Anticipating the future of Industry 4.0 for manufacturing SME's with the Extended Smart Industry Maturity Scan (E-SIMS)

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ABSTRACT,
The Fourth Industrial Revolution is currently changing the manufacturing landscape drastically by combining Industrial manufacturing and Information and Communication Technologies (ICT) to enhance the competitiveness of manufacturing firms. Nevertheless, current research has focused on Industry 4.0 adoption strategies by larger enterprises while Small-Medium Sized Enterprises (SME's) are left behind. SME's face different hurdles than larger enterprises due to their lack of clearly defined strategies, fewer resources, lack of IT standards, resistance towards change and less access to required expertise. Therefore, this research aims to give insight into the hurdles SME's face when adopting Industry 4.0 and how SME's can and try to overcome these hurdles. By applying the extended science-based Smart Industry Maturity scan (E-SIMS) to two manufacturing companies in the Netherlands their performance and the strategies the SME's adopted to overcome the Industry 4.0 obstacles could be measured systematically across 15 dimensions of Industry 4.0 identified by the scan (Ungerer, 2019). Both companies scored low in their Industry 4.0 maturity and showed an overall lack of knowledge on Industry 4.0. The results of the scan were further analyzed and discussed in follow-up workshops with the case companies to give insight into the main obstacles and how SME's plan to improve their Industry 4.0 performance. Furthermore, based on the results of the case studies and findings from the literature review, recommendations for practice are discussed to help guide SME's Smart Industry agenda and help them overcome the obstacles they face. The results of this study can be insightful for both company management and public administration to help SME's find their way and take the next step in their Industry 4.0 journey.

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Industry 4.0, Industrial Internet of Things, Smart Industry, Smart industry maturity scan, Barriers to Industry 4.0, Challenges of Smart Industry, Hurdles of Industry 4.0, SME's, Small and Medium-sized enterprises, Smart Manufacturing, case study

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1. INTRODUCTION

1.1 Topic relevance

We are currently witnessing the beginning of a new era, the Fourth Industrial Revolution, that will change the way manufacturing companies work drastically. Industry 4.0 (I4.0), also known as the Industrial Internet of Things (IIoT) or Smart Industry, is the future for manufacturing companies. The term Industry 4.0, or in German "Industrie 4.0", was first introduced in 2011 by Germany which is the third leading global manufacturing country according to a global survey conducted by Deloitte (2016). The "Industrie 4.0" initiative was part of a high-tech strategy which introduced the idea of a fully integrated manufacturing industry (Hofmann & Rüsch, 2017). Industry 4.0 aims to realize a digital and intelligent factory by integrating Information Communication Technologies (ICT) and industrial technology (Matt et al., 2020; Oluwaseun Adebayo et al., 2019). When successfully implemented, Industry 4.0 offers great opportunities to enhance the competitiveness of SME's (Matt et al., 2020). However, most existing research has focused on Smart Industry implementation in larger multinationals, causing small to medium enterprises (SME's) to be left behind. SME's represent 99% of businesses in Europe signifying the importance of SME's in the economy, but only a fifth is highly digitalized (European Court of Auditors, 2019; Matt et al., 2020). At a survey conducted among 1,194 Dutch SME's just 15% mentioned knowing the terms Smart Industry or Industry 4.0 (Smetsers, 2016). This shows a lack of knowledge and awareness of Smart Industry by SME's. Furthermore, there are several barriers to the adoption of Industry 4.0 by SME's. The implementation of Smart Industry can require significant investments and SME's have less access to financial resources, making technological adoption more difficult (Haseeb et al., 2019). On top of that, the lack of automation and insecurity of future perspectives are barriers that prevent SME's of participating in Smart Industry at the same rate as larger companies (Radziwon et al., 2014). Because SME's often lack a comprehensive digital strategy and uniform standards, the difficulty of implementing Industry 4.0 in SME's is exacerbated (Schröder, 2016). Thus, there is a research gap for the implementation of Smart Industry by SME's and how to overcome the barriers that are accompanied by it.

1.2 Research objective

This research aims to give insight in the Industry 4.0 maturity levels of manufacturing SME's. Moreover, because Smart Industry implementations can require significant investments and SME's have less access to financial resources making technological adoption more difficult (Haseeb et al., 2019), this research aims to give insight in the main hurdles of Smart Industry adoption by SME's, to explore how SME's tackle these hurdles, and to improve the adoption of Smart Industry technologies while also helping them anticipate Industry 4.0 developments in the future. Therefore, the research question *"To what extent have SME's implemented Industry 4.0, what are the main challenges and how can these challenges be overcome?"* was investigated with the help of two manufacturing SME's operating in the East of the Netherlands. Company A operates in a niche market for custom fireplace solutions while Company B is a manufacturer in the steel and metal bending industry.

1.3 Research question

The following research question was formulated based on the research objective:

"To what extent have SME's implemented Industry 4.0, what are the main challenges and how can these challenges be overcome?"

The research aims to answer the following sub-questions:

- To what extent have SME's implemented Industry 4.0?
- How can the maturity of Industry 4.0 adoption by SME's be assessed?
- Which challenges of adopting Industry 4.0 by SME's are identified in the literature?
- How can these challenges be determined in practice?
- What strategies for adopting Industry 4.0 are identified in the literature?
- How can these strategies be applied in practice?

1.4 The structure of the thesis

In the introduction, the relevance of the topic and the objective of the research is discussed. Then, an extensive literature review has been conducted on the key elements of Industry 4.0, the innovation strategies adopted by SME's, and the barriers SME's face when implementing Industry 4.0. Furthermore, existing Smart Industry scans that measure Industry 4.0 maturity were compared. In the methodology, the research setting and data collection method are discussed. After this, the empirical findings from the E-SIMS scan and minigroup workshops are summarized, and in the following chapter, the theoretical and practical implications are discussed. In the next chapter limitations and suggestions for future research are covered, followed by the conclusions and acknowledgements. At the end, the reference list and appendices can be found.

2. THEORETICAL FRAMEWORK

To answer the research question, the key concepts of Industry 4.0 must be explained. Following the key concepts, the main barriers to Industry 4.0 adoption by SME's will be discussed as well as innovation strategies for SME's. Next, Smart Industry scans that assess Smart Industry maturity will be explored.

2.1 Industry 4.0 in manufacturing companies

There is not a single agreed-upon definition of Industry 4.0, Smart Industry, or the Industrial Internet of Things (IIoT). For Industry 4.0, the technological basis is the smart automation of cyber-physical systems (CPS) with the connectivity of the Internet of Things (IoT) and Internet of Services (IoS) (Boyes et al., 2018; Hermann et al., 2016; Lu, 2017; Rojko, 2017). The Internet of Things (IoT) facilitates and connects physical objects through wireless networks, smart objects and sensor technologies, allowing them to communicate with one another to make autonomous and de-centralized decisions (Boyes et al., 2018; Oluwaseun Adebayo et al., 2019; Rojko, 2017). Together, CPS and IoT-based manufacturing generate huge amounts of data which is typically stored in the cloud (Almada-Lobo, 2016). Big data analytics and machine-learning algorithms can utilize this data to fully understand the manufacturing process and support smart decision-making (Almada-Lobo, 2016; Rojko, 2017; Zheng et al., 2018). This facilitates so-called "Smart Factories" where manufacturing systems are fully integrated, intelligent and respond in real-time through smart decision-making to e.g., meet changing demands, customer needs or respond to changing conditions in the factory (Hermann et al., 2016; Zheng et al., 2018). Smart factories also produce 'smart' products with embedded sensors that can be used e.g., localization or measuring product health (Rojko, 2017). Moreover, by analyzing the data recorded by smart products, innovative services can be offered to customers in the future (Kagermann et al., 2013).

Altogether, the utilization of Industry 4.0 technologies has huge potential for SME's to meet customer needs, increase the

flexibility and efficiency of production, create value opportunities through innovative services, improve quality control, increase sustainability, and effective communication and collaboration with partners (Kagermann et al., 2013; Maskuriy et al., 2019). Nonetheless, SME's are faced with considerable challenges that must be resolved to successfully implement Industry 4.0 in their organization.

2.2 Barriers to Industry 4.0 implementation by SME's

SME's face several hurdles that must be overcome to benefit from implementing Industry 4.0. According to Schröder, the biggest challenges SME's face when adopting Industry 4.0 are the development of an appropriate digital strategy, a cost-benefit analysis of the relevant technologies, and a lack of data security and uniform standards (2016). SME's have fewer financial resources available and often lack employees with the appropriate knowledge and talent for the implementation of Smart Industry technologies (Matt et al., 2020; Mittal et al., 2018; Peillon & Dubruc, 2019; Schröder, 2016; Smetsers, 2016). Furthermore, many SME's do not have their own IT department and due to the lack of standards, security concerns hinder the implementation of Smart Industry practices which is exacerbated by a company culture that shows resistance to change towards data sharing (Müller et al., 2018; Radziwon et al., 2014; Schröder, 2016; Smetsers, 2016). The lack of IT standards at SME's also increases the difficulty of internally and externally integrating systems for data sharing with partners which is vital for the successful implementation of Industry 4.0 (Schröder, 2016). Müller et al. also identified the lack of standardization of processes in SME's as a key challenge of adopting Smart Industry, as well as fewer resources, data security concerns and less automated production processes (Müller et al., 2018). Furthermore, Müller et al. found the large investments required for Smart Industry adoption and the uncertain profitability a deterrent for Industry 4.0 adoption by SME's (2018), which is in accordance with the findings of Matt et al. (2020), Mittal et al. (2020), Schröder (2016), Smetsers (2016) and Peillon (2019). Moreover, a resistance to change among employees of SME's due to fear of losing their jobs has a significant negative effect on the adoption of new technologies (Müller et al., 2018; Peillon & Dubruc, 2019; Schröder, 2016). Due to the short-term strategies that most SME's have, the resistance to change barrier is exacerbated (Radziwon et al., 2014; Schröder, 2016). This short-terminism by SME's is often caused by unclear or non-existent innovation strategies due to a focus on operational activities and insufficient time available for strategic issues (Edvardsson & Durst, 2013; Müller et al., 2020). In the next paragraph, innovation strategies which can help SME's overcome these hurdles are explored.

2.3 Innovation strategies for SME's

SME's usually suffer from unclear or absent innovation strategies because they lack the time or skills required for these strategic issues (Edvardsson & Durst, 2013; Müller et al., 2020). SME's generally focus on operational activities and that short-term focus hinders long-term investments which can result in a culture that is resistant to change (Moeuf et al., 2018). Therefore, long-term innovation strategies are key to reduce the tendency of SME's to avoid new technologies (Radziwon et al., 2014; Somohano-Rodríguez et al., 2020). Innovation strategies guide the decisions on how resources should be allocated and identifies the technologies and market the organization should focus on to meet corporate objectives and to create value and competitive advantage (Dodgson et al., 2008). For SME's to become and successfully remain innovative it is key to align the innovation strategy to support the overall business strategy, goals and vision (Pisano, 2016). For Industry 4.0, these innovation strategies involve the alignment of resources with a digitalization or Smart Industry strategy and require a commitment by management to reduce resistance to change concerning new technologies or other new market conditions (Radziwon et al., 2014; Yeow et al., 2017). Therefore, it is key for management to formulate and communicate a clear vision and clear goals that can guide the allocation of resources. Having a clear innovation strategy also allows SME's to compare this strategy with partners, which can help identify where in the value chain innovations can make the most impact (Carraresi et al., 2016; Kagermann et al., 2013; Maskuriy et al., 2019). Shafique and Kalyar also state that leaders with a clear vision can stimulate employees to innovate and go beyond what is expected from them (2018). Furthermore, Hadded et al., states that for SME's to become and remain innovative it is required that SME's incorporate innovation into the company's culture (2019). To create an open and innovative culture, SME's should encourage employees to share ideas and experiment while allowing for honest criticism and feedback (Haddad et al., 2019; Padilha & Gomes, 2016; Sattayaraksa & Boon-itt, 2018). Moreover, SME's should maintain constant communication with their customers to access information on customer needs and experiences and to gain insight into new business opportunities (Brunswicker & Vanhaverbeke, 2019). Another important aspect of innovation strategy for SME's, and a vital aspect of Smart Industry, is that of collaboration and partnerships. The method of open innovation through external collaborations can make innovation more accessible because the risks and resources can be shared among partners (Carraresi et al., 2016; OECD, 2019). This is especially useful for SME's because of their limited access to resources, allowing them to reach goals that could not be reached individually.

However, most existing innovation strategies for SME's do not cover all the dimensions which Industry 4.0 entails. In the next chapter, Smart Industry scans are explored to identify the different dimensions of Smart Industry.

2.4 Exploring existing Smart Industry scans

Before an organization can improve on Smart Industry aspects, the current performance must be measured, thus identifying the aspects of Smart Industry the organization is leading and lagging in. There are a wide variety of "Smart Industry maturity scans" or "Industry 4.0 maturity scans" available and these will be explored in this section. Some existing Smart Industry scans are summarized below in Table 1.

Table 1: Existing Industry 4.0 maturity scans

Model name	Assessment
IMPULS' Industry 4.0 Readiness online self-check	IMPULS' Industry 4.0 readiness online self-check offers 5 readiness levels: outsider, beginner, intermediate, experienced, expert and top performer. The readiness level is based on 19 measurement questions across 6 dimensions, namely Strategy and organization, Smart factory, Smart Operations, Smart products, Data-driven services and Employees, and is assessed by 18 items (IMPULS et al., 2015).
Webs' Digital Maturity Model	Webs' Digital Maturity Model offers 5 digital maturity levels: basic, tactical, optimizing, strategic and engaging. The maturity level is

	based on the score of 5 different aspects measured by 14 measurement questions: Strategy and organisation, Online channels, Customer focus, Success and Technology (Webs, n.d.).
Digital Leadership Ltd.'s Digital Maturity tool	Digital Leadership Ltd.'s Digital Maturity tool offers an online assessment with the following maturity levels: Level 0 0-29%, Level 1 30-49%, Level 2 50-69%, Level 4 70-89% and Level 5 90 100%. It identifies 15 key aspects of Industry 4.0: Culture, Leadership, Budget, Innovation, Capacity, Recruitment, Learning, Project management, Technology, Data, Reporting, Insight, Communications, Service delivery and Internal systems. They offer tips on how to improve and advance to the next level (Digital Leadership Ltd., n.d.).
Deloitte and TM forum's Digital Maturity Model	Deloitte and TM forum's Digital Maturity Model offers 3 digital maturity levels: Early, Developing and Maturing. The model evaluates digital capability across 5 business dimensions and is measured by 179 criteria: Customer, Strategy, Technology, Operations and Organisation & Culture. The report also offers tips on how to improve the digital maturity of the organisation (Deloitte & TM forum, 2018).
Ungerer's Smart Industry Maturity scan	Ungerer's Smart Industry Maturity scan offers 5 maturity levels: starting implementation, average implementation, semi-advanced leaders, advanced leaders, and expert leaders. The maturity level is based on 86 measurement questions across 15 dimensions namely: Strategy, Employees, Management & Leadership, Organizational Culture & Knowledge Management, Marketing & Sales, Customer Services, Channels, Institutional Awareness, Inbound Logistics Activities, Outbound Logistics Activities, Products & Services, Production & Process, IT Management, and Industry 4.0 Technologies (Ungerer, 2019).

For this research, the extended science-based multi-dimensional scan for assessing Industry 4.0 maturity by Ungerer was used to assess the current Industry 4.0 performance of the participating companies (2019). This scan is based on the review of eleven existing Smart Industry or Industry 4.0 scans and has been reviewed by 21 specialists in the field (Ungerer, 2019). The selection process for the review of existing scans was based on 3 criterions namely the completeness of the aspects, the availability of measurement questions and the availability of maturity levels (Ungerer, 2019). The completeness of the aspects is required to properly measure all the relevant aspects of Industry 4.0. The measurement questions are the actual measurement tool, and maturity levels are used to indicate after the analysis of the results to what extent the organization has implemented Industry 4.0 practices.

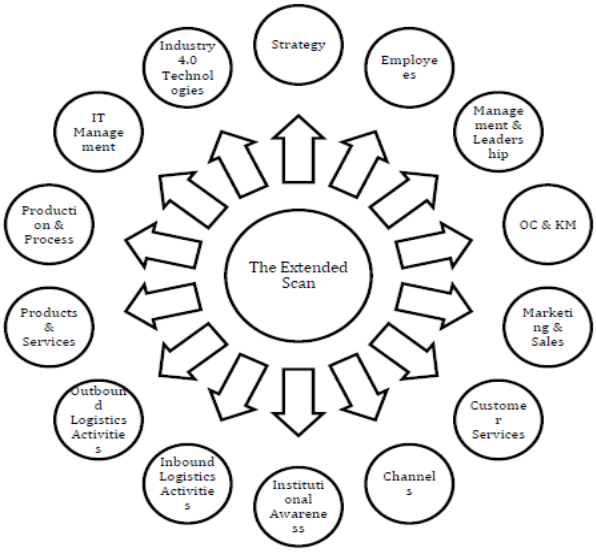

Figure 1. The distribution of the aspects. Reprinted from L.V. Ungerer 2019 retrieved from http://essay.utwente.nl/80073/1/Ungerer_MA_BMS .pdf

All measurement questions for the scan can be found in Appendix D. Every aspect will be assessed by measurement questions on a Likert scale ranging from (1) not at all to (5) fully, where (1) is the least favourable outcome and (5) the most favourable outcome (Ungerer, 2019). Based on the results of the extended multidimensional scan by Ungerer, the performance on each of the 15 Smart Industry aspects, the maturity level and maturity type of the companies can be determined. Ungerer identified 5 maturity levels and 3 maturity types based on the scores of the scan which can be found in figure 2 (2019). Thus, the scan measures Industry 4.0 performance in a holistic and integrated way.

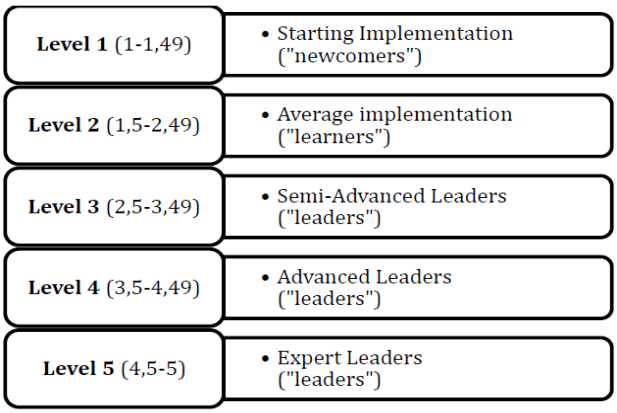

Figure 2. Maturity levels and Maturity types. Reprinted from L.V. Ungerer 2019 retrieved from http://essay.utwente.nl/80073/1/Ungerer_MA_BMS .pdf

3. METHODOLOGY

3.1 Research setting

The research strategy is a qualitative in-depth case study with no stimulus and where contact with the subjects is allowed. The role of the researcher is that of a participant-as-observer because it allows the researcher to gather data accurately and objectively by utilizing both formal and informal interview techniques in addition to the data gathered through observation (Babchuk, 1962). As a participant-as-observer, the researcher can ask structured questions to ensure relevant data is collected. Furthermore, the researcher can ask specific participants questions and compare the responses to verify the reliability of the responses (Babchuk, 1962). The literature study and in-depth case study of the companies are of a qualitative and descriptive nature. Moreover, data was gathered on a quantitative level by using the extended multi-dimensional scan developed by Ungerer (Ungerer, 2019). Therefore, this research makes use of triangulation, which is the combining of qualitative and quantitative methods, to improve the validity of the research (Cooper & Schindler, 2013; Risjord et al., 2001).

Company A is a B2B company located in the East of the Netherlands that manufactures decorative and technical solutions for custom fireplaces. Company A has a revenue of less than 5 million euros and less than 25 employees in total. Company A produces its products exclusively by hand to create the most realistic looking products for the high-end custom fireplace segment. Therefore, the production process of Company A is very labour intensive. They have a single machine which is used for packing the final products so that they are ready for shipment.

Company B is a business to business (B2B) company located in the East of the Netherlands that operates in the steel manufacturing or construction market with a focus on bending and welding steel. Company B has a revenue of less than 5 million euros and less than 25 employees in total. Company B has automated parts of the production process with the help of machinery.

3.2 Research design

The research population are manufacturing SME's in the East of the Netherlands. The subjects, in this case, are managers, CEO's, company representatives and employees of the respected manufacturing SME's who participated in the data collection. The convenience sampling method was used, which is a nonprobability sampling method where the sample is based on certain convenient characteristics like the availability at the time of conducting the research, the proximity to the researcher, and the willingness to cooperate (Etikan, 2016). This sampling method reduces the generalizability of the research findings. However, the aim of this research is not generalizability but instead aims to achieve an in-depth understanding of the Industry 4.0 maturity levels of SME's, the challenges that they face with implementing Industry 4.0 and how the SME's try to overcome these challenges. The time dimension is that of a cross-sectional study because the collected data reflects a snapshot of time and the study was not repeated over an extended period of time (Cooper & Schindler, 2013; Kesmodel, 2018).

3.3 Data collection

3.3.1 The E-SIMS scan

The multidimensional scan was conducted online in the form of a survey. The survey was conducted with the researcher present to ensure all companies had the same understanding of the scan and any questions the respondents may have had could be explained. Throughout the research process, there was a collaboration between the researcher and the original author of the scan to ensure the validity and interpretation of the scan. The number of respondents per company that filled in the survey ranged from three respondents for Company A to two respondents for Company B. According to Muller & Voight, SME's tend to have a single focused business model that is generalizable for the entire organization (2018). Therefore, SME's are particularly suitable to be investigated by conducting surveys that have a single informant as opposed to larger organizations that often employ different business models for different divisions (Müller & Voigt, 2018). Nevertheless, when possible more than 1 respondent filled in the survey because it increases the validity of the results. Furthermore, it allowed the opportunity of cross-case analysis. Besides, any contradictory scores between the respondents of the same company could offer interesting insights and a base for discussion during the company workshops.

The results were visualized by using radar plots because they are a useful way of presenting multivariate data, which is applicable for this research due to the 15 aspects of the scan (Saary, 2008). However, there is a critique of the use of radar plots. For instance, their circular layout makes them harder to read than for example a bar plot, especially if there are many variables or webs (Nowicki & Merenstein, 2006). Despite that, because there were less than 3 respondents per company and 2 companies in total all charts had a maximum of 2 webs per radar chart, thus the readability of the radar plots was sufficient. When choosing which colours to use in the radar charts, colour-blindness was taken into consideration ensuring the readability of the charts.

3.3.2 Company tour

A company tour was given by both participating companies to familiarize the researcher with the organization and its processes. The tour for Company A was given by the owner/general manager and for Company B by the general manager. During the tour, plans for future implementations and hurdles encountered thus far were also discussed. The observations made could then be used and compared to the results of the scan and thus increase the validity of the results by making use of triangulation (Risjord et al., 2001). The key observations made during the company tours are summarized in the table below.

Table 2: Key observations of company tours

Company A	Company B
- No innovation or digital strategy - The production process is completely manual, single machine for wrapping - Logistics process is manual - No inventory management system present - IT is outsourced - Work instructions not paperless - No meetings with workforce	- No innovation or digital strategy - Production process supported by machines, but no automation or sensors - Logistics process is manual - Inventory management system present, but no automation - IT is outsourced - Work instructions not paperless - Infrequent informal meetings with workforce

- No (digital) system in place for sharing ideas	- No (digital) system in place for sharing ideas

3.3.3 Company workshops

After the analysis of the results of the scan, it could be determined to what extent Industry 4.0 has been adopted in the companies. The results will be presented to the company at the beginning of the workshops and future Smart Industry implementations will be explored via a group interview workshop called *minigroups*. Minigroups function essentially the same as focus groups but have fewer participants, generally between 2-6 participants (Greenbaum, 1998). Minigroups were chosen as opposed to the more popular *focus groups*, which have between 6-10 participants, because of the small size of the SME's studied. Participants should be able to articulate their ideas, offer a wide range of positions yet their backgrounds should not be too far from each other because this could generate conflict (Cooper & Schindler, 2013). Therefore, the number of participants that could be selected who fit those criteria made minigroups the preferred option over focus groups.

Group interviews are a valuable method to interpret previously measured quantitative results, in this case the E-SIMS scan, stimulating new ideas and highlighting opportunities making it particularly suited to explore how SME's try to overcome the challenges associated by implementing Smart Industry (Cooper & Schindler, 2013). The role of the researcher here is that of a moderator. A moderator's role is to guide the process instead of giving recommendations to the companies. A list of questions was prepared to guide the discussion and ensure all topics were covered. The list of questions used by the moderator can be found in Appendix B. By using this method, we can get a view of how SME's look at the results of the scan and explore how they plan to improve their Industry 4.0 performance based on the results, or whether they plan to improve at all. However, on request of the companies, an advisory report was delivered with suggestions on how to further incorporate Industry 4.0 technologies and practices in their companies. Afterwards, the participants were debriefed so that their insights could enrich the interpretation of the data.

4. EMPIRICAL RESULTS

In this chapter, the results of the E-SIMS scan and the workshops of both companies will be presented and analyzed. On top of that, cross-case analysis will be conducted. We will first look at the maturity level of both companies and highlight some of the highest and lowest scoring aspects, followed by the results of both the E-SIMS scan and the minigroup workshops which will be discussed and analyzed in-depth for both companies.

4.1 Maturity assessment

A summary table of all the average scores per aspect for both companies can be found in Table 3.

Average of all aspects (A)	1.809

Company A has a total average score of 1.809. This fits a maturity level 2 (score between 1.5 – 2.49) which is the "Learners" category with average implementation.

The highest scoring aspects of Company A are A8: Institutional awareness (3.3) and A3: Management & Leadership (2.6). The lowest scoring aspects of Company A are A15: Industry 4.0 technologies (0.5), A13: Production & Process (1) and A10: Inbound logistic activities (1.2).

Average of all aspects (B)	1.774

Company A has a total average score of 1.774. This also fits a maturity level 2 (score between 1.5 – 2.49) which is the "Learners" category with average implementation.

The highest scoring aspects of Company B are A3: Management & Leadership (4) and A1: Strategy (2.857). The lowest scoring aspects of Company B are A15: Industry 4.0 technologies (1), A9: Sustainability (1), A7: Channels (1.2) and A11: Outbound logistic activities (1.2).

4.2 E-SIMS & Minigroup workshops

In this chapter, the results of the E-SIMS scan and the minigroup workshops are summarized and analyzed for both companies. Certain aspects were not applicable or did not give any interesting insights into one or both companies researched and are therefore not covered in this chapter. A complete per aspect analysis for both companies can be found in Appendix C. Below in table 3 all average scores per aspect are summarized for both companies.

Table 3: Summary of average scores per aspect per company

Summary of average scores	Company A	Company B
Aspects	Scores	Scores
Introduction questions	2.318	2.727
A1: Strategy	2.286	2.857
A2: Employees	1.833	2.333
A3: Management & Leadership	2.6	4
A4: Company culture & Knowledge management	2.5	2.2
A5: Marketing & Sales	1.5	1.4
A6: Customer services	1.6	1.4
A7: Channels	1.4	1.2
A8: Institutional awareness	3.3	1.4
A9: Sustainability	1.7	1
A10: Inbound logistic activities	1.2	2
A11: Outbound logistic activities	1.6	1.2
A12: Products & Services	1.571	1.714
A13: Production & Process	1	1.3
A14: IT Management	2.55	1.6
A15: Industry 4.0 technologies	0.5	1
Total average of all aspects	1.809	1.774

Below in figure 3, a radar chart can be found that summarizes the average score per aspect for both companies. A larger version of the chart which has improved readability can be found in Appendix A.

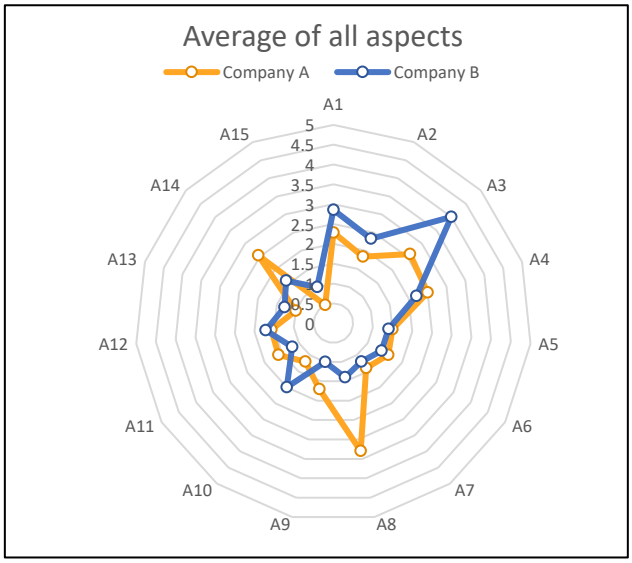

Figure 3. Average of all aspects of all companies.

4.2.1 *Industry sector*

Average of Introduction questions (A)	2.318

The introduction questions show us that employees in the sector of Company A, a niche manufacturing market for custom fireplace solutions, view the sector as generally stable with no large growth in revenue. The sector is not challenged by new competitors or new innovative products. On the other hand, there are a lot of technological developments undergoing, like Smart Industry technologies, that are expected to influence the sector Company A operates in.

Average of Introduction questions (B)	2.727

The introduction questions show us that employees in the sector of Company B, the manufacturing or construction sector with a focus on metal and steel bending, view the sector as generally stable but still growing. However, compared to other sectors the growth of the sector is not viewed as rapid growth. The sector is not challenged by new competitors or new innovative products. However, current competitors do constantly challenge the position of Company B and the threat of cheap substitutes is also higher than in the sector of Company A.

4.2.2 *Aspect 1 – Strategy*

The strategy aspect explores how important Industry 4.0 is to the success of the organization and to what extent a clear strategy has been adopted by the organization for the implementation of Industry 4.0.

Average of A1 – Strategy (A)	2.286

Company A indicated that the adoption of Industry 4.0 is not viewed as important for the success of the organization. During the workshop, it became clear that the strategy aspect was viewed as vital for the successful implementation of Industry 4.0 in the organization. Nevertheless, management has ideas on how to improve Smart Industry adoption, but a clear vision or strategy, as well as intent and a budget, are still lacking.

Average of A1 – Strategy (B)	2.857

Company B's has a relatively high score of 2.857. For Company B the adoption of Industry 4.0 is viewed as important for the success of the organization, which is partly due to the metal manufacturing sector that they operate in. Company B does have plans and budgets for investing in Industry 4.0, which will be explored in the following aspects, but a clear digital vision was still lacking.

4.2.3 *Aspect 2 – Employees*

Aspect 2 explores how information and developments are communicated within the organization, whether employees are stimulated to share ideas and whether there is a digital system in place to support this.

Average of A2 – Employees (A)	1.833

Company A does communicate developments to their employees to keep them up to date. However, there are no regular meetings to discuss developments and share new ideas. Information on the opportunities of Industry 4.0 is not shared with employees at all. Company A explained that the reason for this is that they have a lot of workers with low education that handle manual labour tasks. Furthermore, there is no digital system in place that encourages information sharing. The work instructions for employees are still printed on paper, although Company A does plan to digitalize this in the future.

Average of A2 – Employees (B)	2.333

Company B also communicates developments with their employees to keep them up to date. Furthermore, the owner and management do frequently share information and ideas, also regarding Industry 4.0, but through informal meetings. There is no digital system in place that encourages information sharing nor are there plans for it in the near future. The work instructions are not paperless yet either, but Company B does plan to digitalize this in the future as well. Company B did indicate during the workshop that they view employees as an important aspect for adopting Industry 4.0.

4.2.4 *Aspect 3 – Management & Leadership*

Aspect 3 Management & Leadership explores how much management supports the adoption of Industry 4.0, whether management has the necessary skills to adopt Industry 4.0 practices and to what extent employees from all departments are involved in making important business decisions.

Average of A3 – Management & Leadership (A)	2.6

Aspect 3 is one of the highest-scoring aspects for Company A, Question 25 and 27 focus on to what extent the management supports the implementation of Industry 4.0 and to what extent they have the necessary skills required to support the implementation. These scored very high, but it is important to note that the respondents were the owner and people in a management position which could have possibly biased the results. The other questions regarding more practical applications of Industry 4.0 like the extent management encourage trying out Industry 4.0 technologies in daily practices or to what extent management currently uses Industry 4.0 technologies for decision-making were all scored with none (1). During the workshop, Company A did state that it views management & leadership as a vital aspect for the adoption of Industry 4.0, but it was not actively encouraged and being implemented yet.

Average of A3 – Management & Leadership (B)	4

The Management & Leadership aspect is the highest scoring aspect for Company B. However, during the workshop it became apparent that the adoption and use of Industry 4.0 technologies is not as actively encouraged as the score would make it appear. It is possible to explain this discrepancy because the general manager and owner filled in the scan together, possibly biasing this result. The aspect is viewed as critical for the successful

implementation of Industry 4.0, but the company is not actively implementing Smart Industry technologies yet.

4.2.5 Aspect 4 – Company culture & Knowledge management

Aspect 4 tries to gain insight in the company culture and knowledge management by asking questions like to what extent training is offered to employees, to what extent out of the box thinking is encouraged to create new innovative ideas and whether the organisation puts enough effort in making the organisation "smart".

Average of A4 – Company culture & Knowledge management (A)	2.5

Scores for Company A ranged from none (1) to great (4), scoring questions regarding the application of gained knowledge and supporting out of the box thinking high, but questions regarding digitization and smart factory were all scored either none or low. The company experiences a lack of expertise in the workforce and there is no training regarding Smart factory.

Average of A4 – Company culture & Knowledge management (B)	2.2

Company B's scores ranged from none (1) to moderate (3). There is no training for the workforce regarding smart factory, but the company does try to improve the knowledge about digitization except this is mainly for people working in management positions. Company B does put more effort in trying to make the organisation smart, although it became apparent during the workshops that this still involves incorporating Industry 3.0 technologies.

4.2.6 Aspect 5 – Marketing & Sales

Aspect 5 Marketing & Sales explores to what extent online behaviour is monitored and utilized by the Marketing & Sales department and to what extent the sales process is done digitally.

Average of A5 – Marketing & Sales (A)	1.5

Company A admitted marketing does not have priority because there is no need in their B2B setting with close relations with their customers. There is no dedicated marketing department, and no online behaviour is tracked and utilized for marketing purposes. The company has no plans to do so in the future either.

Average of A5 – Marketing & Sales (B)	1.4

For Company B there is no focus on marketing because the company is currently capped in its production due to the size of the facility. Therefore, they cannot produce more than they currently are and thus there is no need for marketing. There are no plans to move to a larger facility at this moment. The company hinted that without the capped production, they likely still would not track customer behaviour online because they do not believe it is vital for a B2B company.

4.2.7 Aspect 10 & 11 – Inbound & Outbound logistic activities

Aspect 10 and 11, Inbound & Outbound logistic activities, explores to what extent the organization collaborates with their suppliers and customers, and the extent I4.0 technologies are used for inbound and outbound logistic activities.

Average of A10 – Inbound logistic activities (A)	1.2
Average of A11 – Outbound logistic activities (A)	1.6

Aspect 10 is one of the lowest scoring aspects of Company A Nothing is automated or paperless when it comes to inbound deliveries. Furthermore, there is no collaboration with suppliers. Because of the lack of a digital inventory management system, there is no option and plan to do so in the future.

Aspect 11 scores a little higher than the previous aspect for Company A because of the question about automatic tracking of products in transit which is standard for most deliveries in the Netherlands.

Average of A10 – Inbound logistic activities (B)	2
Average of A11 – Outbound logistic activities (B)	1.2

Company B has recently improved their logistics. Instead of using pallets, they have switched to plastic trays that are labelled for each product. They have horizontally integrated this system with their suppliers, meaning their suppliers deliver their products in the labelled trays. The trays are then returned empty by Company B and the process repeats. Company B plans to improve this system in the future by adding QR-codes to the trays so that they can simply be scanned and automatically logged in an inventory management system. Company B did state that they perceive any plans for horizontally integrating systems with suppliers as a difficult task because most companies operating in the industry do not focus on Smart Industry and have no plans to do so in the future.

Aspect 11 is one of the lowest scoring aspects for Company B Company B's current focus is on improving the Outbound logistic activities. They have already started incorporating these improvements for the Inbound logistic activities which explains why this aspect scores lower.

4.2.8 Aspect 12 – Products & Services

Aspect 12 Products & Services explores to what extent Industry 4.0 technologies support servitization, whether data is used to improve current products and services and to what extent that is done digitally.

Average of A12 – Products & Services (A)	1.571

Because of the nature of the semi-finished products Company A produces, there is no option for technologies like sensors to track e.g., product health. However, the organization does develop some new products using digital means like CAD software design and plans to use and explore these methods more in the future.

Average of A12 – Products & Services (B)	1.714

Due to the nature of the semi-finished products Company B produce there is no option e.g., sensors to detect product health either. Company B does use data to improve their current products and services but during the workshop, it became apparent this is only actual feedback received from customers.

4.2.9 Aspect 13 – Production & Process

Aspect 13 Production & Process explores to what extend the production process is automated, to what extent Industry 4.0 technologies are used to monitor and improve the process, and whether production-related data is shared with partners.

Average of A13 – Production & Process (A)	1

This is the lowest scoring aspect of Company A with every question scoring none (1). This is due to the production process being very labour intensive. Everything is done by hand to create a realistic look of the product. Company A does not plan to improve this aspect because their current production process is considered vital for their business and their main selling point.

Average of A13 – Production & Process (B)	1.3

For Company B, the production process is less labour intensive than Company A and uses more machines. However, nothing is automated nor monitored, and no data is collected and therefore shared with partners. The company indicated their main bottleneck is currently in logistics and inventory management.

Furthermore, they are currently capped in production due to the size and thus improving this aspect does not have priority.

4.2.10 Aspect 14 – IT Management

Aspect 14 IT Management explores to what extent data is collected, the extent to which the organization can respond to changes regarding IT, the level of IT security and whether IT is integrated with suppliers and customers.

Average of A14 – IT Management (A)	2.55

Company A's scores scored high on questions about IT security and the functionality of the website. However, there is no internal IT system and IT department because anything related to IT is outsourced to a third party, which is often the case for SME's. There is no data being collected and utilized either. The organisation does not plan to improve this aspect in the future, viewing IT Management as something that needs to work but not something that can create and add value.

Average of A14 – IT Management (B)	1.6

For Company B, the only question that was scored with very great was the question concerning the website being operative on all desired platforms. Company B also outsources anything IT related. Due to the lack of expertise within the company and viewing IT Management as something that needs to work instead of value creation, they do not plan to improve this aspect in the future. Furthermore, Company B showed a reluctance towards openly sharing data with potential partners out of fear that the data can be used against them.

4.2.11 Aspect 15 – Industry 4.0 technologies

Aspect 15 explores what Industry 4.0 technologies specifically have been adopted thus far in the organization.

Average of A15 – Industry 4.0 technologies (A)	0.5

Company A only makes use of Cloud Computing out of convenience because they have no internal IT system and IT department. Therefore, their data is stored in the cloud.

Average of A1 – Industry 4.0 technologies (B)	1

Company B uses Cloud Computing and Advanced Materials. Company B uses Cloud Computing out of convenience just like Company A. They also do not have an internal IT system and department; thus, their data is stored in the cloud. During the scan, the respondents filled in they make use of Advanced materials but during the workshop, the participants could not elaborate what kind of advanced materials specifically.

5. DISCUSSION

In this chapter, the empirical results of the E-SIMS scan and the minigroup workshops from the previous chapter are compared to the findings from the literature. Moreover, the theoretical and practical implications of this research are discussed as well as some recommendations for practice to help SME's take the next step in their Industry 4.0 journey.

5.1 Theoretical implications

The main aim of this research was to give both theoretical and practical insights into how SME's anticipate Industry 4.0, what the main barriers are and how they try to overcome these barriers. In this section, we will explore the main hurdles the researched companies faced and whether these are in line with the findings of previous literature.

The main hurdles the researched companies faced when implementing Industry 4.0 are the lack of a clear innovation or digital strategy which is in line with the findings of Radziwon et al., 2014; Schröder, 2016. Moreover, both researched companies showed an attitude towards change where the driver is necessity instead of opportunities which is in line with theories of Müller et al., 2018; Radziwon et al., 2014; Schröder, 2016; Smetsers, 2016. Both companies showed a resistance to change which is often seen by SME's when adopting new technologies. This resistance to change by employees is partly explained as the fear of the unknown due to a lack of understanding of new technologies (Peillon & Dubruc, 2019; Schröder, 2016; Smetsers, 2016). From a management point of view, another factor playing a role in the resistance to change attitude by SME's can be the short-termism and focus on operational activities as well as a lack of knowledge concerning new technologies. During the workshops Company B also showed a reluctance towards the sharing of data with potential partners out of fear that this data can be used against them. Moreover, they mentioned this negative attitude towards openly sharing data is common among the companies they work with.

Furthermore, both companies made it clear they experience a lack of financial resources as well as access to employees with knowledge of Industry 4.0 required for Smart Industry implementations. This results in the inability to identify all opportunities of Industry 4.0 for SME's due to lack of expertise and knowledge available while also exacerbating the already difficult task for SME's to incorporate and create new smart business models like servitization, which is in line with the theories of Matt et al., 2020; Mittal et al., 2018; Peillon & Dubruc, 2019; Schröder, 2016; Smetsers, 2016. The lack of available experts in the field of Smart Industry makes it difficult for SME's to implement Smart Industry technologies independent of the availability of financial resources.

In addition, a vital aspect of Smart Industry is cooperation and partnerships with customers and suppliers due to the integration of systems but when customers and suppliers are not involved in incorporating Industry 4.0 it is difficult and less effective for companies to do so. Many SME's do not have supporting structures like their own IT system and the lack of uniform standards among SME's complicates this integration process even further. This was also experienced by Company B and is in line with the theories of Müller et al., 2018; Radziwon et al., 2014; Schröder, 2016; Smetsers, 2016.

5.2 Practical implications

The empirical results show us that a Smart Industry scan is a low threshold way for SME's to gain insight into the different dimensions of Smart Industry and their current performance across these dimensions. This is especially helpful for lower maturity SME's because they often lack knowledge and awareness of Smart Industry. Therefore, a Smart Industry scan can guide the SME's agenda for future implementations and helps allocate their limited resources more effectively.

5.2.1 Recommendations for practice

In this section, we will explore suggestions that can help guide SME's agenda when implementing Industry 4.0 in their organization as well as proposing ideas to overcome some of the barriers SME's face so they can take the next step in their Industry 4.0 journey. A distinction has been made for internal and external recommendations.

5.2.1.1 Internal recommendations practice

When implementing Industry 4.0 SME's need to develop a clear business and innovation strategy. By determining long-term business and innovation strategies, SME's can better allocate their limited resources by establishing goals, deadlines, and budgets, which can help overcome the short-termism and resistance to change barrier that SME's face when implementing Industry 4.0 innovations (Moeuf et al., 2018; Pisano, 2016; Radziwon et al., 2014; Somohano-Rodríguez et al., 2020). Also,

it is important to communicate these strategies and goals with employees to encourage the sharing of information and ideas. Therefore, it is suggested to have regular work meetings and an online platform where knowledge, ideas and feedback can be shared (Haddad et al., 2019; Padilha & Gomes, 2016; Sattayaraksa & Boon-itt, 2018). Because the success of the organization is largely based on the skills of the employees it is recommended to offer training and workshops to increase their Industry 4.0 knowledge and skills (Industry Working Group of Universiteit Twente, 2018). Another recommendation is to allow your customers to communicate with you via multiple channels e.g., website, phone, and e-mail. Regular contact with your customers can give insights into customer needs and helps identify opportunities for new products and services. Besides, multiple digital channels allow for the monitoring and the collection of data to identify trends and customer needs. Data analytics is an essential aspect of Industry 4.0 and fundamental for many Industry 4.0 technologies like artificial intelligence, machine learning, and predictive maintenance. Moreover, it does not require large capital investment for SME's to be able to utilize data analytics. Therefore, it is recommended to start with collecting and analyzing data. Data analytics can for example in lower maturity SME's guide marketing or product decisions based on your customer demographic. Additionally, as a next step data analytics combined with sensors and the IIoT allows for the automation of processes e.g., automatically ordering new supplies when inventory drops below a specific value or predictive maintenance to reduce production downtime. Overall, it is important for SME's to incrementally implement Industry 4.0 technologies in their organization while focusing on transforming their organizational culture to be more open and innovative.

5.2.1.2 External recommendations practice

There are a variety of external opportunities available for SME's that can help overcome the barriers they face when adopting Industry 4.0.

There are funding programs available in the EU, US and several Asian countries for SME's that want to implement Industry 4.0 which can help overcome the hurdle of the lack of financial resources (Matt et al., 2020). Another external opportunity to overcome the financial resource barrier is to utilize pay-per-use contracts, leasing of machinery and financing by customers (Müller, 2019). Moreover, there are "Industry 4.0 field/test labs" available for SME's to try out, develop and test new I4.0 technologies without solely having to take out funds or loans for the innovation (Industry 4.0 Advanced Manufacturing Forum, 2021; Stolwijk & Punter, 2019). These field labs can increase the understanding and knowledge of Industry 4.0 which can help SME's identify the opportunities of Smart Industry. This can reduce the fear towards new technologies and help reduce the resistance to change barrier SME's face. Moreover, partnerships and collaborations are of high importance when successfully implementing Industry 4.0 and can help SME's overcome several barriers. Partnerships can help overcome the financial resource barrier because the costs and risks of innovation can be shared among partners. Furthermore, because collaborations help SME's find partners with an interest in Industry 4.0 it can help set uniform standard for SME's while possibly starting to integrate systems with the participating partners. In addition, collaborations can help share information, train employees, and meet experts which can improve the access to a workforce with Smart Industry knowledge and skills.

5.3 Limitations and future research

This research has several limitations because of limited resources and time constraints due to the research product being a bachelor thesis. Unfortunately, the COVID-19 situation exacerbated this, making it even more difficult to find companies willing to participate in this research. Therefore, the small sample size of two companies is too small to make a general insight into the implementation of Industry 4.0 for SMEs and how they overcome the challenges associated with it. Furthermore, both companies studied were closer to small-sized companies rather than medium-sized and both were in the earlier stages of Industry 4.0 maturity. Working with lower maturity companies was more difficult because they have less awareness and understanding of Industry 4.0 concepts. On top of that, some of the questions used by the E-SIMS scan to assess the maturity level were not applicable or relevant for companies on the smaller side. Unfortunately, the number of respondents for the E-SIMS scan and the company workshops are also lower than was preferable due to the COVID-19 situation, reducing the validity of the results.

It would have been interesting to have included an SME company that has already successfully implemented Industry 4.0, fitting the higher maturity categories i.e., advanced leaders or expert leaders, to explore successful strategies to overcome the barriers SME's face when adopting Industry 4.0. Unfortunately, it was not possible to find a high maturity level SME to participate in this research and hence a suggestion to be explored in future research. Another suggestion for future research is to establish guidelines for SME's in the form of a roadmap that can guide the implementation of Smart Industry. It is recommended to separate this roadmap in categories based on characteristics like company size, because a small-sized enterprise generally operates drastically different from a medium-sized enterprise, and the industry the company operates in.

6. CONCLUSION

This research attempts to provide comprehensive insights into the adoption of Industry 4.0 by manufacturing SME's by exploring the challenges they face and how these challenges can be overcome, leading to practical recommendations to guide SME's Industry 4.0 journey. Therefore, this research contributes to the current body of knowledge regarding Industry 4.0 adoption by developing a theoretical and conceptual framework built on current research on Industry 4.0 adoption, current research on SME's innovation strategies and the E-SIMS scan. Moreover, this research is especially interesting because its focus on SME's contributes to bridging the research gap that exists because most existing research on Industry 4.0 adoption has focused on larger enterprises. SME's face different barriers than larger enterprises when adopting Industry 4.0. The main barriers of Industry 4.0 adoption by SME's identified in this research are the lack of knowledge and awareness of the concept, lack of overall innovation and Smart Industry strategies, fewer financial resources, short-termism, resistance to change, lack of access to employees with Smart Industry knowledge and skills, lack of uniform standards, and security concerns. Long-term innovation strategies are key to overcome barriers like short-termism and resistance to change by guiding the allocation of resources and identifying which technologies align with corporate objectives to create value. A Smart Industry scan can help guide SME's agenda for future Industry 4.0 implementations by identifying the performance on the different dimensions of Industry 4.0. Moreover, SME's should foster an open and innovative culture that encourages the sharing of ideas and experimentation by employees through e.g., regular work meetings and an online communication platform. Furthermore, SME's should also foster communication with their customers to gain insight into trends and customer needs. External opportunities like open innovation, partnerships and Industry 4.0 field labs can make Smart Industry innovations for SME's more accessible by sharing knowledge,

the financial resources and risks, training employees in Smart Industry skills, and help set uniform standards. The main limitation of this research is the small sample size of two case companies that are both closer to small-sized companies than medium-sized and both were in the earlier stages of Industry 4.0 maturity. Thereby, for future research, it could be very interesting to include higher maturity level SME's to explore their successfully adopted Smart Industry innovation strategies and develop a roadmap for SME's Smart Industry adoption.

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APPENDICES

8.1 Appendix A: Summary average scores for all companies

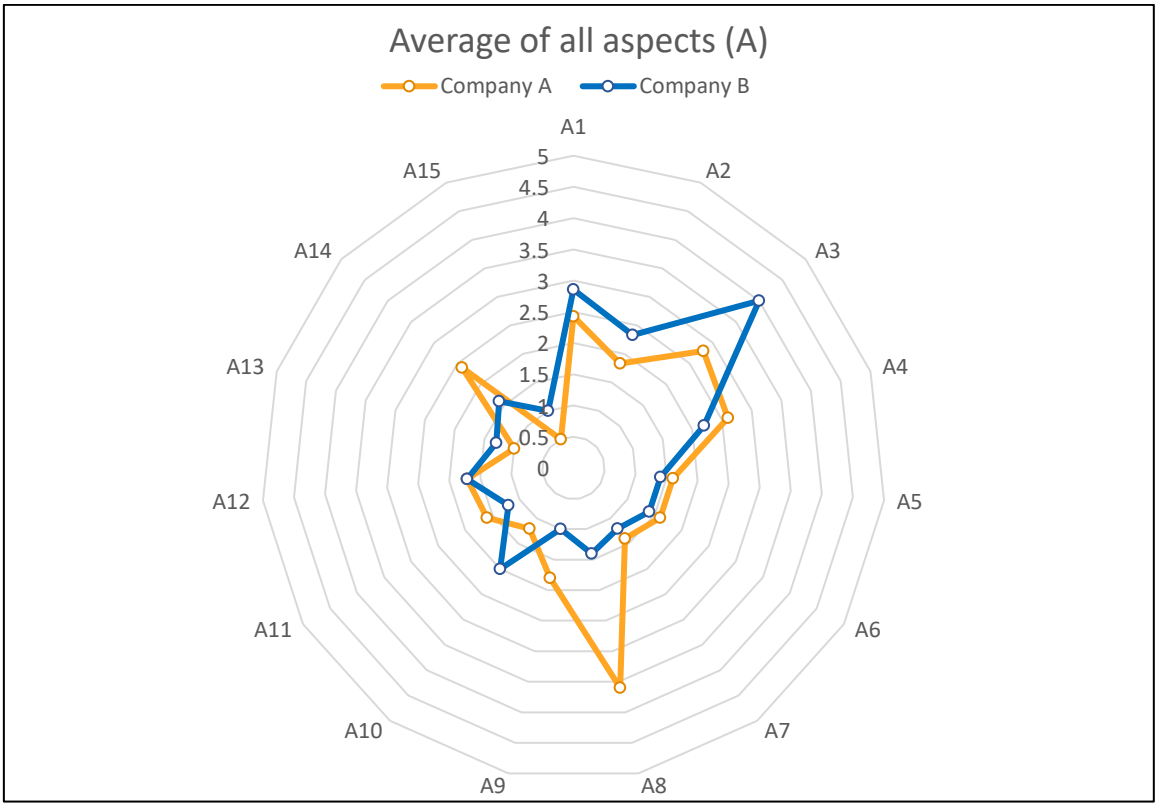


Figure 4. Radar chart with averages of all aspects for both companies.

Table 4: Summary of average scores per aspect for company A.

Company A	
Aspects	**Score**
Introduction questions	2.318
A1: Strategy	2.286
A2: Employees	1.833
A3: Management & Leadership	2.6
A4: Company culture & Knowledge management	2.5
A5: Marketing & Sales	1.5
A6: Customer services	1.6
A7: Channels	1.4
A8: Institutional awareness	3.3
A9: Sustainability	1.7
A10: Inbound logistic activities	1.2
A11: Outbound logistic activities	1.6
A12: Products & Services	1.571
A13: Production & Process	1
A14: IT Management	2.55
A15: Industry 4.0 technologies	0.5
Total average of all aspects	**1.809**

Table 5: Summary of average scores per aspect for company B.

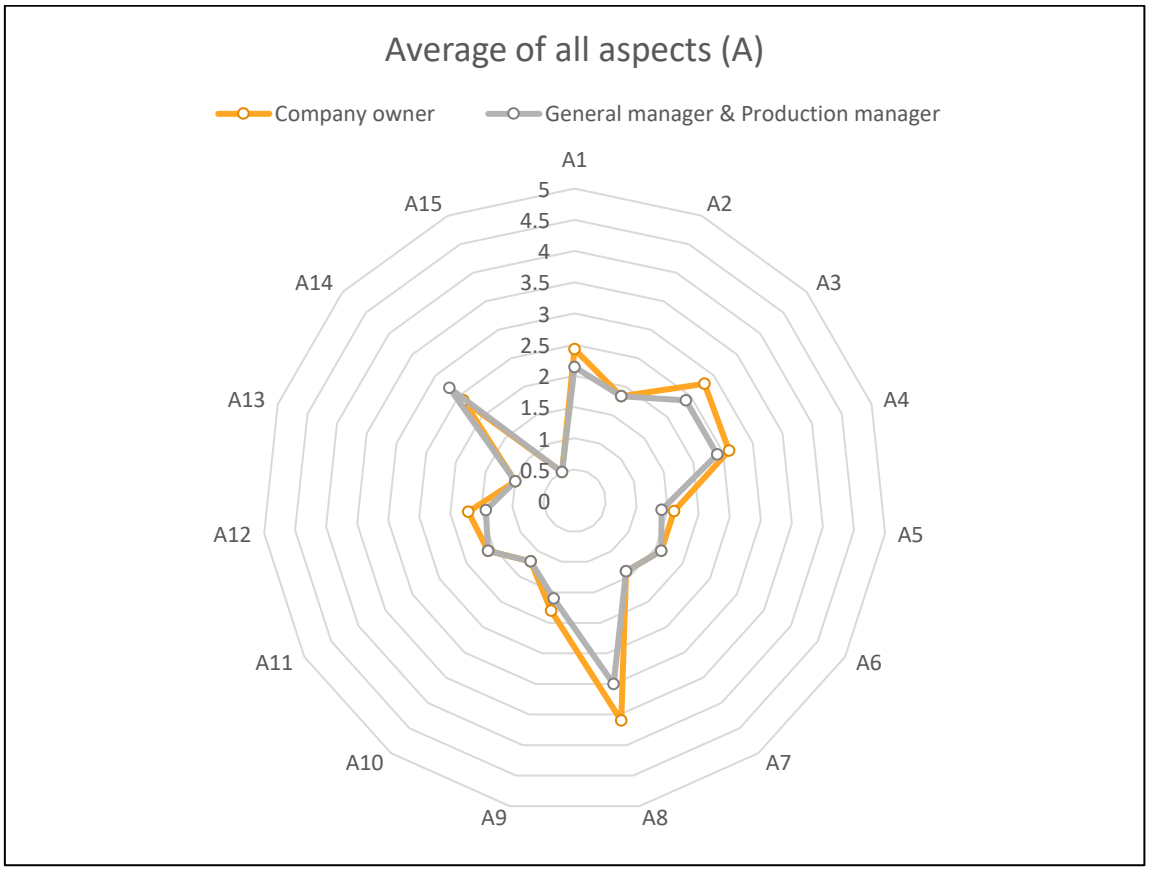
Company B	
Aspects	**Scores**
Introduction questions	2.727
A1: Strategy	2.857
A2: Employees	2.333
A3: Management & Leadership	4
A4: Company culture & Knowledge management	2.2
A5: Marketing & Sales	1.4
A6: Customer services	1.4
A7: Channels	1.2
A8: Institutional awareness	1.4
A9: Sustainability	1
A10: Inbound logistic activities	2
A11: Outbound logistic activities	1.2
A12: Products & Services	1.714
A13: Production & Process	1.3
A14: IT Management	1.6
A15: Industry 4.0 technologies	1
Total average of all aspects	**1.774**

8.2 Appendix B: List of questions used by the moderator during minigroup workshops

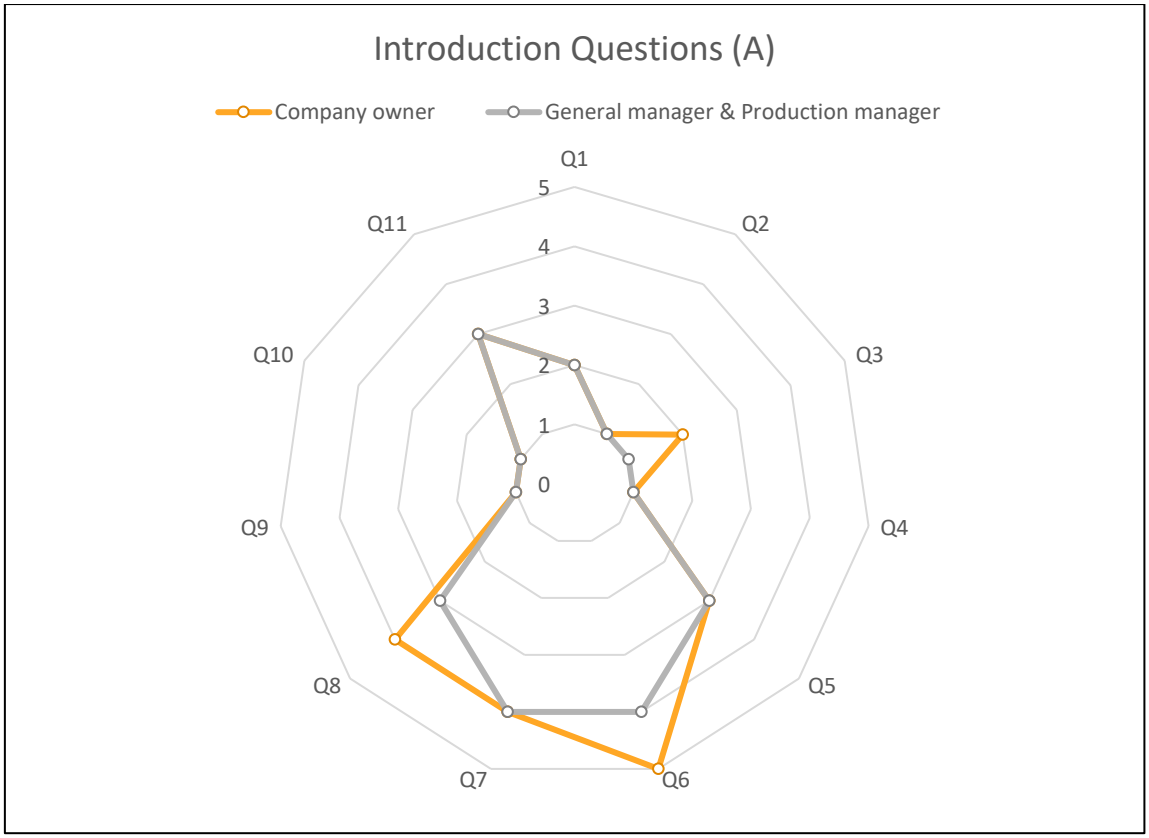
Table 6: List of questions used by the moderator during minigroup workshops

To what extent is your company involved in Industry 4.0? - Does your company have a clear strategy involving Industry 4.0?
What do you think of the results of the scan? - Are the results as expected? - Are there any scores that stand out to you? - Why do those scores stand out?
Which aspects are most important for your business operations? - Why do you believe those aspects are most important for your business operations?
Based on the results, which aspects would you like to improve? - Which aspects have priority? - Why do you focus on those aspects? - How do you think you can improve those aspects? - What specific actions can you take?
Within what timeframe do you want to improve those aspects/take action?
Which aspects do your competitors focus on? - Relative to your competitors, what aspects do you believe you are lagging? - Relative to your competitors, what aspects do you believe you are ahead?
What do you believe are the main opportunities of Industry 4.0? - What aspect(s) would these opportunities include?
What do you find most difficult about Industry 4.0? - What challenges do you encounter? - What are the most challenging aspects for you? - Why are those aspects most challenging? - How do you plan to overcome these challenges?

8.3 Appendix C: Radar charts & Aspect analysis of both companies.

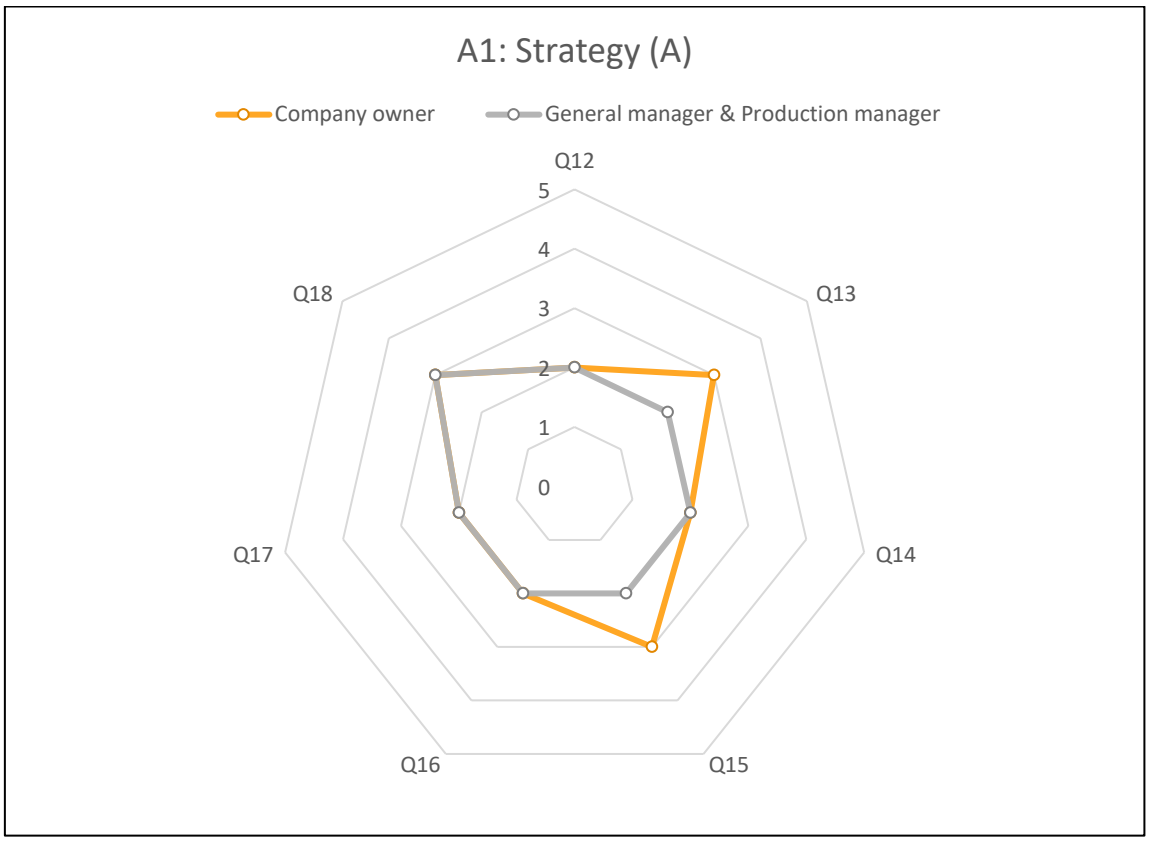


Total average of all aspects (A)	1.809



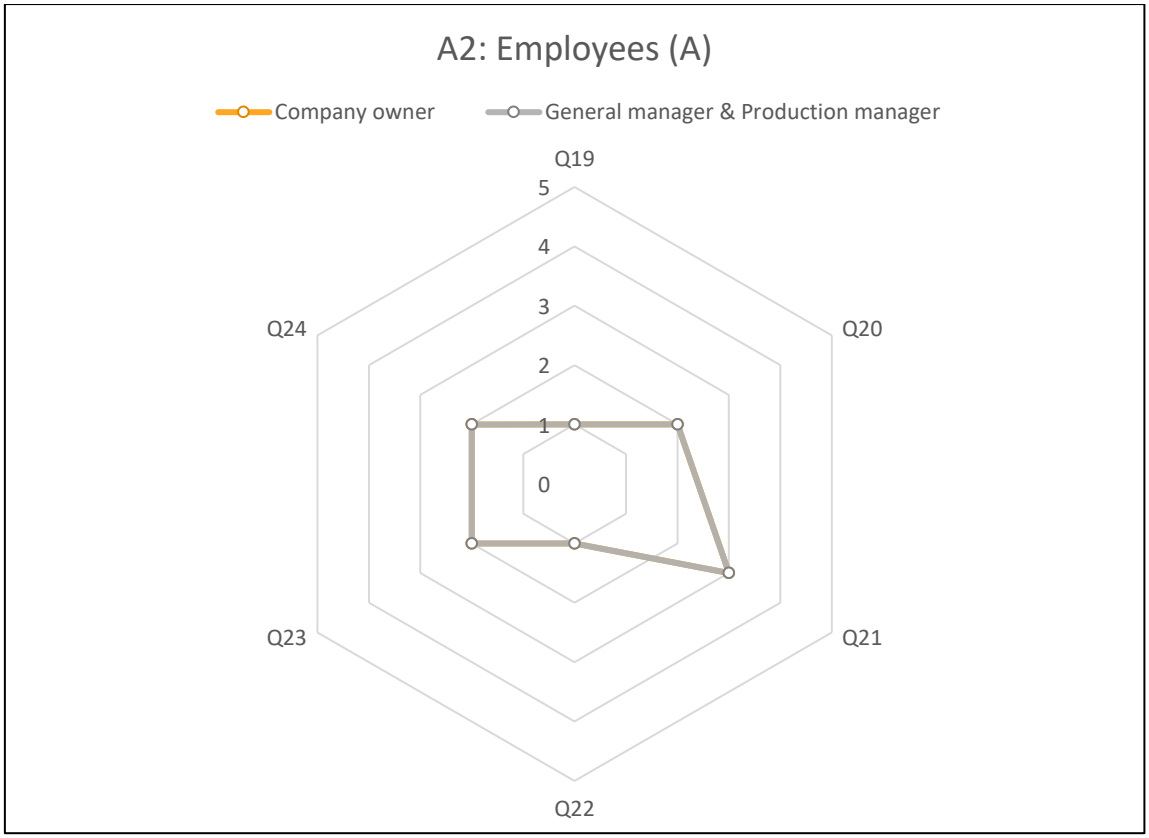
Average of Introduction questions (A)	2.318

The introduction questions show us that employees in the sector of Company A, a niche manufacturing market for custom fireplace solutions, view the sector as generally stable with no large growth in revenue. The sector is not challenged by new competitors or new innovative products. On the other hand, there are a lot of technological developments undergoing that influence the sector Company A operates in.



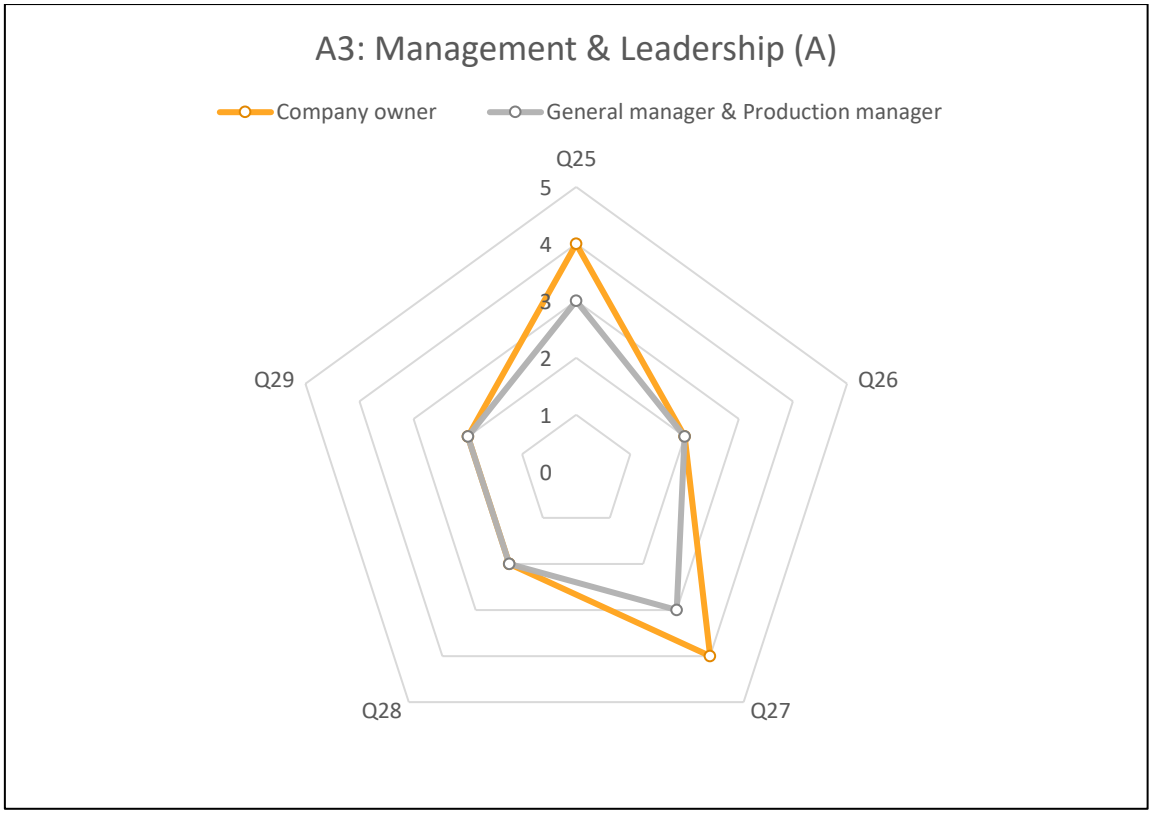
Average of A1 – Strategy (A)	2.286

The strategy aspect explores how important Industry 4.0 is to the success of the organization and to what extent a clear strategy has been adopted by the organization for the implementation of Industry 4.0. In general, the results for strategy for Company A range from low (2) to moderate (3). Company A indicated that the adoption of Industry 4.0 is not viewed as important for the success of the organization. During the workshop, it became clear that the strategy aspect was viewed as vital for the successful implementation of Industry 4.0 in the organization. Nevertheless, management has ideas on how to improve Smart Industry adoption, but a clear vision or strategy, as well as intent and a budget, are still lacking.



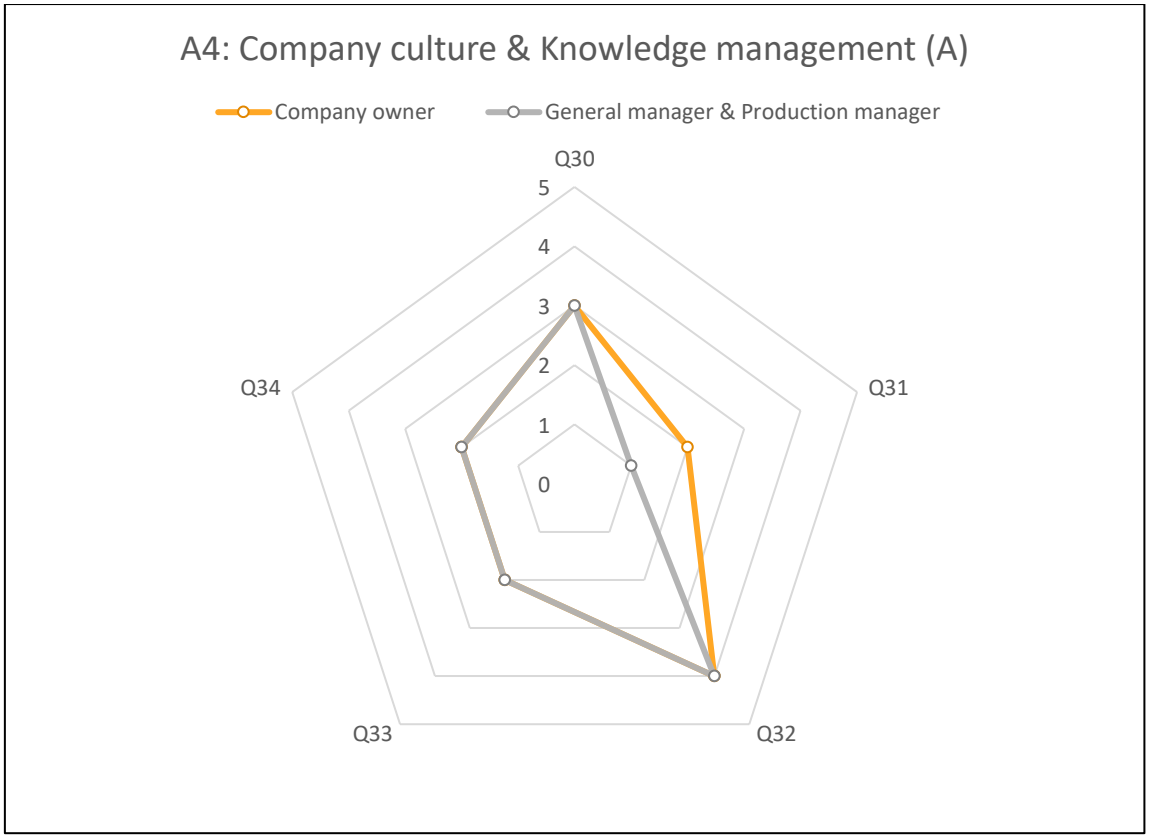
Average of A2 – Employees (A)	1.833

Aspect 2 explores how information and developments are communicated within the organization, whether employees are stimulated to share ideas and whether there is a digital system in place to support this. The scores for Company A ranged from none (1) to moderate (3). Company A does regularly communicate developments to their employees to keep them up to date. However, there are no regular meetings to discuss developments and share new ideas. Information on the opportunities of Industry 4.0 is not shared with employees at all. Company A explained that the reason for this is that they have a lot of workers with low education that handle manual labour tasks. Furthermore, there is no digital system in place that encourages information sharing. The work instructions for employees are still printed on paper, although Company A does plan to digitalize this in the future.



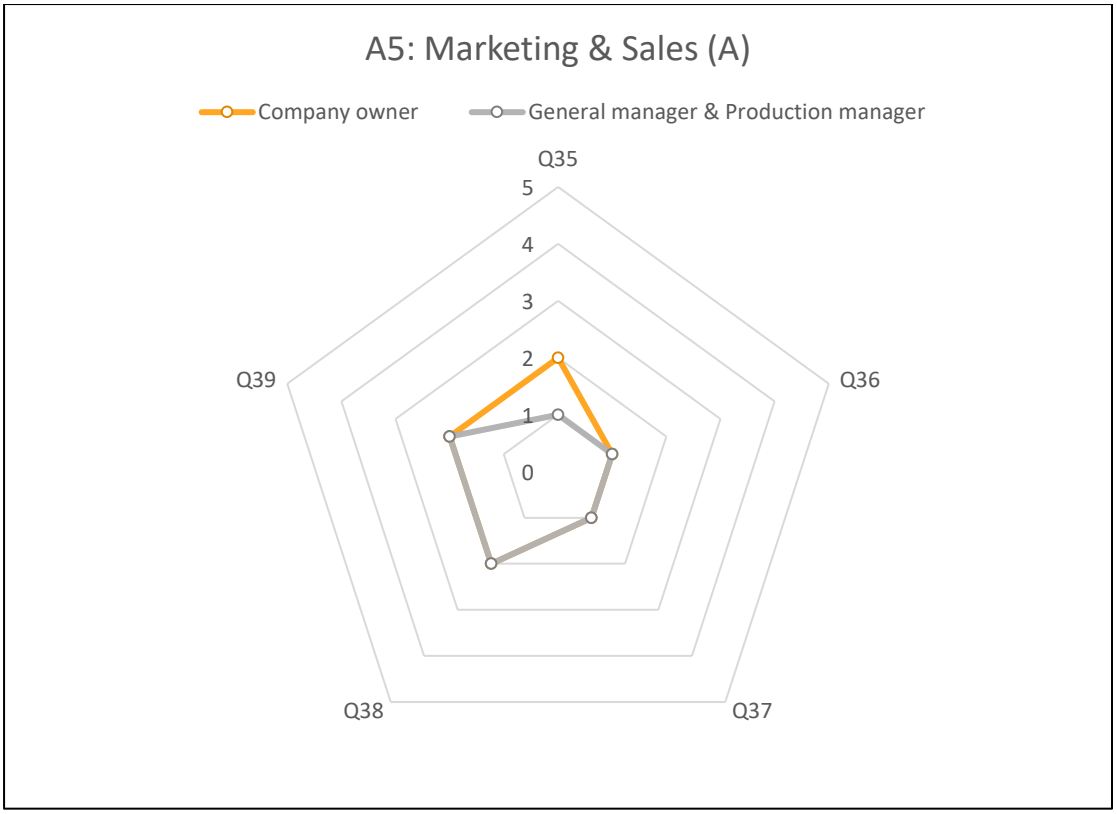
Average of A3 – Management & Leadership (A)	2.6

Aspect 3 Management & Leadership explores how much management supports the adoption of Industry 4.0, whether management has the necessary skills to adopt Industry 4.0 practices and to what extent employees from all departments are involved in making important business decisions. Aspect 3 is one of the highest-scoring aspects for Company A, with the scores ranging from none (1) to great (4). Question 25 and 27 were questions regarding to what extent the management supports the implementation of Industry 4.0 and to what extent they have the necessary skills required to support the implementation in the organization. It is important to note that the respondents were the owner and people in a management position which could have possibly biased the results. The other questions regarding more practical applications of Industry 4.0 like the extent management encourage trying out Industry 4.0 technologies in daily practices or to what extent management currently uses Industry 4.0 technologies for decision-making were all scored with none (1). During the workshop, Company A did state that it views management & leadership as a vital aspect for the adoption of Industry 4.0, but it was not actively encouraged and used yet.



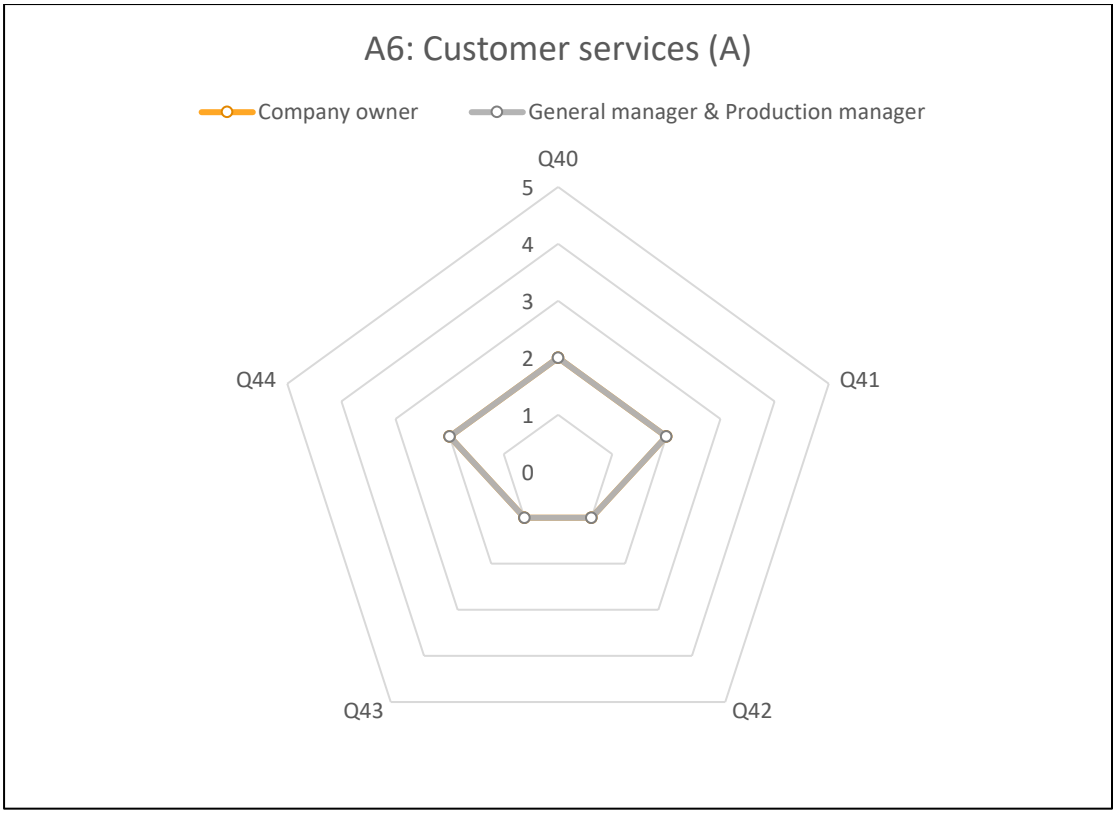
Average of A4 – Company culture & Knowledge management (A)	2.5

Aspect 4 tries to gain insight in the company culture and knowledge management by asking questions like to what extent training is offered to employees, to what extent out of the box thinking is encouraged to create new innovative ideas and whether the organisation puts enough effort in making the organisation "smart". Scores for Company A ranged from none (1) to great (4), scoring questions regarding the application of gained knowledge and supporting out of the box thinking high, but questions regarding digitization and smart factory were all scored none or low. The company experiences a lack of expertise in the workforce and there is no training regarding smart factory.



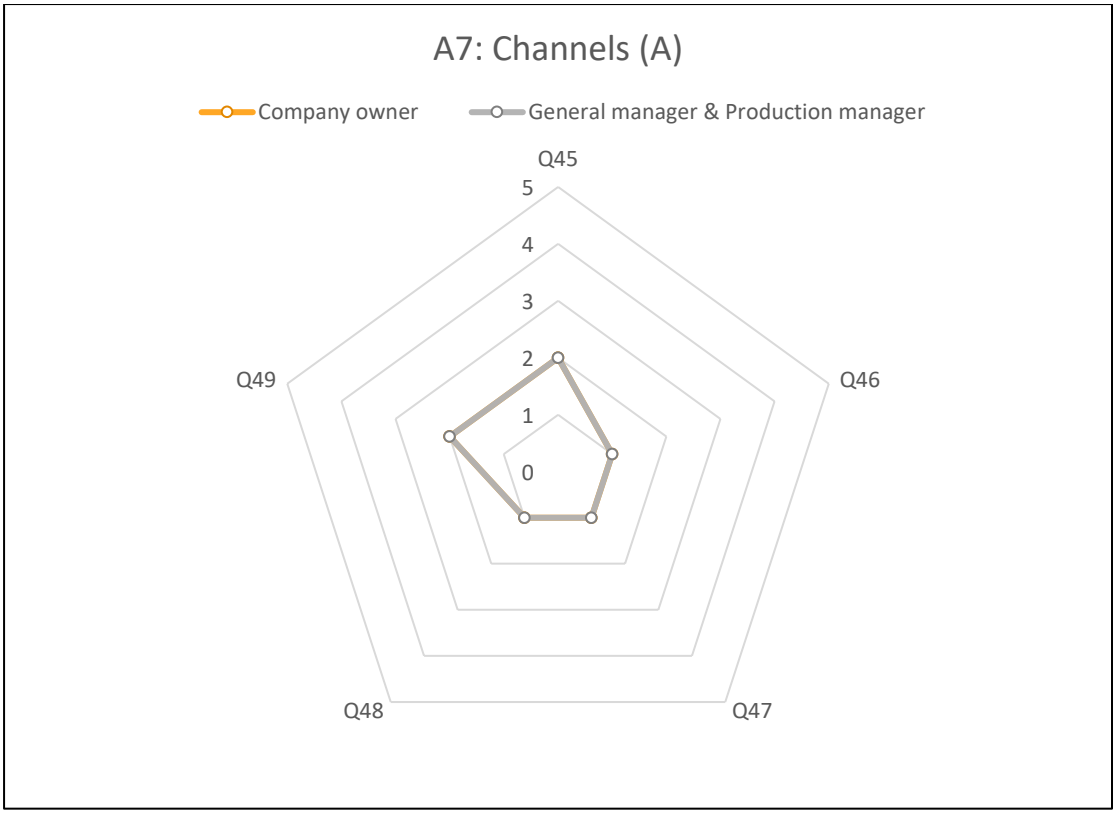
Average of A5 – Marketing & Sales (A)	1.5

Aspect 5 Marketing & Sales explores to what extent online behaviour is monitored and utilized by the Marketing & Sales department and to what extent the sales process is done digitally. Company A scores ranged from none (1) to low (2). Company A admitted marketing does not have priority because it is a B2B company and it has close relations with its customers. There is no dedicated marketing department, and no online behaviour is tracked and utilized for marketing purposes. The company has no plans yet to do so in the future either.



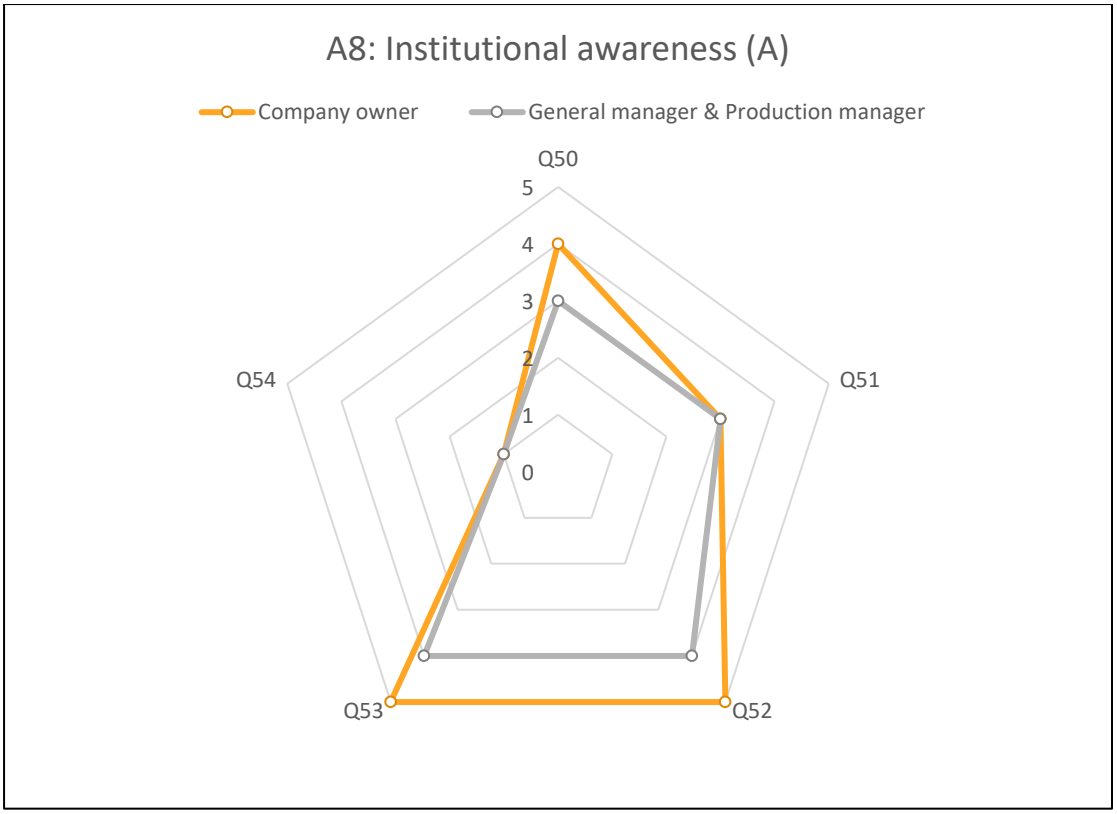
Average of A6 – Customer services (A)	1.6

Aspect 6 explores to what extent Industry 4.0 technologies are incorporated to automate customer services and to what extent customer services are offered digitally. Company A's scores ranged from none (1) to low (2). The questions regarding the products are not relevant to the semi-finished nature of the products. Furthermore, it is a B2B company and during the workshops it became apparent this aspect is not viewed as important.



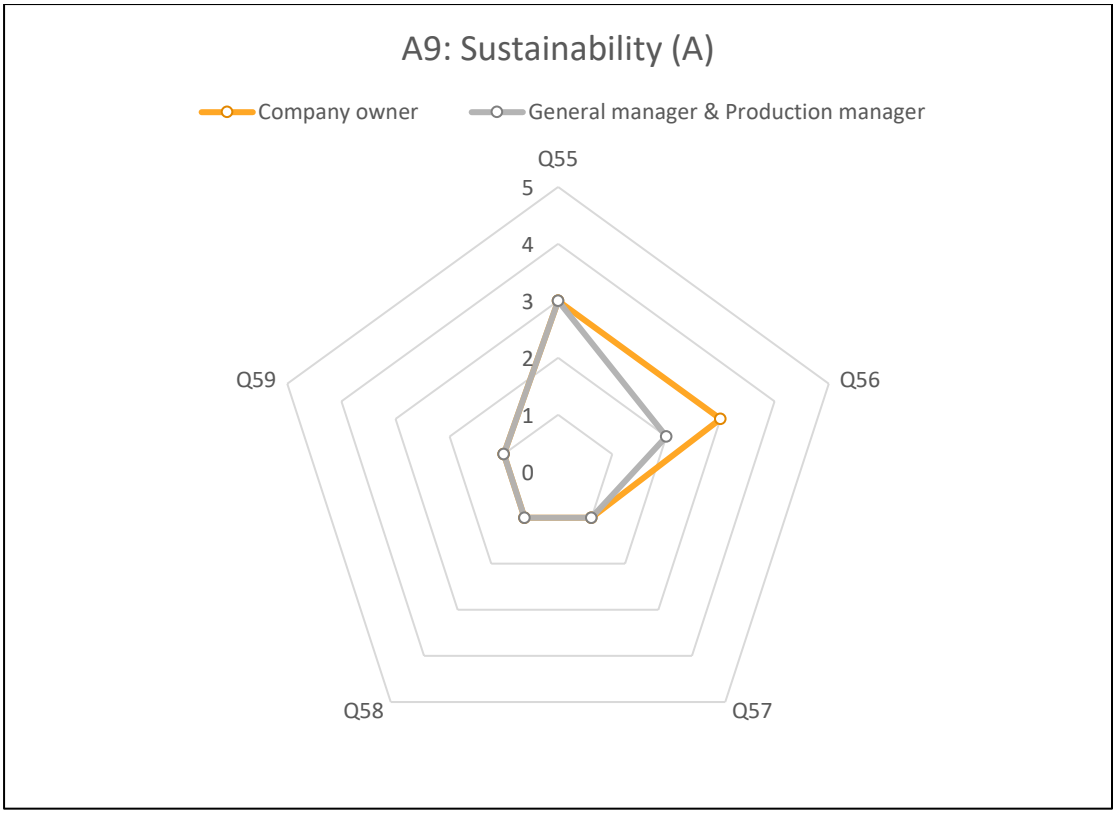
Average of A7 – Channels (A)	1.4

Aspect 7 Channels explores the degree to which the organization can communicate with their customers through different channels. For Company A scores ranged from none (1) to low (2). There are multiple channels available for customers like phone, e-mail, website, but besides tracking information nothing is monitored or automated. There are also no plans to improve this in the future due to the low importance of customer services.



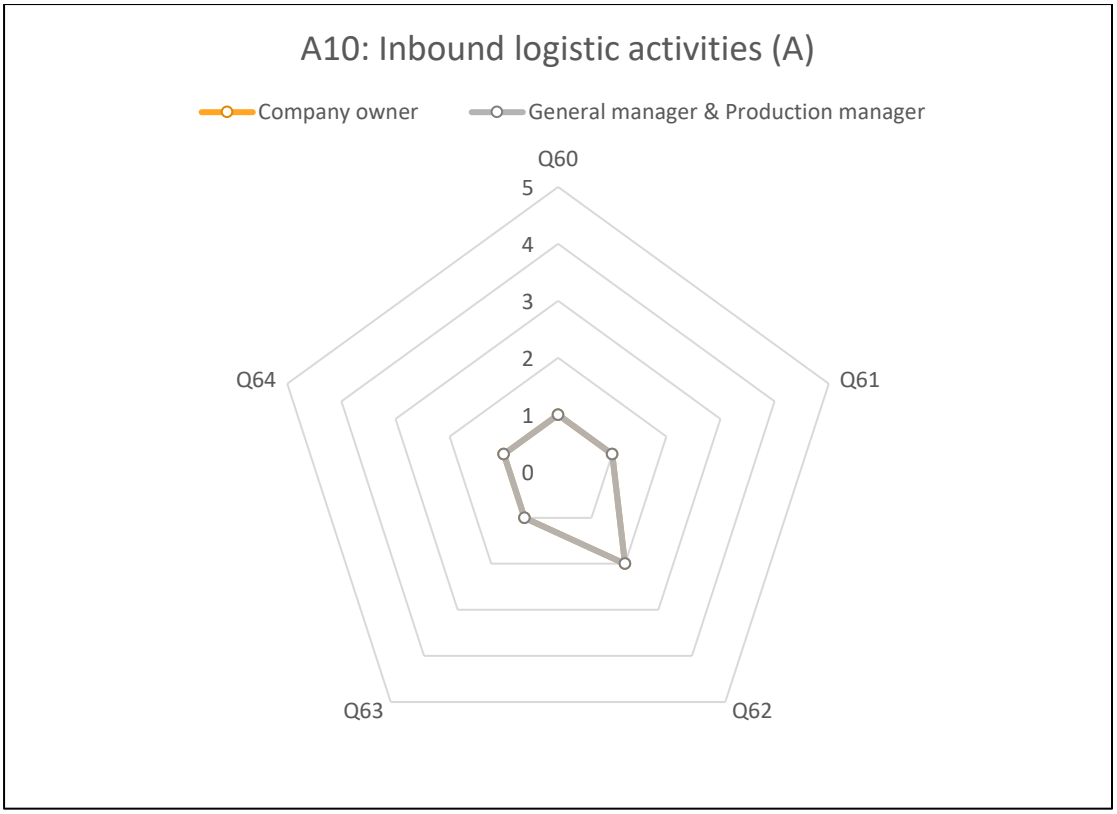
Average of A8 – Institutional awareness (A)	3.3

Aspect 8 Institutional awareness explores to what extent the organization is aware of privacy and security risks of implementing I4.0, has protected the IP of their products, and has automated privacy requests relating GDPR. This the is the highest-scoring aspect of Company A with scores ranging from moderate (3) to very great (5). This is mostly due to high scores on the questions about the awareness of possible risks and tax effects of implementing I4.0. This aspect was viewed as required but not the focus.



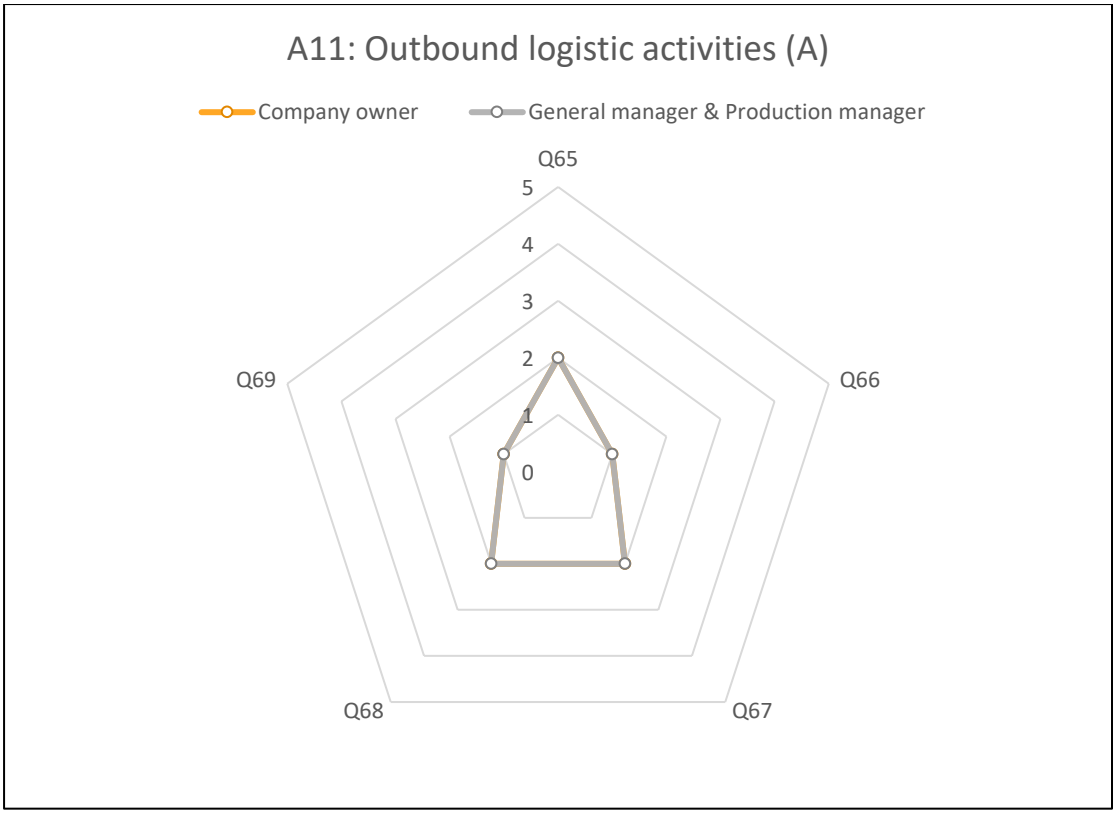
Average of A9 – Sustainability (A)	1.7

Aspect 9 Sustainability explores to what extent Industry 4.0 technologies are utilized to improve the sustainability of the organization. During the workshops, it became apparent that Company A does not focus on sustainability. It is not a priority nor do their customers view it as important. The higher score indicates there is still some confusion on what Industry 4.0 technologies implies.



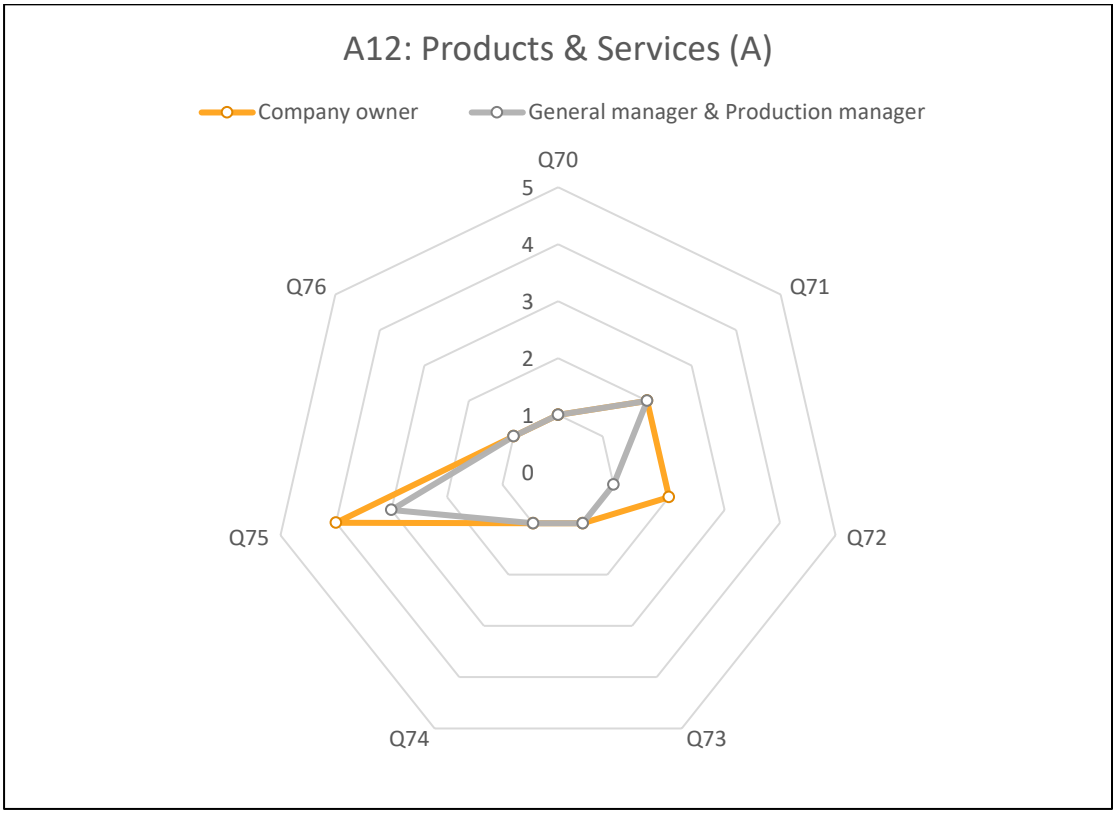
Average of A10 – Inbound logistic activities (A)	1.2

Aspect 10 Inbound logistic activities explores to what extent the organization collaborates with their suppliers, and the extent I4.0 technologies are used for inbound logistic activities. This aspect is one of the lowest scoring aspects of Company A with scores ranging from none (1) to low (2). Nothing is automated or paperless when it comes to inbound deliveries. Furthermore, there is no collaboration with suppliers. Because of the lack of a digital inventory management system, there is no option and plan to do so in the future.



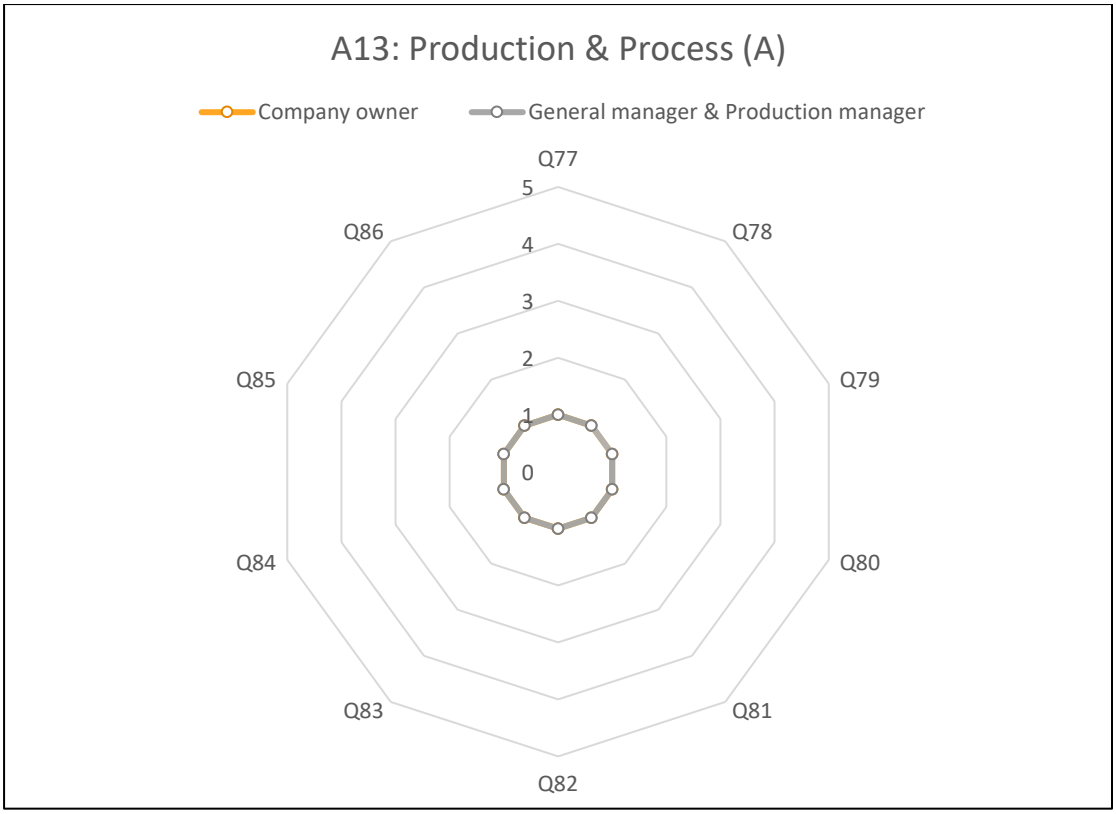
Average of A11 – Outbound logistic activities (A)	1.6

Aspect 11 Outbound logistic activities explores to what extent the organization collaborates with their customers, and the extent I4.0 technologies are used for outbound logistic activities. This aspect scores higher than the previous aspect for Company A because of question 65 which is about the automatic tracking of products in transit.



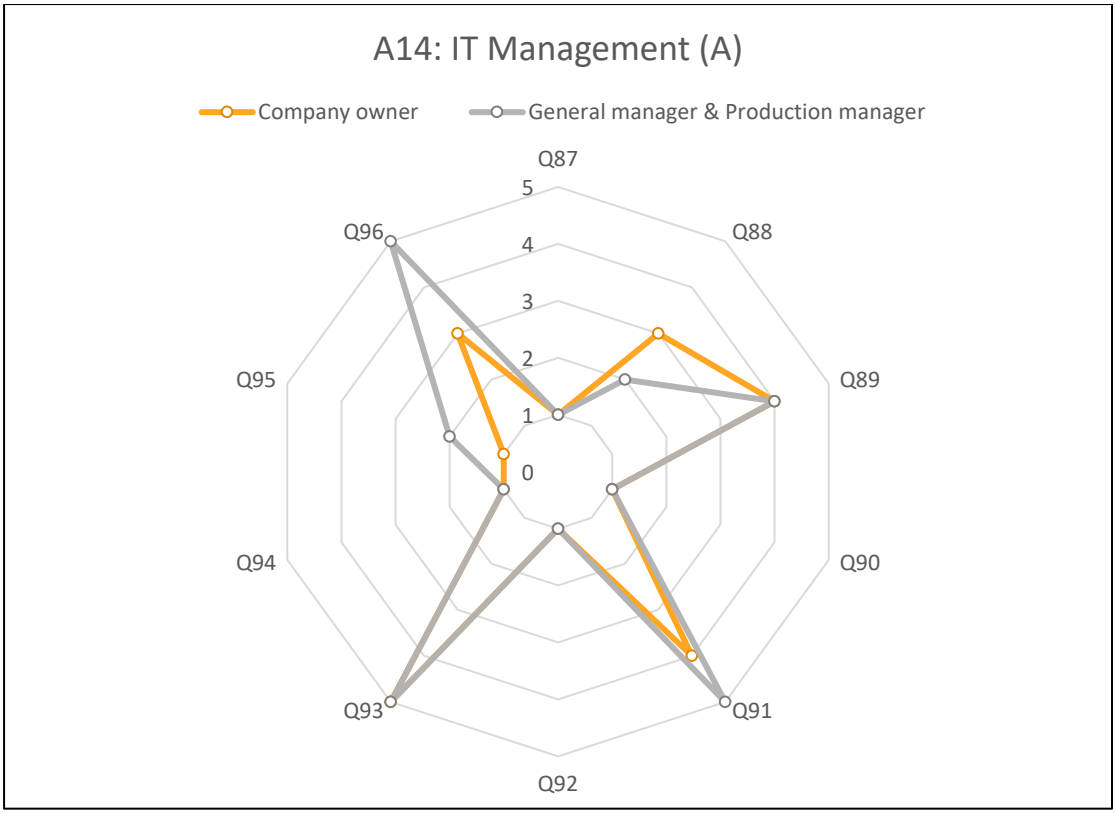
Average of A12 – Products & Services (A)	1.571

Aspect 12 Products & Services explores to what extent Industry 4.0 technologies support servitization, whether data is used to improve current products/services and to what extent that is done digitally. Company A's scores ranged from none (1) to great (4). Because of the nature of the semi-finished product Company A produces there is no option for sensors to detect product health etc. However, the organization does develop some new products using digital means and plans to use this method more in the future.



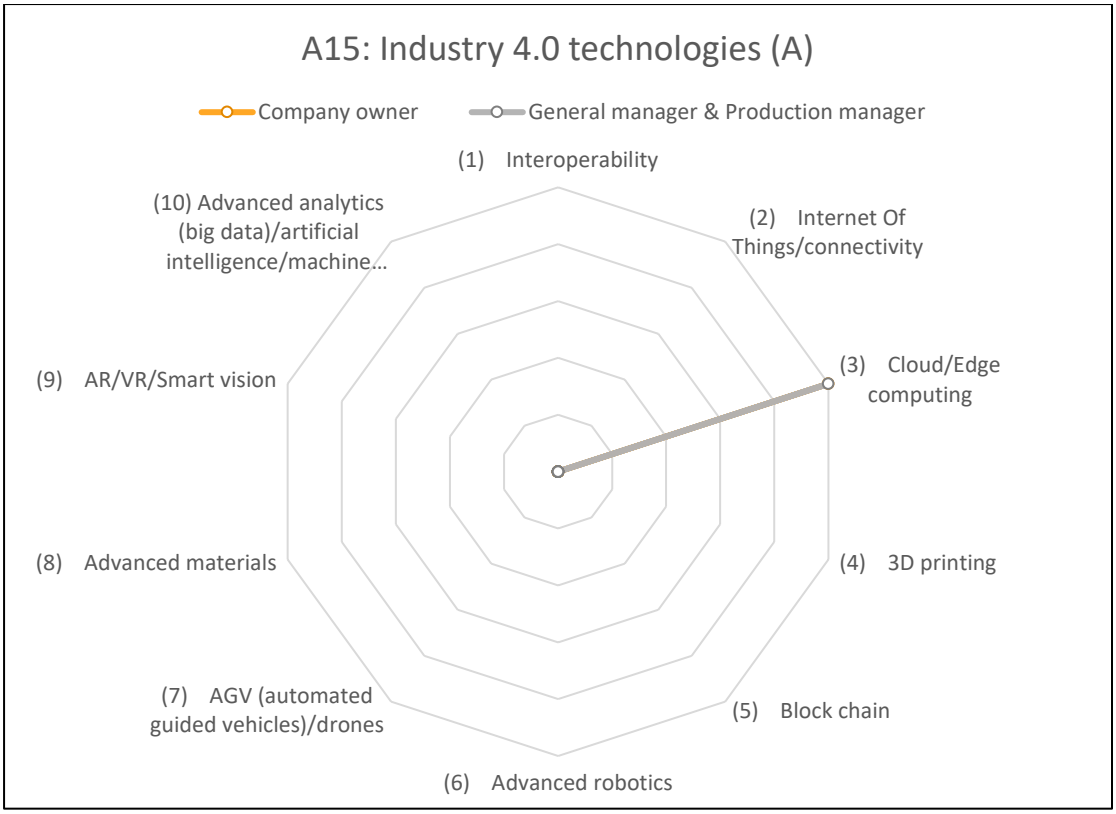
Average of A13 – Production & Process (A)	1

Aspect 13 Production & Process explores to what extend the production process is automated, to what extent Industry 4.0 technologies are used to monitor and improve the process, and whether production-related data is shared with partners. This is the lowest scoring aspect of Company A with every question scoring none (1). This is due to the production process being very labour-intensive. Everything is done by hand to create a realistic look of the product. Company A does not plan to improve this aspect because their current production process is vital for its main selling point.



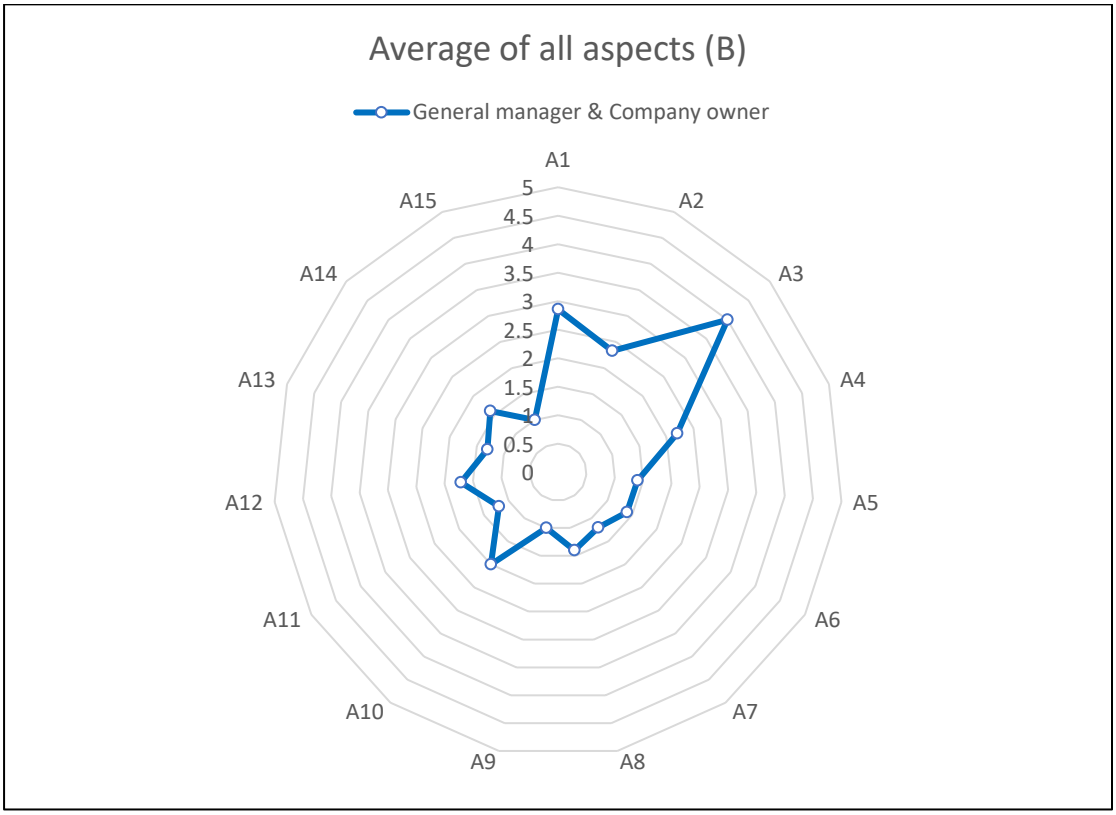
Average of A14 – IT Management (A)	2.55

Aspect 14 IT Management explores to what extent data is collected, the extent to which the organization can respond to changes regarding IT, the level of IT security and whether IT is integrated with suppliers/customers. Company A's scores ranged from none (1) to very great (5). Scoring high on questions about IT security and the functionality of the website. However, there is no internal IT system and IT department because anything related to IT is outsourced to a third party, which is often the case for SME's. There is no data being collected and utilized either. The organisation does not plan to improve this aspect in the future, viewing IT Management as something that needs to work but not something that can create and add value.

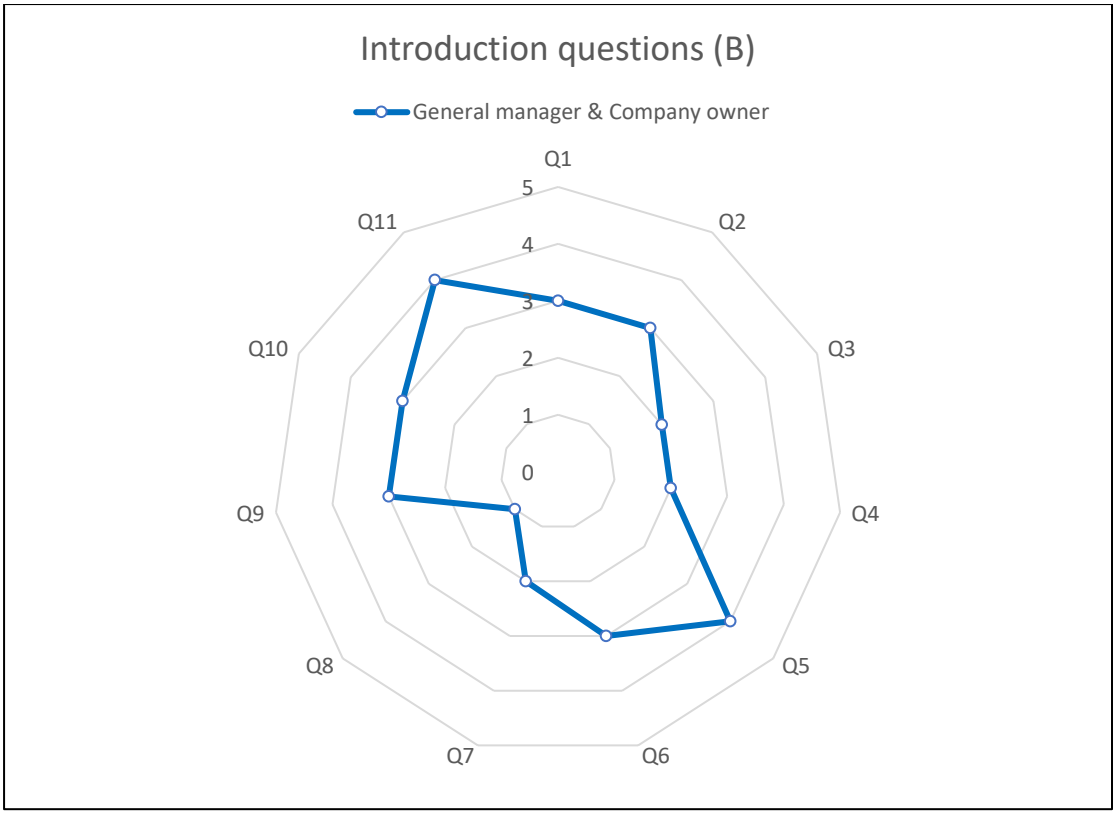


Average of A15 – Industry 4.0 technologies (A)	0.5

Aspect 15 explores what Industry 4.0 technologies specifically have been adopted thus far in the organization. Company A only makes use of Cloud Computing out of convenience because they have no internal IT system and IT department. Therefore, their data is stored in the cloud.

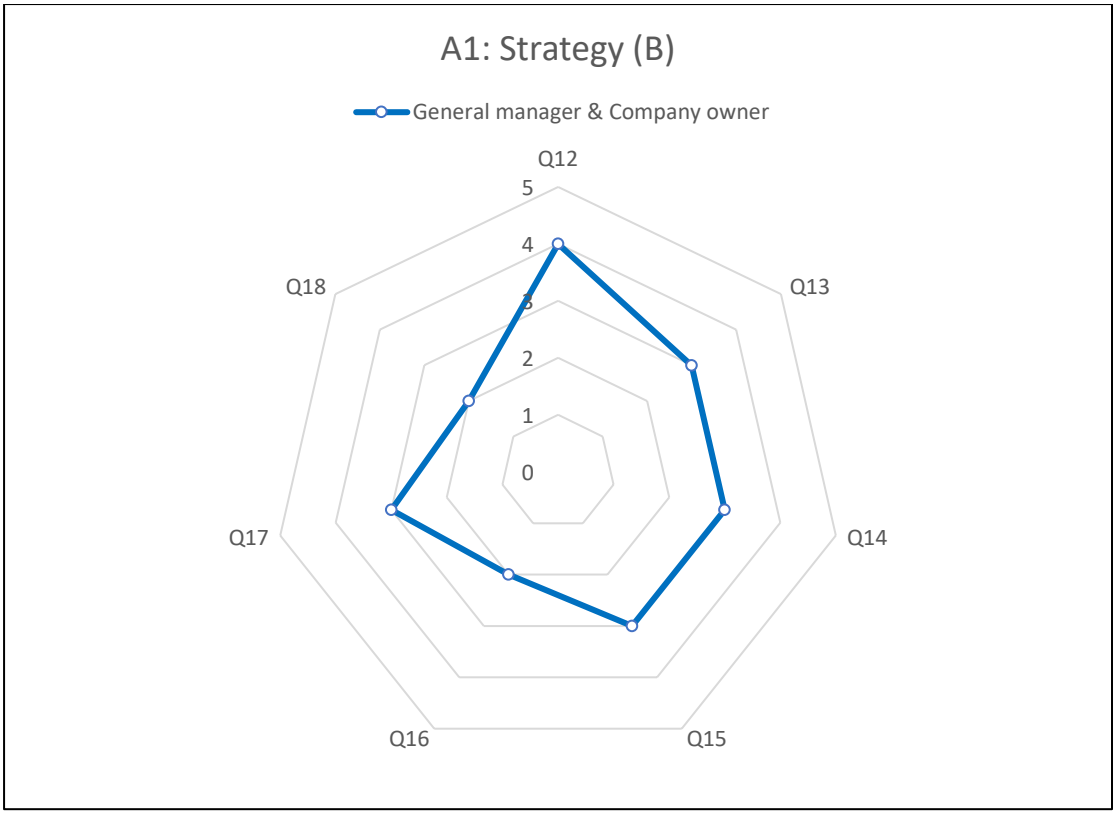


Total average of all aspects (B)	1.774



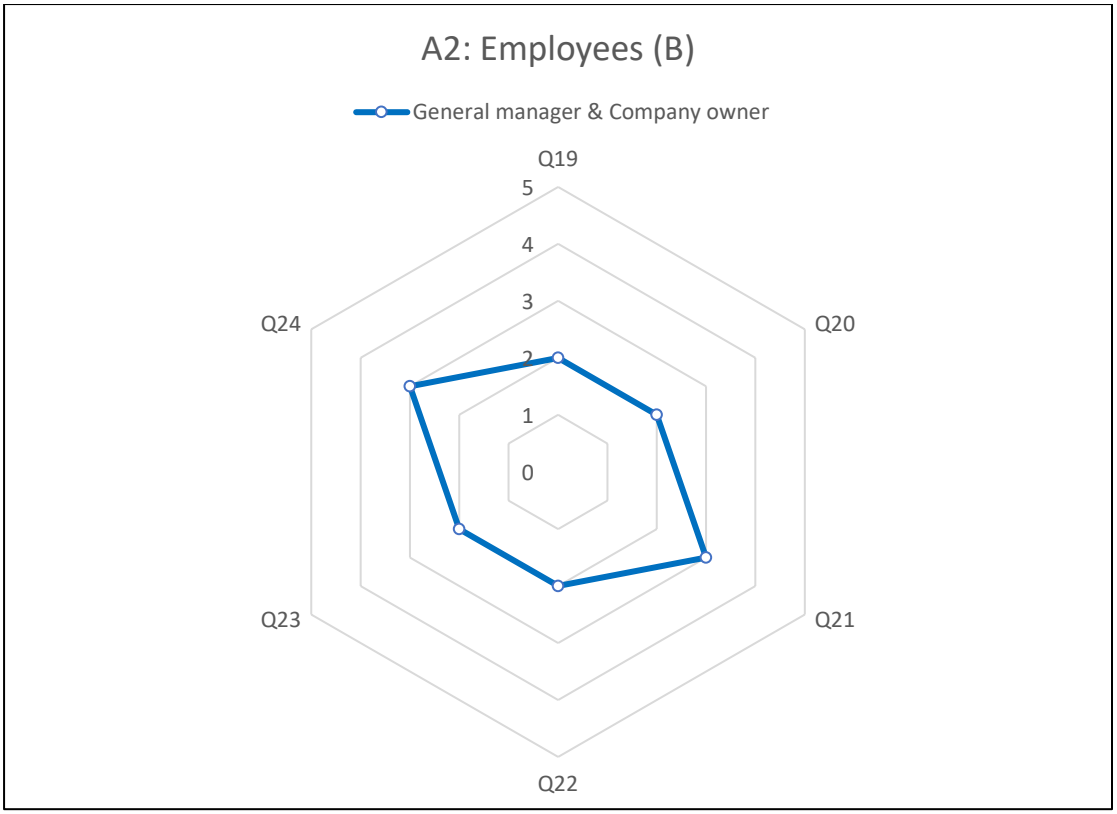
Average of Introduction questions (B)	2.727

The introduction questions show us that employees in the sector of Company B, the manufacturing or construction sector with a focus on metal and steel bending, view the sector as generally stable but still growing. However, compared to other sectors the growth of the sector is not viewed as rapid growth. The sector is not challenged by new competitors or new innovative products. Nevertheless, current competitors do constantly challenge the position of Company B and the threat of cheap substitutes is also higher than in the sector of Company A.



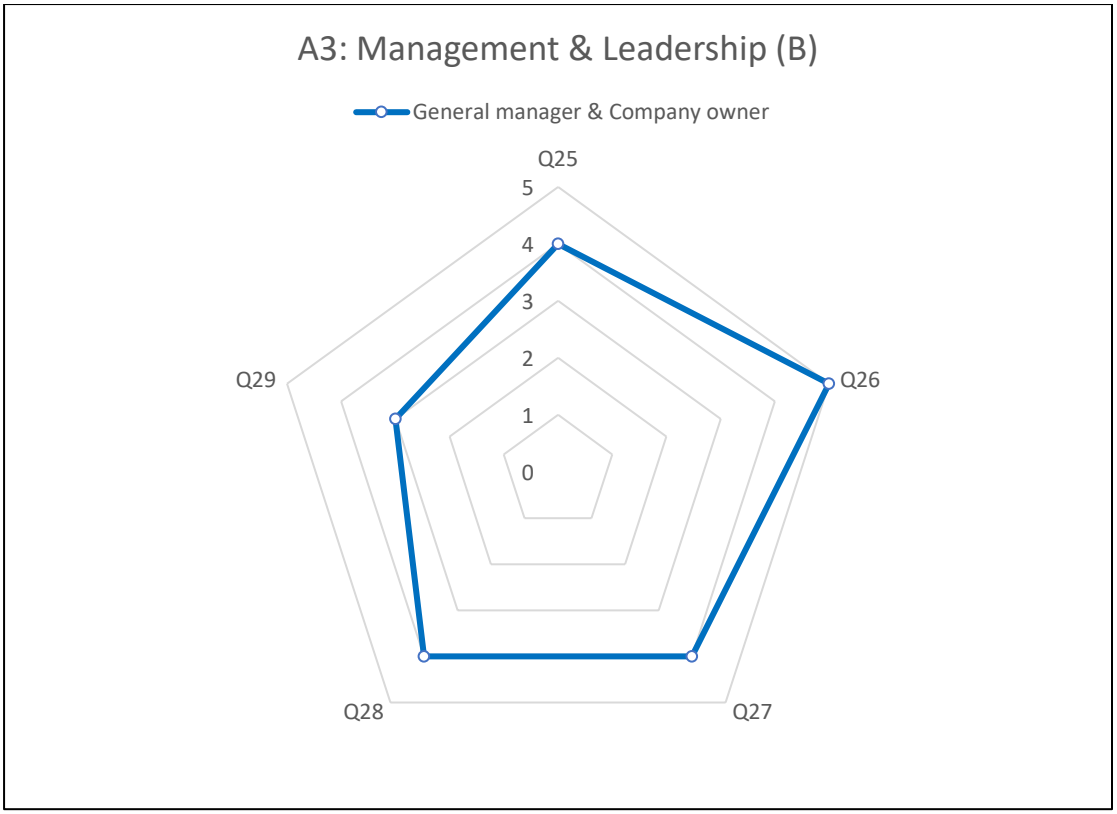
Average of A1 – Strategy (B)	2.857

The strategy aspect explores how important Industry 4.0 is to the success of the organization and to what extent a clear strategy has been adopted by the organization for the implementation of Industry 4.0. Company B's results for strategy range from low (2) to great (4) and has a relatively high score of 2.857. For Company B the adoption of Industry 4.0 is viewed as important for the success of the organization. During the workshop, it became clear this is partly due to the metal manufacturing sector that they operate in. Company B does have plans and budgets for investing in Industry 4.0, which will be explored in the following aspects, but a clear digital vision was still lacking.



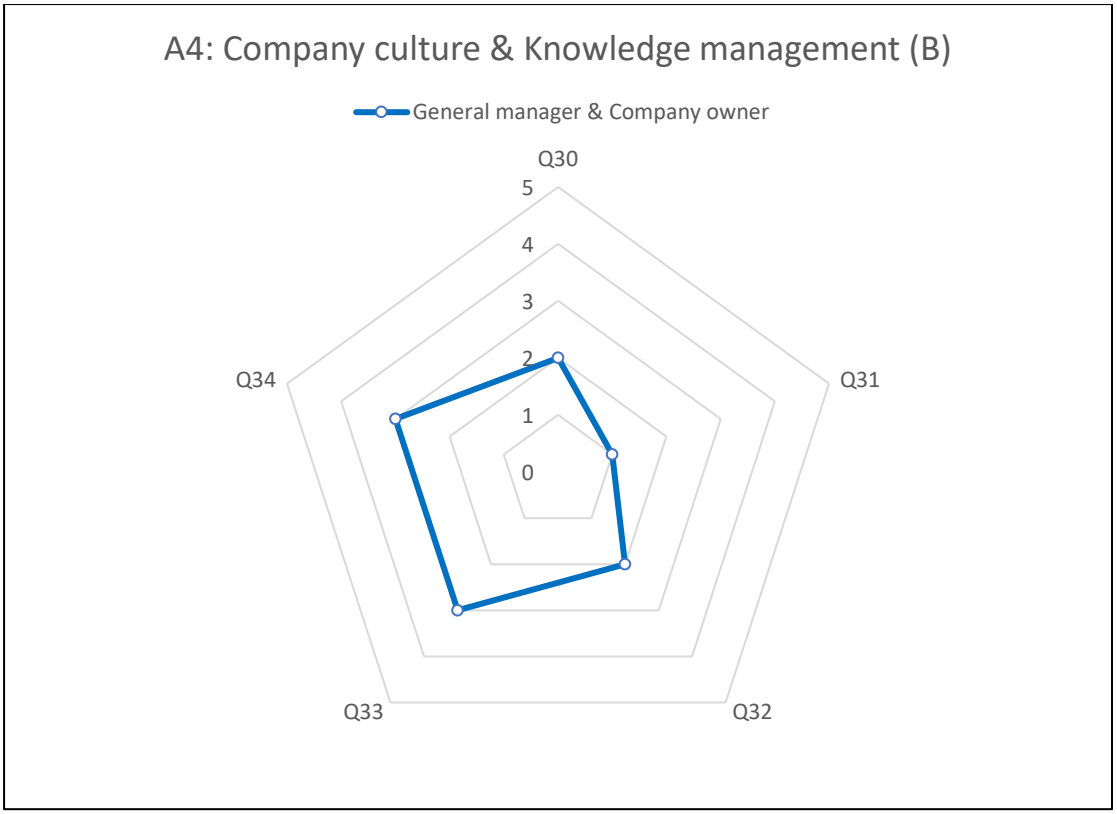
Average of A2 – Employees (B)	2.333

Aspect 2 explores how information and developments are communicated within the organization, whether employees are stimulated to share ideas and whether there is a digital system in place to support this. The scores for Company B ranged from low (2) to moderate (3). Company B also regularly communicates developments with their employees to keep them up to date. Furthermore, the owner and management do frequently share information and ideas, also regarding Industry 4.0, but through informal meetings. There is no digital system in place that encourages information sharing nor are there plans for it in the near future. The work instructions are not paperless yet either, but Company B does plan to digitalize this in the future as well. Company B did indicate during the workshop that they view employees as an important aspect for adopting Industry 4.0.



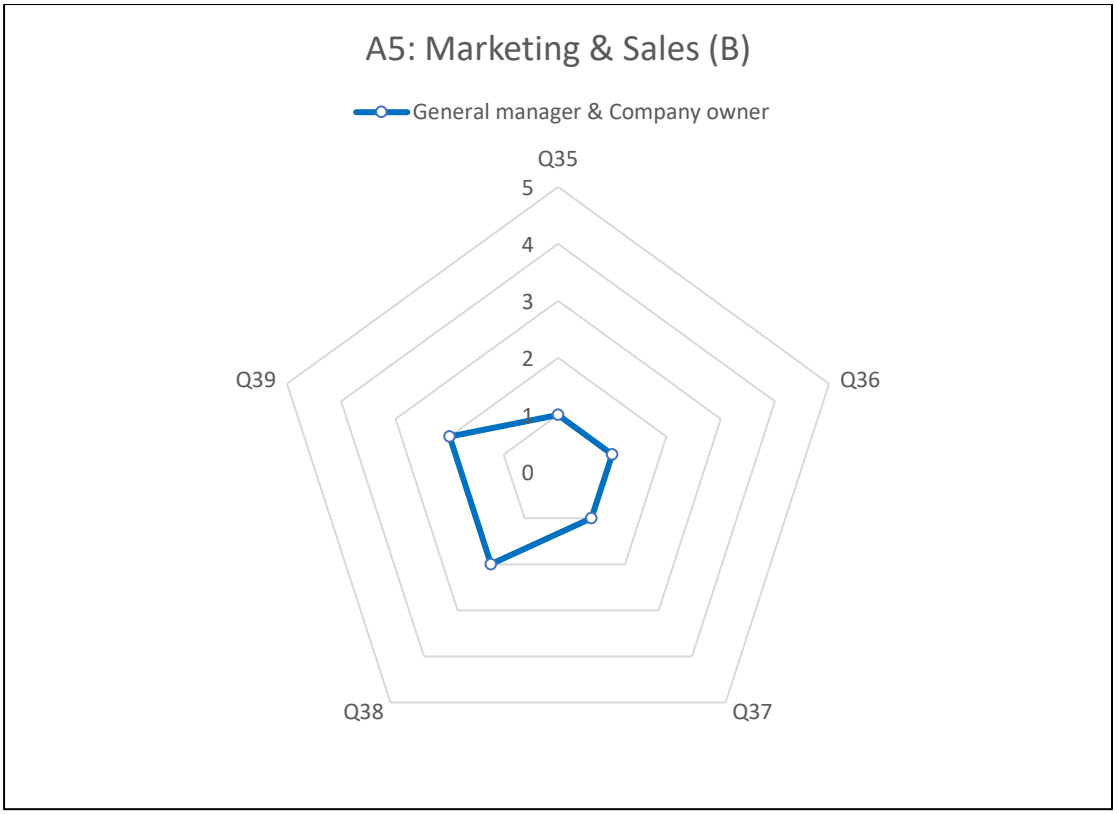
Average of A3 – Management & Leadership (B)	4

Aspect 3 Management & Leadership explores how much management supports the adoption of Industry 4.0, whether management has the necessary skills to adopt Industry 4.0 practices and to what extent employees from all departments are involved in making important business decisions. The management & leadership aspect is the highest scoring aspect for Company B with scores ranging from moderate (3) to very great (5). However, during the workshop it became apparent that the adoption and use of Industry 4.0 technologies is not as actively encouraged as the score would make it appear. It is possible to explain this discrepancy because the general manager and owner filled in the scan together, possibly biasing this result. The aspect is viewed as critical for the successful implementation of Industry 4.0.



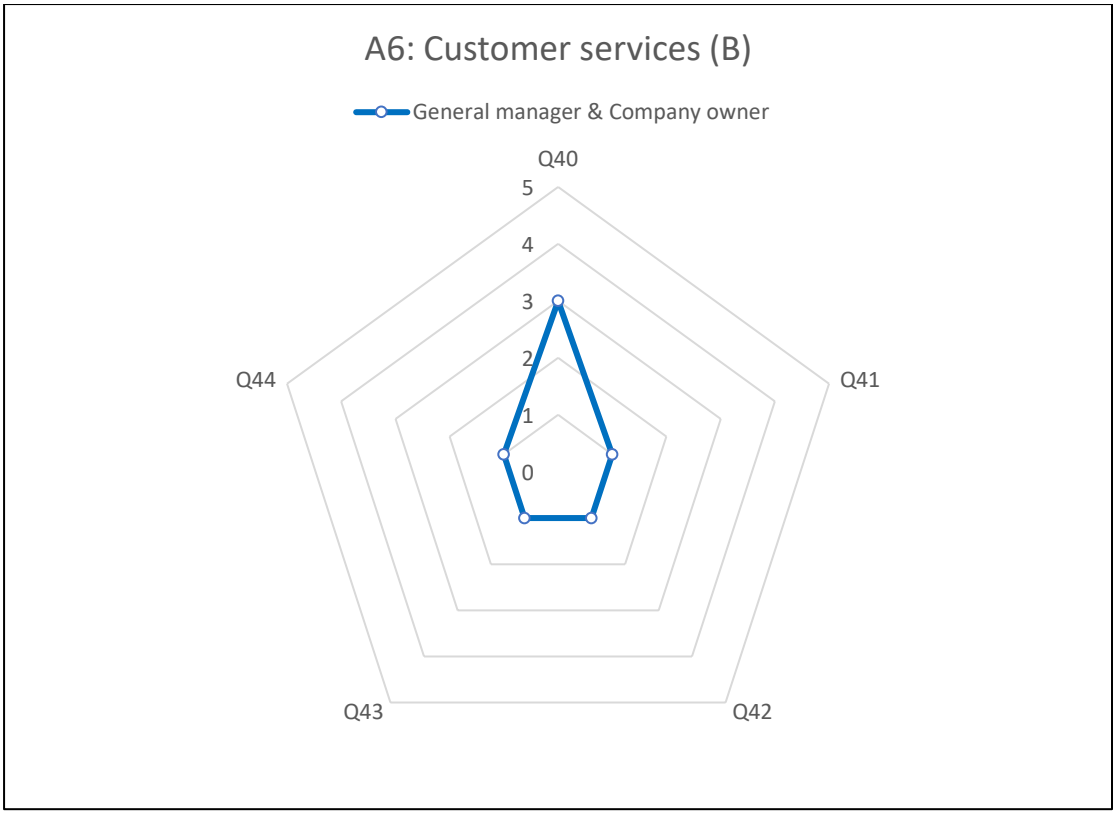
Average of A4 – Company culture & Knowledge management (B)	2.2

Aspect 4 tries to gain insight in the company culture and knowledge management by asking questions like to what extent training is offered to employees, to what extent out of the box thinking is encouraged to create new innovative ideas and whether the organisation puts enough effort in making the organisation "smart". Company B's scores ranged from none (1) to moderate (3). There is no training for the workforce regarding smart factory, but the company does try to improve the knowledge about digitization except this is mostly for people working in management positions. Company B does put more effort in trying to make the organisation smart, although it became apparent during the workshops that this still involves incorporating Industry 3.0 technologies.



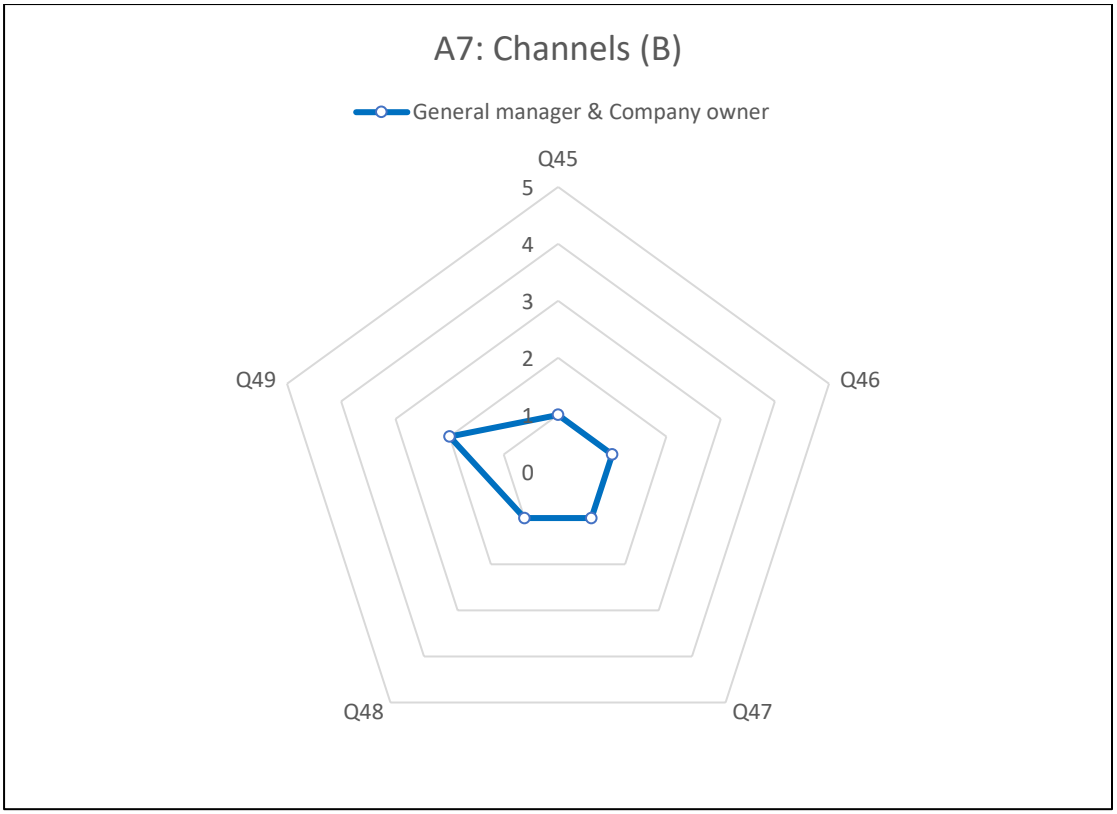
Average of A5 – Marketing & Sales (B)	1.4

Aspect 5 Marketing & Sales explores to what extent online behaviour is monitored and utilized by the Marketing & Sales department and to what extent the sales process is done digitally. Company B's scores also ranged from none (1) to low (2). There is no focus on marketing because the company is currently capped in its production due to the size of the facility. Therefore, they cannot produce more than they currently are and thus there is no need for marketing. There are no plans to move to a larger facility at this moment. The company hinted that without the capped production, they likely still would not track customer behaviour online because they do not believe it is vital for a B2B company.



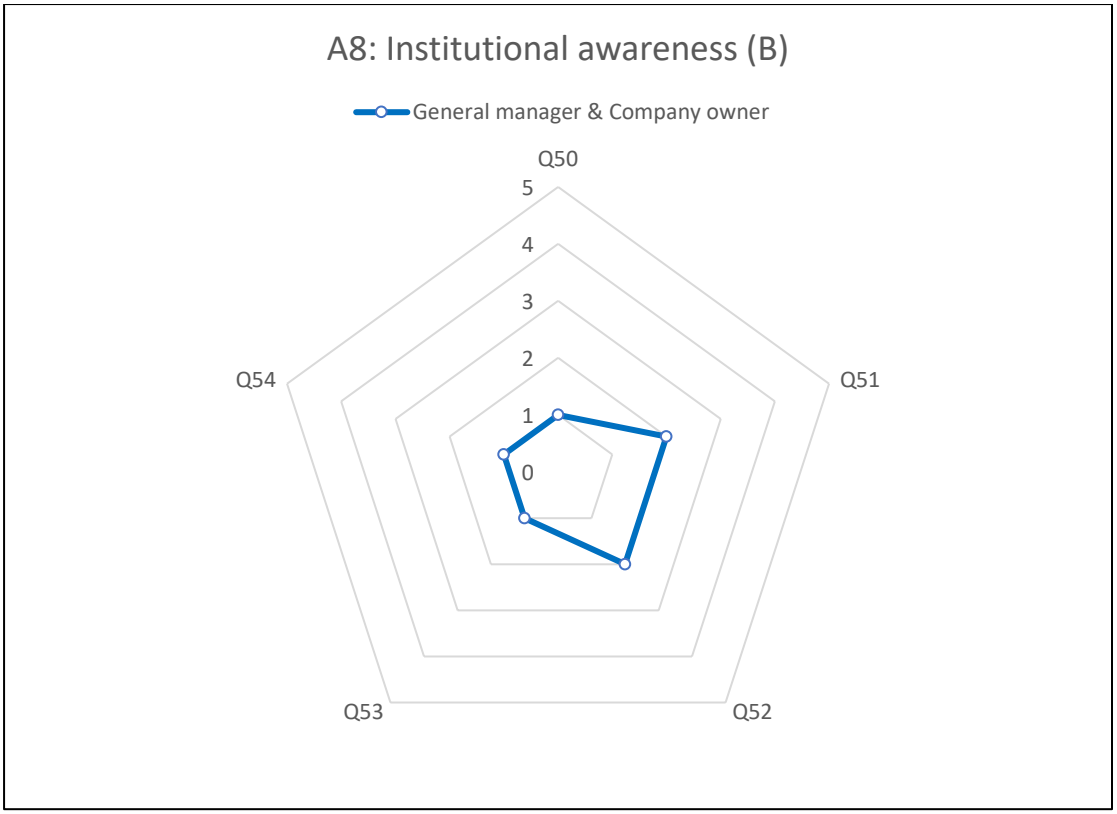
Average of A6 – Customer services (B)	1.4

Aspect 6 explores to what extent Industry 4.0 technologies are incorporated to automate customer services and to what extent customer services are offered digitally. Company B' scores also ranged from none (1) to low (2) and the same situation as for Company A applies due to the B2B setting and the production of semi-finished products.



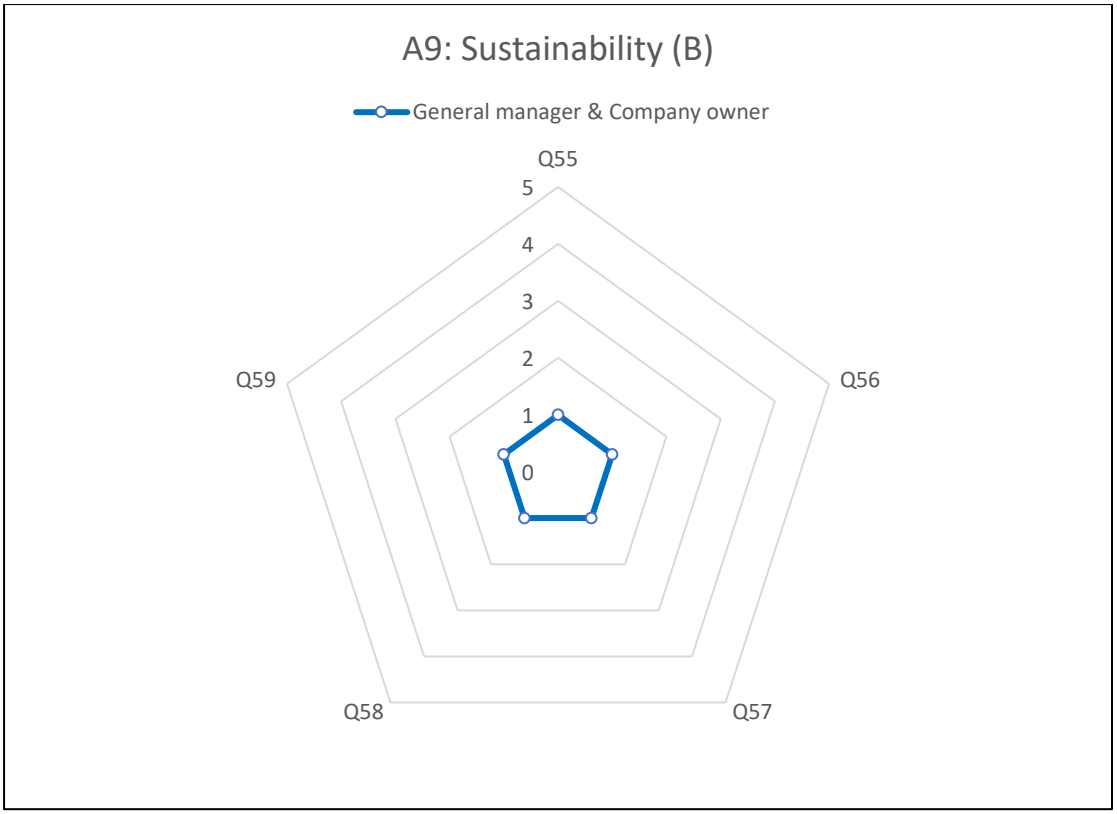
Average of A7 – Channels (B)	1.2

Aspect 7 Channels explores the degree to which the organization can communicate with their customers through different channels. This is one of the lowest scoring aspects for Company B. The same situation applies as for Company A, customer services are not viewed as important for value creation and there are no plans to improve the aspect in the future.



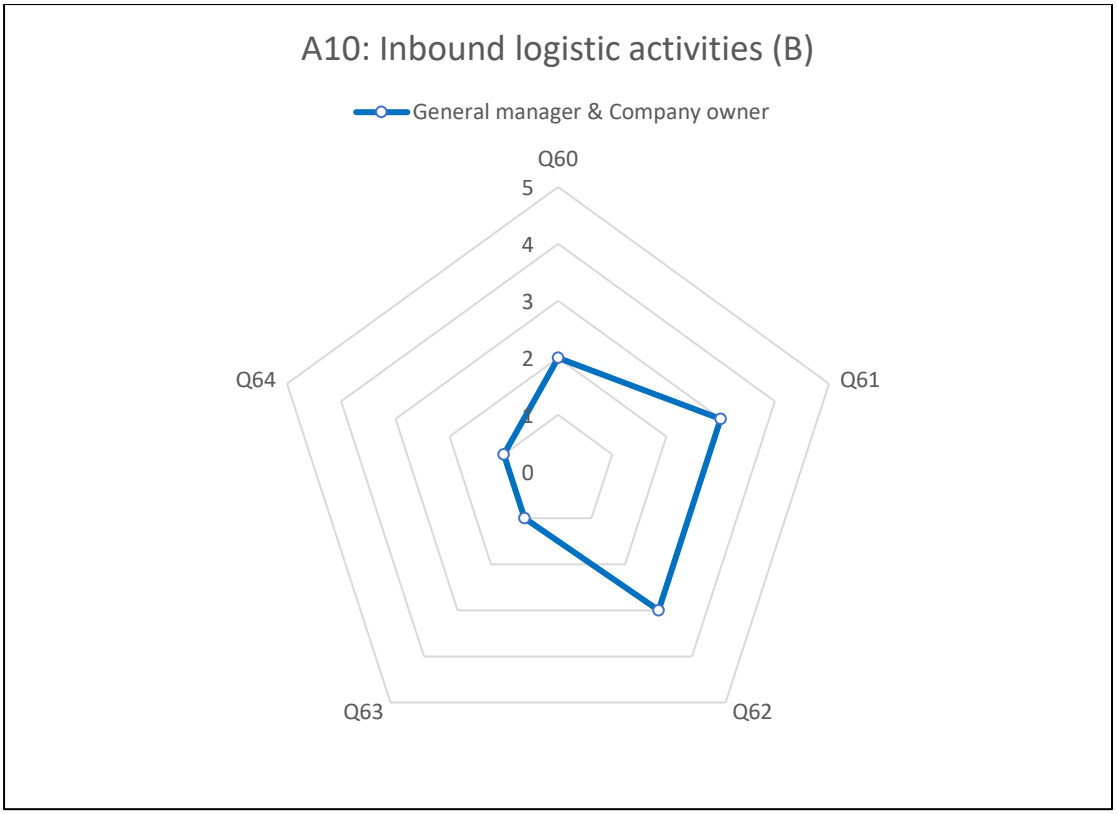
Average of A8 – Institutional awareness (B)	1.4

Aspect 8 Institutional awareness explores to what extent the organization is aware of privacy and security risks of implementing I4.0, has protected the IP of their products, and has automated privacy requests relating GDPR. Company B scored much lower with scores ranging from none (1) to low (2). They have some ideas about possible risks when implementing I4.0 but admit that they could improve this aspect. However, the aspect was not viewed as very important which is also the cause of the low score.



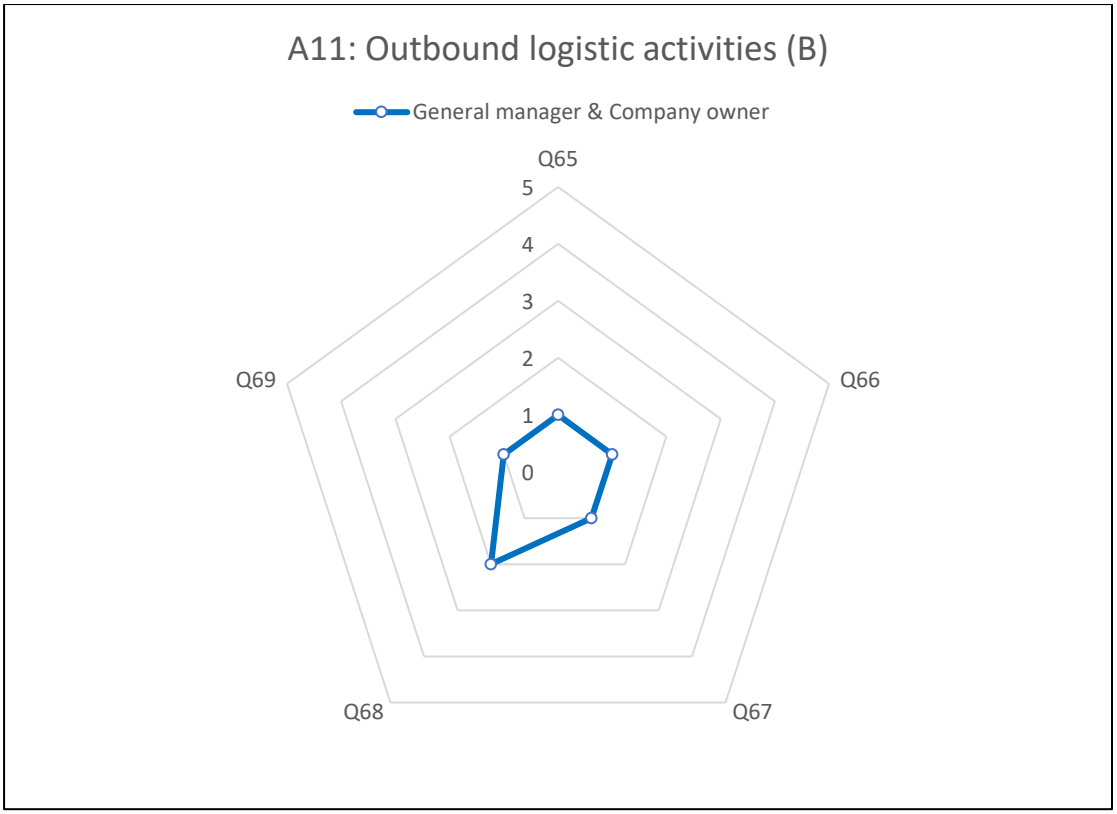
Average of A9 – Sustainability (B)	1

Aspect 9 Sustainability explores to what extent Industry 4.0 technologies are utilized to improve the sustainability of the organization. This aspect has the lowest score for Company B, scoring none (1) on all questions. Company B has no focus on sustainability. They make sure to conform to the requirements by law, but it has no priority and is no selling point for their customers.



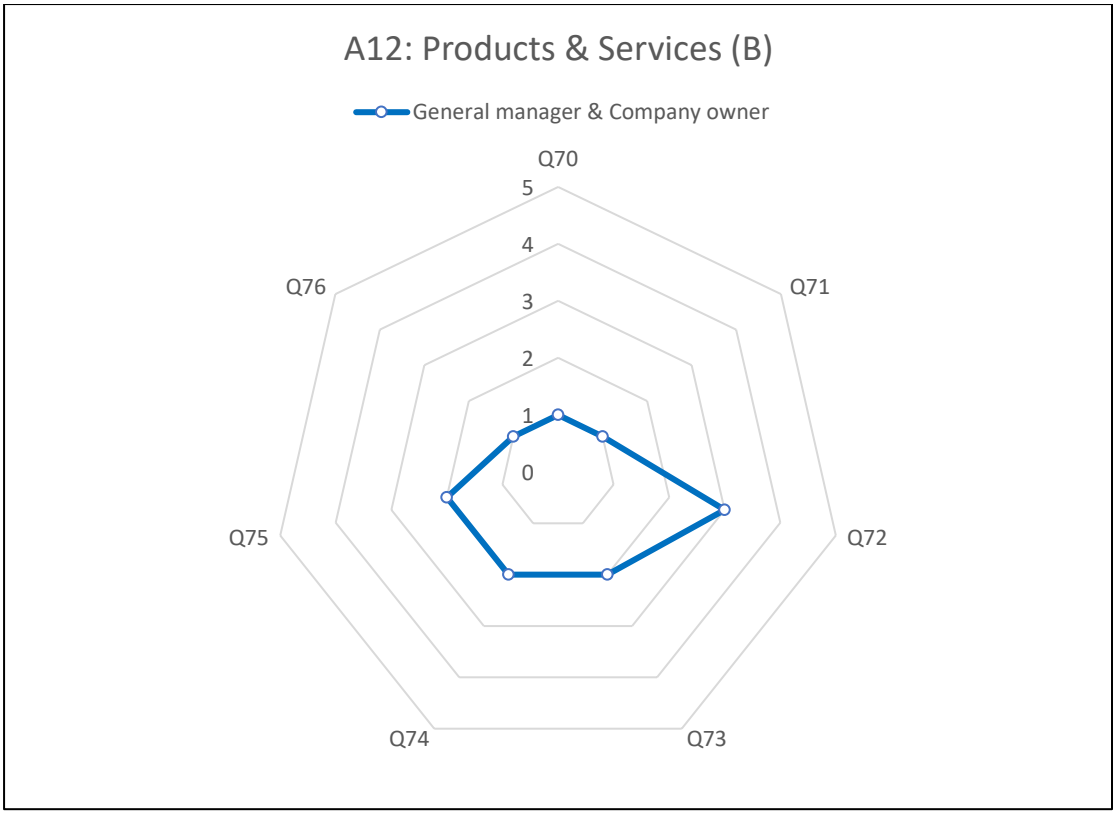
Average of A10 – Inbound logistic activities (B)	2

Aspect 10 Inbound logistic activities explores to what extent the organization collaborates with their suppliers, and the extent I4.0 technologies are used for inbound logistic activities. Company B scores ranged from none (1) to moderate (3). The company has recently improved their logistics. Instead of using pallets, they have switched to plastic trays that are labelled for each product. They have horizontally integrated this system with their suppliers, meaning their suppliers deliver their products in the labelled trays. The trays are then returned empty by Company B and the process repeats. Company B plans to improve this system in the future by adding QR-codes to the trays so that they can simply be scanned and automatically logged in an inventory management system.



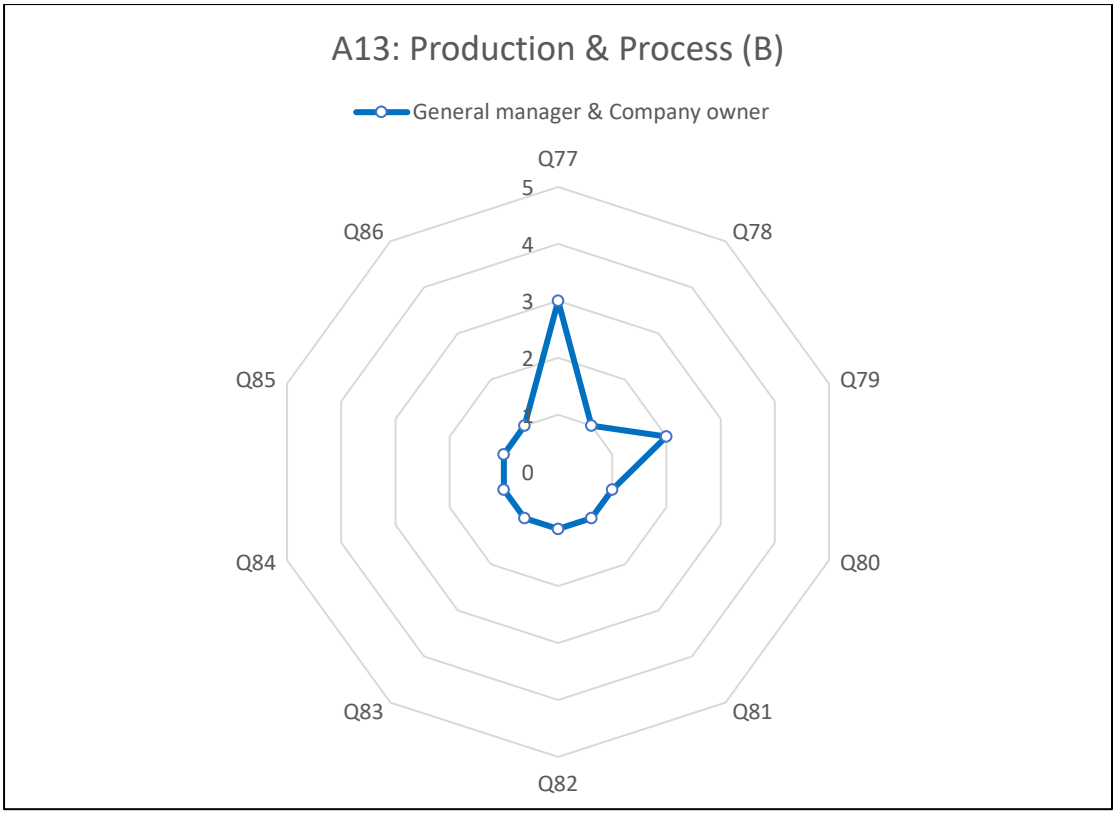
Average of A11 – Outbound logistic activities (B)	1.2

Aspect 11 Outbound logistic activities explores to what extent the organization collaborates with their customers, and the extent I4.0 technologies are used for outbound logistic activities. This is one of the lowest scoring aspects for Company B with scores ranging from none (1) to low (2). Company B's current focus is on improving the Outbound logistic activities. They have already started incorporating these improvements for the Inbound logistic activities which explains why this aspect scores lower.



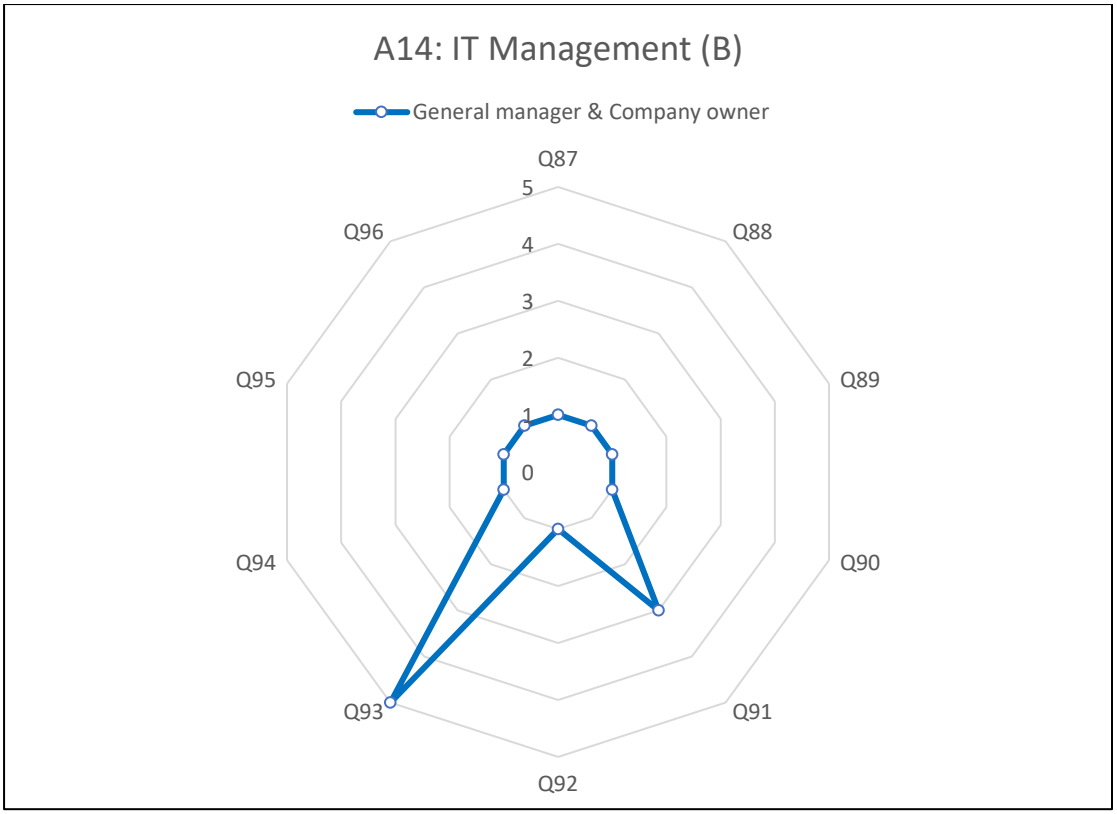
Average of A12 – Products & Services (B)	1.714

Aspect 12 Products & Services explores to what extent Industry 4.0 technologies support servitization, whether data is used to improve current products/services and to what extent that is done digitally. Company B's scores ranged from none (1) to moderate (3). Due to the nature of the semi-finished products they produce there is no option for sensors to detect product health etc. either. Company B does use data to improve their current products and services, but during the workshop it became apparent this is only actual feedback received from customers.



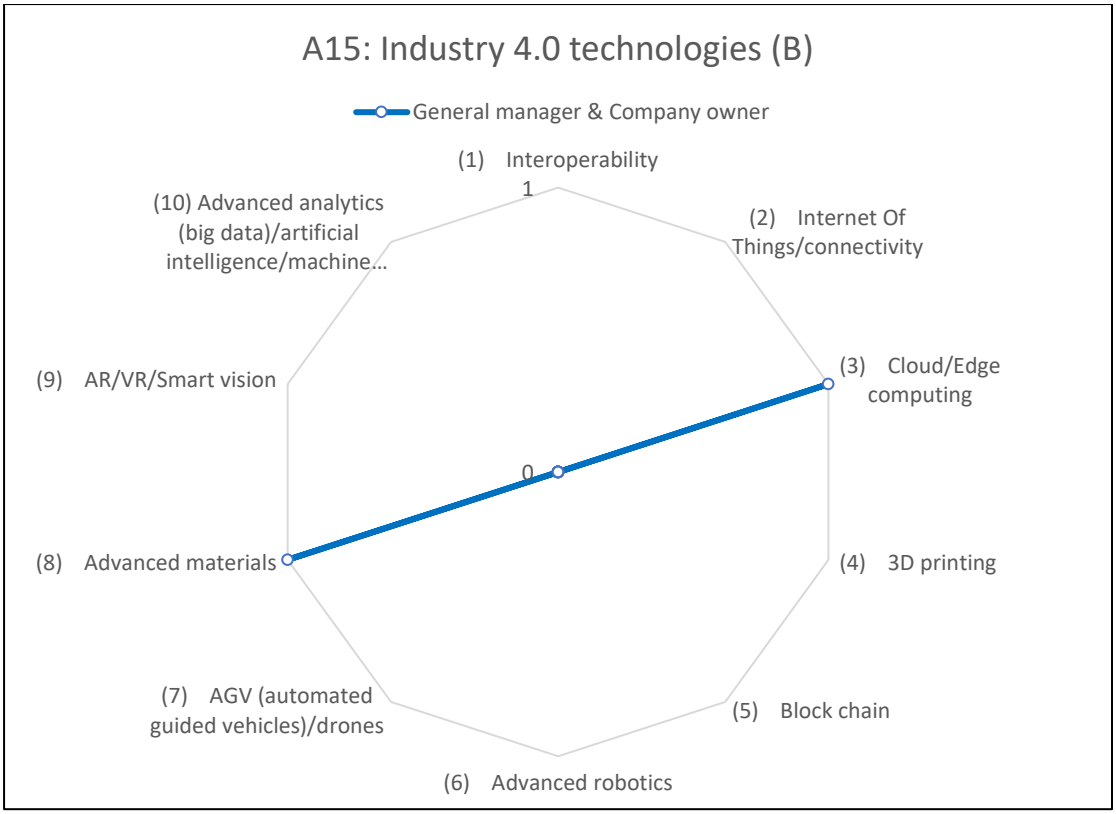
Average of A13 – Production & Process (B)	1.3

Aspect 13 Production & Process explores to what extend the production process is automated, to what extent Industry 4.0 technologies are used to monitor and improve the process, and whether production-related data is shared with partners. Company B's scores ranged from none (1) to moderate (3). The production process is less labour-intensive than Company A and uses more machines. However, nothing is automated nor monitored and no data is collected and therefore shared with partners. The company indicated their main bottleneck is currently in logistics and inventory management. Furthermore, they are currently capped in production due to the size and thus improving this aspect does not have priority.



Average of A14 – IT Management (B)	1.6

Aspect 14 IT Management explores to what extent data is collected, the extent to which the organization can respond to changes regarding IT, the level of IT security and whether IT is integrated with suppliers/customers. Company B's scores ranged from none (1) to very great (5). The only question that was scored with very great was the question concerning the website being operative on all desired platforms. Company B also outsources anything IT related. Due to the lack of expertise within the company and viewing IT Management as something that needs to work instead of value creation, they do not plan to improve this aspect in the future. Furthermore, Company B showed a reluctance towards the sharing of data with potential partners out of fear that the data could be used against them. They also mentioned this attitude towards open data sharing is common among the suppliers they currently work with.



Average of A15 – Industry 4.0 technologies (B)	1

Aspect 15 explores what Industry 4.0 technologies specifically have been adopted thus far in the organization. Company B uses Cloud Computing and Advanced Materials. Company B uses Cloud Computing out of convenience just like Company A. They also do not have an internal IT system and department; thus, their data is stored in the cloud. In the scan they respondents filled in they make use of Advanced materials, but during the workshop the participants could not elaborate what kind of advanced materials specifically.

8.4 Appendix D: E-SIMS scan for assessing Industry 4.0 maturity

Table 5: Extended science-based multi-dimensional scan for assessing Industry 4.0 maturity by Ungerer (2019)

Aspects	Measurement questions	Possible answers
Introduction questions	1. The total sales of our sector grow very fast compared to other sectors. 2. The sales in recently opened niches within our sector grow very fast. 3. The pace of change in our sector is very fast compared to other sectors. 4. New competitors enter the sector with innovative products very often. 5. The technological frontier advanced very rapidly in our sector 6. External factors are forcing unpredictable transformations in our sector 7. The boundaries of our sector are undergoing a major redefinition. 8. Established competitors constantly challenge our positions. 9. Established competitors constantly challenge our positions 10. Myriads of actions by our rivals continually erode our advantage. 11. Our products are constantly under attack from low-cost substitutes.	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A1: Strategy	12. To what extent is the implementation of industry 4.0 important for the success of the organisation? 13. To what extent does your organisation have plans to invest into industry 4.0 objectives? 14. To what extent is there a dedicated budget for implementing new digitalisation initiatives? 15. To what extent is data used as an asset in order to create value from? 16. To what extent does your organisation have a coherent digital business strategy supporting industry 4.0 practices? 17. To what extent do industry 4.0 technologies contribute to the value creation of the organisation? 18. To what extent is there a clear vision for a digital journey?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A2: Employees	19. To what extent are the employees aware of the opportunities that industry 4.0 has to offer? 20. To what extent do the employees have enough knowledge to implement industry 4.0 technologies?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent

	21. To what extent are developments that happen in the business environment communicated immediately within the organisation? (So everyone is up-to-date) 22. To what extent do employees regularly meet in order to discuss new events? 23. To what extent is your organisation "paperless" in the workplace? 24. To what extent do employees have the right tools to develop the necessary skills in order to thrive in a digital business environment?	
A3: Management & Leadership	25. To what extent does the management bolster the implementation of industry 4.0 practices? 26. To what extent does the management encourage to try out industry 4.0 techniques in daily activities? 27. To what extent does the management have the ability to lead the organisation into new industry 4.0 practices? 28. To what extent does management use industry 4.0 techniques (data driven, analytics) in decision-making? 29. To what extent do team members of all departments contribute to the final decision-making process when it comes to change management?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A4: Organisational culture & Knowledge management	30. To what extent is your organisation capable to apply gained knowledge? 31. To what extent are trainings/workshops offered to employees to enable them to understand what a “smart factory” is? 32. To what extent does the culture support to think out of the box and create new innovative ideas? 33. To what extent does the organisation allow employees to improve the knowledge of digitalisation within the organisation? 34. To what extent do you think that your organisation puts enough effort in making the organisation "smart"?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A5: Marketing & Sales	35. To what extent does the marketing & sales department know the online behaviour of its target groups? 36. To what extent do you monitor the performance of online marketing techniques?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent

	37. To what extent do you improve online marketing techniques by measuring their performance? 38. To what extent is the sale process done in a digital manner? 39. To what extent is the website of the organisation optimally utilized for gaining necessary information about your products/services?	
A6: Customer services	40. To what extent are industry 4.0 technologies involved in customer services? 41. To what extent are customers automatically notified on information regarding their orders? 42. To what extent can customers digitally access the performance information of their product? 43. To what extent are machines equipped with sensors/algorithms/modelling, so customers can be automatically notified when maintenance is needed? 44. To what extent are different channels available for customers to (24/7) access important information regarding the organisation?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A7: Channels	45. To what extent are customers able to access the product/service by multiple integrated digital channels? 46. To what extent are the developments of customer needs per channel continuously monitored? 47. To what extent do automatised processes facilitate the channels? 48. To what extent are data analyses used as a source in order to improve the channels? 49. To what extent are multiple channels used in order to keep customers up to date regarding company information?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A8: Institutional awareness	50. To what extent can you guarantee that digital business policy is up-to-date and sufficiently developed? 51. To what extent is the intellectual property for products and services of your company protected? 52. To what extent are employees of your organisation aware of the privacy and security risks concerning the implementation of Industry 4.0 technologies? 53. To what extent are you aware of possible tax effects of new circumstances as a result of Industry 4.0 applications? 54. To what extent are you able to handle privacy requests for access	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent

	following the new European privacy legislation (GDPR) automatically?	
A9: Sustainability	55. To what extent have industry 4.0 technologies improved the environmental sustainability of the organisation? 56. To what extent has industry 4.0 enabled the implementation of sustainable management strategies? 57. To what extent is the sustainability of your products measured by using industry 4.0 technologies? 58. To what extent are the production emissions measured by the using industry 4.0 technologies? 59. To what extent are emissions from your product in the field measured by using industry 4.0 technologies?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A10: Inbound logistic activities	60. To what extent does your organisation establish collaborations on industry 4.0 topics with your suppliers? 61. To what extent are industry 4.0 technologies used in the collaboration with partners/suppliers? 62. To what extent is the organisation digitally connected with its suppliers? 63. To what extent do industry 4.0 technologies help to get a good overview of the warehouse? 64. To what extent are the actions automated after processing the data of incoming deliveries from your suppliers?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A11: Outbound logistic activities	65. To what extent can you automatically keep track on products in transit? 66. To what extent does the organisation institutionalize collaboration on industry 4.0 topics with its customers? 67. To what extent are industry 4.0 technologies used in order to collaborate with the end customers? 68. To what extent is your organisation digitally connected with your customers? 69. To what extent do you use industry 4.0 technologies in order to optimise the amount of inventories?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A12: Products & Services	70. To what extent do industry 4.0 technologies support servitisation? 71. To what extent do industry 4.0 technologies help you to offer your services more efficiently?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent

	72. To what extent is data used in order to improve existing products/services? 73. To what extent is the mainstream product/service in your product portfolio digitalised? 74. To what extent can you follow/track your product performance in the field? 75. To what extent is the development of a new product done in a digital way? 76. To what extent do industry 4.0 technologies help in ensuring the quality of products/services?	
A13: Production & Process	77. To what extent is the production directed by automated processes? 78. To what extent are production machines equipped with sensors that allow tracking the condition of these machines? 79. To what extent do you use industry 4.0 technologies to make processes more efficient/cheaper? 80. To what extent are industry 4.0 technologies used to recognise undesired variations in the production process? 81. To what extent does the organisation provide you with the possibility to see how industry 4.0 technologies are influencing production processes? 82. To what extent is a digital model of the factory already created? 83. To what extent is the production equipment digitalised/enhanced with industry 4.0 technologies? 84. To what extent are machines equipped with technologies that allow them to detect deviations in the process? 85. To what extent are machines equipped with technologies that allow them to detect deviations in the product specification during the production process? 86. To what extent is production related data shared with partners in a manner that is beneficial for all partners in the supply chain?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent
A14: IT Management	87. To what extent does your organisation collect relevant data that is available to you? 88. To what extent is IT prepared for rapid changes in business requirements caused by the digital journey?	(1) Not at all (2) To a small extent (3) To a moderate extent (4) To a great extent (5) To a very great extent

	89. To what extent is the organisation able to adjust the IT architecture to a digital organisation? 90. To what extent is your IT integrated with customers/suppliers? 91. To what extent are sufficient ICT security measures taken for data exchange/storage to protect all company data? 92. To what extent do you use data from processes/products to make real-time autonomous ERP/MRP decisions? 93. To what extent is the website operative on all desired platforms? 94. To what extent are industry 4.0 technologies important for enabling (new) business operations? 95. To what extent does your IT/ICT infrastructure support innovative industry 4.0 based solutions? 96. To what extent are sufficient ICT security measures taken when designing new systems/website/apps?	
A15: Industry 4.0 technologies	Which Industry 4.0 technologies are you already using (multiple answer options are possible)?	(1) Interoperability (2) Internet of Things/connectivity (3) Cloud/Edge computing (4) 3D printing (5) Block chain (6) Advanced robotics (7) AGV (automated guided vehicles)/drones (8) Advanced materials (9) AR/VR/Smart vision (10) Advanced analytics (big data)/artificial intelligence/machine learning

Table 6: Extended science-based multi-dimensional scan for assessing Industry 4.0 maturity by Ungerer in Dutch (2019)

Aspecten	Vragen	Mogelijke antwoorden
Introductievragen	1. De totale verkoop in onze sector groeit zeer snel. 2. De verkoop in recent geopende niches binnen onze sector groeit zeer snel 3. Het tempo van veranderingen in onze sector is zeer snel vergeleken met andere sectoren. 4. Er komen heel vaak nieuwe concurrenten de sector binnen met innovatieve producten.	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate

	5. De technologische grenzen veranderen in toenemende snelheid in onze sector. 6. Externe factoren zorgen voor onvoorspelbare transformaties in onze sector. 7. De grenzen van onze sector ondergaan een grote herdefinitie. 8. Onze sector maakt belangrijke ontwikkelingen door die niemand had voorzien. 9. Gevestigde concurrenten dagen onze posities voortdurend uit. 10. Talloze acties van onze rivalen dagen onze posities voortdurend uit. 11. Onze producten worden voortdurend aangevallen door goedkope vervangers.	
A1: Strategie	12. In welke mate is de implementatie van industrie 4.0 belangrijk voor het succes van de organisatie? 13. In welke mate heeft de organisatieplannen om te investeren in industrie 4.0 toepassingen? 14. In welke mate is er een geoormerkt budget voor het implementeren van nieuwe industrie 4.0 doelstellingen? 15. In welke mate wordt data gebruikt als aanwinst om waarde mee te creëren? 16. In welke mate beschikt de organisatie over een samenhangende digitale bedrijfsstrategie die industrie 4.0 toepassingen ondersteunt? 17. In welke mate dragen industrie 4.0 technologieën bij aan de waarde creatie van de organisatie? 18. In welke mate is er een duidelijke visie voor een "digital journey"?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A2: Werknemers	19. In welke mate zijn de werknemers op de hoogte van de kansen die industrie 4.0 te bieden heeft? 20. In welke mate hebben de werknemers genoeg kennis om industrie 4.0 technologieën te implementeren? 21. In welke mate worden ontwikkelingen die plaatsvinden in de bedrijfsomgeving direct gecommuniceerd binnen de organisatie? (Zodat iedereen up-to-date is) 22. In welke mate komen werknemers regelmatig samen om nieuwe ontwikkelingen te communiceren? 23. In welke mate is de organisatie "papierloos" op de werkplaatsen? 24. In welke mate hebben werknemers de juiste middelen om essentiële	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate

	vaardigheden te ontwikkelen om te gedijen in een digitale bedrijfsomgeving?	
A3: Management & Leiderschap	25. In welke mate ondersteunt het management de implementatie van industrie 4.0 praktijken? 26. In welke mate moedigt het management aan om industrie 4.0 technologieën uit te proberen in dagelijkse activiteiten? 27. In welke mate heeft het management de vaardigheden om de organisatie te leiden m.b.t. nieuwe industrie 4.0 praktijken? 28. In welke mate gebruikt het management industrie 4.0 technologieën bij het maken van beslissingen? 29. In welke mate dragen werknemers van alle afdelingen bij aan het maken van belangrijke beslissingen m.b.t. het beheren van veranderingen?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A4: Bedrijfscultuur & Kennismanagement	30. In welke mate is de organisatie bekwaam om opgedane kennis toe te passen? 31. In welke mate worden er trainingen/workshops aan werknemers aangeboden om hen te laten inzien wat een "smart factory" inhoudt? 32. In welke mate ondersteunt de cultuur om "out of the box" te denken en zodoende innovatieve ideeën te creëren? 33. In welke mate ondersteunt de organisatie het vergaren van kennis door werknemers m.b.t. de digitalisatie van de organisatie? 34. In welke mate denkt u dat de organisatie genoeg inspanning levert om de organisatie "smart" te maken?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A5: Marketing & Sales	35. In welke mate is de marketing & sales afdeling zich bewust van het online gedrag van de doelgroep(en)? 36. In welke mate wordt de prestatie van verschillende online marketingtechnieken gecontroleerd? 37. In welke mate worden online marketingtechnieken verbeterd aan de hand van het meten van hun prestaties? 38. In welke mate verloopt het sales proces op een digitale manier? 39. In welke mate wordt de website van de organisatie optimaal benut voor het opdoen van informatie omtrent uw producten en diensten?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A6: Klantenservice	40. In welke mate wordt er gebruikt gemaakt van industrie 4.0	(1) Helemaal niet (2) In geringe mate (3) In zekere mate

	technologieën bij diensten voor klanten? 41. In welke mate worden klanten automatisch op de hoogte gehouden van informatie? 42. In welke mate kunnen klanten de informatie omtrent prestaties van hun producten digitaal inzien? 43 In welke mate zijn machines uitgerust met sensoren/algoritmen/modellering, zodat klanten automatisch op de hoogte worden gehouden wanneer onderhoud nodig is? 44. In welke mate zijn er verschillende kanalen beschikbaar voor klanten zodat zij (24/7) toegang hebben tot belangrijke informatie omtrent de organisatie?	(4) In grote mate (5) In zeer grote mate
A7: Kanalen	45. In welke mate hebben klanten toegang tot het product/service via meerdere geïntegreerde digitale kanalen? 46. In welke mate worden ontwikkelingen van klantbehoeften per kanaal continu gevolgd? 47. In welke mate faciliteren geautomatiseerde processen de kanalen? 48. In welke mate worden data-analyses gebruikt om de kanalen te verbeteren? 49. In welke mate worden er meerdere kanalen gebruikt om klanten up-to-date te houden omtrent bedrijfsinformatie?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A8: Institutioneel bewustzijn	50. In welke mate kunt u garanderen dat het digitale bedrijfsbeleid up-to-date is en dus voldoende ontwikkeld? 51. In welke mate is het intellectuele bezit voor de producten en diensten van uw bedrijf beschermd? 52. In welke mate zijn relevante werknemers binnen uw bedrijf op de hoogte van de wet- en regelgeving rondom de implementatie van industrie 4.0 technologieën en werkwijzen? 53. In welke mate bent u bewust van mogelijke fiscale effecten binnen uw bedrijf die nieuwe omstandigheden ten gevolge van industrie 4.0 met zich meebrengen? 54. In welke mate bent u in staat om privacy toegangsverzoeken volgens de Europese privacywetgeving (AVG) automatisch af te handelen?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A9: Duurzaamheid	55. In welke mate hebben industrie 4.0 technologieën bijgedragen aan het verbeteren van de duurzaamheid in de organisatie?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate

	56. In welke mate heeft industrie 4.0 het implementeren van duurzame strategieën mogelijk gemaakt? 57. In welke mate wordt de duurzaamheid van uw producten gemeten door gebruik te maken van industrie 4.0 technieken? 58. In welke mate wordt de uitstoot tijdens productie gemeten met behulp van industrie 4.0 technieken? 59. In welke mate worden de milieu-effecten van geleverde producten gemeten met behulp van industrie 4.0 technieken?	(5) In zeer grote mate
A10: Inkomende logistieke activiteiten	60. In welke mate brengt uw organisatie samenwerkingen tot stand met leverancier over industrie 4.0 onderwerpen? 61. In welke mate worden industrie 4.0 technologieën gebruikt in de samenwerking met partners/leveranciers? 62. In welke mate is de organisatie digitaal verbonden met haar leveranciers? 63. In welke mate dragen industrie 4.0 technologieën bij aan een goed inzicht in het inkomende logistieke proces? 64. In welke mate zijn de acties geautomatiseerd na het verwerken van gegevens voortkomende uit inkomende leveringen van leveranciers?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A11: Uitgaande logistieke activiteiten	65. In welke mate kunt u producten die onderweg zijn geautomatiseerd volgen? 66. In welke mate institutionaliseert de organisatie samenwerkingen met klanten omtrent industrie 4.0 onderwerpen? 67. In welke mate wordt er gebruik gemaakt van industrie 4.0 technologieën om samen te werken met klanten? 68. In welke mate is de organisatie digitaal verbonden met klanten? 69. In welke mate wordt er gebruik gemaakt van industrie 4.0 technologieën voor voorraadoptimalisatie?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A12: Producten & Diensten	70. In welke mate dragen industrie 4.0 technologieën bij aan servitisatie? 71. In welke mate helpen industrie 4.0 technologieën mee om diensten efficiënter aan te bieden? 72. In welke mate wordt er gebruik gemaakt van data om bestaande producten/diensten te verbeteren?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate

	73. In welke mate is het doorsnee product/service in de product portfolio gedigitaliseerd? 74. In welke mate kunt u de prestaties van geleverde producten volgen/traceren? 75. In welke mate wordt de ontwikkeling van nieuwe producten op een digitale manier gedaan? 76. In welke mate dragen industrie 4.0 technologieën bij aan het waarborgen van de kwaliteit van producten/diensten?	
A13: Productie & Proces	77. In welke mate wordt de productie gestuurd door geautomatiseerde processen? 78. In welke mate zijn machines die gebruikt worden voor de productie uitgerust met sensoren die het toelaten om de conditie van deze machines te traceren? 79. In welke mate worden industrie 4.0 technologieën gebruikt om processen efficiënter te maken? 80. In welke mate worden er industrie 4.0 technologieën gebruikt om ongewenste variaties in het productieproces te herkennen? 81. In welke mate biedt de organisatie u de mogelijkheid om te zien hoe industrie 4.0 technologieën productieprocessen beïnvloeden? 82. In welke mate is er een digitaal model van de fabriek gemaakt? 83. In welke mate is de productieapparatuur uitgerust met industrie 4.0 technologieën? 84. In welke mate zijn machines uitgerust met technologieën waarmee ze afwijkingen in het proces kunnen detecteren? 85. In welke mate zijn machines uitgerust met technologieën waarmee ze afwijkingen in de productspecificatie tijdens het productieproces kunnen detecteren? 86. In welke mate worden productie gerelateerde data gedeeld met keten partners op een manier die toegevoegde waarde heeft voor alle keten partners in de supply chain?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate
A14: IT Beheer	87. In welke mate verzamelt uw organisatie de data die voor u beschikbaar is? 88. In welke mate is de IT voorbereid op snelle veranderingen op zakelijk gebied die worden veroorzaakt door de "digital journey" die u ondergaat?	(1) Helemaal niet (2) In geringe mate (3) In zekere mate (4) In grote mate (5) In zeer grote mate

		89. In welke mate kan de organisatie de IT-architectuur aanpassen aan een digitale organisatie? 90. In welke mate is uw IT geïntegreerd met klanten/leveranciers? 91. In welke mate worden er voldoende ICT-beveiligingsmaatregelen genomen voor de data uitwisseling/opslag om alle bedrijfsgegevens te beschermen? 92. In welke mate gebruikt u data uit processen/producten om realtime autonome ERP/MRP beslissingen te nemen? 93. In welke mate werkt de website op alle gewenste platforms? 94. In welke mate zijn industrie 4.0 technologieën belangrijk om (nieuwe) bedrijfsvoering mogelijk te maken? 95. In welke mate ondersteunt uw UT/ICT infrastructuur innovatieve industrie 4.0 gebaseerde oplossingen? 96. In welke mate worden er voldoende ICT-beveiligingsmaatregelen genomen bij het ontwerpen van nieuwe systemen/websites/apps etc?	
A15: Industry 4.0 Technologieën		Geef aan welke industrie 4.0 technologieën u al gebruikt (meerdere antwoordmogelijkheden zijn mogelijk).	(1) Interoperabiliteit (2) Internet of Things (IOT)/connectiviteit (3) Cloud/Edge computing (4) 3D printen (5) Block chain (6) Geavanceerde robotica (7) AGV (automated guided vehicles)/drones (8) Geavanceerde materialen (9) AR/VR/Smart visie (10) Geavanceerde analyses (big data)/kunstmatige intelligentie/machine learning