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

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

ABSTRACT,
Today, the industrial production firms are aiming to improve competitiveness through the fourth industrial revolution technologies, which incorporates a fusion of physical production with the digital world of information technology. The potential benefits Industry 4.0 will bring are clear, however, there is a shortage of practical research on actual hurdles confining employment as well as how those are predicted to be overcome by SMEs. In order to gain a profound opening of the phenomenon implementation in practice with all of its challenges, a study was done in three case companies operating in the timber industry in Eastern Latvia. First, descriptive data were collected with the use of SIMS scan developed by Ungerer (2018), which were further used for the collection of the qualitative data by workshops at the manufactories. The study indicates several factors that hinder the employment of the new production revolution technologies. The main challenge on Industry 4.0 implementation is the shortage of technology experts in the region as well as in the timber industry, which hinders the possibility of inter-firm connectivity due to the slow individual firm progress. Further, the SMEs lack financial resources necessary for modern machinery acquisition and it has been concluded that, although there are certain benefits, Industry 4.0 employment is highly case-specific and cannot be suited to every firm in the industry due to the strategical differences. Findings of the influence of Industry 4.0 belong to a new research field, however, the literature review on different aspects aligns with the overall findings. Limitations of this study include limited sample size and the size and origin of the case companies themselves, which restricts the validity and the international generalizability of the research.

Graduation Committee members:
1st supervisor: Dr. R.P.A. Loohuis
2nd supervisor: H.G. Hanna MSc

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1. INTRODUCTION

1.1 Topic relevance

We are currently witnessing the beginning of a new stage of a far-reaching scientific and technological industrial manufacturing transformation (Beier at. al 2017, Kang et. al., 2016), which is occurring due to the merge of physical manufacturing systems with the digital technologies and known under the term of Industry 4.0 (I4.0) or Industrial Internet of Things (IIoT). Industry 4.0 aims at the development of an accessible, smart manufacturing platform for industrial-networked information operation by actual time data monitoring, tracking status and positions of products as well as instructing control over the production processes (Vaidya et. al, 2018). The benefits and motivating factors of (often theoretical) IIoT employment are widely known and frequently mentioned in the scientific literature, where, from the economic perspective, implementation of the Industry 4.0 practices lead to manufacturing cost reduction, leads time shortening, quality enhancement, production flexibility, equipment effectiveness and resource efficiency (Peukert et al., 2015; Kagermann et al., 2013). Moreover, Industry 4.0 technique fulfillment allows mass-customized production implementation because of the system capability to handle high complexity by incorporating self-controlling systems (Brettel et al., 2014). These benefits act as motivators combined with a number of CSR (corporate social responsibility) enhancing factors such as reduced waste and energy consumption and flexible work environment (Carvalho et al., 2018; Muller, Kiel and Voigt, 2018; Kiel et al., 2017, Beier et al., 2017, Wang et al., 2016). Moreover, nowadays CSR serves as an important motivator element due to the fact that ethical aspects of corporate social responsibility have a significant influence on consumers perceptions of brand equity (Yang and Basile, 2019).

There are all types of benefits associated with the Industry 4.0 implementation by manufactories in the literature, however, whether there is and what is the actual pace of technology implementation and what is the future still lacs the research base, together with the hurdles which may hinder the process. Moreover, a lack of empirical data, therefore, may cause a denial or ignorance of the implications of the new era by the manufactories, creating drawbacks in terms of incorrect response to the situation or use of underperforming way of work, which, however, causes financial shortcomings. The “hype” around the topic in sync with the unknown state of the art in Industry 4.0 and possible hurdles forms the main need to address the topic of current Industry 4.0 implementation and future anticipation by the SMEs.

1.2 The objective of the research

One of the aspects of the research is the aim to assess small and medium-sized companies by emphasizing the ones with limited access to funds, as pointed out by Safar et.al (2018) - especially for manufacturing SMEs with significantly limited resources, compared to large enterprises, special guidance could be a good starting point for implementation of Industry 4.0 elements. And as found out by Ghulam (2019), younger and smaller firms are more likely to have their credit applications rejected, minimizing the chances of development. Taking into account the difficulty of the situation for the SMEs, the purpose of the research is based on a necessity to find out how and whether SME’s as manufactories react on the industry change, what are the hurdles and what is their planned future action. With the information regarding the actual anticipation of Industry 4.0 by SMEs and its aspects, a pathway for each individual company can be developed as well as a broad overall situation in the market can be understood.

In order to develop the deepest qualitative judgment on the topic, the research question "How do small and medium-sized manufacturing companies anticipate on Smart Industry Revolution and deal with the challenges accompanied by it?" will be investigated in three manufacturing SMEs in Eastern Latvia, operating in the timber industry.

The state of the art of the companies will be explored using the Smart Industry Maturity Scan (SIMS) by Ungerer (2018) as a data collection method. Furthermore, the triangulation method with the aim to generate as precise portray as possible will be used, by uncovering the Industry 4.0 implementation and future action foresight state from 7 different perspectives with regard to possible challenges and future actions by the means of workshops with company managers and employees.

Based on both qualitative and quantitative data, patterns and similarities regarding the current state and future actions between the three investigated companies will then be explored and serve as a ground for cross-case analysis as well as a discussion in order to draw conclusions and answer the research question.

1.3 The structure of the thesis

The thesis consists of ten chapters. Following the introduction, a scientific literature review is conducted on two topics most related to the research objective: hurdles and the current state of Industry 4.0 implementation, as well as an explanation of the main aspects of the term Industry 4.0. Further, the different tools, methods, and strategies used are explained and justified in chapter three. After this, the empirical findings are summarized and cross-case analysis is conducted in chapter four, with the result interpretation on the basis of theoretical findings conducted in chapter five. In chapter six limitations and future research suggestions are uncovered, following with the conclusions in chapter seven and acknowledgments, references and the appendices in chapters eight to ten.

2. THEORETICAL BACKGROUND

In order to answer the research question, it is important to understand the term of Industry 4.0 and its technological core. Further, the benefits of the complementary technology and system implementation serving as motivator factors are discussed. Following hurdles on Industry 4.0 implementation are outlined, leading to the findings of previous studies on phenomenon employment.

2.1 Industrial Internet of Things

Although there is no approved definition for the IIoT (Industrial Internet of Things) (Kiel et al., 2017), the term can be explained as continuous digitization and agile connection bringing benefits to the entire value chain by consolidating all organizational functions and operations, products and services. The technological core of the IIoT is formed by the Cyber-Physical Systems (CPS), a term offered to the public by Helen Jill in the year 2006 (Ivanov et al., 2018). CPS are systems consisting of various material objects, artificial subsystems, and controllers, which form a single whole (Zhuge, 2015). From the previously existing mechatronic systems, CPS differ in the presence of intelligence (knowledge and procedures for their formation, replenishment, manipulation) and the ability to interact with their environment; plan and adapt their own behavior according to the environment; learn new patterns and behaviors and be self-optimizing (Ivanov et al., 2018). CPS forms the technological core which is integrated into the industrial production resulting in a digitized connection across the value chain (Kagermann et al., 2013; Kiel et al., 2016). The trend in the manufacturing businesses is also referred to as the fourth industrial revolution or I4.0 (Industry 4.0), a term popularized in Germany around 2013 (Burmeister et al., 2016).

2.2 Hurdles on INDUSTRY 4.0 Introduction

The most often mentioned hurdle (60.8%) by managers clarified during a case study with 46 respondents by Kiel et al. (2017) is technical integration, thus, the need for intra- and inter-firm connection. This, however, requires technical modernization and large investments by the main constituent of the companies operating within the industry (Kagermann et al. 2013), which is in line with Muller and Voigt (2018), who found that the main challenge of the IoT implementation in SMEs is financial resource availability. Moreover, existing studies reveal that SMEs' challenges differ from those of large companies in Industry 4.0, thus, for SMEs it specifically implies resource limitations and low bargaining power (Muller, 2019; Muller, Kiel and Voigt, 2018).

After a survey with more than 100 IIoT executives, the main challenge on IoT implementation discovered is dealing with "legacy" devices and software, mentioned by 53.1% of respondents, while connectivity is mentioned by 48.9% (IoT World, 2018). Only 37.4% of the respondents mention managing the department operations, which does not fully support Iyer (2018) with the statement that the critical challenge for manufacturers is addressing managerial decision making. Moreover, Kiel et al. (2017) also do not find managerial issue the top challenge, while Bauer et al. (2016) states difficulty in coordinating actions across different organizational units as one of the top challenges, therefore forming a basis for further discussion.

2.3 Industry 4.0 Employment

The main finding of Bauer et al. (2016) was that in general, 6 out of ten companies feel prepared for Industry 4.0, although only 16% of manufacturers have Industry 4.0 strategy - data after a survey with 300 industry experts from Germany, US, and Japan. Ivanov et al. (2018) state that the companies lack an overall and intra- and inter-connectivity, but technological novelties such as sensors or 3D printers are used only contextually in order to solve separate problems. Researchers link this to the current state that there are numbers of engineering solutions for IIoT with limited participation of economists and ceos in Industry 4.0 projects. Oesterreich and Teuteberg (2016) share similar findings that despite the availability and maturity of many beneficial technologies, their widespread adoption has not taken place, together with Thoben et al. (2017), claiming that Industry 4.0 is in its early stage and that the near future ought to present developments in the area. Wang et al. (2016) in contrary, state, that although the implementation of smart manufactory is possible, there are still shortages in technology and the promotion of technical advancements is necessary, adding that application of Industry 4.0 can only be done in a progressive way.

Although data protection remains a prominent concern, 72.2% of the respondents in interview conducted by IoT World are ensured that security is incorporated into the design or life cycle of the product (IoT World, 2018), meaning that currently some of the hurdles on Industry 4.0 employment are being solved by the proposed progress with security. Ancarani et al. (2019), however, add that the adoption pace of Industry 4.0 practices is significantly related to the product quality priority, thus, in industries requiring high manufacturing precision, like food processing or machinery manufactories.

Muller (2019), states that manufactories using Industry 4.0 technologies predominantly mention key partners that are experts in machines and IT as especially important for operation and control of Industry 4.0 based systems. Moreover, Geissbauer et al. (2014) states that more than a half of companies implementing Industry 4.0 are convinced that close co-operation with value chain partners is of high importance, together with Burmeister et al. (2016) who revealed that partnerships are important since good hard- and software skills are necessary to be combined in order to compete in the market. This can be linked to limited possibilities of SMEs to train or hire experts (Muller, 2019), while Thiede et al. (2016), states that education and training is the key success factor for manufactories implementing technological novelties.

2.4 Timber Industry 4.0

The research and scientific literature on Industry 4.0 in the context of the timber industry is very limited. After literature research on the topic, Muller et. al (2019), concluded that the term Industry 4.0, IIoT or similar terms are not used in the context with the timber industry and that there are only four articles discussing I4.0 in the context of timber, whereas only two are available and applicable. The main finding by Bo and Wang (2011) applicable to the current case study is that the scale cost for IOT facilities is very crucial, as well as that the realization in forestry industry still needs time. Furthermore, Fitzgerald (2016), states that right now in the sawmills there is a massive opportunity to use the big data and become more networked due to the fact that the information currently does not flow from one machine to another through sawmills. However, the amounts of the data generated at one particular place at the mill can create an unbearable amount of data, requiring maybe even inaccessible amount of computing power. Moreover, Fitzgerald (2016), states that forestry is one of the "technology laggard" industries, contributing to the finding of Bo and Wang.

Other findings in the literature are related mainly to the opportunities of Industry 4.0 in fire detection and some to the inventory mapping (Muller at. al, 2019), meaning that the term Industry 4.0 is very rarely used within the sector, therefore making this case study the only of a kind.

3. METHODOLOGY

The literature review has been formed in a way to conceptualize theoretical concepts and their attributes and then have a look at previous research. Because of scarce previous research data on Industry 4.0 implementation by manufacturing SMEs (Burmeister et al.,2016; Brettel et al., 2014; Kiel et al., 2017; Kiel et al., 2016, Muller, 2019); an exploratory qualitative research

design was chosen. As a sampling procedure, a non-probability purposive sampling method was implemented, thus, observation units for the sample were chosen by the researcher because of certain characteristics (Black, 2010). Three manufacturing SMEs were chosen in Eastern Latvia, fulfilling the criteria for SMEs conforming to the definition of the German Institute of SME research (less than 500 employees and an annual turnover smaller than €50m).

As a descriptive data collection method, a multi-dimensional smart industry scan developed by Ungerer (2018) was used, consisting of 35 ordinal measurement level questions, which can be found in chapter 10 in appendix 1. In order to make sure all of the participants had the same understanding of Industry 4.0, everyone was provided with a short explanation of Industry 4.0 features, which, as the scan was translated to Latvian. The scan surveys were held face-to-face with all of the participants separately in order to prevent possible bias and to explain the survey questions if necessary. The current state of each company Industry 4.0 implementation was measured over 7 dimensions – Strategy & Organization, Products & customer services, People & Organizational Culture, Customer Interfaces, Value chain, Technology & IT Management, and Institutional Awareness. For each of the dimensions there are 5 questions, all of which were asked to the manager of the company as well as other employees. The overall number of respondents is 25. Scan participants were asked to give their personal estimation of how these dimensions are influenced by the changes induced by Industry 4.0.

In order to validate the research, a triangulation method was used, thus, after the status quo of the companies in Industry 4.0 was obtained with the use of the scan, workshops with the company CEOs and one of the CEO-selected employees were held. During the workshops designated to last less than half an hour, the survey data were analyzed on each dimension separately and altogether with the use of radar charts, leading to possible conclusions regarding the Industry 4.0 employment, hurdles, and future action. Due to the fact that the data obtained with the scan is quantitative and that there are five questions on one aspect, the data represented to the company were provided in radar charts, which can be found in the appendix in chapter 10. Further, the results of Industry 4.0 implementation and the next steps of SMEs are inductively analyzed by conforming to qualitative content analysis as well as a cross-case analysis.

4. EMPIRICAL RESULTS

In this chapter, the results of the scan and the workshops of all three firms are presented and the cross-case analysis is conducted.

In order to be able to perceive the results of the research to a higher extent, it is necessary to understand the main differences between the three manufactories operating in the timber industry. First, company “A” is least automated and using old-world machines. Company "B", in the contrary, is the one with the largest number of employees between all three firms and using somewhat automated technologies, with a large interest in future developments. Firm "C" is the smallest one, using human craftsmanship together with modern technologies.

All three manufactories consider their industry as rather characterized by many rules and regulations, certain future developments with a few competing technologies for production and products and little cross-fertilization with other industries. Moreover, companies view the industry as changing very incrementally without rapid developments and its past forming a good representation of the future, with a little difference for company B – it hopes and is working on future technology and machinery developments.

4.1 Aspect 1 (A1) – Strategy and Organization

The descriptive questions of A1 measure the extent to which Industry 4.0 is included in firm strategy with digital features, data and innovation inclusion and monitoring.

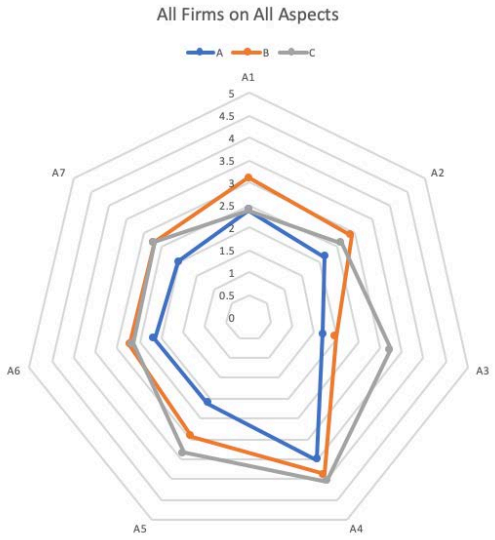

Figure 1. Radar chart on all aspects all firms

Manufactories A and C perform equally on the first aspect – strategy and organization (see Figure 1) therefore reaching the second level and becoming “learners” as stated by Ungerer (2018) (see Figure 2) However, firm B sees Industry 4.0 more as a part of its strategy, due to the fact that it is focusing on innovations in machinery and looking for new ways of accomplishing current tasks. Moreover, in the future foresight, the company is even ready to cooperate with engineering firms for the production of the machinery which is unavailable in the market although possible for production but necessary to automate the work of the plant. Although the firm indeed outperforms the two other manufactories in including Industry 4.0 in its strategy, this can mainly be associated with the innovation need and an interest in modern technology introduction in the future but not so much with the other constituents of an actual implementation of Industry 4.0. Firm B foresees technology introduction possible when there will occur the development in the industry forming a basis for new machinery production.

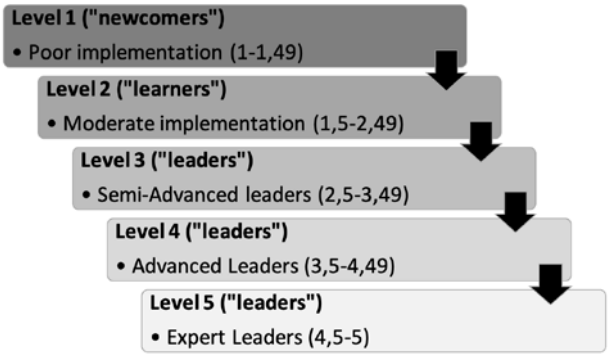

Figure 2. Maturity levels adapted from Ungerer (2018)

In contrary to the case company B, firm A does not find many opportunities for it to develop in line with Industry 4.0 due to the lack of resources. In order to implement at least some of the Industry 4.0 aspects and technologies, the manufactory needs almost a complete modernization, but the company CEO does not consider the business rentable enough for large future investments and is unwilling to have any financial attachment.

Different situation is with the firm C – it is interested in Industry 4.0 technologies, however, introducing them would mean that the specifics of the firm by using old-fashioned way of production with the craftsmanship is lost, while the firm is unwilling to change its strategy to such a large extent in the nearest future and anticipates no change in the market the firm currently operates in.

4.2 Aspect 2 (A2) – People and Organizational Culture

The scan questions of aspect 2 measure the extent to which employees and managers are trained for I4.0 implementation and to what extent is the current organizational culture stimulating employees for IIoT technology appliance.

On A2 company B again performs best, although a little worse than on the first aspect. The firm stays on the "semi-advanced leader" level with an average score of 2,93. The weakest point of the firm is training for Industry 4.0 readiness. Company manager does not see an available option in the region for professional training and does not find himself competent enough for information sharing with the employees. Additionally, the tough economic situation in the region was mentioned making it even more difficult to acquire expertise. Future action is anticipated to include employee training when there occurs opportunity, either with the help of the government projects either by cooperation with large enterprises when the situation stabilizes.

The firm C has also reached "leader" level with a score of 2,6 and has the same weakness – employee training. Here specifically Industry 4.0 is not a part of the future strategy of the company and therefore not in its interest field. On the other hand, in the company there is a high level of high-tech and industry-specific instruments which do require expertise which is shared by the machinery providers. For the reason, the employees consider themselves as able to learn quickly, with the company manager being less optimistic regarding the issue.

On the second aspect company A performs the worst over all three firms with an average score of 2,16. On the 15th question regarding the frequency of consideration of Industry 4.0 related issues between the employees, the firm manager states more often discussion about the theme than the company employees. After the workshop, it was clarified that the difference in the opinions has occurred due to the misunderstanding of the employees that some of the technical issues can be related to the IIoT. Although this can be linked to the fact that the employees lack training and even theoretical understanding of the phenomenon, company manager does not consider it a problem to be solved in the future, since there is no employee involvement in the strategical subject and overall no interest and opportunity for Industry 4.0 implementation yet.

4.3 Aspect 3 (A3) – Products and Customer Services

Aspect three questions are in part related to the extent to which manufactured products are equipped with Industry 4.0 technologies and in part with customer service digitization.

Because of the low performance of manufactories A and B on the questions regarding the product relatedness to Industry 4.0, which is linked to the simplicity of the timber end-product, there is a comparatively higher performance of company C on the questions because of more technology involved in the firm's end-products. In result, firms A and B are on the "learners" level with 1.69 and 1,98, but firm C has the highest score of 3,2. Both "learner" firms do not see certain opportunities in the closest future to improve on the aspect due to the industry specifics. However, all three firms with the firm C first share that they work a lot on receiving the customer feedback and that customer feedback automated data use may become an actual state in the farther future. Company C is the closest to the end user among the case companies, which may serve as a ground of even larger interest and sensitivity in customer satisfaction. Moreover, there is a common tendency over all three firms – managers see their interest in positive customer feedback more outstanding than the employees (see Figure 3). When discussed with the firms it was linked to the narrow job responsibilities of the employees, who do not have nor communication with the company clients nor financial interest in the customer satisfaction but rather in fast production. However, the employees were aware that if the customer requirements are not met the firms may face difficulties reflecting on them as well.

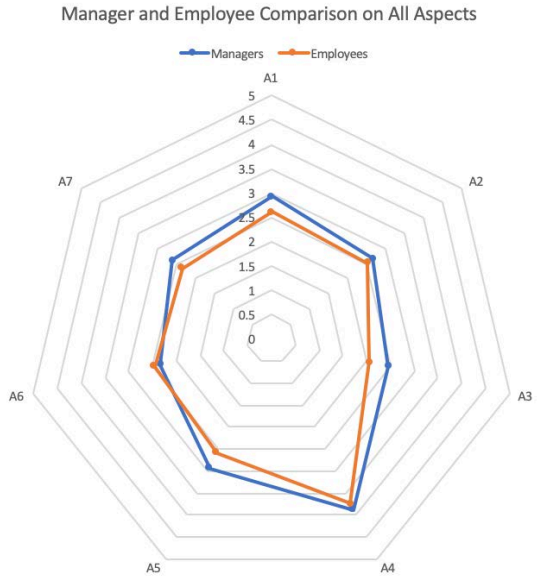

Figure 3. Radar chart on all firm manager and employee comparison on all aspects

4.4 Aspect 4 (A4) – Customer Interfaces

Aspect 4 is measured over the questions related to customer interaction methods and digitization of the customer journey. A4 is where all of the firms perform the best overall seven aspects (see Figure 1).

Firm C performs the best overall three firms and reaches the score of 4, while firm B is not much behind with 3,89. Firm A again has a little lower score of 3,51. However, the descriptive results of the scan were disputed during a workshop with firm A manager and one of the employees. In appendix 2, it can be seen that on question 26 regarding the extent of digitization of the customer journey the managerial and employee judgment differs. Company CEO considers that the customer journey is to a large extent digitized and taking into account that the amount of time employees are interacting with the customers is minimal in comparison with the managerial, their view, although in superiority, is not considered as representative. Therefore, in fact, it can be considered that all three firms perform equally on A4.

Only company C predicts actually possible developments in customer interaction digitization in the nearest future, while both company A and B consider customer interaction being led successfully without a necessity for making it more digitized, also due to the fact that A4 is where the firms perform best overall seven aspects and therefore find other issues more important.

4.5 Aspect 5 (A5) – Value Chain

Descriptive questions of the SIMS scan on aspect 5 measure the extent to which the value chain of the product manufactory and delivery process is digitized.

Company A again performs the worst over all three firms and can be considered a "learner" with a score of 2,11 on the scan results. The company sees a large opportunity for improvement as well as its weakest point in terms of Industry 4.0 implementation exactly the digitization of the value chain. Currently, there is no system for raw material and end product logistics and delivery information. In the nearest future, the case company finds as only available option cooperation with leading logistics or timber companies in order to minimize the time necessary for coordination and control, if the price of the digitization will be considered bearable and trustful connectivity can be reached.

Firms B and C are “semi-advanced leaders” on A5 with the descriptive scores of 2,93 and 3,4. At the moment, company B has been less focused on improving the digitization of the value chain, while firm A has implemented more in order to achieve the currently available maximum level. However, manufactory B is looking for future improvement opportunities in the value chain when there occurs necessary for the development of machinery renewal in the plant. The future outlook is the main difference with firm C and commonality with the case company A.

4.6 Aspect 6 (A6) – Technology and IT Management

Measurement questions on A6 are devoted to the clarification of the extent of data protection and usage with the Industry 4.0 technologies.

Companies B and C again have almost equal results – 2,71 and 2,7, but 2,15 for manufactory A. Manufactory A is unable to make autonomous decisions in real time with the data in hand and perceives it a very complicated issue. First of all, because it lacks smart machinery which generated data automatically, second, due to the necessity of huge amounts of data storage and analysis where specific expertise is necessary and therefore can be achieved only with costly outsourcing, all of which is not in the future plans of the firm.

However, in company C there are being conducted small automated operations with the real-time data because of the use of modern technologies in instruments available at the market. The difference can be perceived because of the price of the machinery – in firms A and B “smart” machinery means new strategy and business model, large debts and more complex and lengthy switch, which was clarified during the workshops. However, for firm C switch to different instruments and technology used for production is a practically more easily accomplishable task, while, as previously mentioned, the company is unwilling to switch to more mechanized production strategy in the nearest future. The company B predicts more automated operations to occur in the future with the plant machinery renewal.

4.7 Aspect 7 (A7) – Institutional Awareness

Institutional awareness aspect includes questions on firm maturity on compliance with laws and regulations, estimation of risks, taxes and security issues.

Again, firms B and C perform equally – 2,69 and 2,7, while the firm A has the lowest score which equals 2 and after the scan is classified as the only “learner” among the firms.

In firms A and C there is a larger differentiation between the managerial and employee opinion on scan questions than in firm B (see appendices and figure 3). This was further explained occurring due to the difference between the manager and employee understanding of legal matters. Another commonality between the firms occurred that the employees tend to slightly overestimate the managerial and technological capability of Industry 4.0 readiness. Thus, when the questions measure respondent’s knowledge, employees have lower answer scores than the managers, however, when the questions measure firm’s readiness on Industry 4.0, employees usually slightly overestimate, comparing to the managerial opinion.

The CEO of company A finds Industry 4.0 technology introduction highly complex also in terms of legal issues in the country, while firm B manager does not perceive Industry 4.0 as a problematic legal issue but rather as a solution for many problems. For firm B, more modern technology involved in the plant is anticipated to immediately decrease the employee number and therefore also the costs of the production and workplace safety increase, therefore minimizing the current complication sphere. Manufactory C representatives are also rather neutral regarding the legal issues but more alarmed with the data security Industry 4.0 introduction may bring. The company itself is unable to ensure complete data security, therefore the decreased security side effect of even more automated technology introduction is considered as a possible hurdle for the firm.

4.8 Summary of the Results

Further the results of the cross-case analysis are summarized in text and in the table (see table 1) in order to give an expositive answer to the research question of the study - “How do small and medium-sized manufacturing companies anticipate on Smart Industry Revolution and deal with the challenges accompanied by it?”

Overall, the main commonality in the firm future outlook was that the case companies A and C both do not expect to strategically introduce the Industry 4.0 with its accompanying technologies, while manufactories B and C are both currently technologically better developed, comparing to the case company A.

For firm A, the main reason for a more pessimistic view on Industry 4.0 has been formed because of the resource limitation hurdle and the unwillingness to attach any more funds to the firm. However, the firm does place some hopes on Industry 4.0 in terms of firm interconnectivity with its suppliers as well as the customers. This is because it is seen as a more easily accomplishable task in the future than forming full intra connectivity within the firm. Thus, the firm is looking for a solution for one specific problem instead of strategically approaching Industry 4.0 through the operations.

For the case company C, the introduction of more smart and automated machinery would involve strategy change from craftsmanship to a fully automated plant. This would mean losing the specifics of the firm as well as a complete change on its market segmentation, which is not in line with the plans for the nearest future of the strategical development of the firm. The

only future improvement is expected to occur within the customer journey. The firm anticipates developing highly interactive digitized customer experience, linked to the operations in the firm, while the main hurdle on the development is ensuring sensitive data security.

In contrary to the two other cases, firm B owns high expectations regarding the Industry 4.0 technology use, while currently there has not occurred actual opportunity to introduce it because of unavailability of the specific machinery necessary for the operations. The firm owns strongly positive outlooks and hopes Industry 4.0 to solve existing problems, even regarding the legal terms, while the main hurdle on the development is the lack of the expertise in the field and in the region.

Moreover, regional specifics with the drawbacks have been mentioned also by the two other case companies. This is regarding the limited skilled workforce as well as regarding the overall expertise in the field also within the large manufactories. This is because the region the firms operate in is rather rural and the situation improvement would be tough to achieve only with the influence SMEs own in the market.

It can be concluded that the case companies mainly anticipate on very gradual change to occur, which is because it is anticipated to be, first, segmented and meant for specific task solving, and second, developing slowly with large own involvement due to the unavailability of the machinery as well as experts in the field.

Table 1. Summary of the Results

Aspect	Company A		Company B		Company C	
	Action	Anticipation	Action	Anticipation	Action	Anticipation
1. Strategy and organization	Almost no strategical focus on I4.0 implementation.	Does not predict strategical I4.0 implementation in the future due to the large investment needed.	Seeks opportunities in machinery development, Industry 4.0 strategy introduced to a minimal extent.	Predicts a rapid development in the market as well as in the company when there occurs an availability for modern machinery.	Almost no strategical focus on I4.0 implementation.	Does not predict strategical I4.0 implementation in the future due to the technology misalignment with the firm's strategy.
2. People and organizational culture	No employee training has caused a lack of employee understanding of the phenomenon of I4.0.	The problem with the employee training will not be addressed in the nearest future because no need is predicted.	The firm encounters problems with acquiring the necessary expertise.	Employee training is predicted to form the main problem in the future, due to the unavailability of experts in the field.	Employees are to some extent trained to work with high-tech machinery.	The problem with the employee training will not be addressed in the nearest future because no need is predicted.
3. Products and customer services	No technology involved in the end-product. Customer services are digitized.	Technology involvement in the end product is impossible in the future. Overall, more customer service digitization is anticipated.	No technology involved in the end-product. Customer services are digitized.	Technology involvement in the end product is impossible in the future. Overall, more customer service digitization is anticipated.	More technology involvement in the end-products; customer services operated with high care.	Customer services are predicted to become even more sensitive with the use of data gathered with smart technologies.
4. Customer interfaces	Customer journey is digitized.	More digitization of the customer journey is not predicted in the nearest future.	Customer journey is digitized.	More digitization of the customer journey is not predicted in the nearest future.	Customer journey is highly digitized.	More digitization of the customer journey is predicted in the nearest future.
5. Value chain	No current focus on the value chain digitization.	The value chain is anticipated to be made digitized in the future.	No current focus on the value chain digitization.	The value chain is anticipated to be made highly digitized.	The value chain is digitized to some extent.	No digitization of the value chain is predicted in the nearest future.
6. Technology and IT management	Manufactory is unable to make autonomous decisions in real time.	High technology involvement in the plant is not	Some operations are automated with the use	Data use is predicted for automated operations in the future	Small automated operations are conducted in real time.	No future improvement is predicted.

		predicted in the nearest future.	of real-time data.			
7. Institutional awareness	Currently, I4.0 does not form problematic issues.	I4.0 is predicted to be highly complex with the jurisdiction of the country.	Currently, I4.0 does not form problematic issues.	I4.0 implementation is anticipated to solve current legal issues.	Legal issues are well handled. Improvements are needed with data security.	Ensuring data security is predicted to form a hurdle on I4.0 implementation.

5. INTERPRETATION

In the previous section, the cross-case analysis has been conducted with the use of data gathered with the SIMS scan and with the information obtained during the workshops in three firms. In this section, the results of the analysis will be compared to the information available in the literature regarding the Industry 4.0 implementation and hurdles on it as well as the current theoretical state will be advanced with the findings of the research.

The main hurdles in Industry 4.0 technology implementation within the firms were the lack of resources and a lack of expertise by the company itself as well as in the market. In order to ensure employee capability to deal with IIoT, one of the companies considers the training of the existing employees, however, there are no actual opportunities to do that with quality in the region. Furthermore, in discussion with the company B manager it was revealed that even currently occurring technical issues are hardly manageable in a short time span due to the lack of experts. This is in line with Muller (2018), who states that for SMEs integrating current employees with Industry 4.0 requires training and qualification and is especially challenging. Furthermore, the hurdle of a lack of expertise is unpredictable when will be overcome also due to the industry specifics – as mentioned earlier, Industry 4.0 in relation to the timber industry is rarely used (Fitzgerald, 2016) and therefore, even the existing experts in IIoT may be unable to serve for timber industry technologies as well. The importance of partners is emphasized in the theoretical literature, which states that the key partners may be especially important for Industry 4.0 technology control and operation for SMEs (Kagermann et al., 2013). However, with the regional specifics another hurdle is formed – the region lacks technology experts because of tough economic situation, thus, acquiring expertise for the manufactory would require either costly training far from the plant, either costly specialist recruitment, if found, forming an endless circle tough to breach if there is no outside involvement. Thus, the current study regarding the SME Industry 4.0 technique implementation lacks insight in the situation in the regions where expertise is unavailable, which is one of the contributions of the research to the current theoretical development in the field.

The main hurdle on firm A was limited resources for technology modernization. The firm CEO does not even consider the introduction of Industry 4.0 technologies in the plant in the nearest future because of costly machines necessary for the implementation, as well as because of unbearable costs of further data management and analysis. The expenses are considered outperforming any further benefits, which is in line with Muller and Voigt (2018), who state that the resource limitations are one of the primary SME hurdles on Industry 4.0 implementation. The only possible future modernization considered by the company A is related to the firm inter-connectivity, which can be done if there occurs a technology-driven logistics company with an acceptable price for the firm A, however, the future prospect currently lacks implementation opportunities for several reasons. First, as stated earlier in the section, there is a shortage of Industry 4.0 expertise in the region, especially within the timber industry, and second, as found out in the research by the Internet of Things World (2018) as well as by Kiel et al. (2017), connectivity is a major obstacle among the firms introducing IIoT.

Furthermore, the hurdle on the technology implementation within the plant of the company B is the unavailability of the machinery. This forms a great contribution to the earlier research by Bo and Wang (2011), where it is said that Industry 4.0 implementation within the timber industry still needs time. Currently, the situation in the region the case companies operate in has not changed, because there is no ready to offer machinery in the market. Thus, the research particularly adds to the scientific discussion of Industry 4.0 because of its specifics - it investigated SME's which operate in the timber industry in terms of Industry 4.0, which, as clarified in the second chapter, owns a very limited research base. Taking into account that the two qualities are combined, a reason is formed to suppose that the research is the only one of a kind.

6. LIMITATIONS & FUTURE RESEARCH

The research cannot be generalized and lacks validity because of several limitations on the basis that the results are drawn from, although the conclusions are derived from empirical results. First of all, the sample size is too small for the research to make an insight into the industry and even more to serve as a ground for a valid overall future of SMEs anticipation. Furthermore, the companies participating in the research were rather small than medium-sized, and rather at the start of the Industry 4.0 implementation, although can generally be considered representative for the region of the study. Moreover, as a limitation may be seen the fact that all of the companies are from the same industry and the same region, therefore the context and scope of the research are limited to the timber Industry 4.0 in Eastern Latvia. On the other hand, the triangulation approach by using both quantitative and qualitative data with many several respondents allows the development of a deep and many-sided understanding of a situation in each company. Moreover, it allowed clarification of the issues due to the opinion misalignment between the employees and managerial workforce, and therefore the approach is highly recommended to use for future research. This industry-specific research methodology on Industry 4.0 employment may serve as a good starting point for more extensive future research in the timber industry in order to provide suited recommendations. The last limitation of the research has been the strict time limitation in the framework of the bachelor thesis, and as a result in two of the companies there was an opportunity to work with the scan with less than a half of the company employees.

For future research, there is an opportunity and necessity to expand in the actual situation evaluation. Nevertheless, there is an uncovered research area for Industry 4.0 in relation to the

timber industry, and collecting data from other SMEs is to be recommended, as it would test the conclusions the thesis has come to. Conducting cross-case analysis among different sized companies is likely to result in additional insight. Moreover, as already stated by Müller, Buliga, and Voigt (2018), research in terms of SME employment of technologies still remains rare, and taking into account the limited resources of the SMEs (Safar et.al, 2018) guidance on the Industry 4.0 practices is especially necessary. Therefore, the vision is to further investigate how SMEs anticipate Industry 4.0 and the main hurdles on actual employment in terms of different industries and regions. The cooperation between practitioners and academics should guide the next phases of the research in order to reach actual and applicable results.

7. CONCLUSION

Industrial production currently is undergoing a transformation towards interconnected and digitized manufacturing (Beier et al., 2017). This thesis discusses the changes the transformation brings about in the sector and what are the hurdles on modern technology implementation as well as what are the future prospects of the three case manufactories, in order to answer the research question "How do small and medium-sized manufacturing companies anticipate on Smart Industry Revolution and deal with the challenges accompanied by it?". The academic contribution of the work is in its empirical cross-case comparison with the use of triangulation method, thus, the use of both descriptive and explanatory data gathering methods, as well as in the case company qualities. Triangulation approach allowed for an extensive each case company investigation and detail specification, where drawbacks and errors were eliminated with further understanding development of the region and industry specifics with the use of cross-case analysis. The empirical results are presented, compared and discussed in the previous sections.

The results of the cross-case analysis indicate that, although Industry 4.0 aspects are differently perceived by the case companies, the main hurdles on actual implementation remain the same – first, there is a lack of experts in the region. The companies understand the benefits and the main constituents of the Industry 4.0, however, it cannot be practically implemented with the available workforce for a number of reasons. First, Industry 4.0 lacks overall use within the timber industry, second, there are no experts even among the large enterprises yet in the field in the region either, furthermore, there is a shortage in the necessary machinery provision. Therefore, it is advised to the companies willing to become more digitized in the region, first, to cooperate with the providers of available technologies in the market and second, ask for the government support and then form the future of the timber industry itself, due to the fact that, as previously clarified, SMEs lack market influence in order to change the situation alone, but together as an industry the situation may change with the influence coming from outside. Moreover, with the cooperation, an opportunity for the timber industry to overcome also the hurdle of the resource limitation may occur, further serving as an opportunity to develop a stable basis for the industry and then to develop trusty inter and intra-firm connectivity as well as common standards among the firms.

Moreover, it can be concluded that each case company develops different future anticipation vision accordingly to its current state as well as its future strategy. Therefore, it is difficult to predict the future for the SMEs in general, however, the basis for the necessary future action important to foster the development within the industry has been derived taking into account shared hurdles on Industry 4.0 practice implementation.

In conclusion, it can be said that the ongoing transformation of industrial processes provides large opportunities for the timber industry but in order to be exploited requires an increase in the number of experts in the region and in the sector. Accordingly, this digitalization should receive more attention from researchers and leading timber industry companies as well as from the government to ensure proper exploitation of opportunities of Industry 4.0 also within the specifics of the timber industry and identification of potential hurdles and corresponding countermeasures.

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10. APPENDICES

10.1 Appendix 1: Multi-dimensional smart industry scan by Ungerer (2018)

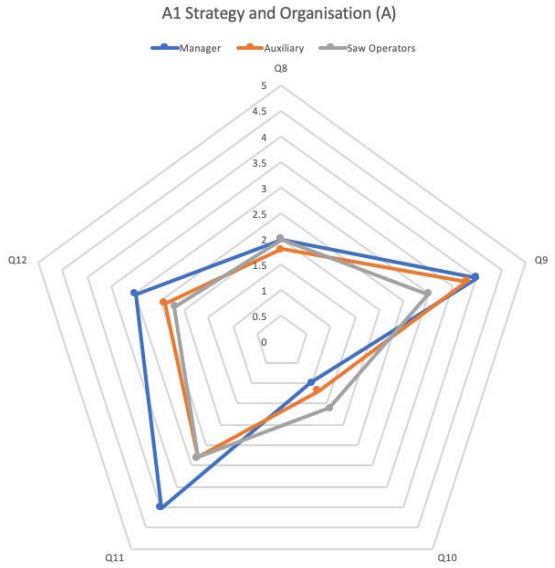
Table 2. Multi-dimensional smart industry scan by Ungerer (2018)

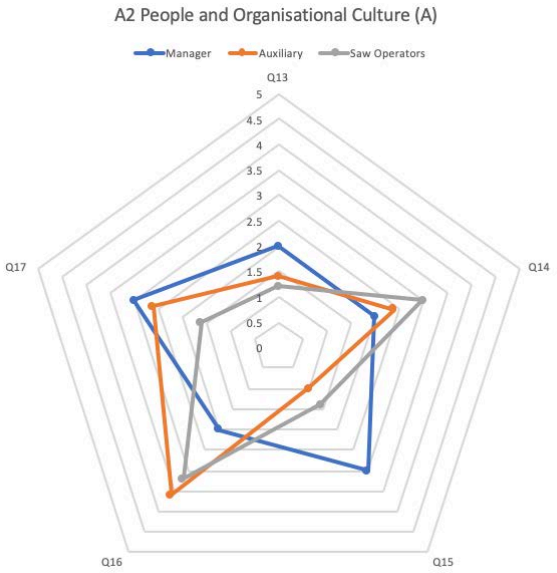
Aspects	Measurement Questions	Answers: (1) Not at all, (2) to some extent, (3) advanced, (4) semi advanced, (5) fully
Introduction questions	1. Our industry is characterized by many rules and regulations (1), a small number of dominant technologies (2) and is unique and isolated from other industries (3)	
	2. Our industry is characterized by clear rules and regulations (1), there are a variety of proven dominant technologies for both production and products themselves (2) which provide perspectives for the future.	
	3. Our industry is characterized by few rules and regulations (1), uncertainty of future developments, many competing technologies for both production and products themselves (2) and there is a large amount of cross-fertilization with other industries (3).	
	4. Our industry changes rapidly over time.	
	5. We can form a good picture of what our future looks like and what opportunities we can take advantage of.	
	6. We are mainly concerned with what is going on in our market today and there are opportunities but also uncertainties that we are trying to understand.	
	7. We mainly rely on experiences from the past when opportunities arise.	
1. Strategy and organization	8. To what extent are industry 4.0 strategies implemented within the organization	
	9. To what extent do digital features, products & services contribute to the overall value creation of your organization?	
	10. To what extent do you record and tail the implementation status of your industry 4.0 strategies?	
	11. To what extent do you use the data gathered for creating value within the organization?	
	12. To what extent is innovation essential within the strategic plans of the organization?	
2. People and organizational culture	13. To what extent are employees within your organization up-to-date with the knowledge regarding industry 4.0?	
	14. To what extent is the management focusing on implementing industry 4.0?	
	15. To what extent is the communication between management and employees open?	
	16. To what extent do employees easily adapt to changes and learn to apply this new knowledge?	
	17. To what extent is the culture within your organization capable and willing to carry out the effort to transform the organization in order to digitalize?	

3. Products and customer services	18. To what extent are the products offered by your organization digitized?	
	19. How would you rate the current implementation of industry 4.0 related to the products in your product portfolio?	
	20. How would you rate the current implementation of industry 4.0 throughout the phases, which your product goes through?	
	21. To what extent do you gather customer feedback for improvements in the future?	
	22. To what extent does digitization within your organization help you to satisfy your customers?	
4. Customer interfaces	23. To what extent do clients use the Internet as a tool to interact with your organization?	
	24. To what extent do you use different channels for interaction with your customers?	
	25. Customer data can be gathered in different ways. To what extent do you use customer data to boost the judgement about your customers?	
	26. The customer journey entails the phases, which a customer goes through when communicating with an organization. To what extent is your customer journey digitized?	
	27. To which extent does the digitization within your organization enable you to work together with customers?	
5. Value chain	28. To what extent does your organization focus on improving digitization within the value chain?	
	29. The horizontal value chain entails the chain from customer order, production, logistics, and marketing to service (Michael Porter, 1985). To what extent is your horizontal value chain digitized?	
	30. To what extent are you already collecting machine data and process data during the production of a product?	
	31. To what extent do you experience delays in your value chain?	
	32. Do you consider the machinery used in the value chain to be digitized?	
6. Technology and IT management	33. To which extent do your focus on new technologies to actively contribute and empower operations within the business?	
	34. To which extent is the department that is responsible for the information technologies capable to accomplish business requirements in the requested time, quality and cost?	
	35. To which extent do you manage the overall requirements from digitization and Industry 4.0 of your Information technologies?	
	36. To which extent do you produce value through the use of available technology in your organization?	
	37. To what extent is your organization focused on technology and using technology in their processes?	
7. Institutional awareness	38. To what extent can you ensure that your digital compliance policy is state-of-the-art and is mature?	
	39. To which extent is your intellectual property for your products and services protected?	

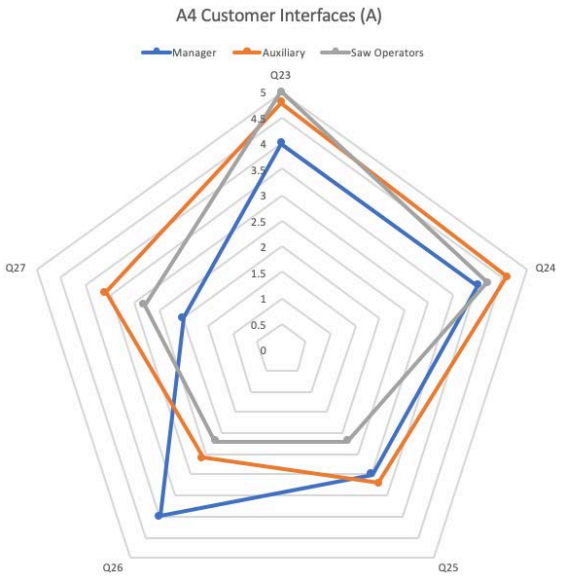
	40. Rules and regulations can be of importance in decision-making. To what extent are you up-todate with regards to the rules and regulations of the implementation of industry 4.0?	
	41. Taxes can be seen as a hidden cost and can bring unforeseen costs. To what extent do you check potential tax impacts when considering new industry 4.0 driven circumstances?	
	42. The new European privacy legislation (GDPR) gives extended rights to consumers and customers. Some of these can be summarized in Subject Access Requests, namely: the right of information, the right of modification, the right to be forgotten and the right of data portability. To what extent are you able to answer Subject Access Request in an automated way?	

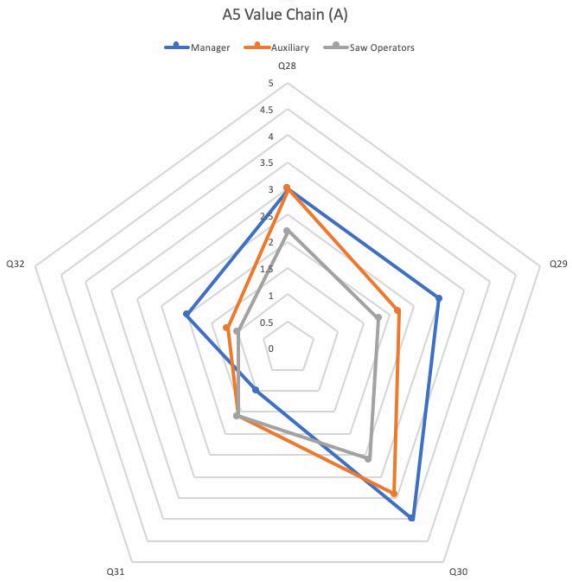
10.2 Appendix 2: Radar charts used during the workshop with the firm A

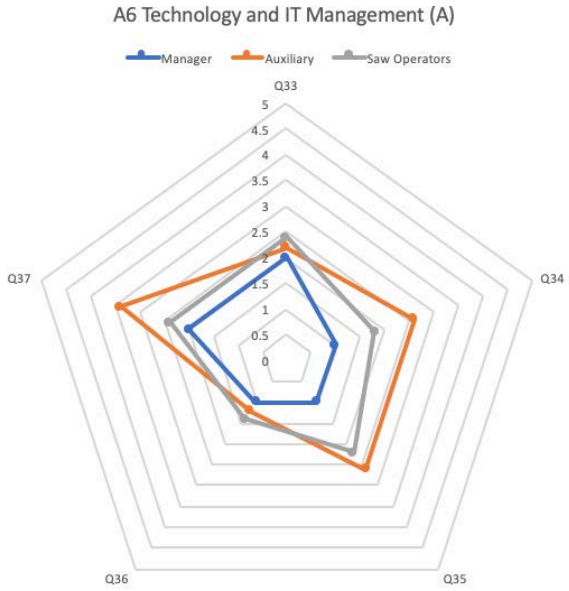


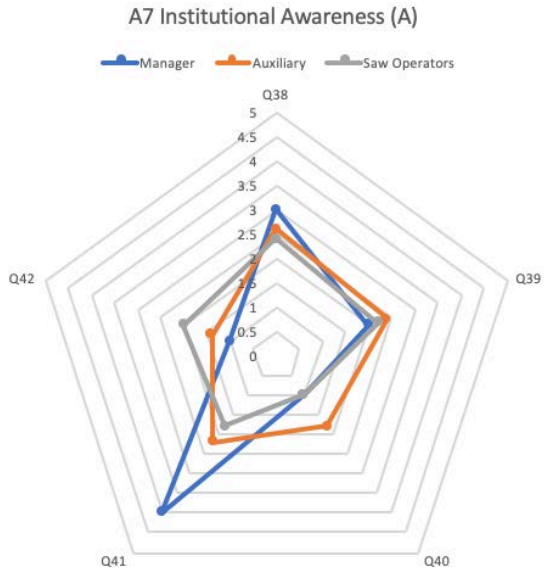

A2 People and Organisational Culture (A)
Manager
Auxiliary
Saw Operators
Q13
Q14
Q15
Q16
Q17
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A3 Products and Customer Services (A)
Manager
Auxiliary
Saw Operators
Q18
Q19
Q20
Q21
Q22
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

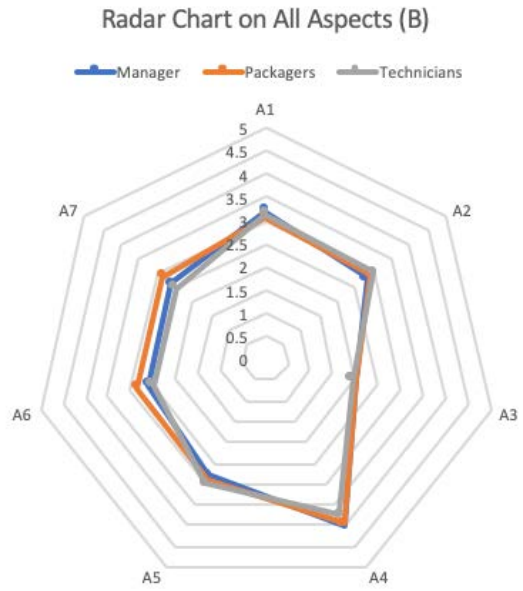

A4 Customer Interfaces (A)
Manager
Auxiliary
Saw Operators
Q23
Q24
Q25
Q26
Q27
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

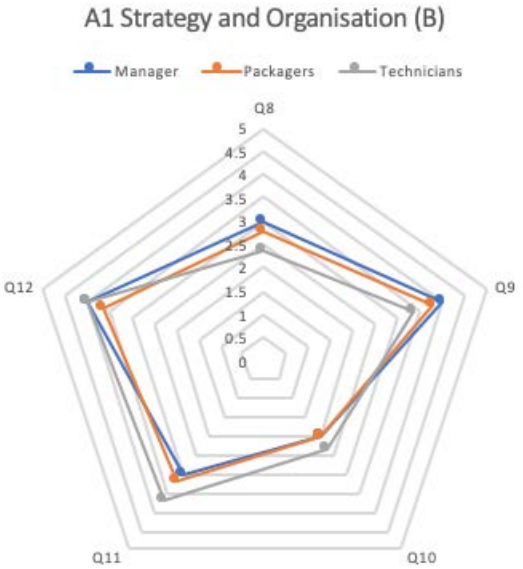

A5 Value Chain (A)
Manager
Auxiliary
Saw Operators
Q28
Q29
Q30
Q31
Q32
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

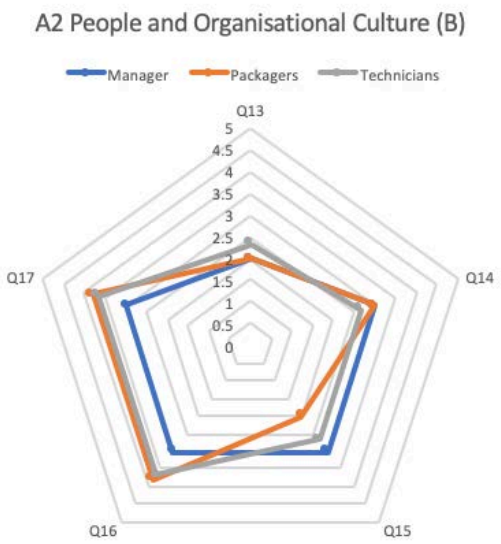

A6 Technology and IT Management (A)
Manager
Auxiliary
Saw Operators
Q33
Q34
Q35
Q36
Q37
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

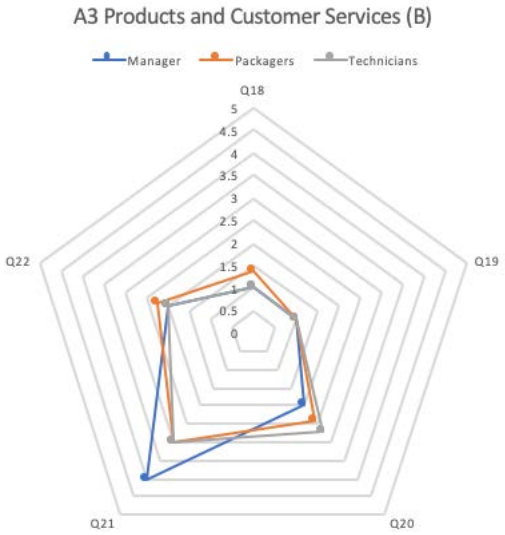

A7 Institutional Awareness (A)
Manager
Auxiliary
Saw Operators
Q38
Q39
Q40
Q41
Q42
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

10.3 Appendix 3: Radar charts used during the workshop with the firm B

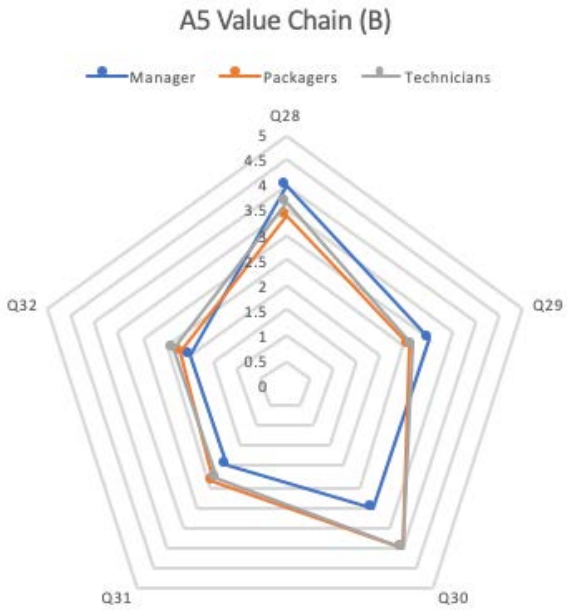


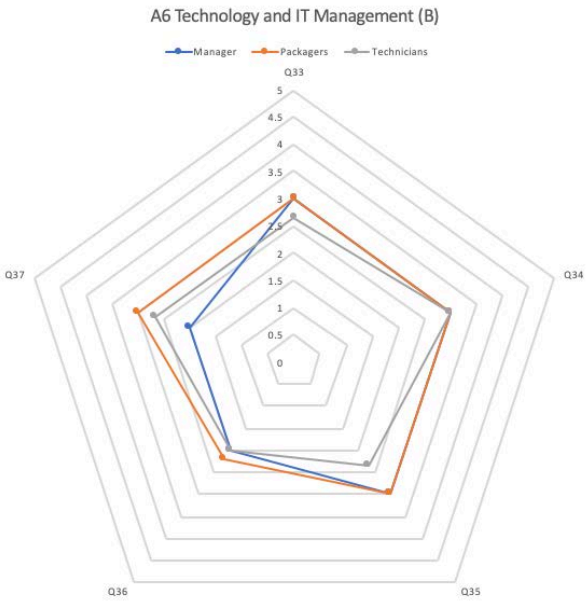


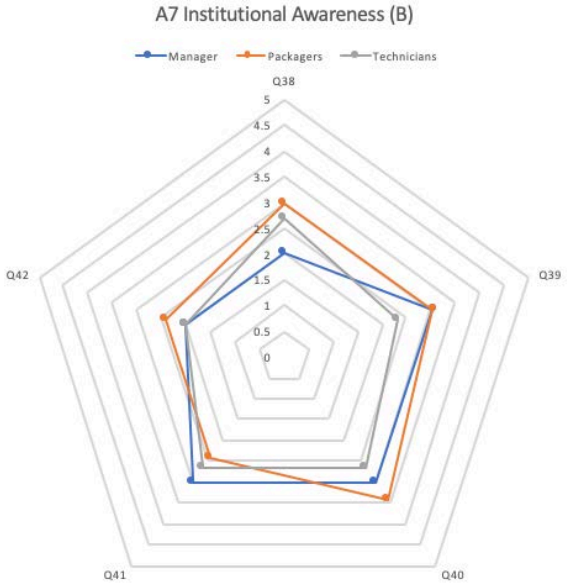

A2 People and Organisational Culture (B)
Manager
Packagers
Technicians
Q13
Q14
Q15
Q16
Q17
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A3 Products and Customer Services (B)
Manager
Packagers
Technicians
Q18
Q19
Q20
Q21
Q22
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

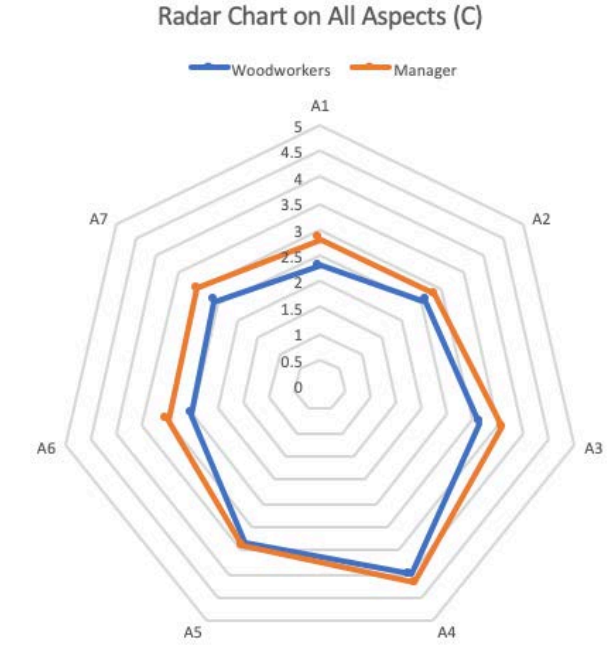

A4 Customer Interfaces (B)
Manager
Packagers
Technicians
Q23
Q24
Q25
Q26
Q27
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

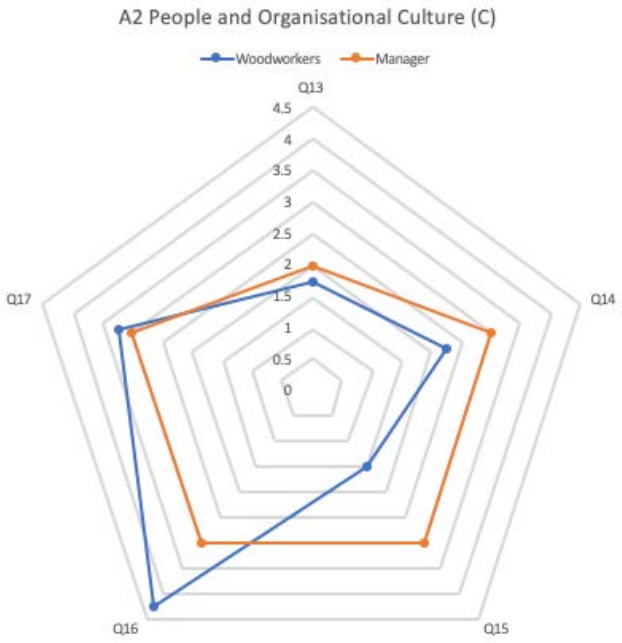

A5 Value Chain (B)
Manager
Packagers
Technicians
Q28
Q29
Q30
Q31
Q32
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A6 Technology and IT Management (B)
Manager
Packagers
Technicians
Q33
Q34
Q35
Q36
Q37
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

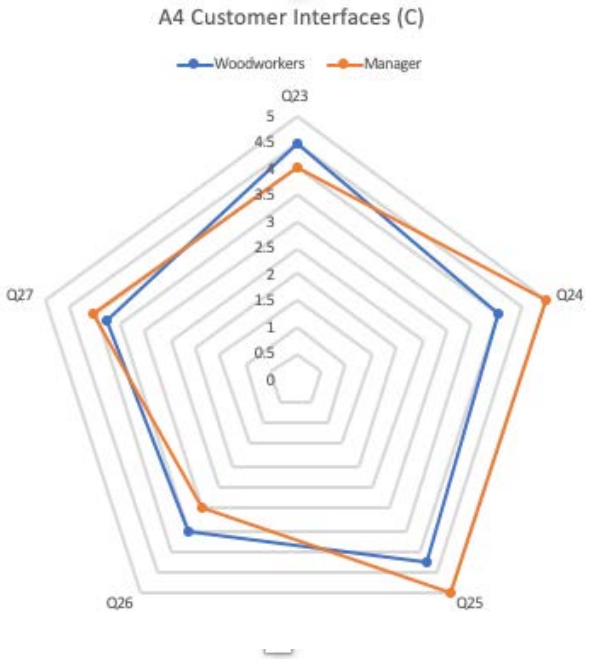

A7 Institutional Awareness (B)
Manager
Packagers
Technicians
Q38
Q39
Q40
Q41
Q42
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

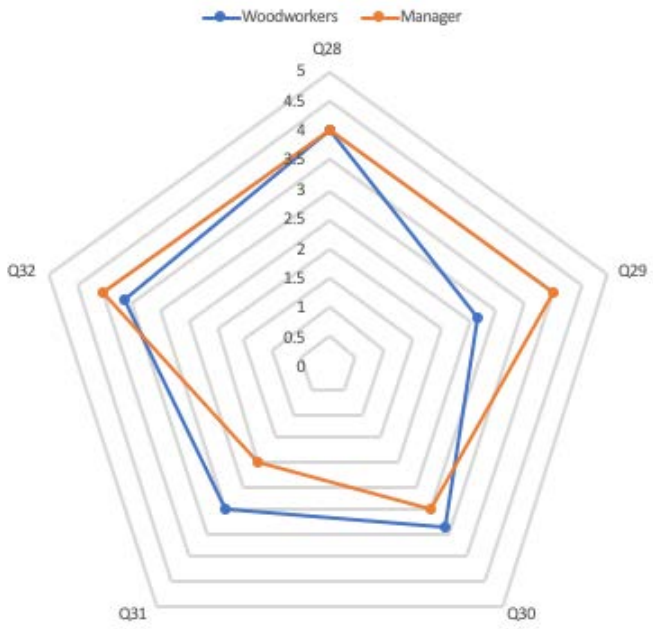
10.4 Appendix 4: Radar charts used during the workshop with the firm C

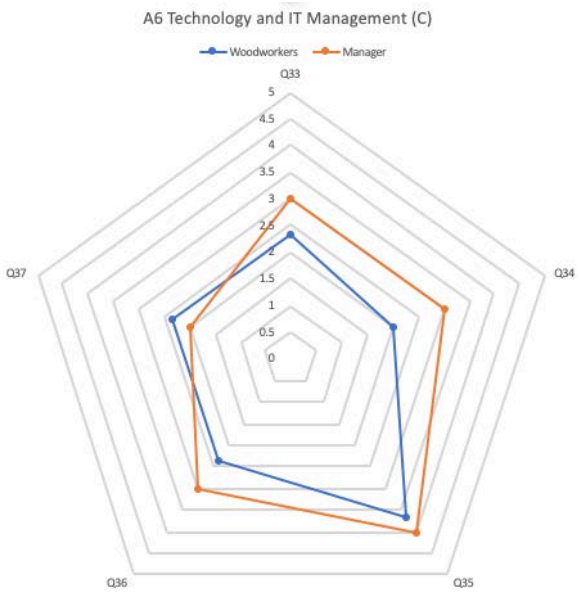


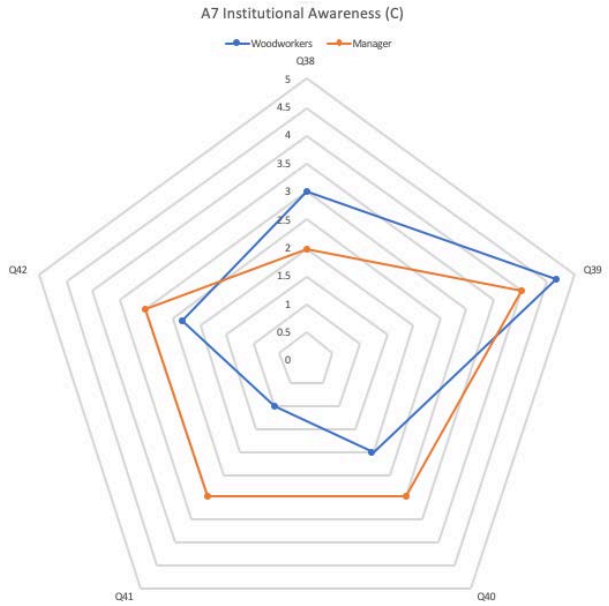

A2 People and Organisational Culture (C)
Woodworkers
Manager
Q13
Q14
Q15
Q16
Q17
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A3 Products and Customer Services (C)
Woodworkers
Manager
Q18
Q19
Q20
Q21
Q22
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A4 Customer Interfaces (C)
Woodworkers
Manager
Q23
Q24
Q25
Q26
Q27
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A5 Value Chain (C)
Woodworkers
Manager
Q28
Q29
Q30
Q31
Q32
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A6 Technology and IT Management (C)
Woodworkers
Manager
Q33
Q34
Q35
Q36
Q37
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


A7 Institutional Awareness (C)
Woodworkers
Manager
Q38
Q39
Q40
Q41
Q42
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0