A brain of metal: Responsible strategic action for metal manufacturing SMEs in a smart industry context

Author: Guus Holst
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT,
Industry 4.0 is becoming an inescapable part of the way future manufacturing will look. Thus, companies need to find ways to adapt to the more digital environment, connectivity of machines and a more demanding customer. SMEs face different challenges than larger companies do when adapting to industry 4.0. To analyze how SMEs in the metal industry in the Netherlands best can overcome these challenges, first, descriptive data about 15 dimensions is gathered using a scan, second using empirical data the importance of each dimension is identified. Using these measurements, multiple requirements, that SMEs need to meet, are identified to overcome potential obstacles. The main finding of the research is that there is a significant lack of knowledge in the industry concerning industry 4.0, its potential, the technologies and how to adapt. Next to that, the focus of SMEs in this industry lies on the production possibilities of industry 4.0, almost completely neglecting the servitization aspects that industry 4.0 offers. Furthermore, a threat is identified that SMEs might not oversee the potential of new industry 4.0 technologies that can replace a part of the manufacturing process.

Graduation Committee members:
Dr R.P.A. Loohuis MBA
Drs. P. Bliek

Keywords
Industry 4.0, Smart Industry, Metal industry, SME, manufacturing, maturity scan, case study, explorative research.

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1. INTRODUTION

1.1 Relevance

Industry 4.0 refers to a new industrial revolution, involving many different smart networking systems (Ivanov et al., 2019). The development of adapting to these systems sometimes requires significant investments and SME's often face significant financial constraints (Mittal et al., 2018). Next to that SME face different challenges than large multi-national companies do (Wadhwa, 2012). Even though most of the research for preparations for the fourth industrial revolution has been done for large enterprises (Müller et al., 2018), SME's are for some sectors economically the most dominant drivers (Schiersch, 2013). And even more so, it is likely for smaller manufacturers to feel overwhelmed and they might avoid this technology development, out of fear of not having the technology and design principles in place (Ghobakhloo, 2018).

In this thesis, the focus lies on the metal industry. Or rather more on the cutting of metal in this industry. Data management can be difficult in this industry. Often devices that generate data have specialized data algorithms, limited amounts of data or are not standardized and metal industries can encounter difficulties on planning procedures on implementing or adopting new technologies (Motabele, 2016). Furthermore, the metal cutting industry needs to cope with large fluctuations in demand. Industry 4.0 can help, using amongst others, machine to machine communication, to solve these logistical difficulties (Barreto et al., 2017). This makes the metal industry a relevant and interesting topic to study in an industry 4.0 context.

1.2 Research objective

Considering the financial constraints and the importance of SMEs in driving the economy, it is important to know how these SMEs can best prepare for this industrial revolution. However, to make a good assessment of how these SMEs can best prepare, it is first required to know at what level their current preparations are and how industry 4.0 fits to the current situation of the company.

In this bachelor thesis, an assessment is made towards the current level of preparedness of metal cutting SMEs for the new industrial revolution. Next to that, there is an assessment on which areas the SMEs can improve and what transition strategy they can use best, to overcome these challenges. With this information, the SMEs can adapt themselves better to Industry 4.0.

Therefore, the following research question is formulated: ***How can manufacturing SMEs in the metal industry best adapt to the industry 4.0 developments?***

1.3 Practical and academic contribution

The research in industry 4.0 is rapidly developing, however, most of this research is into the consequences for large companies and SMEs are often not taken into account. (Müller et al., 2018). Furthermore, in this research the focus lies on the metal industry. Even though there already has been one paper focusing on the steel industry in a smart industry context, and according to the European Union the steel industry is a subpart of the metal industry (*The EU Steel Industry | Internal Market, Industry, Entrepreneurship and SMEs*, n.d.), this thesis is different in the sense that it focusses on SMEs in the metal industry and that it uses a scan to assess the maturity levels. Furthermore this thesis focusses on the transition to industry 4.0, rather than only the current level.

Next to providing academic insight, in this thesis, companies are involved to improve their strategy and current situation when it comes to the preparation of industry 4.0. This is done by assessing the performance of a company and afterwards giving a workshop on how the company can improve. Furthermore, this research provides insight into metal manufacturing SMEs on what areas they best can improve in.

1.4 Structure

In this thesis, there will first be a set of used definitions, since these definitions are not always generally accepted. Next, an insight will be given into why and which maturity models are used, followed by a chapter about the selection of a scan. Afterwards, an insight will be given about the theory and drivers of transitioning to industry 4.0 in this specific context. Then the methodology will be discussed on how the descriptive and empirical data is gathered. The results using these methods are then elaborated upon, followed by the implications of these results. Then the limitations and possible future research are discussed, followed by the conclusion and acknowledgements. Finally, an overview of the references is given and some additional used materials are given in the appendix.

2. THEORETICAL BACKGROUND

2.1 Key definitions

To align this thesis with previous research it is important to provide definitions of the concepts used. A generally accepted definition does not yet exist (Ivanov et al., 2019). As there are many concepts involved in industry 4.0, there are also different interpretations of what industry 4.0 is.

One definition is: "*Industrie 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross- organizational*

services are offered and utilized by participants of the value chain." (Hermann et al., 2015). With CPS meaning Cyber-physical systems, IoT Internet of Things, and IoS Internet of Systems. However not all researchers use this definition, many researchers see industry 4.0 "*as factory concepts that share attributes of smart networking"* (Ivanov et al., 2019). In this thesis when referring to industry 4.0, it refers to the concepts: smart factory, cyber-physical systems, self-organization, new systems in distribution and procurement, new systems in the development or product and services, adaptation of human needs and corporate social responsibility. (Lasi et al., 2014). The latter is the used definition because the scan used in this research uses the same concept of industry 4.0. The scan will be further explained in subchapter the scan in theoretical framework.

The concept of smart factory plays a key role in industry 4.0 (Kagermann et al., 2013). *"The Smart Factory is defined as a factory that context-aware assists people and machines in execution of their tasks. This is achieved by systems working in background, so-called Calm-systems and context aware means that the system can take into consideration context information like the position and status of an object. These systems accomplish their tasks based on information coming from physical and virtual world. Information of the physical world is e.g. position or condition of a tool, in contrast to information of the virtual world like electronic documents, drawings and simulation models. […] Calm systems are referring in this context to the hardware of a Smart Factory. The main difference between calm and other types of systems is the ability to communicate and interact with its environment."* (Lucke et al., 2008)

When discussing servitization the concept of adding value by adding services is meant (Vandermerwe & Rada, 1988).

SMEs in this context are defined as companies with less than 250 employees. According to the European Commission, SMEs are companies with less than 250 employees and with a balance sheet of fewer than 43 million euros (European Commission, 2003). Therefore, this is measure is handled as a requirement for participating SMEs.

2.2 Performance of SMEs and industry 4.0

There has already been quite some research in SMEs and it's adapting to other market influences. For instance, leadership, networking with government bodies and academic institutions, and fact-based decisions are critical factors in the success of manufacturing SMEs from the United Kingdom and Australia when it comes to adopting quality management (Kumar et al., 2014). Furthermore, according to a study into Indian manufacturing SMEs knowledge management, industry-academia and social network are critical factors for success and were found in India to be lacking behind (Vasudevan & Chawan, 2014).

The above are areas manufacturing SMEs, in general, can improve in, but specific constraints for SMEs in the context of industry 4.0 that are found include standardization, personnel resources, financial resources, and a belief in digitization (Julian M Müller & Voigt, 2017).

Most research for industry 4.0 is focused on holistic models and not taking into account SME constraints (Mittal et al., 2018). However, the holistic models do give a good base measure on the performance on how SMEs are performing in the context of Industry 4.0. A pilot study in the Basque region proposes a model to analyze the maturity of SMEs in the context of SMEs: envision, enable and enact (Ganzarain & Errasti, 2016). Each of these three steps then has 5 maturity levels. The first maturity depending on the industry's specific vision and the last maturity level focusing on future challenges.

Another maturity model is the system integration maturity model industry 4.0 or SIMMI 4.0, which provides 5 maturity levels: basic digitization, cross-departmental digitization, horizontal and vertical digitization, full digitization and optimized full digitization (Leyh et al., 2016). In the creation of the extended scan used in this research, (Ungerer, 2019) used the SIMMI 4.0 model (Leyh et al., 2016).

2.3 The scan

There are already multiple industry 4.0 scans. For this research, the scan providing the most detailed yet global overview of the strategy of a company was selected. Next to that, it is important for the scan to provide multiple maturity levels. For these maturity levels can help to categorize performance in different strategic aspects. As far as the literature research reached the so-called extended scan created by Ungerer (2019) was the scan that fitted best with the aim of the research, this being to provide a good and complete view of the current level of preparedness for Industry 4.0. Next to that it provided insights in performance using maturity levels. Therefore, this scan forms the backbone of this research.

The extended scan is created from 15 different aspects. These different aspects categorize different areas of strategic performance in an industry 4.0 context. These aspects are visualized In figure 1. Note: OC&KM is short for organizational culture and knowledge management.

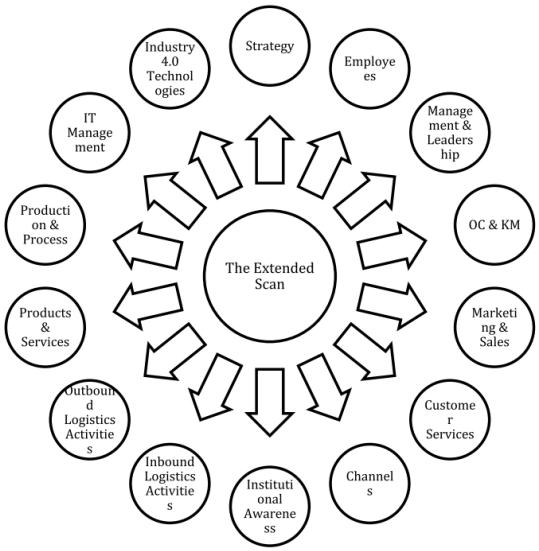

Figure 1 The extended scan (Ungerer, 2019)

The scan aims to assess what aspects a company is lacking behind on and what aspects it is leading in. This is done using maturity levels. The results of the scan can measure what the maturity level for each of the aspects is.

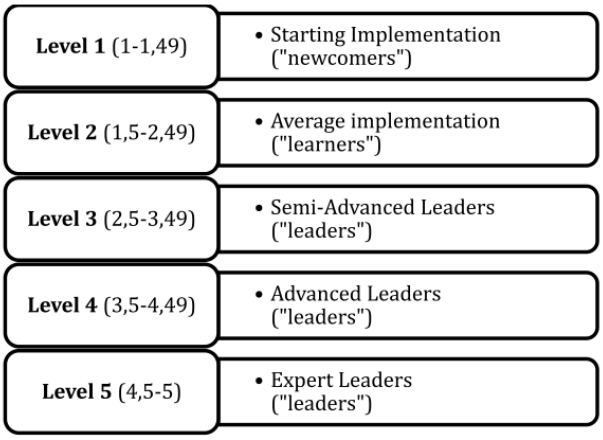

Figure 2 Maturity levels and maturity types (Ungerer, 2019)

These maturity levels give a good assessment of how a company is performing in an industry 4.0 context in terms of different aspects of strategy.

2.4 Transition to industry 4.0

Using this assessment, the transition to industry 4.0 can be determined. Industry 4.0 does not only challenge the capability to innovate but also to adapt the strategy (Ghobakhloo, 2018). The transition process to industry 4.0

The implementation strategy can differ per sector and size of the company. For SMEs according to Müller, Kiel, et al., (2018) the following factors can have a large impact on the tendency to implement industry 4.0 changes for SMEs in the steel industry:

- Operational opportunities (positive impact)
- Environmental and social opportunities (positive impact)
- Challenge of having unqualified employees (positive impact)
- Competitiveness of industry (negative impact)

Furthermore, Müller, Kiel, et al., (2018) also identified the factors that have an impact on the tendency to implement industry 4.0 changes for the steel industry:

- Operational opportunities (positive impact)
- Environment and social opportunities (positive impact)
- Organizational and production fit (negative impact)

Combining both the SME category and the steel industry category, it can be assumed that operational opportunities and environmental and social opportunities have the largest impact on steel industry SMEs and these are both important drivers for adapting to industry 4.0.

3. METHODOLOGY

This research is exploratory of nature in the form of a case study. Case studies are useful in exploratory research as they provide rich data. This allows assessing the strategic and managerial issues, which in turn can provide an insight into the current state of the literature and where it needs to be improved. (Eisenhardt & Graebner, 2007).

This exploratory case study includes quantitative data but is in a qualitative form because the data gathered is too small to form a concreate big data study. The data is gathered by using the scan created by (Ungerer, 2019). This scan is filled in by 2 companies from the region of Twente, with at least 4 employees per company filling it in.

The scan consists of 86 measurement questions, which can be found in appendix B. The scan was distributed to a management contact person of the companies and was sent to the employees the contact person deemed capable enough to answer the questions. This means that there is a form of preselection in the participants of the company according to the view of the management.

The data gathered is analyzed, compared to literature and the base level is assessed. Based on the literature, a suggestion of strategic actions is formed, so that the SME can improve their current approach to the industry 4.0 concept.

After the scan, a focus group will be held where the results of the scan will be shown. The companies are not aware of the results beforehand and their direct reaction will be measured. A discussion takes place to identify the importance of each aspect according to the opinion of the company. This focus group will address future actions instead of an imagined future organizational structure, this gives a better view of the challenges and drivers in the organization. Already existing processes usually will come to a good end and therefore might not reveal potential difficulties. (Czarniawska, 2004).

These drivers will then be compared to each other in order to find which drivers align and which will not.

In this research the participants will know each other, as they are part of the same company. This can be seen as a limitation because it can impact the spontaneousness and honesty of the participants (Rabiee, 2004). To deal with this an open environment was created by asking questions in a non-suggestive manner and modearate the conversation so everyone was allowed close to equal speaking time. On the other hand, having acquainted participants may also positively impact the brainstorming during the focus group, since the participants could relate to each other perspectives and may challenge each other more (Rabiee, 2004).

4. RESULTS

In this chapter, the results of the scan and the workshop will be discussed. The results of 2 companies and a total of 5 employees are discussed. An overview of the results radar charts can be found in Appendix A

The results will be discussed as follows. First, the current state of each category based on the scan will be discussed, followed by a summary of the focus group, and the importance of each category based on the point of view of the company will be assessed. In the chapter interpretation, these results will be compared with previous findings on this topic.

4.1 Summary of the results

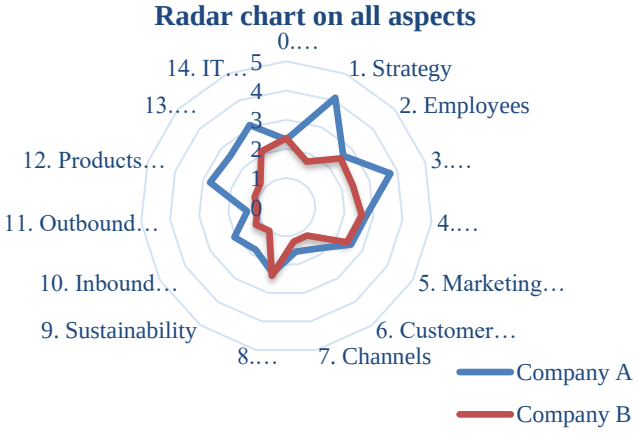

Figure 3 Summarizing radar chart on all aspects of the scan

As the radar chart above shows the metal industry SME's from this sample score high on strategy and on management and leadership while scoring low on channels, and outbound logistics. In the focus group, the results were mostly expected. However, the participants found it surprising that the employee score was low, considering that both strategy and management & leadership both scored high. The focus group showed that companies had no to very little knowledge and experience with Industry 4.0. In the focus group, Products & Services and Production & Process were highlighted as the most important for this industry.

4.2 Results introduction

The introduction questions show that employees in this sector generally think that the sector grows moderate to quickly, however, change is seen as moderately slow with very little new innovative entrants. Furthermore, factors relating to fluctuations in the market are seen as low. There are different opinions on the competitive rivalry in the sector, whether from long-existing competitors as new competitors, however, the average is that there is moderate to little competitive rivalry. In the focus group, the fluctuations in the score for competitive rivalry were expected as the technical staff may have a less complete view than the marketing & sales staff. Furthermore, the metal industry was described as conservative and the potential of new replacing products like 3D printing was discarded as not being able to replace the metal industry.

4.3 Results strategy

The score on strategy is the highest of all aspects. Industry 4.0 is seen as important in the metal sector and organizations have made plans and set budgets to invest in Industry 4.0. Furthermore, data and other industry 4.0 technologies are already used in value creation and there is a moderately coherent digital transformation strategy. In the focus group, it was surprising that the mindset and ideas were present, however, that a vision for a digital journey lacked. Strategy was seen as a vital part for a good transition to industry 4.0

4.4 Results employees

In general, the results on employees are moderate to low. The knowledge and skills of the employees are moderate relating to industry 4.0, however, the communication about industry 4.0 developments is low. Also, the current state of work is not paperless. In the focus group, it was emphasized that it differs per employee whether they were in a position or if they had an idea about future possibilities. Discussions about the input of employees working in production were inconclusive, as most ideas end up in failures and management needs to spend a lot of time on the monitoring of these ideas. A paperless organization is a goal, but not achievable. In the opinion of the focus group the generation working at the company still often requires paper to read well. Employees are important for a good transition to industry 4.0.

4.5 Results management & leadership

The score on management & leadership is relatively high. Management tries to encourage, and support industry 4.0 initiatives and they have the skills to lead the organization in industry 4.0 practices. They also use some industry 4.0 practices in decision making and the employees have a moderate contribution to decision making. In the focus group, there was a consensus that industry 4.0 was the goal, however, how to get there was still unsure. The focus group found it surprising that the scan result suggested that management had enough skills to lead the organization to the change to industry 4.0. Management & leadership are vital for a good transition to industry 4.0.

4.6 Results organizational culture & management

The score on organizational culture & management is average. The organization is moderately competent to practice industry 4.0 principles. However, the employees have had little to no training about a smart factory. Out of the box thinking is supported but limited. The information-gathering done by employees using digitization is moderately supported and there is a moderate amount of effort spent on making the organization smart. In the focus group, it was made clear that the employees on the work floor were not looking forward to any kind of change and that workshops and trainings were not popular. There is a culture, where management makes the decisions. Organizational culture & Management was seen as an expect where many improvements can be made, but not as vital as management and strategy.

4.7 Results marketing & sales

The results of marketing & sales are average. The online behaviour of customers is limitedly studied and there are limited performance measurement and improvement of online marketing techniques. The sales process is moderately digital and the website is limitedly used for acquiring information concerning products and services. Marketing & Sales is not important to improve to industry 4.0, as the customers are mostly reached. However, the customers often do not understand the production process and some more information can be given in that area.

4.8 Results customer services

The score on customer services is low. Some industry 4.0 techniques are used in services for customers, but there is a low score for automatic updates to customers and customers have little digital insight concerning the performance of their products. The machines are no to little equipped with sensors, algorithms, or modelling to give automatic updates on when maintenance is required. Furthermore, there are not many different channels available for customers to reach the organization for information. In the focus group, it was made clear that more influence from the customer was undesirable.

4.9 Results channels

The score on channels is low. Customers have access to the product with little to no different digital integrated channels, the customer requirements are not actively and continuously followed and there are no automated processes to facilitate the customers. Data analysis is little to not used to improve channels and there are no to little different channels to keep customers up to date. In the focus group, while referring to the topic customer services, there was a fear that the customers could have a too large influence in the planning and the production process and that was described as undesirable. The consensus was that channels are not relevant to this industry.

4.10 Results institutional awareness

The score on institutional awareness is relatively low. The digital company policy is moderately up to date. The intellectual property for products and services is relatively well protected. The employees are little to moderately aware of the rules and procedures surrounding industry 4.0 technologies. There is a limited awareness surrounding tax effects on implementing industry 4.0 technologies. GDPR requests cannot be taken care of automatically. In the focus group, it was discussed that the companies have no cloud environment, no website to log in and thus institutional awareness is not an important factor for industry 4.0 in this industry.

4.11 Results sustainability

The score on sustainability is low. Industry 4.0 techniques have not to moderately contributed to enabling and improving sustainability. Industry 4.0 techniques are not to moderately used to measure the performance of the organization's sustainability. Emissions and other climate effects are not measured using industry 4.0 techniques. In the focus group, sustainability was not seen as an important topic for this industry. If the customer views sustainable production as an added value, investments in sustainability can be justifiable, however, sustainability was not seen as an important factor for industry 4.0.

4.12 Results inbound logistics

The score for inbound logistics is average. Based on the scan there are little to moderate collaborations with partners and suppliers concerning industry 4.0 and industry 4.0 technologies are little used in existing collaborations. The organization is a little digitally connected with its suppliers and industry 4.0 techniques give a moderate insight into inbound logistical processes. Actions are moderately automized for data processing forthcoming out of inbound logistics. In the focus group, it was highlighted that, though there are some development projects with suppliers, these were not focused on industry 4.0 practices. This dimension was not deemed important for industry 4.0 transition for the industry.

4.13 Results outbound logistics

The score on outbound logistics is the lowest. There is little to no automized tracing products, which are on their way to suppliers, there are no collaborations with customers on industry 4.0 topics, there is no to little use of industry 4.0 topics to collaborate with customers and the organization is a little digitally connected with its customers. There are no industry 4.0 technologies used in stock optimization. In the focus group, it was remarked that there are opportunities in the form of cooperation with distributors, though this is not a priority and this dimension was not deemed important for industry 4.0 transition for the industry.

4.14 Results products & services

The score on products & services is relatively average to high. Industry 4.0 techniques are moderately used in servitization and they are also moderately helping to offer services more efficient. There is a moderate to high data usage in improving existing products and services. The average products and services offered in the product portfolio are little digitized and the performance of delivered products are limitedly tracked. The development of new products is done moderately digital and industry 4.0 techniques are moderately contributing to safeguarding the quality of products and services. In the focus group, this dimension was very important for a transition to industry 4.0. The consensus was that if it contributes to the performance of the product, it is worth looking into.

4.15 Results production & process

The results on production & process are average. Production is moderate to highly influenced by automized processes and machines are moderately equipped with sensors to trace the condition of the machines. Industry 4.0 technologies are relatively highly used in making processes more efficient and moderately used to limit unwanted variations in the production process. There is a limited opportunity within the organization to see how industry 4.0 can influence production processes and there is a little to no digital map of the factory. The production machinery is moderately equipped with industry 4.0 technologies; however, the machinery is a little equipped with technologies that can measure deviations. Production data is not to limitedly shared with partners in the supply chain to improve the total supply chain. In the focus group, this was a dimension where many opportunities lie and where improvements were viable.

4.16 Results on IT management

The score on IT management is relatively high. The organization is collecting a moderate to high amount of data available and IT is moderately prepared for a change in the digital journey. The organization can moderately adapt IT-architecture to a digital organization. The IT is limited to not integrated with the IT of buyers and suppliers. There is a high amount of measures taken to protect all company data and the data from processes/products is used in Enterprise Resource Planning or Manufacturing Resource Planning. The website works on most platforms, but not on all. Industry 4.0 is seen as important to enable a new company policy. ICT supports innovative industry 4.0 based solutions and many ICT security measures are taken in developing new systems. In the focus group, this dimension was deemed important, it needs to be safe and it needs to work, however, with new software there is a risk for errors.

4.17 Results on already used Industry 4.0 technologies

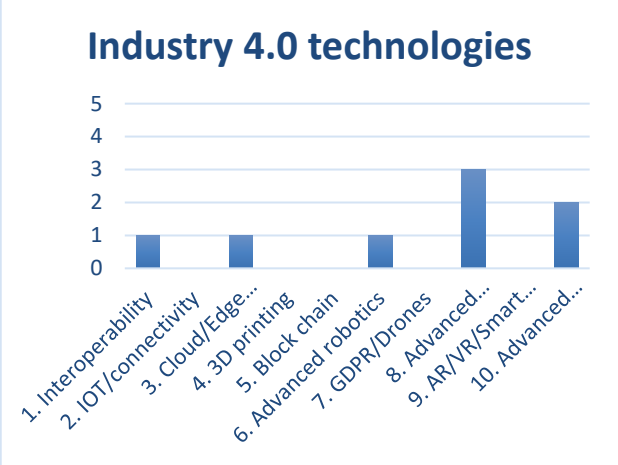

Figure 4 Results on industry 4.0 technologies

In the sample out of a maximum of five votes per technology, interoperability received one vote, as did Cloud/Edge computing and advanced robotics. Advanced analytics received two votes and advanced materials received 3.

5. IMPLICATIONS FOR CHANGE

Based on the exploratory research several things can be concluded.

Firstly, the knowledge about industry 4.0 was limited or not present, before informing the participants about the topic. The scores generated where thus based on organizational improvements made without conscientiously thinking about industry 4.0. This means that companies in this industry already have some investments made in industry 4.0 without thinking about it. This means that strategy and management & leadership with on average the highest scores are already improved.

More so companies in this industry may have a limited view of potential new threats to the industry. For instance, the companies in the focus group did not recognize 3D printing as a possible new entrant, while there are concrete possibilities for 3D printing in the metal industry (Kietzmann et al., 2015) and according to the Gartner hype cycle the possibilities for 3D printing in operations are growing (*Hype Cycle for 3D Printing, 2019*, 2019).

Thirdly the dimensions focusing on production and products are deemed more important than the dimensions focusing on added value and are not necessarily part of the standard product. This can mean that servitization is deemed less of a factor in the metal industry. Copani (2014) argues that in the machine tool industry, an industry that is very similar to the metal industry (IFO & Sakura, 1997), manufacturers generally are not proactive in offering services due to a conservative cultural approach and when there is a higher degree of servitization it is for larger companies and thus not for SMEs.

Next to the low degree of servitization, there is also limited desirability for supply chain integration. Though there were cases where an SME had a development program with a supplier for a production machine, there was less a desirability for a production cooperation concerning the production of the final product. This was neither the case for suppliers as it was for customers. This too can be related to the conservative culture (Copani, 2014) that may also exist in the metal industry.

Looking at the implications of the dimensions strategy and management & leadership, it can be concluded that there was desirability to adapt to the industry 4.0 principles, however the knowledge and the vision required to do so were not yet present. This implies that there could either be a lack of information about industry 4.0 or that there is a lack of awareness of the existence of industry 4.0 in this sector. However, this is an important dimension because like discussed in the theoretical framework leadership and rational decision making are critical qualities for SMEs when adapting to new influences (Kumar et al., 2014).

5.1 Theoretical and practical implications

Most studies on Industry 4.0 focus on the impact on larger companies. This study contributes to providing information about industry 4.0 for smaller companies. This allows for the study to have several theoretical and practical implications.

Firstly, this study sheds light on the existing knowledge gap that may be present in the metal industry. The academic awareness of the lack of knowledge allows to create studies that can focus on how to decrease the lack of knowledge and find out why there is a lack of knowledge. If the SMEs in the metal industry are aware that there is a lack of knowledge in the industry it can encourage them to seek to decrease this lack of knowledge so that they still can become a frontrunner in this industry when it comes to industry 4.0.

Secondly, this study can contribute to identifying industry 4.0 differences between sectors. Using a generalized and holistic scan or a literature review can allow future studies to identify differences within industries and this study highlights one.

As a practical implication, this study allows companies to identify the general dimensions of interest for SMEs in the metal industry. With this information, a company can seek to fill a potential market gap. For there may not be that many metal industry companies that would focus on servitization for instance.

Lastly, this study confirms the suggestion that operational opportunities are a driver for transitioning to industry 4.0 for the metal industry SMEs (Julian Marius Müller et al., 2018). However environmental and social opportunities are not deemed an important driver industry for SMEs in the metal industry.

6. LIMITATIONS & FUTURE RESEARCH

This research is an explorative case study and comes with some limitations. Though there is descriptive data, the sample size is too small to draw any definitive conclusions for this industry or less so for SMEs in general.

The SMEs analyzed were all small and therefore not the complete scope of SMEs up to 250 employees (European Commission, 2003) has been analyzed. Next to that, some questions in the scan were more relevant for larger companies than for smaller ones.

Thirdly the focus group sessions were conducted by two different researchers, this may have affected the results given. The participants had different levels of knowledge about industry 4.0 and may have therefore given different answers in the scan.

Furthermore, there may be a bias in the results, because all the companies participating did so voluntarily, therefore not the complete industry has been analyzed, but only companies that are interested in the topic.

Next to that, as previously highlighted, a manager preselected the participants filling in the scan and joining the focus group. This could mean that employees may have been deliberately left out of the study, because the manager in question may disagree often with that employee.

Lastly, the scan used in the research is holistic. This means that the scan can also be used in other industries and not all the questions had the same level of relevance for the metal industry.

For future research, it may be interesting to look at an in-depth roadmap on how the transition for companies in the metal industry can look like. Furthermore, the levels of performance per industry in terms of industry 4.0 development can be interesting to compare and to highlight the different aspects.

As described most SMEs in the metal industry focus on the industry 4.0 topics related to production. It can be interesting to research the possibilities of an SME approach in industry 4.0, where the SME will focus on the servitization part of industry 4.0.

Furthermore, as described SMEs in the metal industry may be underestimating the potential of industry 4.0 techniques, amongst which 3D printing. It may be interesting to review the state of operational industry 4.0 technologies, how they can impact the future state of manufacturing and whether companies are aware of new opportunities arising due to industry 4.0 developments.

7. CONCLUSION

Industry 4.0 is becoming more and more relevant, however not all industries and companies are aware of the potential it has to offer. This thesis seeks to answer the question: ***How can manufacturing SMEs in the metal industry best adapt to industry 4.0?*** There are several steps that need to be overcome to adapt to industry 4.0.

First, the companies in this sector need to inform themselves more about the industry 4.0 topic. A lack of knowledge may limit the formulation of a clear vision. Furthermore, the lack of knowledge may be a limiting factor in recognizing company-specific industry 4.0 technology possibilities.

Second, to deal with the financial constraints SMEs face in an industry 4.0 context (Mittal et al., 2018), the companies need to form clear objectives in what areas they want to improve in. For this industry these are most likely production-related improvements.

Third, in terms of diversification, most metal industry SMEs focus on product diversification. Industry 4.0 presents an opportunity to diversify in a new manner.

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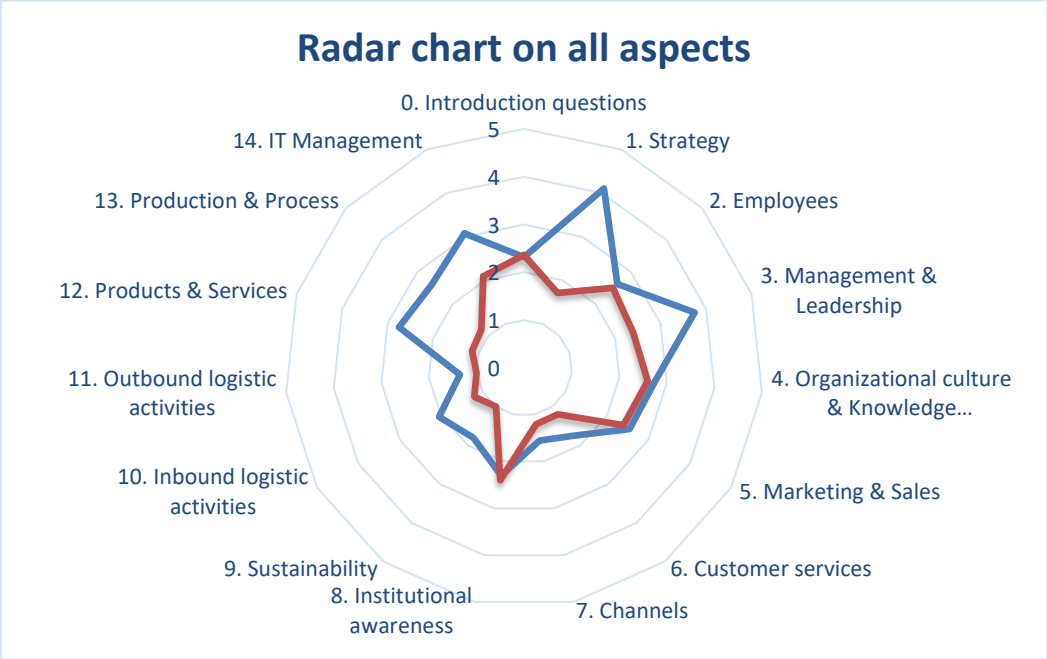
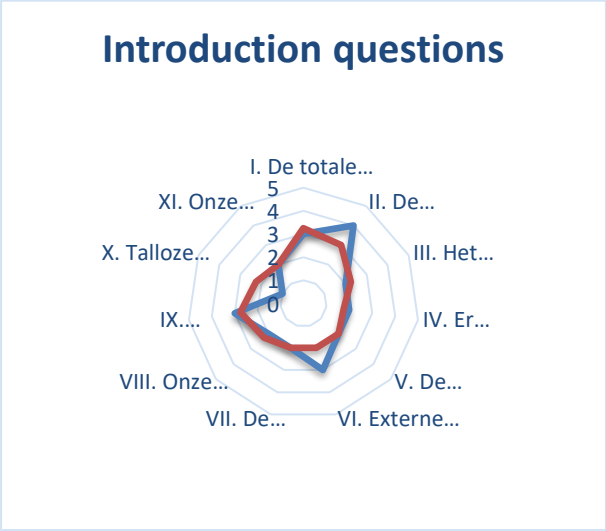
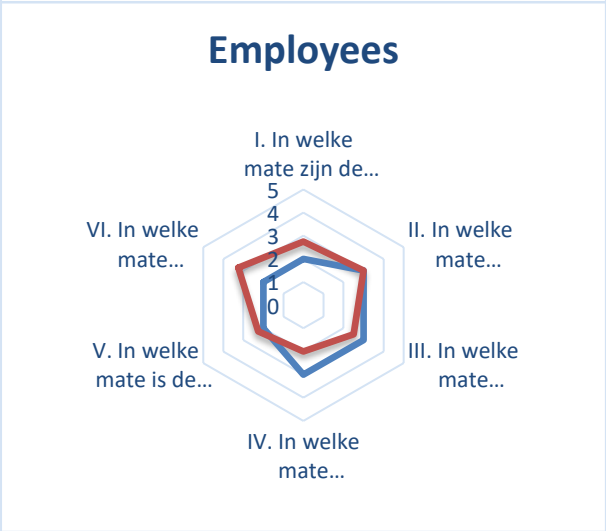
10. APPENDIX

10.1 Appendix A: scan results

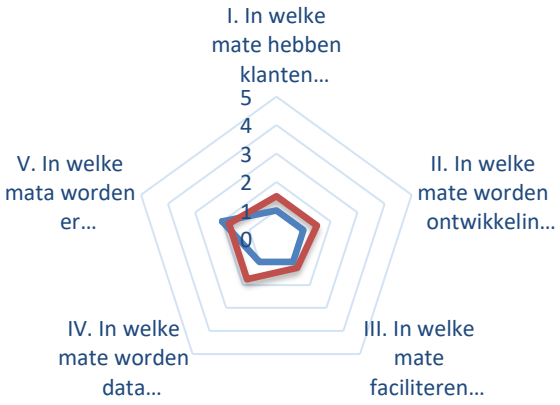






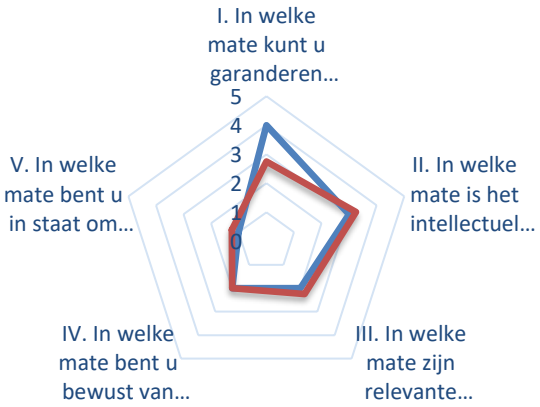
Organizational culture & management

Channels

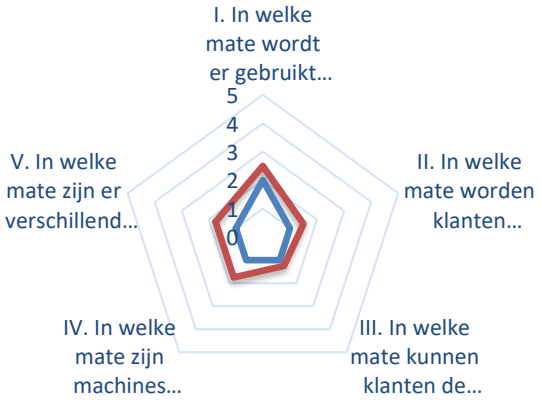


Marketing & sales

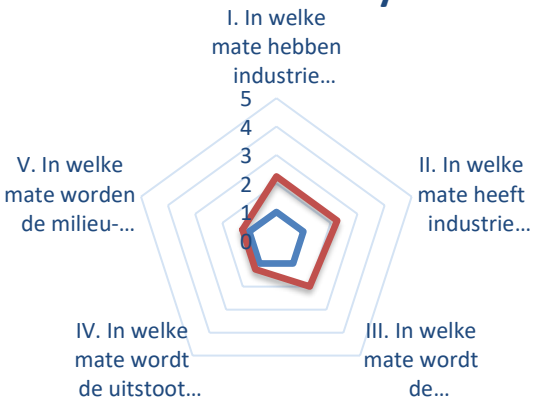
Institutional awareness



Customer services

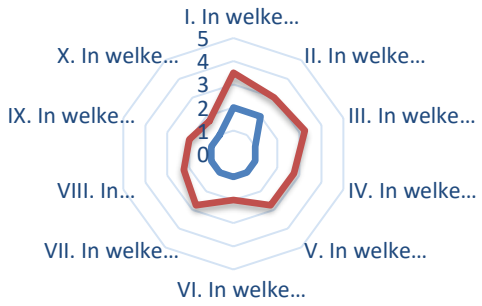


Sustainability



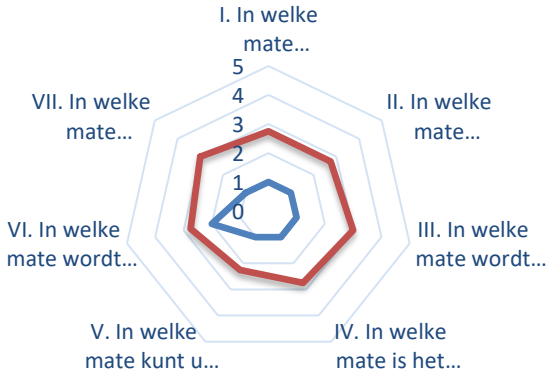
Inbound logistic activities

Production & proces

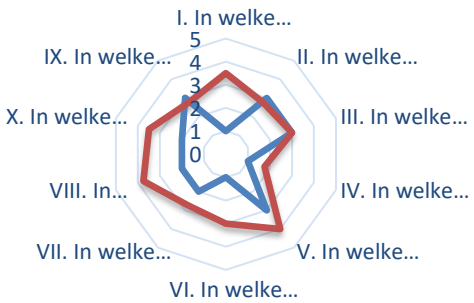


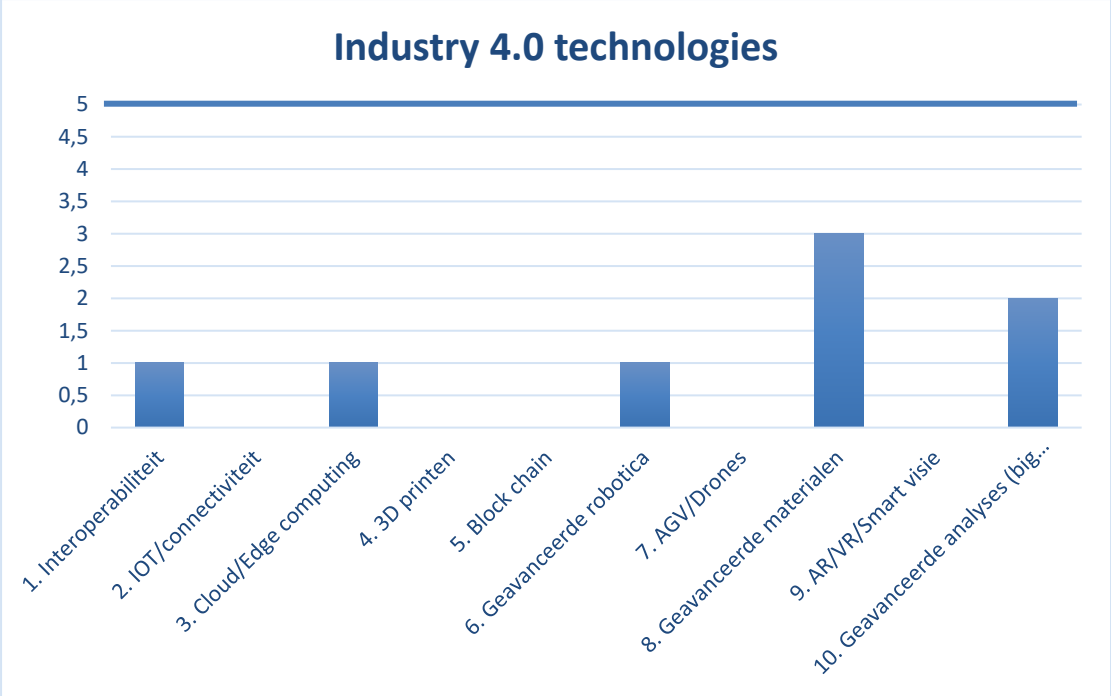
Outbound logistic activites

Products and services



IT management





10.2 Appendix B: scan questionnaire (dutch)

Welkom bij de SIMS Scan.

Deze scan meet de volwassenheid van industrie 4.0 van verschillende bedrijfsaspecten binnen de organisatie. Het resultaat na het invullen kan voor interessante inzichten zorgen omtrent de volwassenheid van de implementatie van industrie 4.0 binnen deze bedrijfsaspecten in de organisatie.

Elke vraag moet worden ingevuld met: (1) Helemaal niet, (2) in geringe mate, (3) in zekere mate, (4) in grote mate, (5) in zeer grote mate.

In deze scan wordt de term industrie 4.0 veelal gebruikt. Deze term is hetzelfde als de veel gebruikt term "smart industry".

Daarnaast is het mogelijk een pauze te houden tijdens het het invullen van de scan. Wanneer u opnieuw inlogt zal de scan verder gaan waar u was gebleven.

General information

Naam student: (Verplicht)

O L. Diepeveen

O G.M. Holst

O L. Schopman

O A. Yakovyna