Anticipating the Future for Manufacturing SME's with the Smart Industry Maturity Scan (SIMS)

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ABSTRACT,
The world is in anticipation of the Fourth Industrial Revolution. The emerging Smart Industrial Revolution is becoming increasingly important for the industrial management of manufacturing, especially for Small-Medium Sized Enterprises (SME). In order for manufacturing SMEs to stay competitive, there is an increasing need for SMEs in manufacturing to anticipate on Smart Technologies and change their business models accordingly to the new industrial era. Manufacturing SMEs need to know how to anticipate on these changes based on their current state and then can engage in strategic re-orientation. There is a need to make aware of and define the challenges and knowledge gaps for adopting Smart Industry approaches, to be able to develop specific action roadmaps for implementing Smart Industry in manufacturing SMEs. This research aims at providing a better understanding of the way to help manufacturing SME's to overcome the challenges of Smart Industry whilst producing contribution to scientific insights and practice on how anticipation in the Smart Industry for manufacturing SMEs occurs. This was done in a case study at an investigated company by applying a quick Smart Industry Maturity Scan designed to qualitatively determine the current state of Smart Industry anticipation over 7 dimensions. The results of this scan were further explored, discussed and explained in a follow-up workshop against a built upon conceptual framework, consisting of identified factors for anticipation of Smart Industry.

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Smart Industry; Small and Medium-sized Enterprises; manufacturing; Smart Industry Maturity Scan; Maturity Assessment; Challenges; Anticipation; Smart Industry Practice

1. INTRODUCTION

The world is in anticipation of the *Fourth Industrial Revolution*. Many countries and regions are set to make strategic approaches to ensure that their industries transit to this new production paradigm, such as *Smart Industry* in the Netherlands, *Industry 4.0* in Germany, China Manufacturing 2025 in China, Smart Manufacturing Leadership Coalition or Advanced Manufacturing in the US. Smart Industry comes from as a successor of the previous installments of the industrial revolutions. The first industrial revolution was based on the mechanical production equipment driven by water and steam power. The second industrial revolution was based on the mass production enabled by the division of labor and the use of electrical energy. The third industrial revolution was based on the use of electronics and IT to further automate production. '*Smart Industry or Industry 4.0'* is now building on the third and making heads as the fourth industrial revolution. Smart Industry is visionary part of the current far-reaching and radical digital transformation, connecting products, machines, and people and new manufacturing technologies. It is a mixture of integrating application of emerging IoT, IoS and CPS technologies into production and industrial value chains in which these technologies, smart objects and machines are interconnected, fully-integrated (Hermann et al., 2015). In production, processes can be self-optimized for faster performance, self-adapt to learn from new conditions, creating new opportunities in value chains, because of the resulting shorter lead times, increased efficiency, and flexibility (Burke et al., 2017).

Smart Industry is becoming increasingly important for the industrial management of manufacturing for SMEs. In order for manufacturing SMEs to stay competitive, there is an increasing need for SMEs in manufacturing to anticipate on Smart Technologies and change their business models accordingly to the new industrial era. However, it is still in its early development phase. There is a great challenge for the future especially in the transfer of Industry 4.0 expertise and technologies in small and medium sized enterprises (SME). Despite the growing interests in the Smart Industry (Industry 4.0), only few small and medium sized enterprises (SMEs) adopt effective Industry 4.0 solutions (Issa et al., 2017). Small and Medium-sized Enterprises (SMEs) in the manufacturing industry remain relatively cautious about it and appear to be particularly overwhelmed with the trends and best practices involved in anticipating on the Smart Industrial revolution. Only around 5 per cent of SMEs are thoroughly networked and a third of them are taking the first steps in that direction or at least have concrete plans to do so (Schröder, 2016).

SMEs often face different challenges than larger companies. Compared to large enterprises SMEs are less likely to influence their external environment and their activities are dictated by the market (Blackburn & Curran, 2001). According to Mittal et al. (2018), SMEs have fewer financial and technical resources, and lack the experience in managing the new Industry 4.0 technologies or also termed 'smart technologies'. As a result, SMEs do not perform well when it comes to research and development. They also lack the IT integration, and thus the software used to maintain the SME records are tailored towards resolving specific issues faced by the SMEs. Due to the limited technical and financial resources, their R&D is not very advanced but their hard work leads to highly specialized products, which is the theme of Smart Industry (I4.0). This can bring desired competitive advantage and differentiation against competitors of SME's. In the context of manufacturing, SME's are of major importance and are interesting to study for four reasons. First, SMEs account for the higher amount of enterprises in comparison with larger enterprises (MNEs) (European Comission, 2018a), and thus represent as a considerable target group for anticipating on Smart Industry (I4.0) in manufacturing industry. Secondly, SMEs compared with MNEs, operate with fewer resources (Muller et al., 2018). Third, SMEs are usually less complex, informal and bureaucratic and generally have greater incentives to be successful than large firms (Muller et al., 2018; Nooteboom, 1994). Fourth, SMEs require alliances with Universities and Research Institutions (Muller et al., 2018), which we aim at contributing in this thesis.

However, why do SMEs in manufacturing need to anticipate on Smart Industry (Industry 4.0) and adopt it at all? Well, SMEs are the bedrock and the driving force for most economies (Issa et al., 2017). They represent the backbone of the manufacturing industry in most economies and are especially important in development programs such as the European Union. In the Netherlands alone, SMEs account for 99.8% of all companies and generate around 61.8% of overall value added in the Dutch economy. They also account for 64.2% of the overall employment (European Commission, 2018c). There is a growing dependence on SMEs in the Dutch manufacturing industry and is valued with high importance. In order to stay competitive, these manufacturing SMEs have to adapt permanently both in products and production. Approaches related to the vision of Smart Industry (I4.0) and its underlying technologies can help SMEs to address these challenges. SMEs' impact on the Smart Industrial Revolution is therefore significant. Subsequently, in the era of Smart Industry, the future of SMEs depends largely on their capacity to respond to client's expectations while maintaining a competitive advantage on their market. (Moeuf et al. 2017; Liker, 2007). However, little is currently known about implementations of Smart Industry in manufacturing SMEs. Therefore, there is a need for SMEs in manufacturing industry to anticipate on Smart Industry.

Many manufacturing SME's struggle with the question how to anticipate within their own business contexts and market(s) as there is this lack of specific knowledge and hence, ambiguity about which actions to pursue. (Kiel, D et al, 2017) On top of that, there is a lack of resources and characteristics for stepping towards the Smart Industry. Which, funnels small and medium-sized companies the lack of comprehensive strategies to tackle the upcoming Smart Industrial revolution and remain rather apprehensive about it. (Schröder, 2016). Moreover, the level of dissemination of Smart Industry (I 4.0) among large companies is higher and they are more likely to deploy the relevant Industry 4.0 technologies than small and medium-sized enterprises. That is due to the nature of the uncertainties of the emerging future of the new Industry 4.0. The reasons for this are manifold: partly internal but also, external from the environment. (Schröder, 2016). SMEs mostly seem to struggle with adapting and implementing Smart Industry technologies (Issa et al., 2018). Therefore it is assumed that the challenges for Smart Industry are more significant in SMEs. However, based on the current research, especially by Mittal et al. (2018), there is little known about the implementation and anticipation of Smart Industry (I 4.0) tailored for SMEs within manufacturing.

Although there is a high potential of Smart Industry being shown in manufacturing industry, based on an extensive literature review by Mittal et al. (2018), he shows that the main reasons SMEs are rather apprehensive about Smart Industry (Industry 4.0) is due to the steps to proceed towards the Smart Industry

tailored for SMEs is commonly missing. Their maturities are not clearly defined and explained, and a readiness assessment tool for transitioning is commonly missing. Thus, there is a lack of concrete models for its implementation and application of Smart Technologies in small and medium enterprises. As a consequence, SME's tend to wait and see how this trend is developing. What is missing is its clear elaboration of Smart Industry specifically for SMEs. (Kleindienst & Ramsauer 2016) There is a lack of formalized processes, lack of ICT knowledge as well as low cost-commercial systems (Dassisti et al., 2018).

Therefore, in this changing business environment, Small Medium Sized Enterprises (SME's) as manufacturing firms are increasingly in need to make aware of and define the barriers and knowledge gaps for adopting Smart Industry approaches, to be able to develop specific action roadmaps for implementing Smart Industry tailored specifically for SMEs. So, in order to successfully anticipate on Smart Technology and change their business models accordingly in the era of the next industrial revolution (I4.0). There is a need to know how SME's as manufactures anticipate on these changes based on their current state and then can engage in strategic re-orientation, shift value logics, adding services (i.e. servitisation), working relationships with customers as co-producers of solutions, change of business processes, capabilities, etc. To further understand the possibilities of Smart Industry in order to determine the best possible strategy for implementing it. Thus, questions arise, how do we make manufacturing companies in SMEs, aware of the major challenges that Industry 4.0 is going to make for them? And, how can we help SME's to overcome these challenges?

1.2 Research objective

The objective of this research is providing a better understanding of the way to help manufacturing SME's to overcome the challenges of Industry 4.0 whilst producing contribution to scientific insights and practice on how anticipation in the Smart Industry for SMEs occurs. In addition, this research will provide a full audit with entrepreneurs and managers in one of the manufacturing SMEs. With a Smart Industry Maturity Scan (SIMS), a tool that measures Industry 4.0 readiness, a scan is conducted to see to what extent they are prepared for the switch to Industry 4.0. The results of this scan are further explored, discussed and explained in a workshops or interviews at the investigated firms. This will act to assist manufacturing SME firms to clearly identify their performance levels of business and production processes in relation to the Smart Industry. After such an audit, they know exactly what the opportunities are and where in their organization change is needed. Then, the objective is to guide them to choose feasible technologies and methods, so that companies can develop their own strategies to tackle the challenges of Smart Industry (Industry 4.0). In all, for manufacturing SMEs to better optimize the framework conditions and support structures so that as many manufacturing SMEs as possible meet the challenge of Industry 4.0 and take advantage of the opportunities of the fourth industrial revolution. Thereby, to successfully achieve to anticipate on the transformation to Industry 4.0 and maintain competitiveness during it. These findings will form the basis for answering the research question needed to produce novel insights for both practice and theory in manufacturing SMEs' anticipation of Industry 4.0.

1.3 Research question

Based on the aforementioned research objective, this study will examine the following research question:

"How do manufacturing SMEs anticipate on the Smart Industry Revolution and deal with the challenges accompanied by it?

Sub-questions in related to the research questions include:

1. How do manufacturing SMEs decide on the adopting Smart Industry as a strategic choice?
2. What are the kinds of expected benefits or opportunities and trade-offs do manufacturing SMEs envision with adopting Smart Industry?
3. What are the potential challenges that manufacturing SMEs might encounter with adopting Smart Industry?
4. How do the potential challenges, benefits and trade-offs affect the feasibility of introducing Industry 4.0 in manufacturing SMEs?
5. How do SMEs expect to successfully overcome the barriers associated with the application of Smart Industry Technologies?

This paper addresses these questions with the help of an in-depth case study (company audit) and workshops accompanied by an interview. As a result, this research presents a contribution of the understanding of how manufacturing SMEs anticipate towards adopting and deploying the technologies and principles of Smart Industry (I 4.0) and how SMEs foresee the opportunities and deal with challenges accompanied by it.

2. THEORETICAL FRAMEWORK

In this section the theoretical framework is aimed at providing an understanding of the research frame for the submitted research and the later built upon conceptual framework of manufacturing SME's anticipation towards Smart Industry (I4.0).

2.1 Current state of research

According to the work by Kiel et al. (2017), on the expected impacts of Industry 4.0 for industrial purposes based on the Triple Bottom Line; the economic impacts, the social impacts, and the ecological impacts, there are many perceived benefits from Smart Industry (I4.0). His research says that economic, ecological and social impacts on the manufacturing industry are expected when implementing Industry 4.0. From the economic perspective, Industry 4.0 aims at cost reductions, enhanced efficiency, increased productivity (Chung, 2015; Schuh, Potente, Wesch-Potente, Weber, & Prote, 2014), flexibility, virtualization of the process and supply-chain (Brettel et al., 2014), mass customization of product and services, individualization of demand or batch size one (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014), with shorter lead times and enhanced quality, creating resilient in dustries (Kagermann, 2015; Lee, Bagheri, & Kao, 2015). Additionally, new business models based on novel value creating mechanisms can achieve increasing customer satisfaction. With respect to ecological and environment aspects, Industry 4.0 contributes to reduction of greenhouse gas emissions, reduction of waste, resource and energy consumption. Also, the reduction of transport and logistics processes, wrong deliveries, waiting time, and damaged goods can be reduced, thereby reducing resource consumption more efficiently. From the social aspect, in Industry 4.0 individual workers will benefit from managing their own work time and will be the center of the working environment, therefore is essential for workers to develop skills that fit the new needs of Industry 4.0 (Kagermann, 2015). Industry 4.0 also, contributes to more fair wages, assessments, human learning, and employee motivation. Although, there is an unclear effect about whether it will lead to an increase or decrease of jobs, further automation of simple tasks is expected, whereas job profiles emphasizing monitoring,

collaboration and training emerge. Further social problems could be caused by the novel professions require novel skilled workers while established job profiles may disappear. Also, organizational transformation of the Industry 4.0 technologies is required with close supervision and predefined implementation processes. And, there are also influences from the embeddedness of company within network, external implementation pressure, politics support and legal conditions.

The problem arises when it comes to the implementation of Smart Industry (I4.0) in SMEs. A recent literature review of Industry 4.0 with a special emphasis on SMEs found that there is a lack of empirical founded research on the application of Industry 4.0 technologies in SMEs (Müller, & Hopf, 2017). Another study has shown that larger companies seem to be more Industry 4.0 ready than SMEs (Stentoft et al., 2017). Especially SMEs seems to struggle with adapting and implementing these technologies (Issa et al., 2018). Thus, it must be assumed that barriers for Industry 4.0 are more evident in such companies. The work of Stentoft et al. (2019) provides an extensive literature review on drivers and barriers of adopting Smart Industry (Industry 4.0) for SMEs. The paper reports on 308 small-medium sized manufacturers about their readiness for Smart Industry (I 4.0) and their actual practice in this area. The paper provides empirical evidence that the perceived benefits and drivers for Smart Industry (I4.0) lead the increase of Smart Industry (I 4.0) readiness, which in turn leads to higher degree of practicing Smart Industry (I4.0). This is significant as it shows that the more manufacturing SMEs are exposed to understanding the benefits and opportunities of Smart Industry, the more beneficial it is for the readiness and consequently their practice on Smart Industry. This means that the more manufacturing SMEs are informed about the potentials of Smart Industry, the better it is for manufacturing SMEs to anticipate on their future. The paper also finds that barriers or challenges that make companies less ready for Smart Industry (I4.0), apparently does not have any significant impact on the practice of Smart Industry (I4.0). Most of which, the literature review shows that the barriers for Smart Industry (I4.0) are lack of understanding of the strategic importance of Industry 4.0, the lack of standards, lack of knowledge about Industry 4.0, or lack of understanding the interplay between the technology and human. There is a need for manufacturing SMEs to have a better understanding of Smart Industry, to be able to tap into its full potential.

In another study by Qin et al. (2016), the achievement criteria for Smart Industry (I4.0) is uncertain. It is an obvious that the current manufacturing has not achieved Industry 4.0 level comprehensively. The roadmap of accomplishing Smart Industry is not clear in industry nor in academia. In her work, the paper focuses on state of current manufacturing systems, and identifies the research gaps between current manufacturing systems and Smart Industry requirements. There are stages to becoming fully implemented into Smart Industry. Those are: (L1) Single-station automated Cells to (L2) Automated Assembly System to (L3) Flexible Manufacturing System to (L4) Computer-integrated Manufacturing System to (L5) Reconfigurable Manufacturing System. The key features of Industry 4.0 in manufacturing systems are the ability to: make decisions, early-aware, self-optimizing, and self-configurable. The researchers propose to address such capability gaps by adopting and implementing I4.0 technologies, as well as digital and smart automation practices.

According to Mittal's et al. (2018), in his critical review of smart manufacturing & Industry 4.0 maturity models for SMEs, Qin's model is not readily available for SMEs and geared more towards MNEs. But for this research, this serves as a good point to understand the reason why it is important to seek to understand the research gaps between manufacturing systems and Smart Industry (I4.0) in SMEs which are unknown and that readily models are not yet presently developed in the science community, and such models like this do not depict the perspective of SMEs. More importantly, the results of his study show that only a limited number of the Smart Industry and Industry 4.0 roadmaps, maturity models, frameworks and readiness assessments that are available today reflect the specific requirements and challenges of SMEs. For this research, we are joining in collaboration of applying the first-time pilot of the Multi-dimensional Smart Industry Maturity Scan created by Future Industries to study this case.

2.2 Strategic Reasoning Process of the Potential Challenges of Smart Industry

Before manufacturing SMEs can move to benefit from the opportunities of Smart Industry adoption, they must be aware of the potential challenges of Smart Industry. As well as to acknowledge the importance to deal with the challenges that come from it. The strategic reasoning process is used as a strategic tool to help manufacturing SMEs understand the structure and underlying cause of the challenges that come from Smart Industry and exploring the ways and solutions to overcome the challenges of Smart Industry adoption. If there are more than one solution available, the manufacturing SME must select the most promising one. A challenge from Smart Industry adoption is only really solved once concrete actions are undertaken that achieve results.

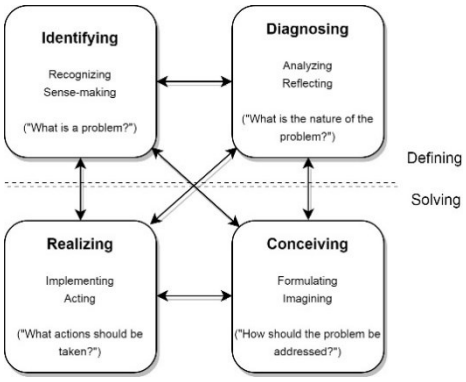

Figure 1. De Wit and Meyer's (2010) Strategic Reasoning Process

There are four phases of strategic reasoning process by De Wit and Meyer (2010, p. 55) which includes identifying, diagnosing, conceiving and realizing. These phases have been configured in this research study presented as:

1. Identifying: We do have the necessary competences in our SME manufacturing to see and recognize the challenges we have with our production in relation to Smart Industry adoption.
2. Diagnosing: We do have the necessary competences in our SME manufacturing to understand the challenges we have with our production in relation to Smart Industry adoption.
3. Conceiving: We do have the necessary competences in our SME manufacturing to suggest competitive solutions to tackle the challenges our production is facing in relation to Smart Industry adoption.
4. Realizing: We do have the necessary competences in our SME manufacturing to implement the solution proposals that are required to handle the challenges our company is facing in production in relation to Smart Industry adoption.

2.3 Conclusion

Based on this, we can conclude that there is a need for manufacturing SMEs to know about their current state of Smart Industry (I4.0) maturity to be able to anticipate and engage on strategic re-orientations, shift value logics, adding services, working relationships with customers as co-producers of solutions, change of business processes, capabilities and so on. The more SMEs are exposed to understanding the current level of their own Smart Industry maturity and what the potential benefits and drivers are to higher levels of maturity, and what this can mean for them, the better they can anticipate on their future and better position themselves to thrive in the industry. While, there is little currently known about implementations of Smart Industry (I4.0) in manufacturing SMEs, manufacturing SMEs are in need of assistance tool that could guide them better to understand the current state of their Smart Industry maturity, tailored especially for them. As well as, understanding the potential benefits and opportunities of Smart Industry (4.0) adoption and, what it means to move to a higher level of maturity in Smart Industry. As shown in the literature review, the more informed manufacturing SMEs are about the potential of Smart Industry, the more it increases their readiness of Smart Industry and subsequently their degree of Smart Industry practice. Moreover, using strategic reasoning process to help identify challenges that come from adopting Smart Industry and understanding of the way to help overcome these challenges will act to help the process of anticipating and the subsequent action planning in the Smart Industry for manufacturing SMEs. Therefore, from this literature review and theoretical framework, we can conclude that there is a need of a tool for SMEs in manufacturing industry to assess themselves to better anticipate on Smart Industry (Industry 4.0). This thesis research will aim in contributing to do so and help manufacturing SMEs anticipate on future with Smart Industry Maturity Scan (SIMS) developed by Future Industries.

3.4 Conceptual Framework

The relevant aspects for the submitted research, resulting from the literature review presented before, have been put together in a conceptual framework which has been used to guide the research into expected benefits and opportunities, as well as challenges of smart manufacturing for SMEs. This study is a continuation of the extensive work done by Ungerer and Future Industries on the Smart Industry Maturity Scan (SIMS). These theories and literatures were used to create a conceptual framework for this thesis.

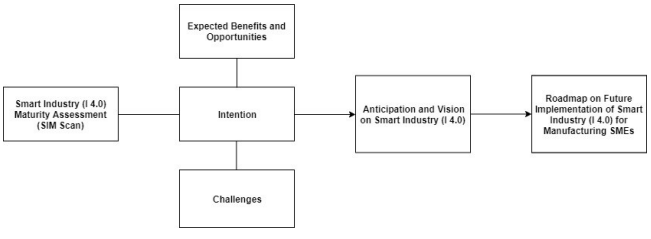

Figure 2. Conceptual framework of Manufacturing SME's Anticipation with Smart Industry Maturity Scan

The conceptual framework followed in this research is depicted in Figure 1 above. This study aims at the expansion on the work of the creator of Smart Industry Maturity Scan (SIMS), Ungerer (2018) and Future Industries, to address a more comprehensive overview of the maturity of where the manufacturing SME is in adopting Smart Industry, and what action can it take for possible future steps to improve on its maturity level it is in. Subsequently, to develop their own anticipation and specific roadmaps towards the Smart Industry based on its intention towards higher maturity levels in adopting Smart Industry (I 4.0) and understanding what are the benefits and how to deal with challenges that are accompanied with it. The gaps in anticipating the future on Smart Industry (I4.0) from the perspective of SMEs within manufacturing are the focus of this research.

Smart Industry (I4.0) Maturity Assessment (SIM Scan)

The Smart Industry Maturity Scan created by Future Industries assesses the current level of Smart Industry (I4.0) maturity. A tool that measures Industry 4.0 readiness, a scan is conducted to see to what extent they are prepared for the switch to Industry 4.0. This will act to assist manufacturing SME firms to clearly identify their performance levels of business and production processes in relation to the Smart Industry.

Expected Benefits and Opportunities

The expected benefits and opportunities seen coming from adopting Smart Industry in manufacturing SMEs have a huge role in the decision-making process, the intent in moving to higher level of Smart Industry maturity, and subsequently the anticipation and vision of the future.

Challenges from Smart Industry adoption

The potential challenges that come from adopting a higher level of Smart Industry maturity and the intent to do so. SMEs are likely to anticipate and get into challenges with moving to higher level of maturity of Smart Industry. The challenges are unknown and literature does not provide potential challenges, as scientific data on Smart Industry in SMEs are limited. The potential challenges of what they might be are researched openly in this thesis in the form of company audits. Strategic reasoning process is used in this thesis research to assess the competency to tackle over the challenges of Smart Industry adoption.

Intention for adopting Smart Industry

Intention for adopting Smart Industry means the motivation behind the extent of how much does the SME consider applying Smart Industry in its manufacturing and to what extent. Manufacturing SMEs that have an intent to adopt Smart Industry and value it as important, will allocate variable resources transform its manufacturing to the standards of Smart Industry. The intent to move higher on the maturity level of Smart Industry is assumed to help anticipate on future specific roadmapping of Smart Industry for manufacturing SME.

Anticipation and Vision of the Future

The manufacturing industry is changing dramatically in the future in the sight of the new fourth industrial revolution and it is likely to affect the whole industry on a large scale. It is assumed that SMEs with a clear vision and anticipation on this future are more likely to intend to adopt Smart Industry in their manufacturing. How providing a better understanding with the Smart Industry Maturity Scan and the expected benefits that come with the intent to adopt higher level of maturity, as well as of the way to help overcome the challenges that comes from it affects the actual practice on the anticipation of Smart Industry for SMEs in manufacturing is to be researched.

Roadmap on Smart Industry Practice

The roadmapping on implementing Smart Industry means to what extent have the SMEs develop specific strategies to tackle the challenges of Smart Industry, and plans on choosing feasible I4.0 technologies and methods to implement Smart Industry in their manufacturing.

4. METHODOLOGICAL APPROACH

4.1 Research approach

The approach of this research presented in this thesis is based on a literature review on SME's anticipation towards Smart Industry (I4.0) followed by a case study in a designated SME firm in the manufacturing industry, otherwise referred as a company audit flowingly in this thesis. In the company audit, a Smart Maturity Industry Scan (SIMS) is applied to determine the current state of Smart Industry (I4.0) anticipation over 7 dimensions. The results of this scan then is further explored, discussed and explained in a workshop at the investigated firm to help answer the research question and to contribute to the theoretical framework set out in the previous section.

4.2 Research method

The approach is summarized in a self-created six-step methodology as follows.

Six-step Methodology

1. Select a manufacturing firm based as a SME
2. Scan the firm with SIMS and assess its maturity level (by filling in the scan with at least 4 members in each dimension)
3. Discuss the results and implications for the firm in workshops
4. Create a guide on choosing feasible technologies and methods for the company to develop their own strategies for anticipating SIR and maintaining competitiveness during Industry 4.0
5. Results of the scan, workshop and guide are reported to the company (2-4 pager)
6. The findings are used to discuss and answer the research question: *how do SME's anticipate on Smart Industrial Revolution and deal with the challenges accompanied by it?*

4.3 Research strategy

Data will be gathered qualitatively and the empirical data used for the company audit and discussion of this thesis to answer the research question and all in all to contribute to the theoretical framework as well as bridging the research gap between current manufacturing systems of SMEs and the Smart Industry (I4.0). The research is exploratory in nature and the study is going to be based inductively as there is little readily framework yet established on anticipation of Smart Industry (I4.0) geared towards SMEs in the science community. Even though, there assumptions made on the thesis, the strategy is to generate some kind of theory and idea on the anticipation based on the emerging of the data in a case study.

4.4 Sampling selection

The unit of analysis is the manufacturing SME firm. The selection of a manufacturing firm is based on the SME's definition according to the European Commission (2018a). Thus, an enterprise that employ less than 250 employees and have an annual turnover less than EUR 50 million, with annual balance sheet less then EUR 43 million. The firm must be within the manufacturing industry, which has a product that could be customized. It does not have to be much customized in the present, but if the product cannot be customized at all then the idea of self-optimizing, customized mass production may not be that relevant. For this case study, manufacturing SMEs in the Netherlands are going to be studied. Extensive research is also made on the understanding of Smart Industry in the Netherlands.

4.5 Data Collection

Case study

- Multi-dimensional Smart Industry Maturity Scan

Qualitatively determines the level of maturity towards the current Smart Industry (I4.0) anticipation/adoption. It is used to reveal the challenges and actions to better anticipate for manufacturing SMEs. There are five question on each key dimension in determining its maturity level. The dimensions from the multi-dimensional smart industry scan are: (1) strategy & organization, (2) people & organizational culture, (3) products & customer service, (4) customer interfaces, (5) value chain, (6) technology & IT management, (7) institutional awareness. The scan comes in 5 maturity levels from (1) not at all to (5) fully, where "fully" is most preferable situation. This is classified into three types of users: "newcomers", "learners", and "leaders".

- Workshops

The research consists of informal workshops to present the results from the multi-dimensional smart industry scan, and to discuss the perception of managers on the results of the scan and their positioning in on the anticipation of their company. The expected benefits and opportunities of anticipating as well as, the challenges and barriers that hinders the anticipation and adoption of Smart Industry (I4.0) are going to be discussed. The questions that are going to be asked and discussed during these workshops in collaboration with the managers are in a qualitative questionnaire format of: (1) *What are the kinds of expected benefits and trade-offs of your manufacturing SME envisioning with adopting Smart Industry?* (2) *What are the potential challenges of your manufacturing SME that might encounter with adopting Smart Industry?* (3) *How do the potential challenges, benefits and trade-offs affect the feasibility of introducing Industry 4.0 in your manufacturing SMEs?* (4) *How can your SME expect to successfully overcome the challenges associated with the application of Smart Industry Technologies?* (see more in appendix 3). As an external auditor with an extensive knowledge, these questions are discussed in terms of various technologies, SME's requirements such as legislation, strategy, management, workforce, positioning in the market, the theoretical framework to explore the understanding of that particulars SME firm's intention to move to higher position in the implementation of the Smart Industry Maturity level. So, in order to help facilitate that chosen company to clearly identify their performance levels of business and production processes in relation to the Smart Industry (I4.0), and then guide them to choose feasible technologies and methods, so that companies can develop their own strategies, thereby successfully achieving the anticipated transformation and maintaining their competitiveness during the Industry 4.0. The data from these workshops are going to be used to answer the research question of this thesis.

5. DATA COLLECTION AND ANALYSIS

5.1 Description of the company case study

In this research, we chose to do a case study and work closely with one of the Smart Industry Fieldlabs, The Garden, who provide support to companies in the east of the Netherlands that invest in Smart Industry innovation solutions and collaborates with SMEs to develop and broaden the knowledge and skills of those involved in the chain cooperation and cyber competencies. Fieldlab The Garden was interested in making use of the Smart Industry Maturity Scan and keen on being associated in the pilot of the Scan. So, for this research we partnered up with Paul W. Burghardt from Fieldlab The Garden to do a case study in one of their partner companies. In this case study we were working closely with an association of construction companies in the

eastern Netherlands called "De BlouwKlup". It is a platform and an association for companies, entrepreneurs and everything and everyone or who has an affinity in the broad construction industry[1]. It involves many *BlouwKlup&Partners companies (BK&P)* who are manufacturing SMEs that are interested in Smart Industry Innovations. For this case study we chose 4 members who represent and have knowledge of where *BK&P companies* associated with De BlouwKlup stand in regards to Smart Industry. The 4 chosen members were audited in a workshop and answered for the 'general overview of the BK&P companies', whom are involved in manufacturing of construction materials.

5.2 Maturity assessment of the company case

The 4 members of the *BK&P* companies were asked to fill in and answer questions in the quick Multi-dimensional Smart Industry Maturity Scan. The resulting scores were put into average in each dimension or as shown in figure 3, aspects. According to Ungerer (2018), A1 represents the aspect of Strategy & Organization, which is the implementation of Industry 4.0 strategies, gathering of data, and essence of innovation. A2 represent the aspect of People & organizational culture, which is the knowledge of employees, involvement of management, communication in regards to Smart Industry. A3 represents the aspect of Products & customer service, which is the product portfolio, gathering of customer feedback, implementation of industry 4.0 within product process. A4 represents the aspect of Customer interfaces, which is the interaction with customers, the use of customer data, and digitization of customer journey. A5 is the aspect of Value chain, which involves questions regarding the vertical and horizontal value chains in relation to Smart Industry, and digitization of machinery. A6 represents the aspect of Technology & IT management, which is the product value through technology, focus on technology and the management of the IT in relation to Smart Industry. A7 represents the aspect of Institutional awareness, and focuses on questions regarding digital compliance policy, taxes, and rules and regulations. All measurements to the survey questions can be found in appendix 1. The scores to each question in each aspect are the averages of the 4 respondents' answers that make up the following radar chart.

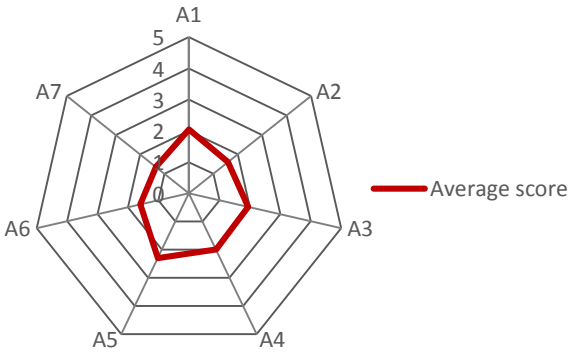

Figure 3. Radar chart of the average scores of all aspects for the typical BK&P companies

In this radar chart aspect 1 to aspect 7 (A1-A8) is provided with an average on a scale from 0 to 5. The results of the scan in this case study of 4 member of BK&P companies showed averages from A1 to A7: 2.05, 1.6, 1.95, 2, 2.3, 1.6, and 1.35. Together the averages count up to the score of 12.85, which is then divided by 7 to get an average score of 1.84. For the complete overview of the results of the scan, see appendix 2. The average score of all aspects is used to classify into five maturity levels, see the distribution of the maturity levels and types in figure 4 below. The distribution was based on an average of the results of all measurement questions. Level 1 indicates an average score of (1-1,49). Level 2 indicates an average score of (1,5-2,49). Level 3 indicates an average score of (2,5-3,49). Level 4 indicates an average score of (3,5-4,49). Level 5 indicates an average score of 4,5 or higher. The maturity levels comes in classification of three user types: "newcomers", "learners", and "leaders".

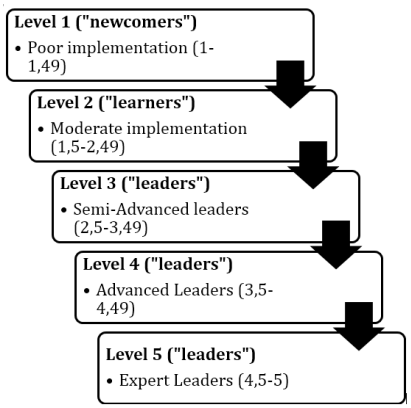

Figure 4. Maturity levels

In this case study for *BK&P* companies the average score of 1.84, fits into the level 2, indicating a "moderate implementation" of Smart Industry, which classifies into user type of "learners", meaning that *BK&P* companies are users who initialize first projects related to Smart Industry. This result is particularly on the lower side of the maturity scale and shows that BK&P companies are not yet taking real actions towards implementation of Smart Industry in their manufacturing. The results from the scan also show that the averages of each of the aspects come in scores in range from the least 1.35 to maximum of 2.3. That means there is not a high deviation between the results of the average aspect scores. This shows that they are not any particularly significant strength scores in any of the aspects for *BK&P* companies. In other words, it shows that BK&P companies are not anticipating on further implementation of Smart Industry to higher maturity level in any aspect. The highest reported average score is in aspect 5, on "Value chains" with 2.3 average score. The lowest average score is reported in aspect 7, on "Institutional awareness" with an average score of 1.35. This is because most of the overall lowest question scores inputted by the respondents (scores 1) are attributed to the aspect on "institutional awareness" (see figure 5).

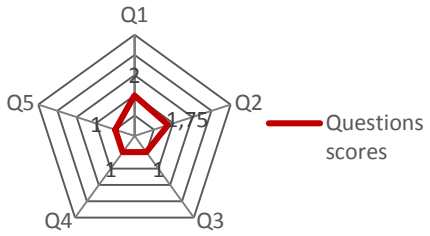

Figure 5. Radar chart of Aspect 7 on Institutional Awareness

In the discussion with the 4 members of the *BKP* companies during a workshop, it has been found that rules and regulations are especially difficult for the methodology of the *BKP*

[1] The BlouwKlup website: https://www.debouwklup.nl

companies approach to Smart industry. They report that there is a lack of standards for implementation of Smart Industry in manufacturing SMEs and thus, are unable and unaware of how to anticipate on Smart Industry and make strategic plans towards implementing it. Overall, *BKP companies* need to improve on all aspects of the Maturity Scan in order to move to higher level of maturity and, the reasons for the current low maturity level from the findings are examined in the following.

5.3 Follow-up workshop

The maturity level with only "moderate level of implementation" and level 2, user type of "learners", presented by the empirical findings from the Smart Industry Maturity Scan on *BKP* companies is discussed in this section on the follow-up workshop. The workshop revolved around a discussion of a followed-up questionnaire to the Smart Industry Maturity Scan against the built upon conceptual framework that was done in section 3.4 (see appendix 3 for the follow-up questionnaire). The workshop also served to examine critical research questions and sub-questions that was established in section 1.3. The workshop took place at an office in Hengelo, The Netherlands.

Intention for adopting Smart Industry

The 4 members of the representative of *BKP* companies were asked to define their level of intention towards continuing to adopt Smart Industry in their manufacturing, after being acknowledged of the results from the scan, on a scale from (1) not at all to (5) to very great extent. This was reported to be an essential driver towards anticipation on Smart Industry and the companies' consideration in further implementation of it. Based on the discussion, the 4 members of the representative of *BKP* companies have reported responses with an average score of 3,5 level of intent in continuing to adopt Smart Industry in their manufacturing. That is an answer between a "moderate extent" to "a great extent" levels of intention. Placed against their current maturity level from the previous findings in the Smart Industry Maturity Scan, we can plot a diagram (on a scale from 1-5) as shown below in figure 5.

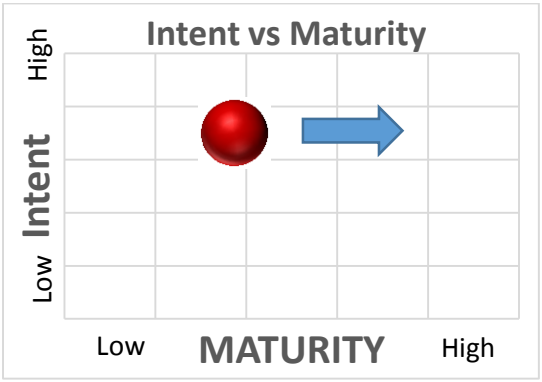

Figure 5. Intention vs Maturity of BKP companies towards Smart Industry adoption after the results of the Scan

The diagram showcases that although, there is a relatively high intention on continuing to adopt Smart Industry in the manufacturing, and their maturity level is on the lower side of the scale, with a score of 1.84 meaning "moderate implementation". They sort of correspond to each other as their maturity user type is described as users who initialize first projects related to Smart Industry, their "moderate extent" to a "great extent" levels of intentions are showcasing the incentive to initialize on implementing Smart Industry, and acts as facilitators of good future anticipating on Smart Industry. However, there is a need to progress on higher maturity in order to match the level of intention. For this factor to work in favor in moving higher with the maturity level, it is assumed based on the conceptual framework to be affected by both the expected benefits and opportunities and the challenges of Smart Industry.

Expected Benefits and Opportunities

Based on the discussion in the workshop, the members of the *BKP* companies anticipate the benefits and opportunities of Smart Industrial Revolution for their manufacturing as a means to "do more with less" resources. They perceive and anticipate Smart Industry as a way to preserve their business continuity and for sustainable production and products. Moreover, they anticipate it to aid in cost reduction, shorter lead time, real time monitoring and control, greater flexibility of production processes, diversity of products, better use of materials, longer/better (more circular) lifecycle and higher quality work. They however perceive the expected benefit of higher quality work with a potential trade-off of that it will decrease volume of jobs or work for their employees. All these perceived expected benefits and opportunities of Smart Industry were reported by the 4 members as driving force for their intention towards the intent to adopt Smart Industry further. They also report that the more collaboration they do with other companies whom are more advanced in regards to Smart Industry, this would fuel them more awareness and understanding of the potential benefits Smart Industry can bring into their own manufacturing.

The Challenges from Smart Industry adoption

The intent to adopt Smart Industry is reported to be hindered by the perceived challenges that come with the anticipating on Smart Industry. The 4 members of the *BKP* companies anticipate further implementation of Smart Industry to come with the changes in the type of work and skills in their manufacturing for both their business model and employees. They perceive that this trade-off is going to come with a strategic reorientation on some of the company's focus on the certain type of work they do with manufacturing construction materials. And the challenge of the potential shift of which employee does what kind of job task and is paid for what type of work. They anticipate that they are going to be faced with a strategic dilemma of either increasing the costs of training the existing employees and acquiring new employees with the required skills, and how to manage this issue. They also foresee trade-offs with buying services that were traditionally made by the companies themselves.

The main challenges that *BKP* perceive most critical for their successful anticipation of Smart Industry are the development of the necessary understanding and awareness of Smart Industry in order to adopt it properly. They report having lack of understanding of Smart Industry, especially the actual action of implementation in their manufacturing. The 4 members report that they anticipate on the need for developing necessary collaboration with other companies to aid in the further implementation of Smart Industry in their manufacturing. This was emphasized as very crucial to their future development and survival of their businesses. Anticipating that necessary implementation of desired changes are needed to be in accordance with the industry as a whole, while being able to stay afloat with a sustainable competitive advantage in the meantime. They also report to have the lack of understanding in accordance to Smart Industry standards. Producing faster, more diverse, cheaper are their mission but, figuring out how is not so obvious. They find it very difficult to adhere to these standards without having the expertise and know-how on how and where to start

implementing the necessary parts for becoming Smart Industry ready.

Furthermore, the 4 members were asked about the effect of potential challenges, benefits and trade-offs together on the feasibility of introducing Smart Industry in their manufacturing SME. They anticipate that there is a risk that Smart Industry will be implemented too slowly in their manufacturing due to lack of understanding and awareness, education and collaboration. It is the reason why it is crucial for them to seek out externals to guide on aiding them in the process of further implementation of Smart Industry. Their further response on the matter is that: "*if our companies are unable to overcome these challenges and trade-offs, they will in future be ordering their homes from Amazon and have to close down their construction manufacturing business. So if we do not make the change feasible this will happen and many companies do not yet see this coming. When the competition comes it will be too late"*. This quote illustrates how this firm is driven by the fear of the future to instill immediate action. There is a perceived emergence of multiple competitive forces. Not only the threat of direct competitors but also emergence of new competitors outside their field, better equipped with variety of competitive advantages as well as financial and technical resources in the digital servitisation era that will be transferring over to take over their market and this drives this firm for anticipation on their own strategic action in servitisation. They foresee buying services that were traditionally made by the companies themselves onto tech giants like Amazon.

On a De Wit and Meyer's (2010) Strategic Reasoning Process, the 4 respondents were asked to define themselves to what extent do they see their manufacturing companies overcoming the challenges of Smart Industry in 4 four stages that was explained in the theoretical framework (section 2.2). They have identified themselves in the first stage, the 'identifying stage', where they have the "*necessary competences in their SME manufacturing to see and recognize the challenges they have with production in relation to Smart Industry adoption*". This means that they are in stage where, they do not yet fully understand the challenges that comes with Smart Industry adoption and are three more stages short in order for them to have the competences to actually implement solution proposals that are required to handle the challenges in production faced with Smart Industry adoption.

Overcoming the challenges. The investigated *BKP* companies anticipate to successfully overcome challenges associated with Smart Industry with: (1) education and subsidized pilot projects; (2) actively being engaged in creating awareness and understanding of what their manufacturing companies want to do with Smart Industry; (3) making clear of the vision and anticipation, (4) have the most progressive companies practice what they preach with regard to Smart Industry and collaborate; (5) business networking should play a leading role in this type of activities (6) perceived change will be led by bold small project that show what is possible.

Anticipation and Vision of the Future

For now the members of the *BKP* report waiting and see what other companies do. There is an awareness and interest for further Smart Industry implementation, but the decision-making for such an action requires more time. The kinds of organizational changes the investigated companies need to anticipate on in their manufacturing to be in accordance with Smart Industry are: (1) the successful pilot projects are a necessary step to achieve a broader adoption of Smart Industry strategies and technologies; (2) requiring a complete redesign of production lines, where data exchange between new internal and external partner and services are carefully considered. (3) More teamwork and collaboration will be necessary where managers give operational personnel more room/flexibility for new processes and methods.

Roadmap on Smart Industry Practice

For now, the investigated companies do not have a manufacturing strategy towards Smart Industry adoption or are thinking about it, but will only develop it when they have a clear threat by competitors. Moreover, they do not have a strategy for investing in feasible new manufacturing equipment nor Smart technologies. Most of the investments they made in relation to Smart Industry are ad-hoc or coincidental.

There is however an interest in improving the digital interaction in the supply and delivery chain and making smarter use of shared available data. There is interest for ICT infrastructure that makes sharing of data flexible and secure. Fragmentary Predictive maintenance and use of Internet of Things. Another application is a proactive design of physical infrastructure that is more sustainable in all respects by means of better collaboration between the many phases of the lifecycle of buildings and neighborhoods.

6. DISCUSSION

In this section the following theoretical and practical implications are discussed from the previously described results. As well as, the limitations and possibilities for future research. Moreover, recommendations are discussed on the quick Smart Industry Maturity Scan and the built-upon conceptual framework of this study. Lastly, a conclusion and acknowledgement to the thesis research are provided.

6.1 Theoretical implications

The main aim of this research was providing a better understanding of the way to help manufacturing SME's to overcome the challenges of Smart Industry whilst producing contribution to scientific insights and practice on how anticipation in the Smart Industry for SMEs occurs. So, "how do manufacturing SMEs anticipate on the Smart Industry Revolution and deal with the challenges accompanied by it? From the results of this case study we learned that it is difficult for manufacturing SMEs who is only initializing first projects and learning about Smart Industry (level 2 maturity and have 'moderate implementation' in their manufacturing) to anticipate on the future implementation of Smart Industry. SMEs in manufacturing with this user type of "learners" are waiting to see what other companies do. There is an awareness and interest for Smart Industry implementation and its technology, but the decision-making for such an action requires more time and will only develop strategies when they have a clear threat by competitors.

The main reasons are of the challenges that hinder the intent and anticipation on how to implement Smart Industry. For the studied case of level 2 maturity level of "learners", the main challenges are the lack of understanding, awareness, and standards on Smart Industry and exactly how to strategically implement it onto their manufacturing. There are other trade-offs and challenges presented in the results (section 5.3), and the competences on overcoming them are not sufficient as shown with the use of De Wit and Meyer's (2010) Strategic Reasoning Process, which aided in understanding the competences towards overcoming challenges of Smart Industry. The case study shows that SMEs in level 2 maturity have the necessary competences to see and

recognize challenges but are far from having solution proposals for them.

This study also confirms the work of Stentoft et al. (2019) that the more manufacturing SMEs are exposed to understanding the benefits and opportunities of Smart Industry, the more beneficial it is for the readiness and consequently their practice on Smart Industry. As the investigated case study showcase that there is a need for manufacturing SMEs to be more informed about the potentials and understanding of Smart Industry, it can better anticipate on its future and drive its intent to implement it.

Moreover, the maturity assessment tool for manufacturing SMEs as presented in the conceptual framework was found to be beneficial. The quick Smart Industry Maturity Scan aided in the process of understanding where the investigated company is in anticipation of Smart Industry and was found to be an important driver of the intent to further implement Smart Industry in the manufacturing. It gave a ground overview of the investigated company and aided in finding out the reasons behind the case's current level anticipation of Smart Industry. The follow-up workshop discussion designed from the built-upon conceptual framework also aided in the process. We found out more awareness of benefits and opportunities drives the intention and challenges have been found to hinder the intention.

Another contribution to the theory is the discovery of drivers such as increasing more education, collaboration with other companies and institutions, and subsidizing pilot projects. Education and collaboration shows the premise of aiding in the understanding and creation of awareness of the potential benefits and opportunities of Smart Industry for manufacturing in SMEs. While, the idea of subsidizing bold pilot projects can help achieve broader adoption of Smart Industry and guide SMEs in this process. The more aware manufacturing SMEs are of the potential benefits and opportunities of Smart Industry, the more they are incline on the intent to implement Smart Industry. Furthermore, the threat by competitors was found to be a driver for deciding on adopting Smart Industry as a strategic choice and road-mapping on its implementation. Based on the findings of the data collection, a close analysis of the conceptual framework (section 3.4) was done, resulting in the following revised conceptual framework. The plus signs represent drivers for a factor, while a minus sign represent hindering.

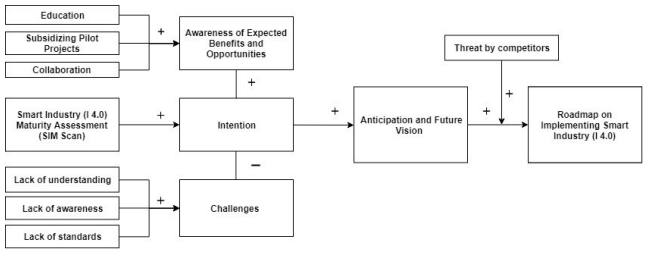

Figure 6. Revised conceptual framework of Manufacturing SME's Anticipation with Smart Industry Maturity Scan

6.2 Recommendations for practice

This research offers SMEs in manufacturing the opportunity to assess themselves regarding their intention and anticipation towards Smart Industry. Given that automation and the far-reaching digitization are of future prospects, SMEs in manufacturing should consider whether implementing Smart Industry is of relevance to them. The quick Smart Industry Maturity Scan is a useful tool that provides an overview of where SMEs in manufacturing are in regards to anticipating Smart Industry in 7 important aspects which aids in the assessment of their current level of anticipation towards Smart Industry and is an essential driver for the intention towards its further implementation. The built-upon conceptual framework provides a better insight in the way SMEs in manufacturing anticipate on Smart Industry, than just by applying only the quick Smart Industry Maturity Scan because it examines the drivers of intention and the challenges that comes with implementing Smart Industry. We identified that the awareness of expected benefits, assessing the competences to what extent they see themselves overcome the challenges of Smart Industry, and understanding of the ways to deal with these challenges could guide manufacturing SMEs in the process.

This research recommends SMEs to seek out and invest in collaboration with other companies, research facilities and other institutions to become aware of the possible benefits, and ways to deal with the challenges that Smart Industry might bring to them. As well as, increasing education on Smart industry and subsidizing pilot projects to create necessary step to achieve a broader adoption of Smart Industry strategies and technologies.

For the Smart Industry as a whole and the Fieldlab programme in the Netherlands, this research should guide in understanding how SMEs in manufacturing anticipate on Smart Industry, most of which are waiting to see what others do. Thus, could help engage all Fieldlabs in starting pilot programmes to further lead SMEs to make first-step actions and help connect in the Smart Industry platform, as suggested with pilot projects. This research confirms that Smart Industry should be driven by collaboration, however the most important aspect is defining a clear strategy and understanding of what Smart Industry means, and is an essential factor for the process of implementing Smart Industry. The future of manufacturing SMEs should be dictated by how to develop Smart Industry strategies to fully engage in the era and sustain competitively for years to come.

6.3 Limitations and future research

The first limitation of this research is the choice of selecting 4 representatives of an association of construction manufacturers. This is a limitation as the 4 members can have variance in the answers of the overview of "typical BKP companies" in regards to anticipating Smart industry, as BKP include multiple construction companies which, assuming each of the companies operate uniquely. Unfortunately for this research, because of the time pressure, managers of the specific companies of the 'DeBlouwKlup' declined the opportunity to be investigated. It would have been a good opportunity for future research to do a more accurate investigation of each of these SME companies related to BKP are in regards to Smart Industry in the East of Netherlands, instead of a general overview of the association of the group of construction manufacturers. Moreover, replication of this study should be done in other industries than construction, like metal, plastics, paper, as well as in other regions, to determine whether they are specific characteristics for Dutch SMEs affecting the research.

Secondly, it is very difficult to find an actual case of SME in manufacturing who has fully implemented Smart Industry that could help in research to understand how the anticipation of a full adopter of Smart Industry occur. With future implementations we should see more cases that could help us debunk the process and have better understanding of the ways to help deal with the challenges designed for SMEs.

Another limitation, is that the quick Smart Industry Maturity Scan only provides a first glance overview of where they are in the anticipation of Smart Industry. The built-upon conceptual helped in understanding on founded ways to deal with the challenges however, not in aiding to create a guide on choosing feasible technologies and methods for the company to develop their own strategies for anticipating Smart Industry and

maintaining competitiveness during Smart Industry. As that comes down to SME's to choose to do or not. This research only helps to understand how SMEs in manufacturing might want to introduce Smart Industry in their manufacturing rather exact strategic guidance on what and how to implement it. The focus is more on the ways to overcome the challenges, than design of the implementation of Smart Industry. A suggestion for future research should examine specific guidelines on helping choosing feasible technologies and methods for different businesses of manufacturing SMEs, as well as how these manufacturing SMEs decide on actual implementation of Smart Industry.

Moreover, the extent of the effect of the presumed education, subsidizing pilot projects and collaboration aiding in helping create awareness of Smart Industry has not yet been thoroughly studied. Therefore, as a suggestion for future research, the effect of these drivers for creating awareness should examined. As well as, the effect in the presence of the threat by competitors, and how this might affect the decision-making on strategies towards Smart Industry implementation. A more quantitative study should be studied based on this research, to test the found assumptions, preferably in countries with higher adoption rate like Germany, US or China.

6.4 Conclusion

In this research, I set out to contribute in giving a more comprehensive guidance for SMEs in manufacturing in regards to overcoming the challenges of Smart Industry. I developed a conceptual framework built on the application of the Smart Industry Maturity Scan developed by Ungerer and Future Industries, to help understand how anticipation on Smart Industry for SMEs occur. Established by the findings, intention was identified as a driver towards anticipating Smart Industry and its subsequent implementation. The quick scan was identified as driver for further intention and help with anticipating Smart Industry. As well as, the awareness of the expected benefits and opportunities. Whereas, perceived challenges of Smart Industry has been found to hinder intention. Education, subsidizing pilot projects and collaboration were found to be drivers of awareness of expected benefits and opportunities and help overcome challenges. Whereas, the lack of understanding, lack of awareness and the lack of standards were found to be the primary challenges of Smart Industry. They were also perceived trade-offs of Smart Industry implementation found including (1) the requirement of the redesign of production lines to accustom the data exchange for both internals and externals to fit Smart Industry, (2) the perceived threat of decreasing volumes of employment, (3) strategic reorientation of the company's focus on work, and (4) the issue with employment management dilemma of either increasing cost of training or hiring new talent. This findings added to the foundation of the conceptual framework and hopes in helping SMEs in manufacturing anticipate on Smart Industry and choosing to start on working on strategic reorientation towards further implementation of Smart Industry based on the proposed ways to overcome the challenges.

6.5 Acknowledgements

I would like to give my thanks to R.P.A. Loohuis, who was guiding me throughout the whole journey in the making of this thesis. Moreover, I would like to give my special thanks to Paul W. Burghardt from Fieldlab The Garden for giving me the opportunity to work together with the members of the DeBlouwKlup Association who represent *BKP* companies and share their experience on Smart Industry adoption in their manufacturing companies with me and made this research possible. Lastly, I would like to give thanks to Future Industries and Ungerer for making and sharing the Multi-dimensional Smart Industry Scan, without which this research would not be realized.

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8. APPENDICES

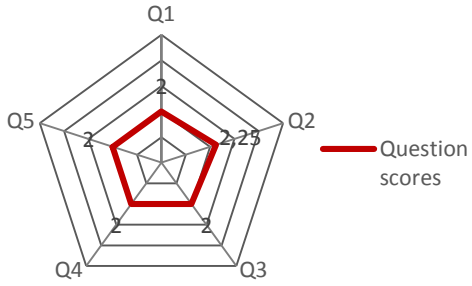
8.1 Appendix 1: Future Industries Multi-Dimensional Smart Industry Scan

Aspects	Measurement Questions	Answers: (1) Not at all, (2) to some extent, (3) to moderate extent, (4) to great extent, (5) to very great extent
1. Strategy and organization	I. To what extent is industry 4.0 part of the strategy of the organization?	
	II. To what extent do digital features, products & services contribute to the overall value creation of your organization?	
	III. To what extend is the progress of the implementation of industry 4.0 aspects monitored or periodically reported?	
	IV. To what extent do you use data gathered for creating value within the organization?	
	V. To what extent is innovation essential within the strategic plans of the organization?	
2. People and organizational culture	I. To what extent are employees regularly trained (with knowledge and skills) to meet future Industry 4.0 tasks and requirements?	
	II. To what extend does your organization's management focus on the implementation of industry 4.0?	
	III. To what extent do you regularly discuss the possible influences of industry 4.0 with your employees and / or colleagues?	
	IV. To what extent do your employees (colleagues) easily adapt to changes and learn how to apply new knowledge?	
	V. To what extent is there a corporate culture in your organization that motivates efforts for changes towards the digitization of the company?	
3. Products and customer services	I. To what extent are your company's products equipped with smart technologies?	
	II. To what extent is industry 4.0 implemented in the products you offer?	
	III. To what extent is industry 4.0 used in the phases of the production process?	
	IV. To what extent do you proactively collect customer feedback to realize areas for improvement for the future?	
	V. To what extent does industry 4.0 help to satisfy your customers within your organization?	
4. Customer interfaces	I. To what extent do customers use the internet in contact with your organization?	
	II. To what extent do you use different channels for contacting your customers?	
	III. To what extent do you collect user data to analyze and better understand customer needs?	

	IV. To what extent has the "customer journey" of your company digitized?	
	V. To what extent does digitization within your organization ensures that you can collaborate better with customers	
5. Value chain	I. To what extent does your organization focus on improving digitization within the value chain?	
	II. To what extent do you collect data (1) in the horizontal value chain?	
	III. To what extent do you collect data about machines and the production process while creating a product?	
	IV. To what extent are smart techniques used to signal disruptions / delays within the value chain?	
	V. To what extent do you consider equipment, hardware and software in the entire process from customer demand to delivery interconnected and provided with smart technologies?	
6. Technology and IT management	I. To what extent is attention paid to industry 4.0 technologies to actively contribute to the work within the company.	
	II. To what extent does the IT department have sufficient knowledge to implement the new industry 4.0 technologies within the agreed time, quality and costs?	
	III. Are sufficient IT security measures being taken to protect company data and to limit the exchange of data to places where this is strictly necessary?	
	IV. Are data from processes and products used to make autonomous decisions in real time?	
	V. To what extent can the production environment adapt quickly to new products and product assemblies by using automated technologies?	
7. Institutional awareness	I. To what extent can you guarantee that digital business policy is up-to-date and sufficiently developed?	
	II. To what extent is the intellectual property for products and services of your company protected?	
	III. Law and regulations can be of great importance when making business decisions. To what extent are relevant employees within your organization aware of the laws and regulations concerning the implementation of Industry 4.0 technologies and methods?	
	IV. To what extent are you aware of possible tax effects of new circumstances as a result of Industry 4.0 applications?	
	V. The new European privacy legislation (GDPR) increases the rights of customers with regard to their data. A number of these rights can be summarized in requests for access, namely the right to access, the right to rectification and addition, the right to oblivion and the right to data portability. To what extent are you able to handle such requests for access automatically?	

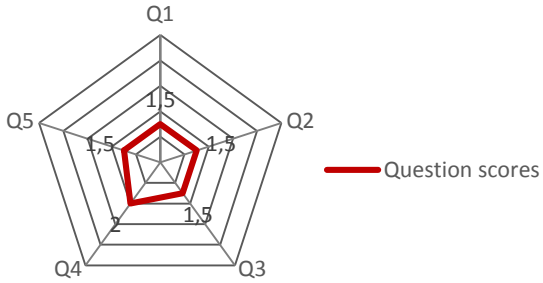
8.2 Appendix 2: Smart Industry Maturity Scan Results

1. Strategy and organisation



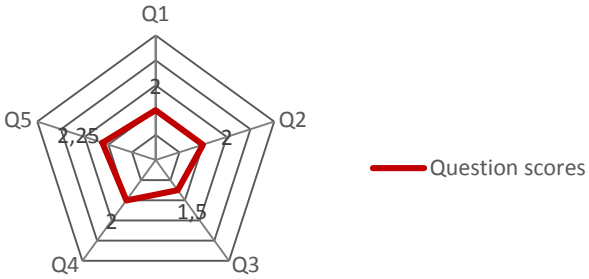
Aspect 1 average score: 2.05

2. People and Organisational culture



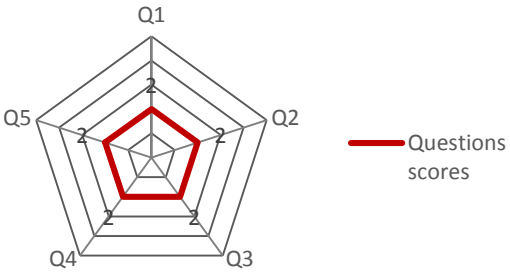
Aspect 2 average score: 1.6

3. Products and customer services



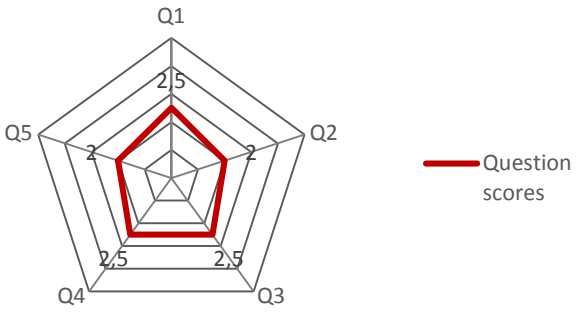
Aspect 3 average score: 1.95

4. Customer interfaces



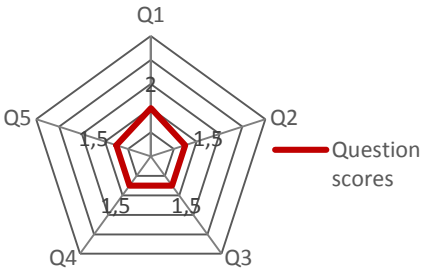
Aspect 4 average score: 2.0

5. Value chain



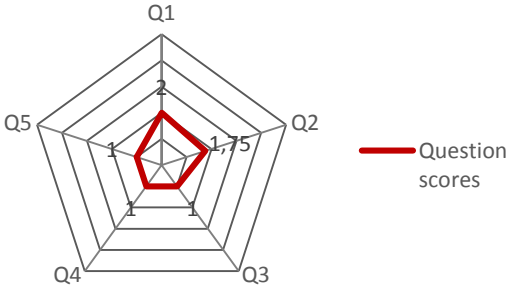
Aspect 5 average score: 2.3

6. Technology and IT management



Aspect 6 average score: 1.6

7. Institutional awareness



Aspect 7 average score: 1.35

8.3 Appendix 3: Workshop Follow-up Scan Questionnaire

SIMS WORKSHOP FOLLOW-UP QUALITATIVE QUESTIONNAIRE

1. After the results of the Smart Industry Maturity Scan, to what extent do you intend on continuing to adopt Smart Industry in your manufacturing companies?

From 1 to 5.

(1) Not at all, (2) to small extent, (3) to moderate extent, (4) to great extent, (5) to very great extent

2. Do your companies have a manufacturing strategy towards Smart Industry adoption that corresponds to your above-selected level of intention?

A. If yes, how do your manufacturing companies decide on the adopting Smart Industry as a strategic choice?
B. How do you anticipate on the future of your manufacturing companies in regards to Smart Industry?

3. Do your companies have a strategy for investing in new manufacturing equipment and Smart Industry technologies?

4. Which Smart Industry technologies and methods are you deploying, or are planning to deploy in your manufacturing? And how?

5. What kinds of organizational changes do you need to make in order to be in accordance with Smart Industry standards?

6. What are the kinds of expected benefits and opportunities do you envision from adopting Smart Industry?

7. What are the kinds of trade-offs do your manufacturing SMEs envision with adopting Smart Industry?

8. What are the kinds of challenges your manufacturing SMEs foresee or already encounter with adopting Smart Industry?

9. How do these (identified) challenges, benefits and trade-offs affect the feasibility of introducing Smart Industry (I4.0) in your manufacturing companies?

10. To what extent do you see your manufacturing companies overcoming the challenges of Smart Industry that you have identified before? (You can circle multiple answers that corresponds to your answer)

A. We do have the necessary competences in our SME manufacturing to see and recognize the challenges we have with our production in relation to Smart Industry adoption
B. We do have the necessary competences in our SME manufacturing to understand the challenges we have with our production in relation to Smart Industry adoption
C. We do have the necessary competences in our SME manufacturing to suggest competitive solutions to tackle the challenges our production is facing in relation to Smart Industry adoption
D. We do have the necessary competences in our SME manufacturing to implement the solution proposals that are required to handle the challenges our company is facing in production in relation to Smart Industry adoption.

11. How can you expect to successfully overcome these challenges associated with the adoption and application of Smart Industry technologies?