Services, Channels, Institutional Awareness, Inbound Logistics Activities, Outbound Logistics Activities, Products & Services, Production & Process, IT Management, Industry 4.0 Technologies.

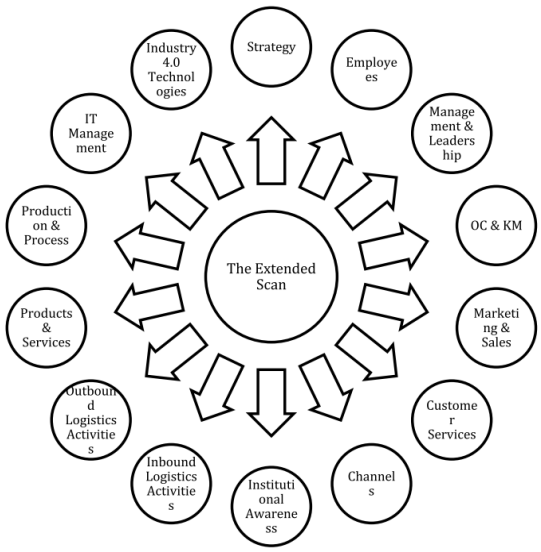

Figure 2: The Extended Scan (Ungerer, 2019).

3.1.2 Interactive workshops

Ensuring data validation for the research is conducted; interactive workshops are used as an addition to the Extended Scan questionnaire, as a triangulation method. Reason for this way of conducting research is the fact that these interactive workshops, so called focus group discussions, have certain relevant advantages.
In these interactive workshops, data obtained with the help of the Extended Scan, is presented, discussed and analysed per dimension. Involving the experts of each company in the discussion and analysing process helps to get a deeper understanding of a companies perception of their implementation of Industry 4.0, compared to the ‘reality’ as shown by the results of the Extend Scan.

3.2 Data analysis

The data obtained with the help of the Extended Scan is of quantitative nature. Responses to the questionnaire provide the necessary data-input, which is used to calculate and represent the maturity levels. A way of presenting the results in a clear way is by the use of radar charts. Which is the most preferred method because it gives an overall result at-a-glance.

This helps in assessing the level of maturity, e.g. level of readiness, a company is in. Which at the same times reveals at which aspects of the Extended Scan a company is lacking behind or is ahead. Each individual dimension will be scored separately, based on the questions for each dimensions. Responses to the questionnaire then serve as data input for the calculation of an overall score. The company receives a total score regarding their business. This overall score can be used to categorise the company regarding the readiness and level of implementation of Industry 4.0.

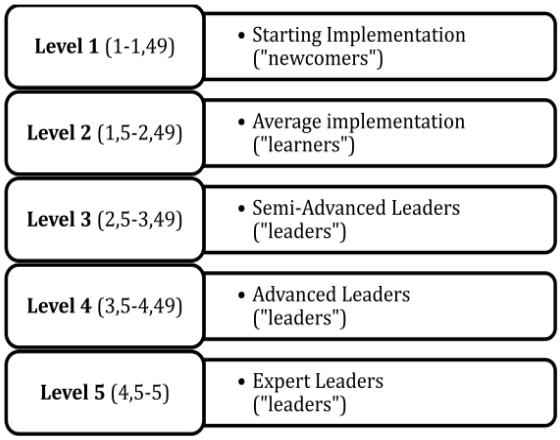

Figure 3: Maturity levels and types (Ungerer, 2019).

These five maturity levels are further elaborated into three maturity types: Newcomers, Learners and Leaders. To distinguish the level of maturity, three categories to underline their position in the process.

4. RESULTS

The results are based on the literature review, the results of the filled out Extend Scan questionnaires and the interactive workshop with the companies.
The results obtained via de Extended scan and the workshops, seen as a multi-case study were held with three companies in the Netherlands. To get a broader view of the implementation process and level within SME companies, different companies, with different levels of understanding of the I4.0 concepts were chosen. In the appendices, all the results of the questionnaire with all companies and participants are shown in radar charts. Due to COVID19, the number of participants is relatively small, at least smaller than anticipated and aimed for.

4.1 Company descriptions

In order to ensure a thorough comparison between the companies and their results related to the literature review is it necessary to describe the companies in order to understand the main differences and similarities between them. For this thesis, the participating companies are named A, B and C, to ensure complete anonymity.
All three companies meet the conditions of a SME, as stated in the definition of an SME by the European Union (2003).

Company	Staff Headcount	Turnover
A	50 - 100	10 - 25 mln
B	< 25	< 5 mln
C	100 - 250	25 - 50 mln

Figure 4: SME conditions details

Company A is specialised in the production of high-quality machines and productions lines for processing a wide range of dry substances. They are focussing on developing, producing and installing their machines and projects in-house. Their strategic focus aims at flexibility and affordable customisation for their customers. Their focus market is the agricultural and industrial sector. They are making use of a lot of automated machines in their production process. Although their automation process is still focussed on the machines itself, and not on the automation of the entire production line.

Company B is specialised in developing process control for industrial production companies. They are focussing on industrial automation for (special) machine construction. They offer IT services for industrial automation with the addition of consultancy and services for the industrial automation process and implementation. Their focus market is the chemical, pharmaceutical, automotive and other food industries sectors. Since they provide mostly IT services, they do not have any machine production facilities themselves. On the other hand, the customers for whom they provide their services do all use machineries.

Company C is specialised in providing advanced thermoset and thermoplastic composite materials for the production of lightweight structures, mostly in the aerospace industry. They aim at being an all-round producer and supplier of composite materials for their customers. This company is the most automated one of the three and is the biggest one in terms of number of employees and turnover.
All three companies are operating in the production industry, mostly focussed on producing components or machines for their customers, supplying them with production facilities and opportunities. They all state that the sales of within their sectors are growing rapidly and the sales in recently opened niches within their sector are growing quite quickly.

Company A is still very new to the world of I4.0, this reflects in their knowledge about the topic of I4.0. While company B and C are already quite familiar with the topic. Company A and B indicate that the level of automation and I4.0 implementation in their sector is still in the early stages of development. Company C indicates that it I4.0 is becoming a hot and dominating factor in the sectors they are operating in.

4.2 The dimensions

The two figures section show the general results, in which all three companies are shown together in order to see their outcomes of the questionnaire. The overview of *figure 5* is based on the results depicted in *figure 6*. These results are the bases for further explanation and discussion of the companies in relation to Industry 4.0 implementation.
For every dimension, the average score was calculated with the help of the answers given to the dimension related questions. Roman numbers are used to indicate each dimension.

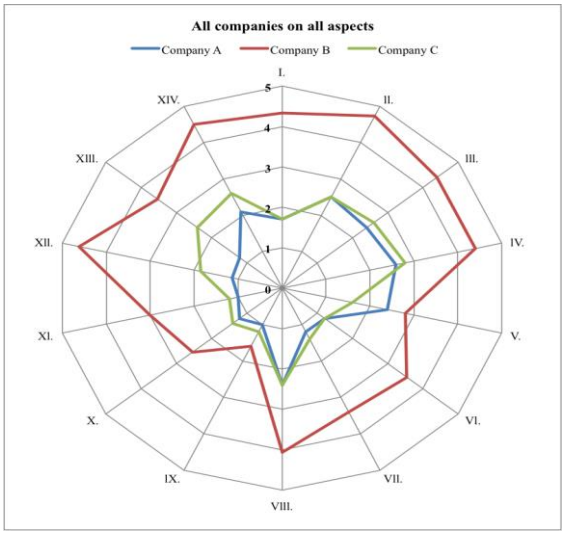

Figure 5: Radar chart visualising I4.0 maturity in fourteen dimensions, for all three companies.

Dimension I represents strategy. This dimension measures the strategic side of implementing I4.0. This includes the companies' strategy regarding digitalisation, data, goals, and innovation inclusion. Dimension II represents employees. This dimension measures the employees' aspect of implementing I4.0. Focussing on vision, knowledge, and tools to develop skills, reflecting the current organisation culture and how employees are trained towards implementing I4.0. Dimension III represents Management and Leadership. This dimension measures to what extend management is supportive, understanding and skilled to bolster and lead the process of I4.0 implementation. Dimension IV represents Organisational Culture & Knowledge management. This dimension measures to what extend the companies' culture is open for and focussed on creativity, knowledge of I4.0 aspects, the effort of paving the way for I4.0 implementation and the companies' focus on improving the company in a 'smart' way. Dimension V represents Marketing & Sales. This dimensions measures to what extend online behaviour of customers is known, online performance is monitored, the digitalisation of sales, and the optimisation of the utilisation of necessary information about products and services is achieved. Dimension VI represents Customer services. This dimension measures to what extend customer service methods and digitalisation meet up to the necessary level of interaction with their customers. Dimension VII represents Channels. This dimension measures to what extend the company makes use of certain channels to communicate, monitor and inform customers. Dimension VIII represents Institutional awareness. This dimension

measures to what extend the company complies with laws, regulations and digitalisation regarding policy, taxes and rules. Dimension IX represents Sustainability. This dimensions measures to what extend all aspects of I4.0 contribute to a more sustainable environment in which companies operate and from the view of their own way of working in relation to sustainability. Dimension X represents Inbound logistic activities. This dimension measures to what extend the incoming of goods in terms of transport, storage and delivery the company uses I4.0 to promote a more efficient and faster way of working in this area. Dimension XI represents Outbound logistic activities. This dimension is the same as the previous one, but is focussed on delivery of goods going out of the business, mostly to customers. Dimension XII represents Products & Services. This dimensions measures to what extend I4.0 helps to offer more efficiency regarding services, improving products, digitalisation, performance monitoring, new product development and quality improvement. Dimension XIII represents Production & Process. This dimension measures to what extend the production processes within the company are ready and improved for and with the help of I4.0, with the new capabilities I4.0 offers. This reflects to efficiency, costs, digitalisation, flexibility and accuracy. With the addition of information sharing with partners with beneficial aspects for the whole supply chain. Dimension XIV represents IT Management. This dimensions measures to what extend the data protection and usage with I4.0 technologies is managed in relation to privacy and security and how it enables new business operations, opportunities and solutions.
The last dimension is not displayed in the radar chart above. This is because this dimensions is not measured by the Likert-scale method and consists of a multiple-answer question: which industry 4.0 technologies you are already using?

4.3 Companies and empirical results

The introduction questions were the starting point of the questionnaire, the results are shown in appendix 2 All of the three companies indicated that the total sales of our sector grows fast compared to other sectors and the sales in recently opened niches within their sector grows fast. They also indicate that myriads of actions by our rivals continually erode our advantage is not the case in their sector and that their products are not constantly under attack from low-cost substitutes. They also indicate that new competitors don't enter their sector with innovative products very often.
These introduction questions show that the sector which they are operating in, is a growing market in terms of sales and newly entered niches are an addition to their activities in terms of sales. When looking at the other indicators, their sector seems to be a stable one with not too many interference by other or new competitors, or low cost substitutes or new innovations.

Figure 6 shows how all three companies scored on these earlier mentioned dimensions. Since this paper focuses on the opportunities and obstacles of Industry 4.0 implementation in SMEs, it is valuable for answering to research question by looking at the dimensions, which are most helpful and supportive in answering the research question. These dimensions are selected on the basis of the questionnaires results and the data gathered during the interactive workshop group sessions.

On the basis of the questionnaire data, the average scores of each dimension were calculated. Based on that, the highest (green) and lowest (red) scores are indicated in figure 6. By doing this, the following dimensions are marked as "interesting & distinctive". For the highest scored (green), those are: 2, 3, 4, 12 and 14, for the lowest scored (red), those are: 5, 6, 9, 10 and 11. During the workshop sessions, those dimensions got an extra focus in the questions asked during the sessions.

As visible in figure 6, all three companies score low(est) on the 9th dimension: Sustainability. During the workshop sessions, they all indicated that is the least interesting dimensions, which they all don not consider a priority to them. Not in general, and not in relation to Industry 4.0. Therefore it is decided to not take the scores for dimension 9 into account during the presentation and discussion of the results.

Dimensions	A	B	C
1. Strategy	1,71	4,33	1,71
2. Employees	2,50	4,72	2,50
3. Management & Leadership	2,40	4,40	2,60
4. Organisational Culture & Knowledge Management	2,60	4,40	2,80
5. Marketing & Sales	2,40	2,80	1,60
6. Customer services	1,20	3,53	1,20
7. Channels	1,20	3,40	1,40
8. Institutional awareness	2,40	4,07	2,40
~~9. Sustainability~~	~~1,00~~	~~1,60~~	~~1,20~~
10. Inbound logistic activities	1,20	2,53	1,40
11. Outbound logistic activities	1,00	3,00	1,20
12. Products & Services	1,14	4,62	1,86
13. Production & Process	1,20	3,53	2,40
14. IT Management	2,10	4,50	2,60
Total average	**1,72**	**3,67**	**1,92**

Figure 6: Results Extended Scan company A, B & C.

Dimension 15	A	B	C
1 . Interoperability		✓	
2. IOT/connectivity		✓	
3. Cloud/edge		✓	
4. 3D printing		✓	
5. Block chain			
6. Advanced robotics			
7. GDPR/Drones			
8. Advanced materials	✓		✓
9. AR/VR/Smart			
10. Advanced data analysis		✓	

Figure 7: Results 15th dimension, company A, B & C.

As seen in the radar chart and the table containing the Extended Scan results, a comparison can be made between the three companies. In appendix 2 all the scores per dimension can be found in radar charts.

4.3.1 Company A

Company A can be classified as level 2, on the basis of their average score (figure 3). The average maturity score is 1,72 and therefore Company A can be seen as a "Learner" maturity type, with an average implementation level regarding I4.0 implementation. Their understanding and knowledge of Industry 4.0 was very low. During the workshop session, they indicated that apart from having heard of it and just some basic research, they were not jet involved in Industry 4.0 or implementing it.

The scores of all fourteen dimensions are between 1,00 and 2,60. This indicated that the company scores average throughout the organisation on each dimension. The highest two scores are obtained for Organisational Culture & Knowledge Management (2,60) and Employees (2,50). The question that stands out most because it got scored significantly higher was: "To what extent does the culture support to think out of the box and create new innovative ideas?" This question is from the 4th dimension. According to the company, they find it important for their employees to not be withheld in their development and expression of creativity. The lowest scores are obtained for Outbound logistic activities (1,00) and Products & Services (1,14).

During the workshop session with the company, the additional questions were focussed on these four dimensions. As for the financial part of implementing I4.0, the company was not able to invest or planning to invest in the I4.0 in the short future. As stated by them: 'we are currently spending a lot of money on remodelling and extending our production facility'. They workshop aimed at gathering additional data through specific questions. When looking at the dimensions, which scored high, this seemed to have nothing to do with I4.0 intentionally. They explained their focus lies on giving their growing and young team enough possibilities to develop themselves, which is very involved in the day-to-day business. As for the digitalisation aspect, they are focussing on that, but that merely is focussing on digitalisation, which is still a form of Industry 3.0. Their current challenges are related to dimension 11 & 12. When asked about this, they stated that it is hard in their industry to digitalise the whole supply chain, because of the weariness of sharing in-depth digital information with others. It all has to do with the IT Management dimension. Doubt and uncertainty about sharing company data, regarding the security and the technological infrastructure. The company also stated that the sector and market in which they operate, does not participate or expect the company to participate in I4.0 implementation.

4.3.2 Company B

Company B can be classified as level 4, on the basis of their average score (figure 3). The average maturity score is 3,67 and therefore Company B can be seen as a "Leader" maturity type, with an advanced leader implementation level regarding I4.0 implementation. Their understanding and knowledge of Industry 4.0 was significant. During the workshop session, they indicated they were well aware of what Industry 4.0 is, what the benefits are and how complex the implementation process is.

The scores of all fourteen dimensions are between 2,53 and 4,72. This indicates that the company scores average on throughout the organisation on each dimension, though on within the higher levels of the maturity model.

The two highest scores are obtained for Employees (4,72) and Products & Services (4,62). The two lowest scores are obtained for Marketing & Sales (2,80) and for Inbound logistic activities (2,53). The question that stands out most because it got scored significantly lower was: "To what extent is the website of the organisation optimally utilized for gaining necessary information about your products/services?" This question is from the 5th dimension. Reason for this, according to the company was the simple fact that they don't have a functioning website at the moment. When looking at the 10th dimension, there were a many differences in the scores given to each questions within that dimension.

During the workshop session held with the company, they indicated that they are specialised in the digital part of Industry 4.0. Since their average score indicated they are a Leader, it soon became clear they had far more knowledge about the topic than the previous company. Their lower scores are because they don't focus on these parts at the moment. They are more focussed on the other dimensions. When asked about it, it became clear that their idea of I4.0 and how to implement really fits in the dimensions of 2 & 12. According to them, this is where the implementation process starts and builds upon. Though, the IT Management dimension again came forward as a very important aspect. They stated that most SME companies outsource all that comes with IT and the management of it. Company B is really focussing on the IT part and does not outsource that. They do experience troubles and doubts on this dimension when looking at others and their customers. They defined data security and data sharing, processing and storage as the main challenge in the full implementation of I4.0.

4.3.3 Company C

Company C can be classified as level 2 as well, just like Company A, on the basis of their average score (figure 3). The average maturity score is 1,92 and therefore Company C can be seen as a "Learner" maturity type, with an average implementation level regarding I4.0 implementation. During the workshop session, in contrary to Company A, they are aware of what Industry 4.0 is. Their knowledge and understanding of the topic was quite good. They are in the early stages of the implementation process and already delved into the topic of Industry 4.0 implementation.

The scores of all fourteen dimensions are between 1,20 and 2,80. This is quite the same like with Company A, scoring quite average over all dimensions, though scoring differently on each dimension when compared with Company A. The three highest scores are obtained for Organisational Culture & Knowledge Management (2,80), and for Management & Leadership and IT Management (2,50). The question that stands out most because it got scored significantly higher was: "To what extent does the management has the ability (1) to lead the organisation into new industry 4.0 practices?" This question is from the 3th dimension. The company stated that their management see implementing I4.0 as part of their strategy, though in the early stage of is, and has the opinion they provide the right basis and support for implementing I4.0 Another question that stood out was the following one: "To what extent are trainings/workshops offered to employees to enable them to understand what a "smart factory" is?". This question,

although from the 4th dimension, which scored high, was answered with a 1: not at all. According to the company, they are in the early stage of exploring I4.0 implementation but their weakest point is providing training for the readiness and understanding of I4.0 in their organisation. When looking at the scores for the 14th dimension, questions with regarding the use of digital integration and digitalised real-time decision-making, where significantly lower scored. The significantly higher scores where for questions regarding security for storing data and designing new systems. During the workshop session, this was discussed. The company explained that they are not yet able to make autonomous decisions because the real-time data aspect is not yet developed enough to support this process. They do emphasise on the security aspect of the gathered data regarding storage and usage. According to them, it is an important pillar in Industry 4.0 and its implementation.
The two lowest scores are obtained for Outbound logistic activities (1,20) and for Customer services (1,20). Although company C sees opportunities and the importance of these dimensions, it is their weakest points of all fourteen dimensions. Mostly because they operate in a B2B environment, again digitalisation and data sharing is a hurdle in the company, in relation to their customers and suppliers. Added to these aspects, the costs of implementing it is also a withdraw.

5. DISCUSSION

In this section, the findings of the literature research and the practical data gathered with the help of the questionnaire and the interactive workshops with the three companies are described. The gathered data will be compared to the information that was obtained during the literature research. All this centred on the research question: *How can SMEs increase their readiness in order to successfully implement Industry 4.0 in their business process?* With the aim of answering the research question and adding significant academic and practical conclusions to the currently existing knowledge about implementing I4.0 in SMEs business processes.

During the literature review, different authors described some main challenges, obstacles and opportunities regarding the implementation of Industry 4.0 into the business processes of SMEs. When looking at the results in the previous section, it appears that mainly Marketing & Sales, Customer services, Inbound logistic activities and Outbound logistic activities are the biggest challenges for participated companies in the implementation process of Industry 4.0. Products & Services seems to be a challenge for one company, and a not a problem at all for another company. The dimension of IT Management is named and marked by all three companies as an important one. Important because of the opportunities and important because of the challenges of gathering and securing the data, and all other digital processes within the companies. Data gathering is mostly done in just a small scale within the companies. Processing that data is another hurdle and big challenge for them. When looking at the literature, the aspects of strategy, level of digitalisation, leadership, understanding of the I4.0 concepts, cost-related challenges, flexibility and employee participation play an important role and are identified as challenges.

Better understanding and implementation of these aspects in the companies can make a positive contribution to the implementation process of Industry 4.0. As can be seen in the results, it appears that mainly Employees, Management & Leadership, Organisational Culture & Knowledge Management, Products and Services and IT Management are the focus of the participating companies, at least at which they scored higher maturity levels.

Statistically, the dimensions on which the companies scored lowest can be considered a challenge. However, during the workshop sessions it became clear that size, focus, priority and the sector in which they operate, are an influencing factor as well, which puts those dimensions and the reason why in a whole other perspective.
The participating companies did agree that the use of the Extended Scan for their companies gave them useful insights in the world of Industry 4.0, their current position in relation to Industry 4.0 and the implementation process of Industry 4.0.

As goes for the theoretical part, the aim of this study was to be able to identify and 'fill' the research gap in the literature. A lack of knowledge and understanding about the subject is something that came forward during this study. In the literature, there is a lot of information about this subject, as is discussed in the theoretical framework. As for SMEs, increasing their knowledge can lead to decreasing the challenges and with that: increase their opportunities for understanding and implementing Industry 4.0. This study can contribute in the first steps of overcoming that research gap by realising that the understanding of the concept is an important and first step in the process: creating awareness.

5.1 Limitations and further research

One of this research limitations' is that it was not conducted in one specific sector. The research was conducted with the help of three companies, which provided the ability to do cross-case analyses and makes comparisons, but these companies where not all active in the same sector. Due to COVID19 and its implications, it was hard to find three suitable companies, within the same sector, who were willing to participate. In addition to this, the former mentioned baseline of having at least four experts to fill out the questionnaire has not been realised. This also had to do with COVID19. Companies were not too eager to participate. The ones that did, were not able to provide that many participants due to the effects of COVID19 which resulted in no time, not our focus, not relevant at them moment etc. In compensation to that, the choice has been made to have three companies participating in this research.
Since the goal of this research is to get an insight in the implementation process of Industry 4.0 within SMEs, the focus of the Extended Scan the focus is on to what extend companies are involved in Industry 4.0 implementation. The questions accompanied with the scan, either gave a good insight in that matter, but only if the company was already aware of the topic and the implications and possibilities of the topic. Companies who weren't aware of the concepts of Industry 4.0, had a harder time to understand the questions and to answer them in the right way without misinterpreting them. This came to light during the workshop sessions.

In addition to this, the length of the questionnaire proved to be too long. The amount of questions resulted in many approached companies to choose not to participate in this research. Partially for the same reasons as the above mentioned drawbacks of COVID19 for this research.
When aiming at getting insight into a specific sector, the sample size of 2 or 3 companies is rather small. It does give some interesting insights, but the sample size is not big enough to generalise the results for the whole sector. Since the requirements of an SME, ranging for example with a turnover of $0 to $50 million per year, is quite broad.
Despite these limitations, this research can be a good starting point to further analysis of the sectors. And for further research it is possibly an improvement to revise the length of the questionnaire. In combination with having enough participants for the research, there is still a lot of the Industry 4.0 concept that can be discovered and further investigated with the additive possibility of collecting more and generally applicable results. Industry 4.0 is still not a generally defined, accepted and implemented concept.

5.2 Conclusion

The revolution of Industry 4.0 is still a hot and on-going topic in the production industry. For some companies its already part of their day-to-day business, for other it is still a novelty, of which they have no clear knowledge and insights. This research describes and discusses the topic of Industry 4.0 implementation in relation to SMEs and the many aspects that come with it. These accompanying aspects are both obstacles and opportunities regarding the implementation process.
After identifying the possible challenges and opportunities, via the conduction of literature research and the conduction of obtaining empirical data, in order to answer the research question *"How can SMEs increase their readiness in order to successfully implement Industry 4.0 in their business process?"* These challenges and opportunities are described in the results section of this research and further discussed in the discussion section. This leads to the conclusion that knowledge of the mentioned challenges and opportunities in the literature review, covers a broad part of the relevant aspects which can influence the readiness of a company in either a positive (opportunity) or a negative (challenge) way. The most important thing for a company is to get to know the concept of Industry 4.0 and relate this knowledge to the specific company: where are we in the process of understanding and implementing Industry 4.0? In contrast to MNEs, SMEs mostly lack the power and influence in the process of changing their surrounding or their markets in which they operate. Although, as a sector, they can have the possibility to change and implement the Industry 4.0 in their business processes. Since implementing Industry 4.0 is not only an in-house process, but also a supply chain wide process, this is where the implementation opportunities lie for most SMEs.

5.3 Acknowledgement

I would like to thank my supervisor, Raymond Loohuis for providing the guidance and structure during this process. In addition to this, I would like to thank Luc Ungerer, the author of the Extend Scan, for providing us with information about the Extended Scan and the support he gave. As for the companies who participated in this research: thank you for providing me the necessary data and information I used for writing this thesis. Finally I would like to thank my fellow bachelor circle students for the useful interaction and support, which helped me finishing my thesis.

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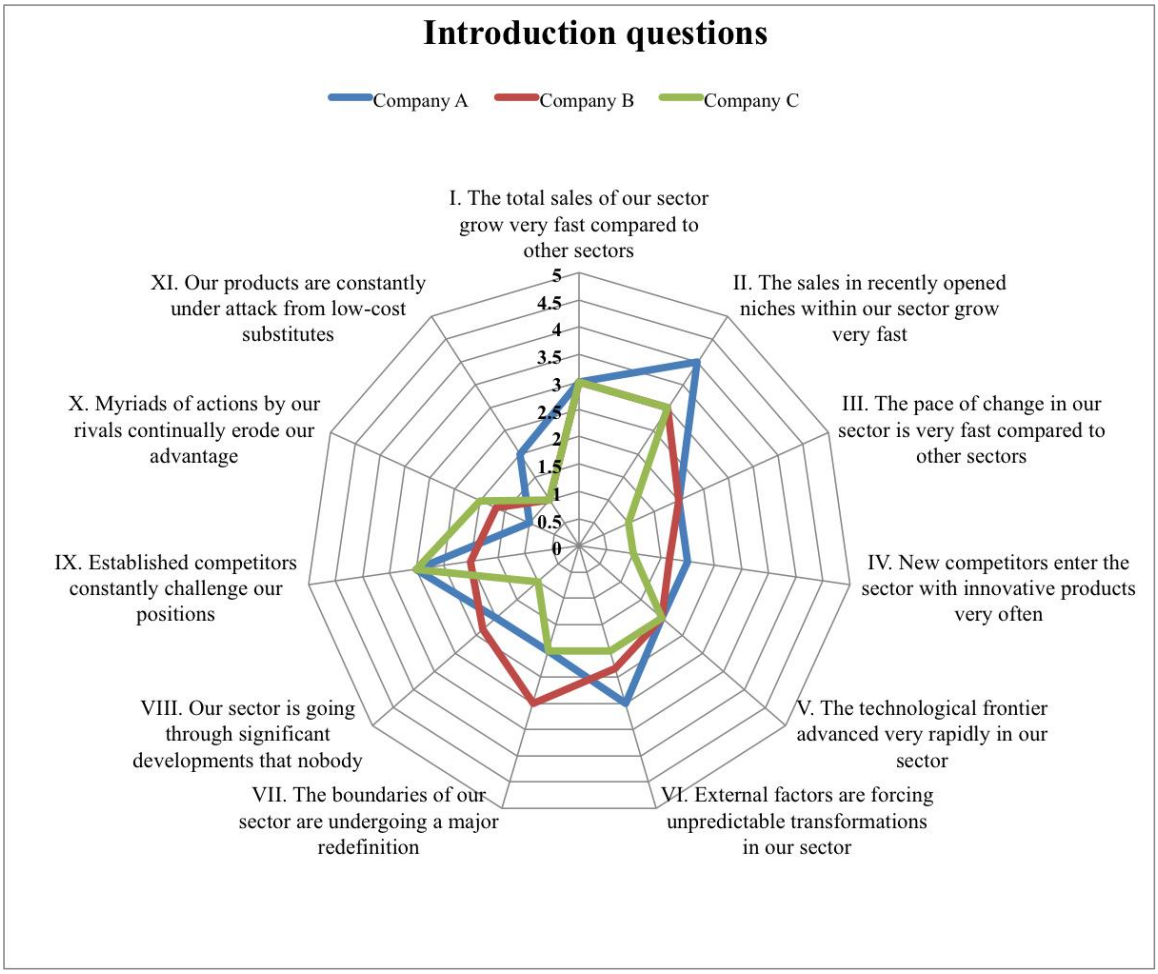
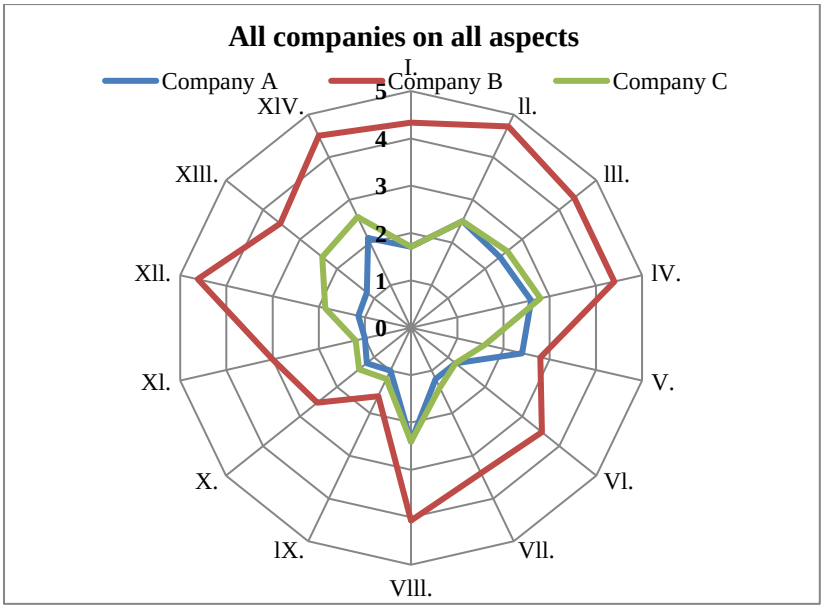
7. APPENDICES

7.1 General questions used during the workshop sessions to start and stir up the conversation.

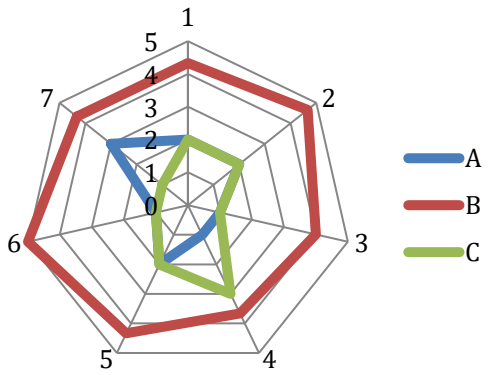
	Vragen
1	Wat weten jullie als bedrijf al van I4.0?
2	In hoeverre zijn jullie binnen het bedrijf bezig met I4.0?
3	Wat vinden jullie van de resultaten?
4	Kunnen jullie je erin vinden? Waarom wel, waarom niet?
5	Welke dimensies vinden jullie zelf het belangrijkst?
6	Gemiddeld scoren jullie … Verbaast het jullie dat jullie lager scoren op … en hoger …?
7	Zijn jullie van plan de laagscorende dimensies te verbeteren?
8	Hoe denken jullie die lage scores te verbeteren? Welke acties kunnen jullie daarvoor ondernemen?
9	Welke dimensies achten jullie zelf als het meest belangrijk voor jullie bedrijf?
10	Welke dimensies zullen prioriteit hebben als het gaat om verbeteren?
11	Hoe snel veranderd de omgeving waarin jullie actief zijn?
12	Hoe gaan jullie met deze veranderingen om?
13	In relatie tot I4.0, waar ligt bij jullie de focus op?

7.2 Radar Charts

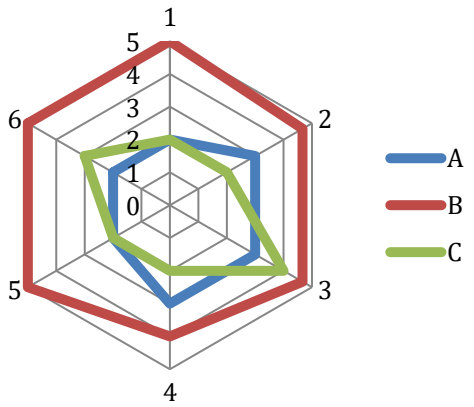




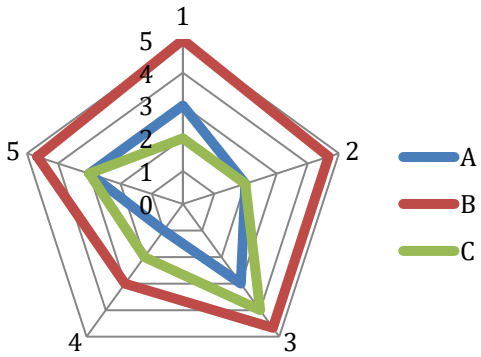
1. Strategy



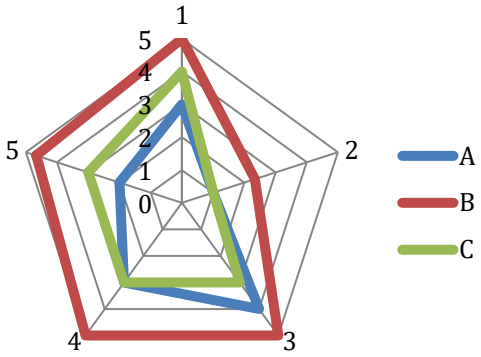
2. Employees



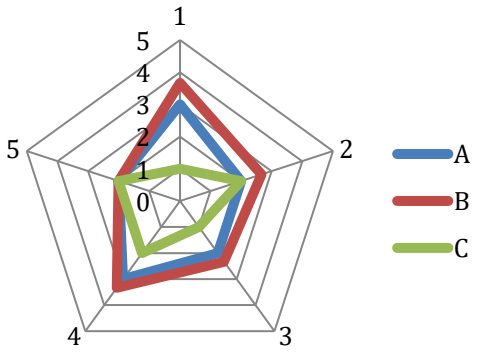
3. Management & Leadership



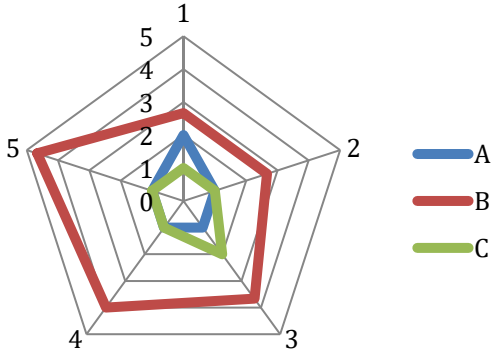
4. OC & KM



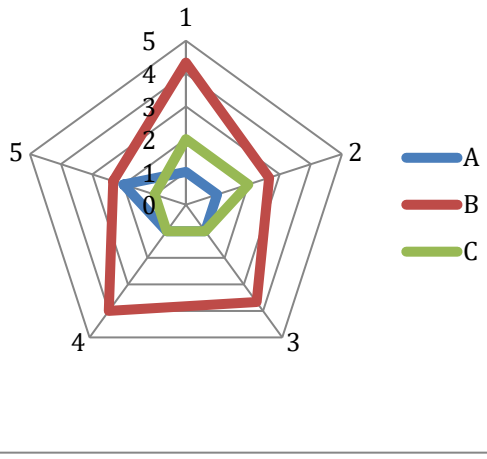
5. Marketing & Sales



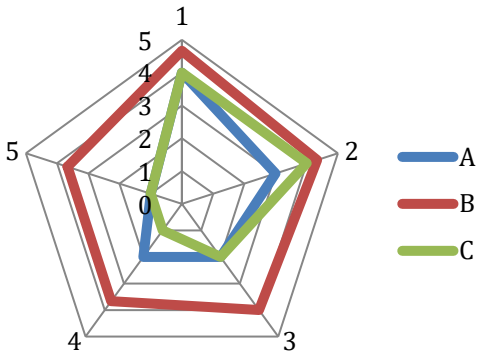
6. Customer services



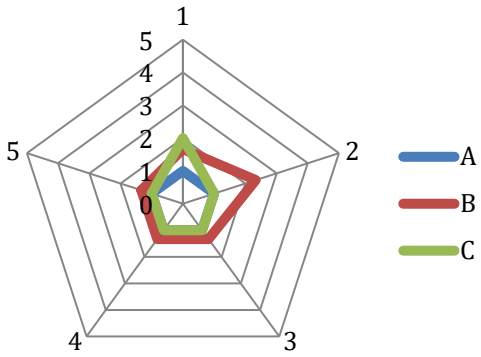
7. Channels



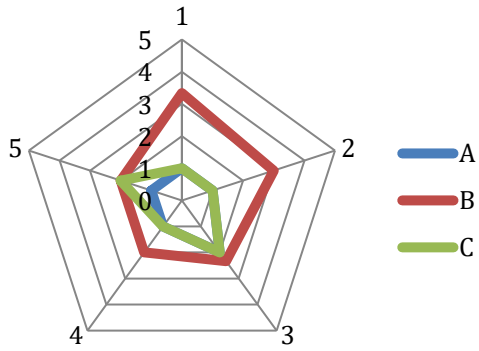
8. Institutional awareness



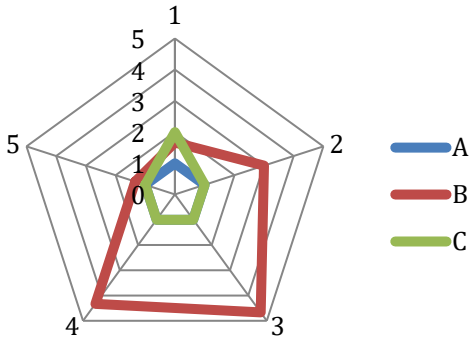
9. Sustainability



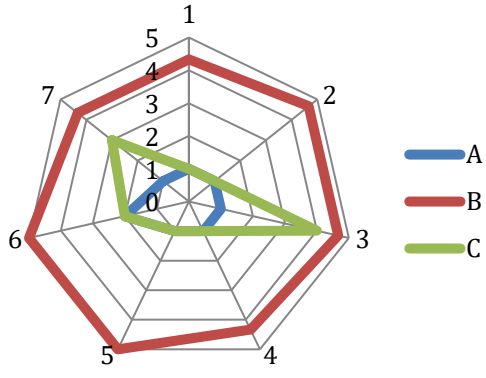
10. Inbound logistic activities



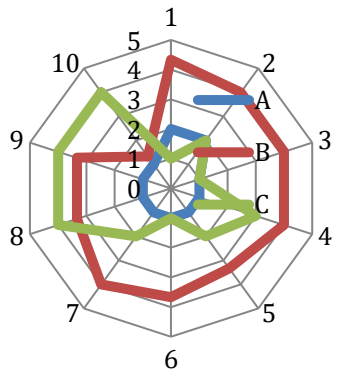
11. Outbound logistic activities



12. Products & Services



13. Production & Process



14. IT Management