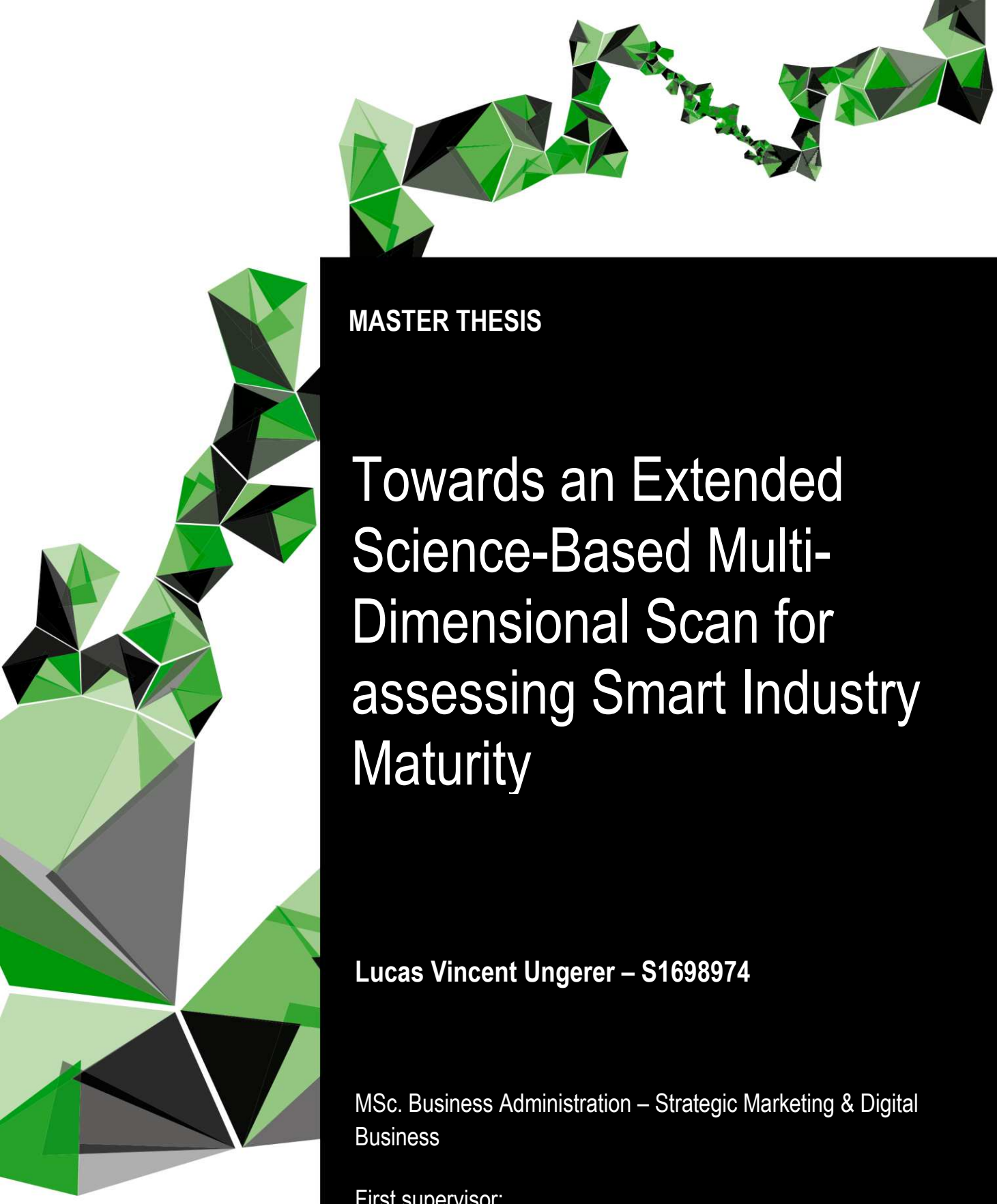

MASTER THESIS

Towards an Extended Science-Based Multi-Dimensional Scan for assessing Smart Industry Maturity

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Abstract

Industry 4.0 or in other words smart industry is becoming increasingly important for organisations. Specifically manufacturing firms are naming industry 4.0 as a top investment priority and are actively investing in the implementation of it in order to stay competitive. Therefore, these manufacturing firms could substantially benefit from a comprehensive overview on the maturity of industry 4.0 implementation. In this research an extended science-based multi-dimensional scan for assessing industry 4.0 maturity is created, here and after known as the "extended scan". This scan measures industry 4.0 maturity on different business aspects throughout the firm. A design research is chosen consisting of steps that were taken to draft and evaluate the extended scan. It started with an extensive literature review towards industry 4.0 maturity and its influence on different business aspects. This was followed up by an exploration of existing industry 4.0 scans including the "multi dimensional smart industry scan" that was created during my bachelor thesis. The combination of these was the foundation of the pre-designed extended scan, which was evaluated by 21 different specialists who provided constructive feedback to further improve the pre-designed scan. The final design consists of fifteen business aspects, 86 measurement questions, five maturity levels and three maturity types.

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Introduction

During the 18th century, the steam engine was introduced, which meant the introduction of the new manufacturing process. It led to a complete transition of the textile industry and the factories that were established led to the development of industrial cities. This period was later referred to as the first industrial revolution. Roughly 150 years later, the invention of the internal combustion engine introduced the second industrial revolution. This invention led to the usage of oil and electricity, which led to rapid industrialization featured by mass production using the assembly line. The third industrial revolution started in 1960 and introduced electronics in order to automate production (Xu, David & Kim, 2016). This period was featured by a shift from mechanical and analogue electronic technology to digital electronics. Currently, we are in, what is called the fourth industrial revolution, which is also called the digital revolution (Vale, 2016). It is featured by technology in the cyber-physical, biological and digital spheres (Xu, David & Kim, 2016).

Part of the fourth industrial revolution is industry 4.0 or in other words smart industry. Industry 4.0 is becoming increasingly important in manufacturing firms. “While in 2015, only half the manufacturing executives interviewed cited digitalization and automation of business processes as a top IT priority, in 2016 more than 90% are investing in these areas (CGI, 2017).” Industry 4.0 and smart factory are terms that are closely related to each other. In a smart factory, smart tools, such as machines, are interconnected and processes are automated. Supply and demand can be seen as an example of an automated process. Smart instruments can notice a possible shortage of supply or demand from customers and increase or decrease the amount of incoming deliveries from the suppliers, to keep the inventory within the organisation stable. One of the main outcomes of a smart factory is the increase of efficiency in the process (Vuksanovic et al, 2016). As mentioned before, within two years there has been an increase from 5/10 to 9/10 of the manufacturing executive stating industry 4.0 practices as a top priority. This increase shows the importance of industry 4.0 implementation. In order for firms to stay competitive the concept of industry 4.0 should be implemented in ones firm (CGI, 2017).

All of this once again shows the importance within this field for a well-organized maturity model for measuring industry 4.0 maturity on different aspects. Maturity models can help an organisation to find out the current status quo of something and can help to figure out what can be improved in order to improve the performance (Fowler, 2014). Schumacher et al. (2016, p162) also state “maturity models are commonly used as an instrument to conceptualize and measure maturity of an organisation or a process regarding some specific target state”. In this research such a maturity model is designed that is called the extended science-based multi-dimensional scan for assessing smart industry maturity, here and after known as ”the extended scan”.

The argumentation behind designing this extended scan is to give a very detailed overview of the implementation of industry 4.0 practices in different business aspects within an organisation, or in other words, display the industry 4.0 maturity of an organisation. The scan is an extension on the more generally oriented "multi dimensional smart industry scan", also referred to as "quick scan" that was designed earlier, in the pursuit of a bachelor thesis assignment (Ungerer, 2018).

The extended scan was created by splitting up the general aspects of the quick scan into multiple aspects. To give an example, value chain was one of the aspects in the quick scan. The extended scan also provided the aspect value chain, however it is now split up into five different aspects, which means that this aspect is assessed in more detail in the extended scan. Next to splitting up the aspects from the quick scan, the extended scan also consists of new aspects that were gathered from an extensive literature review of industry 4.0 implementation and an exploration of existing smart industry maturity scans. This extensive literature review provided a detailed insight into possible input for the measurement questions and aspects. The combination of this extensive literature review and reviewing the existing scans was the foundation of the extended scan.

In this design research, three research questions will be answered:

I. How are the aspects designed, and what argumentation is used in order to design them?
II. How are the measurement questions designed, and what theory is used to design them?
III. How are the maturity levels and maturity types designed?

The paper proceeds as follows: first an exploration will be done on existing smart industry scan, and the most suitable scans will be selected to work with. Next, the aspects will be introduced and the argumentation for using them is provided. Moreover, the literature that is used in order to design the measurement questions is provided, followed up by the construction of the maturity levels and maturity types. Thereafter, the pre-designed scan is shown to specialists and their feedback and insights are shared. Next, some information is provided for practitioners and consultancy in order to make the scan fit for use. Lastly, some ideas for future research are given and the research is concluded.

Step 1: selecting existing Smart Industry Scans

1.1 Exploring existing smart industry scans

In order to draft the extended scan the first step was to conduct an exploration on existing smart industry scans. In the research of Ungerer (2018) four existing scans were reviewed. This theory expands to a total of eleven existing scans. The criterion for selecting them is provided in table 2 in the next paragraph. It provided a greater insight into the existing aspects and measurement questions. These eleven scans consisted of 57 aspects, 402 measurement questions and 37 maturity levels. Table 1 provides a table that shows the foundation of the extended scan. In this figure one can see the different scans that were found when exploring existing smart industry scans. First, the entity that provided the scan is given, followed up by the name of the scan, and lastly the URL or reference of the scan is provided.

Table 1. The details of the scans found

Entity	Scan name	URL/Reference
Webs	*Digital Maturity Scan*	http://www.digitalmaturity.nl
Nom	*Smart Industry Assessment*	https://www.smart-industry-assessment.nl/questions/introduction
AFAS	*N.A.*	https://afassoftware.typeform.com/to/zaD7Q0
PWC	*Industry 4.0 Self Assessment*	https://i4-0-self-assessment.pwc.nl/i40/landing/
IMPULS	*Industry 4.0 readiness Online Self-Check for Businesses*	https://www.industrie40-readiness.de/?lang=en
Rabobank	*Hoe digitaal is jouw bedrijf?*	https://www.rabobank.nl/bedrijven/groei/digitalisering/digitaliseringsscan/
N.A.	*A maturity Model for assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises*	Schumacher, A., Erol, S., & Sihn, W. (2016). A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. Procedia CIRP, 52, 161-166.

Future Industries/ Paul Höppener	*I4 maturity tool*	N.A.
IIC	*IIoT Maturity Assessment*	https://www.smartindustry.com/industrynews/iic-launches-the-iiot-maturity-assessment-explorer/
MITsloan	*2016 Digital Business Global Executive Survey*	Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2017). Achieving digital maturity: Adapting your company to a changing world. Retrieved May 20, 2018. *Deloitte university press, 1-19.*
Ungerer (2018)	*Multi Dimensional Smart Industry Scan*	Ungerer, L., V., (2018) Constructing A Multi-Dimensional Smart Industry Scan, Retrieved from https://essay.utwente.nl/75362/1/Ungerer_IBA_BMS.pdf

1.2 Assessing and selecting existing smart industry scans

For assessing and selecting the existing scans, the criteria by Ungerer (2018) for selecting scans will be used. The criteria will be used in order to select scans that can be used as an inspiration for creating the extended scan. According to Ungerer (2018), the first criterion (C1) is related to the completeness of aspects. The scans that are selected and looked at should contain multiple aspects in order to be useful for designing the extended scan. Next, criterion two (C2) looked at the availability of measurement questions. The scans that will be used as a guideline for drafting the scan should contain measurement questions in order to be useful. Criterion 3 (C3) is related to the availability of maturity levels, maturity levels are important at the end of the scan in order to situate a respondent in a level in industry 4.0 implementation. To select the scans a guideline has been made; if at least two of the three criterions are met, the scan is selected and used to analyse. There is one exception in which the scan didn't have maturity levels and aspects but I still used it. This scan had a lot of measurement questions that were all related to different industry 4.0 topics making it very useful. In table 2 one can see the selected scans and if or if not they meet the criteria that were proposed by Ungerer (2018).

Table 2. Selection criteria

	C1: Availability of multiple aspects	**C2: Availability of measurement questions**	**C3: Availability of maturity levels**
Webs – Digital Maturity Scan	*Achieved*	*Achieved*	*Achieved*
Nom – Smart Industry Assessment	*Achieved*	*Achieved*	*Achieved*
AFAS – N.A.	*Not Achieved*	*Achieved*	*Achieved*
PWC – Industry 4.0 Self Assessment	*Achieved*	*Achieved*	*Achieved*
IMPULS – Industry 4.0 Readiness Online Self-Check for Businesses	*Achieved*	*Achieved*	*Achieved*
Rabobank – Hoe Digitaal is jouw bedrijf?	*Achieved*	*Achieved*	*Not Achieved*
N.A. – A Maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises	*Achieved*	*Not Achieved*	*Achieved*
Future Industries/ Paul Höppener - I4 Maturity Tool	*Achieved*	*Achieved*	*Not Achieved*
IIC – IIot Maturity Assessment	*Achieved*	*Achieved*	*Achieved*
MITsloan – 2016 Digital Business Global Executive Survey	*Not Achieved*	*Achieved*	*Not Achieved*
Ungerer (2018) – Constructing a Multi Dimensional Smart Industry Scan	*Achieved*	*Achieved*	*Achieved*

As stated above, one can see that eleven existing scans were used in order to create the extended scan. Six of these eleven scans met all three criteria; so all of these had aspects, measurement questions and maturity levels. Four of the five remaining scans met two of the three criteria and one only met one criteria. As previously stated, despite the fact that the guideline was that all scans should at least meet two of the three criteria this scan was still used, because the measurement questions significantly contributed to this research.

1.3 Enumeration of the features of selected scans

In table 3 one can see the features of the existing scans that were used for this design research. To summarize, all scans together consisted of 57 aspects, 402 measurement questions and 37 maturity levels. This, in combination with an extensive literature review on industry 4.0 implementation was the basis for the extended scan.

Table 3. The features of the selected smart industry scans

Scan:	Aspects:	Measurement questions:	Maturity levels:
Webs	Strategie en organisatie, online kanalen en content creatie, klant focus, doormeten van succes & techniek	14	Basic, tactical, optimizing, strategic & engaging
Nom	Servitization, Smart Products, Smart Design, Advanced Manufacturing, Digital Factory, Smart Working, Flexible Manufacturing, Connected Factories, Sustainable Factory	33	4.0 achterblijver, 4.0 volger, 4.0 koploper, 4.0 innovator & 4.0 incubator
AFAS	N.A.	13	In de kinderschoenen, Digitale basis & Helemaal digitaal
PWC	Business models & product and service portfolio, market & customer access, IT architecture, value chains & processes, compliance, legal, risk, security & tax and organization & culture	33	Digital novice, vertical integrator and horizontal collaborator
IMPULS	Strategy & organization, smart factory, smart operations, smart products, data-driven services and employees	19	Outsider, beginner, intermediate, experienced, expert and top performer

Rabobank	Kosten besparen, Omzet verhogen,	8	N.A
N.A.	Strategy, leadership, customer, products, operations, culture, people, governance and technology	N.A.	1 to 5 in which 1 describes a complete lack of attributes supporting industry 4.0 and level 5 represents the state-of-the-art of required attributes
Future Industries/ Paul Höppener	Vision & direction & business model, people & organisation, marketing & customer access, product, product development, production process & production control, production automation, performance management, big data analytics	175	N.A.
IIC	Business strategy, Business solution lifecycle, Technology & Security	20	Establishing, Emerging, Developing, Comprehensive & Best practice
MITsloan	N.A.	52	N.A.
Ungerer (2018)	Strategy & Organisation, People & Organisational culture, Products & Customer Services, Customer Interfaces, Value Chain, Technology & IT management, Institutional awareness	35	Poor implementation, moderate implementation, semi-advanced implementation, advanced implementation & Full implementation

1.4 Designing the extended scan

In order to get an extended and detailed view of the status quo of an organisation relating industry 4.0 implementation, the scan consists of 15 different business aspects. These 15 aspects will provide the respondent with an extended overview of the industry 4.0 implementation within their organisation. On different aspects, this implementation is measured to give a very detailed result at the end. In order to get to such a detailed result, the scan consists of 86 different measurement questions that each measure different subjects that are of major importance for becoming a full-scale adaptor of industry 4.0. The questions are not equally spread amongst all aspects, however all aspects have at least 5 measurement questions. To be specific, nine of the 15 aspects consist of five measurement questions and the remaining questions are distributed amongst the other aspects as one can see in table 5. After filling out all the measurement questions the respondent will be provided with an average score per aspect. Next to this, the respondent will see a general result of the whole scan. This result is provided in the form of an average score as well. To give the respondent an indication of what the end-result entails five maturity levels and three maturity types were created. In the next chapters, the argumentation is given in relation to the aspects, the measurement questions, the maturity levels and maturity types.

Step 2: The Aspects

2.1 Introducing the aspects

The extended scan consists of 15 different aspects. Ranging from "strategy" to "IT management" and from "inbound logistics activities" to "outbound logistics activities". According to (Pereira & Romero, 2017) the march of industry 4.0 is affecting the whole supply chain, from product development to outbound logistics. The aspects of this scan will provide one with a deep insight of the status quo of implementation of industry 4.0 practices per aspect. By filling in all the aspects the respondent will get a good overview of the current implementation of industry 4.0 practices, and on top of that, the respondent will be provided with results that show on what aspects improvements can be made. This will contribute to finding the weak spots and eventually growing to a stronger digitized organisation. In figure 1 one can see all fifteen aspects. Note: OC & KM indicates Organisational Culture & Knowledge Management.

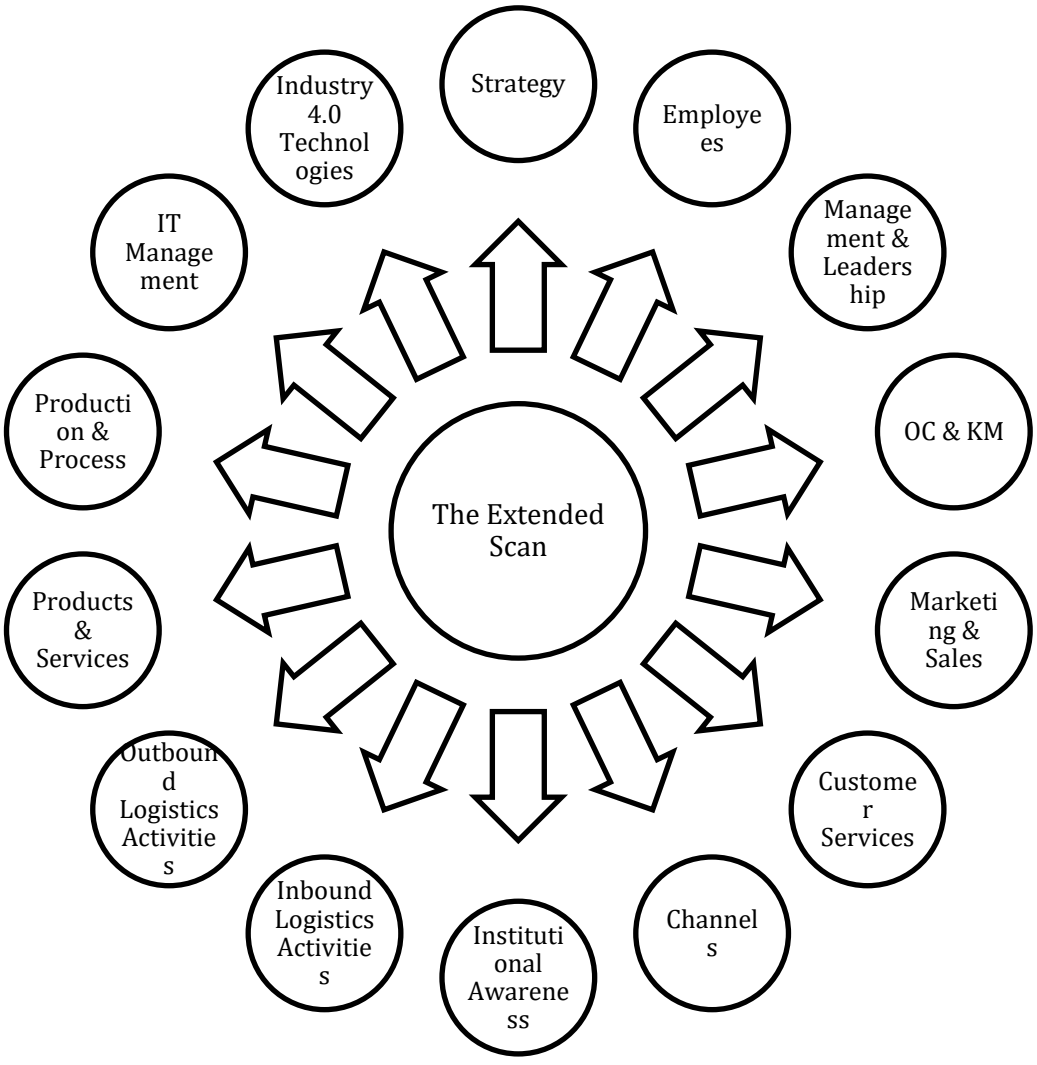

Figure 1. The distribution of the aspects

2.2 Using literature to provide the argumentation for using each aspect

The next chapter will first provide the argumentation of using these 15 aspects. Every aspect has its own argumentation. The argumentation consists of the essence of asking the aspect and why digitization is important within this aspect. Moreover, the aspects are connected to the literature about the aspects. Next to this, the variables that are of major importance will be discussed. After reading this chapter, one will have sufficient knowledge about the argumentation for using the 15 aspects.

2.2.1 Strategy

Strategy is a very broad term, which exists of many things and should be included as an aspect in this scan. Without a well-formulated strategy, there are no clear goals set in order to let an organisation move forward. An organisation will not know its position in the market, and will have a hard time gaining a competitive advantage (liferay, 2019). In this scan, the strategy is assessed based on its focus on industry 4.0 practices.

Recently, traditional strategies are increasingly replaced by digital strategies in which the focus lies on using technology to improve business performance. It indicates the direction and goals that an organization is taking in order to create a competitive advantage with technology. A digital strategy usually indicates changes to business models (Liferay, 2019).

As mentioned before, strategy is a very broad term and exists of many things. To many things to all include in the scan, that's why a selection of subjects is made that were considered important to assess the digital strategy of an organisation. First of all, the questions will assess the current state of industry 4.0 implementation and to what extent it contributes to the success of the organisation. Next this, the questions are related to investments and if there is a dedicated budget to invest in industry 4.0 practices. Furthermore, the use of data and industry 4.0 technologies is assessed. Lastly, of course the vision can't be forgotten.

A vision is a picture that one sees in their mind, in this case the idea for the future for the organisation. According to Westerman, Bonnet & McAfee (2014) a digital vision consists of many things and start with getting familiar with the industry 4.0 topic. Next up, bottlenecks should be identified and a compelling digital vision should be crafted. A vision is something that constantly should be looked at and be extended. To assess the digital strategy of an organisation, the vision is an essential subject that should be looked at.

2.2.2 Employees

The working environment is changing; Industry 4.0 is transforming jobs and required skills to do these jobs. One of the greatest challenges is to avoid technological unemployment, so redefining current jobs and taking measures to adapt the workforce for the new jobs that will be created (Pereira & Romero, 2017). Processes are becoming more complex, which results in a demand for a higher qualified workforce and new competences. This workforce could be selected in the application process, but can also be formed by educating the existing workforce (Hecklau et al, 2016). Next to the complexity, future-working pursuits will also demand new skills and competences from the workforce. For example, industry 4.0 will lead to the increase in automation of tasks, which means that workers should be prepared for performing different tasks (Pereira & Romero, 2017).

On the other hand, according to the research of Müller et al (2017) several companies indicate that industry 4.0 is countering the increasing lack of highly qualified employees to do highly skilled manual work in the technical field. Next to this industry 4.0 is helping employees to ease assignments. To give two examples Muller et al (2017) mention employees using smartphone apps to quickly inform about their availability. Next to this, industry 4.0 facilitates the lower qualified workforce, while machines can explain the remaining steps and guide the low qualified workforce through processes (Müller et al, 2017). However, working positions of employees are going to change. That is why employees should be provided with opportunities to gain these skills and competences in order to be able to overcome these challenges of industry 4.0 implementation. That is one of the reasons that skills development is very important. It will lead to social changes and is one of the important key factors for a successful adoption and implementation of industry 4.0 (Pereira & Romero, 2017).

Next to this, (Heathfield, 2019) mention that good communication is essential during changes like industry 4.0 implementation. Employees should be aware of what is happening, and companies should be transparent towards their employees about the changes. “You cannot over-communicate when you are asking your organization to change (Heathfield, 2019)”.

Following Müller et al (2017) it is very important that employees are motivated to learn and adapt to a working style that is facilitated by industry 4.0. Employees should be aware of the benefits of industry 4.0 implementation to help increase their motivation. However, Müller et al (2017) also note that adapting to industry 4.0 can be particularly difficult for elderly employees and employees that are not very handy with technologies.

2.2.3 Management & leadership

"The implementation of the concept industry 4.0 necessitates involvement from top management promoting comprehensive change management activities and processes for arranging organization and production structures according to the needs of the connected value creation (Mohelska & Sokolova, 2018, p2237)". Managers should have the motivation to convince employees of the benefits of industry 4.0 and openly address their actions. On the other hand, managers should be convinced of the beneficial nature of industry 4.0 implementation, and this can only be achieved by increasing their own awareness and knowledge related to the topic (Mohelska & Sokolova, 2018).

According to Westerman et al (2014, p95) "leadership capabilities are essential to achieve true digital transformation; they turn digital investment into digital advantage". For companies to start the digital journey, the top management should be capable to move the whole company in the same direction. Westerman et al (2014) describe four key capabilities of leadership: (1) crafting your digital vision, (2) engaging the organization at scale, (3) governing the transformation and (4) building technology leadership capabilities. The first step is rather self-explanatory in the sense that it is about familiarizing yourself with digital practices, identifying the risks and bottlenecks, crafting the digital visions and make it precise enough to give your employees a clear direction. The second step is a sequel on giving the employees a clear direction. The employees need to be energized by management. Management should be open and transparent and employees should be given a voice in decision making of the digital transformation. Step 3 is about the digital governance and entails consideration of decision-making, the persons that are in charge of leading the digital transformation and identifying governance mechanisms. Lastly, step 4 is about the quality of skills and competences, management should be capable to assess ability of employees and departments. Management should focus on initial investments and consider the feasibility of the digital transformation (Westerman, 2014).

Mohelska & Sokolova (2018) state that the management should have the right skills and competences to lead the company into the digital transformation. To increase these skills and competences one can plan extensive trainings and workshops towards industry 4.0 specific knowledge and skills, such as for example data management, analytics and human-machine interaction.

2.2.4 Organisational culture & Knowledge management

"Organisational culture is the pattern of values, norms, beliefs, attitudes and assumptions that may not have been articulated, but shape the ways in which people in organisations behave and get things done. Values refer to what is believed to be important about how people and organisations behave. Norms are unwritten rules of behaviour" (Armstrong, 2006, p303).

The organisational culture should be set up in such a way that it allows the implementation of industry 4.0. Mohelska & Sokolova (2018) argue that the culture should promote innovation in order to let the organisation grow into a higher level of digitalization. The importance of organisational culture should not be underestimated and this aspect can be seen of one of the most important building blocks for creating a digital atmosphere.

According to Mohelska & Sokolova (2018) the implementation of industry 4.0 requires continuous innovation and education, which is featured by an adhocracy style of culture. Mohelska & Sokolova (2018) are using the theory of Cameron, Quinn & Wallach (2010) about organisation culture types. According to this theory an Adhocracy is featured by a culture style that allows innovation within the organisation. This style is famous for allowing personal creative freedom, orientation towards change and innovation. A digital organisation needs a culture that bolsters creativity and also rewards employees who are willing to learn and try out new things. The organisation should promote new ideas and not be afraid to take a risk and make a mistake. In this case the internal knowledge and creativity of employees can be used to try out new ideas on a regular base (Mohelska & Sokolova, 2018)

In order to make the digital transformation skills and competences of employees can be of great importance. However, knowledge within the organisation is essential. The paper of Müller et al (2017) argues that organisations need more extensive employee trainings in order to increase skills, competences and knowledge, because the implementation of industry 4.0 asks for completely new ways that are, for example, required with human intervention in case of machine failures.

2.2.5 Marketing & sales

Leeflang et al (2014, p1) state that Wharton Professor George Day "identified the widening gap between the accelerating complexity of market and the capacity of most marketing organizations to comprehend and cope with this complexity". It is believed that the rapid growth of Internet usage is the cause for this widening gap. Over the last years the Internet has become one of the most important tools for transactions. Leeflang et al (2014) provide an example of Amazon to show the magnitude of online selling. On Amazon's peak day, they sell up to 320 products per second, which comes down to more than 27 million products sold on this day. Next to this, social media marketing is increasingly efficient. With billions of users worldwide social media is an amazing way to promote products or services (Leeflang et al, 2014).

The previous example shows that the marketing environment and customer behaviour is changing drastically. The marketing & sales departments of organisations have to transform to these changes rapidly in order to keep a competitive advantage over their

competitors. As written before the Internet usage of people is increasing rapidly. A growing amount of people is becoming digital and this is becoming an increasingly important source of competitive advantage for organisations (Leeflang et al, 2014). A new way of marketing is emerging which is called digital marketing that is replacing traditional marketing. This transformation is influencing the marketing and sales department drastically.

According to Strandberry (2018) the marketing and sales activities for firms are changing and instead of activities to reach out customers through magazines, newspapers, radio commercials, postcards, telemarketing and billboards, the new activities consist of search engine optimization, content marketing, social media marketing, pay per click, marketing automation and email marketing for example. Purchases are more and more done online so online customer behaviour is getting very important for marketing & sales departments, because in some industries sales are set even without face-to-face contact (Strandberry, 2018).

Strandberry (2018) state that the marketing & sales department has a very important role in order to make a digital transformation. This department should be in line with the developments happening in the marketplace. The digital atmosphere is changing marketing and sales pursuits rapidly and it is up to organisation to keep up with these changes and keep developing. In this aspect, the respondents are asked to rate their knowledge related to the online behaviour of customers. Next to this, the website and online marketing techniques are analysed.

2.2.6 Customer services

Customer services are one of the aspects that were added to the extended scan. Customer services are understood as "the support you offer your customers – both before and after they buy and use your product or service – that help them to have an easy and enjoyable experience with you (SalesForce, 2019)." Excelling in customer services can help an organisation to keep customers satisfied and retain them. Satisfied customers can spread their satisfaction, which can result in new customers that can ultimately help your company to grow and gain revenue.

Customer services are essential to keep customers satisfied and to build a good reputation for possible other customers. Satisfied customers can quickly share their satisfaction online and reach a large amount of potential customers, but this is also applicable the other way around, in which unsatisfied customers share their experiences online. You don't want this to happen, because it can damage you reputation severely. It is also one of the reasons why customer satisfaction is very important.

Today's customer services goes far beyond traditional customer services, such as a telephone support agents. Even though telephone support agents are still used for

communication purpose with customers, today's communication tools have expanded to also entail social media, text messages, email communication and self-service possibilities via the website (SalesForce, 2019). Moreover, customer services consists of more than only communication tools to reach out to the organisation. Customer services can also be done by using sensors in the offered products, which is not applicable for all organisations, but definitely the case for manufacturing companies.

In the questions related to this aspect, we will of course ask about the customer services that are related to communicating with the organisation. However, we go one step further and will also ask about the extent to which sensors are used in products to indicate the performance and when maintenance has to be done for products. Next to this, a question is related to automatic notifications of customers on information regarding, for example, their orders. This aspect gives a good overview of the amount of automation and digitization in customer services for the organisation.

2.2.7 Channels

According to Heinonen & Michelsson (2010) channels can be seen as the set of activities, people and distributors that are vital in bringing the product or service from the place of production to the place of consumption, in other words: the customer. The products or services that are distributed to the end-customer are distributed through the channels of the organisation. Channels help organizations to reach out or expand their scope, and could ultimately assist to increase revenue. There are different channels, and each channel will obviously have its own benefits and drawbacks. From all channels, the online channels are fast gaining more ground. The usage and advantages of online channels has gained increasing attention in recent years (Heinonen & Michelsson, 2010).

It is essential for organisation to improve their channels continuously. As mentioned before, in recent years the usage of online channels has gained increasing attention (Heinonen & Michelsson, 2010). It is the task of organization to keep up their channels up to date and expand their online channels in such a way that customer can reach out to the organisation in multiple ways in this digital era.

One of these online channels is a website. Gotter (2018) argues that interested customers will come to your website to check out the products or services. A website should offer a good representation of the product or service and should be clear to customers. Next to this, social media is a major player in the online world. By using social media an organisation can reach out to many potential customers. Lastly, email is still very important, by reaching out to emails that are in your database, from for example existing customers, one can potentially gain new leads that could result in revenue (Gotter, 2018).

These are some examples of online channels that can be used to reach out to customers. In the questions that are related to this topic the channels are tested. The questions are about the amount of channels, so if multiple digital channels are used. Moreover, the extent to which channels are monitored by data in order to track their performance is tested and to improve them in case of non-performance.

2.2.8 Institutional awareness

Institutional awareness is a collective term that is used for a couple of important subjects. The aspect consists of five different questions that all have to do with the institution and that's why these questions are situated in this aspect. The questions are related to the digital policy, intellectual property, security, taxes and privacy laws.

Digital policy entails the awareness of regulations of digital or electronic communications. It is a very broad term, because it also has to do with information security and network security. Besides, lee & Cole (2003) argue that intellectual property entails the ownership of the knowledge for a product or service. The ownership of this knowledge is owned by a certain organisation. It is very important that this knowledge is owned by the organisation and no one else can just use it without permission. Some organisations use the crowd to promote knowledge creation, called community based knowledge creation, which is also promoted by the digital era (Lee & Cole, 2003). This question can create a useful insight and starting point for a discussion.

One of the most important concerns in institutional awareness is the protection of privacy, because in the digital era data will be collected throughout the organisation. The new European privacy legislation (GDPR) promotes the privacy of customers. A certified data protection officer informed me about this topic during a meeting. To summarize, customers can ask to delete or adjust their personal data from an organisation's database. These requests need to be dealt with within one month, so to safe out time, especially in big organisation, these requests could be dealt with automatically. Next to privacy concerns security concerns are important as well. Müller et al (2017) state that cyber criminality is a very important concern, which is related to becoming a digital organisation. In order to counter cyber criminality, companies should know how to cope with their own data security, but also with the data security of partners within the supply chain. Employees should be aware of the fact that implementing industry 4.0 technologies introduces new privacy and security risk (Müller et al, 2017).

Lastly, taxes are very important to consider whenever businesses are considering industry 4.0 driven opportunities. According to Pritchard et al (2017) many organisation experience taxes as a "hidden costs" that can create unexpected costs. Next to only the costs, a changed tax position can result into a change in tax obligations, which could result in changes in the organisation's cash flows. Organisations that are starting

to apply industry 4.0 technologies are likely to increase capital expenditures, in order to create a valid return on investment the organisation has to look into possible tax costs (Pritchard et al, 2017).

2.2.9 Sustainability

"In manufacturing, sustainability refers to the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources (Meng et al, p5, 2018)". In order to minimize negative environmental impacts and conserve energy and natural resources, the concept of sustainable manufacturing has been introduced. Sustainable manufacturing aims to change the traditional way of manufacturing and make manufacturing more environmental friendly. Many countries have already introduced policies to promote sustainable manufacturing, such as restricting emissions of factories and promoting renewable energy (Meng et al, 2018).

There are multiple smart techniques that can be used in sustainable manufacturing. Meng et al (2018) name the following smart techniques: deep learning, smart grid, smart metering, radio-frequency identification (RFID), big data analytics, data mining, cloud computing and additive manufacturing. Introducing smart techniques to an organisation can help to work more efficient and thus reduce emissions and the use of raw materials (Meng et al, 2018).

In this aspect, the questions are related to industry 4.0 technologies used to increase environmental sustainability and if industry 4.0 technologies have helped to introduce sustainability to the organisation. Moreover, the questions are related to the monitoring of emissions from machines and products.

2.2.10 Inbound logistics activities & outbound logistics activities

In this part the two aspects inbound logistics activities and outbound logistics activities are explained together. However, in the scan these are two separate aspects both consisting of five different questions.

Logistics is the general term, which consists of both inbound and outbound logistic activities. First, let's separate the term and give a small introduction to the meaning of both. "Inbound logistics refers to the transport, storage and delivery of good coming into a business (Ingram, 2019)". On the other side, outbound logistics refers to the delivery of goods going out of the business, most likely to customers. Just like every other aspect of the scan, logistics has also been influenced by the digital era. Barreto, Amaral & Pereira (2017) refer to as logistics 4.0 or smart logistics when they talk about the combination of logistics and industry 4.0, in which they combine the term smart industry and industry 4.0 with logistics.

The general idea of combining industry 4.0 and logistics is not to replace human work. Its idea is to avoid inaccuracies in the processes and promote a more efficient and faster process in which real time information can be accessed at all time (Barreto, Amaral & Pereira, 2017). Smart technologies such as sensors can help to indicate deviations in the processes. Hecklau et al (2016) provide an example, in which one could think of an incoming delivery that is delayed, because of bad weather. When sensors are implemented into the incoming delivery, the organisation can be notified automatically and could adjust their pursuits accordingly. However, to achieve this, cooperation of both the suppliers and the organisation and on the other hand the customers is needed. That's why Logistics 4.0 increases the need for collaboration. As previously mentioned organisation must align with their suppliers in order to stay competitive. This could lead to more complexity in the processes (Hecklau et al, 2016). If used correctly, the implementation of industry 4.0 in logistics activities can enhance flexibility, efficiency and improve customer satisfaction. If the logistics department is automatically notified of incoming and outgoing deliveries, they can situate the warehouse accordingly, which decreases storage costs.

As previously mentioned, the scan consists of both inbound and outbound logistics. Inbound logistics will contain questions related to collaboration between organisation and suppliers and to what extent smart technologies are used in this collaboration. Moreover, the respondent is asked to what extent smart technologies, such as warehouse management systems are used in the warehouse. A warehouse management system is an intelligent system that is able to select a docking slot for incoming deliveries, which optimizes just-in-time delivery (Barreto, Amaral & Pereira, 2017). The outbound logistics part is related to collaboration and connections with customers. Next to this, if transported products are monitored and kept track on.

2.2.11 Products & services

In this part the argumentation for using both products and services is provided. Their importance with regards to industry 4.0 implementation is discussed and the reasoning behind the subjects for the measurement questions is given.

Products are very important for organisations that want to implement industry 4.0. Smart connected products are products that are equipped with industry 4.0 techniques. According to Porter & Heppelmann (2015) smart connected products share three core elements. First of all, smart connected product share a physical component, such as physical parts of the product. Secondly, smart connected products share the smart component, such as sensors, data storage and other industry 4.0 technologies. Lastly, they share a connectivity component that consists of networks of communication and antennae in order for products to stay connected. In order to implement smart connected products the organisation should change accordingly. Next to this an

organisation is dependent on their own skills, but also on the willingness of partners and customers. Smart connected products require a whole new infrastructure in which products provide real time data to customers. If implemented in the right way, smart connected products provide new capabilities. They can monitor and report at all time, providing useable insights. They can be controlled by the user, which provides the user more flexibility in functions and performance. Thirdly, the combination of monitoring and control provides data that can be used for product optimization, such as performance and utilization optimization. Lastly, the above-mentioned capabilities can support algorithms to become autonomous and learn from the user's environment and preferences (porter & Heppelmann, 2015).

Next to smart connected products, services can also benefit from industry 4.0 implementation. Many service industries rely on products that can become smart and connected. Porter & Heppelmann (2015) provide an example in which an airline with smart and connected airplanes can reach higher efficiency. By implementing smart and connected product in airplanes maintenance issues can be detected in flight and the needed work or parts can be waiting on the plane when it lands (Porter & Heppelmann, 2015). Resulting into better services, which also introduce the topic of servitisation.

According to Müller et al (2017) servitisation allows new forms of value captures. They mention that companies that introduce services in their value offers are the organisations that are most likely to the profit the most from industry 4.0. Servitisation represents a switch from having a business model that is product-based to being demand-oriented. This switch allows companies to target new customers, but also to switch from payment per product to payment per feature or payment per use. Organisations can provide their customers with repairs and maintenance, and the products are real time followed by the use of sensors (Müller et al, 2017).

This aspect consists of measurement questions that analyse the industry 4.0 implementation in an organisation's products and services. These measurement questions are related to e.g. tracking, monitoring, the product line and servitisation.

2.2.12 Production & process

Smart connected machines and its new capabilities create new production processes at manufacturing plants. The smart connected machines are increasingly connected and can be linked together. These smart connected machines can fully automate and optimize production (Porter & Heppelmann, 2015). "Industry 4.0 allows us to more quickly react to malfunctions, as different interfaces become faster and more precise, Production know-how can seep faster in new product development" (Müller et al, p7, 2017). Next to this, production data can be shared with suppliers and customers in order to share knowledge with each other. The paper of Müller et al (2017) argues that in order to benefit from industry 4.0, it is essential for an organisation to learn how to

share production related data with its partners within the supply chain. This sharing of production data is beneficial for all parties and is one of the things that are tested in the extended scan. The measurement questions related to production in the scan will give a status quo of the maturity of industry 4.0 implementation in this field.

Processes will also be affected by the increasing implementation of industry 4.0. Processes are becoming more complex, which leads to an increasing demand for higher qualified jobs, therefore organisation need to qualify their employees to do these jobs (Hecklau et al, 2016). Smart connected machines and optimized production will be far more productive and processes throughout the organisation should be adapted to this. An increasing amount of processes can be automated and optimized in order to reach a higher efficiency throughout the process. This efficiency result in money savings and savings in time for example (Porter & Heppelmann, 2015). In order to find out the industry 4.0 implementation in the field of processes measurement questions are constructed.

The measurement questions in this aspect is related to for example automated processes, implementation of industry 4.0 techniques and to what extent the production equipment, such as machines are interconnected.

2.2.13 IT management & Industry 4.0 technologies

In this part both the aspects IT management and Industry 4.0 technologies are discussed. It management contains measurement questions that have to do with the implementation of industry 4.0 technologies. The measurement questions in the extended scan are related to data gathering, IT collaborations, data exchange, data storage, ERP/MRP decisions, applying industry 4.0 technologies, IT security measures and general IT management.

Resulting from the growth of technology usage throughout organisations, the organisation should be able to deal with huge amount of data in an efficient manner. According to Hecklau (2016) an organisation can deal with this “big data”, by looking into implementing IT infrastructures. Moreover, it is necessary to collaborate with partners to operate together on different platforms. Big data also raises the concern of cyber security, as data should be protected. However this was discussed in the institutional awareness aspect, so no need to discuss this anymore (Hecklau, 2016). In order to find out if the organisation’s IT management is as advanced to deal with e.g. these huge amount of data, the measurement questions can be filled out to find out their maturity in this field.

The aspect of Industry 4.0 technologies has no similarities with all the other aspects and is purely added for educational purposes. The aspect consists of one measurement question. The measurement question is a multiple-choice question in which multiple

answers are possible. The measurement question is based on the yearly publish of Gartner, in which they mention the top 10 industry 4.0 technologies of that year. The measurement question is there to indicate which of these technologies the organisation is currently using (Gartner, 2019). It provides an insight into the amount of industry 4.0 technologies used inside an organisation.

Step 3: The Measurement Questions

The scan consists of 86 measurement questions divided across 15 business aspects as discussed in the second step. In the previous chapter, the aspects were explained in detail. This chapter contains the argumentation for drafting the measurement questions as they are. The literature used in order to draft the measurement questions and formulate the answer options are provided in this chapter.

3.1 Using literature to draft the measurement questions

"Constructing a questionnaire involves many decisions about the wording and ordering of questions, selection and wording of response categories and formatting and mode of administration of the questionnaire (Martin, p3, 2006)."

As mentioned before, the extended scan consists of 86 measurement questions. These measurement questions were drafted by conducting an extensive literature review into the topic of questionnaire construction and by assessing existing scans. Table 1 provides information about the different scans that were used in order to come up with the content for the measurement questions. Next to this, the reference list contains a lot of references that were used to gain knowledge related to the importance of certain subjects for the measurement questions.

During the literature review, several papers were selected that mentioned different requirement for constructing questionnaires. These requirements ranged from avoiding double-barrelled questions to avoiding ambiguity. In table 4 one can see a display of these requirement. This chapter will provide clear explanations of these requirements and their influences on the measurement questions.

The literature review provided seven papers that were considered useful for constructing the measurement questions. These papers provide a lot of requirement for constructing measurement questions in questionnaires. One of the most mentioned requirements is to avoid double-barrelled questions. Four of the seven papers mentioned this requirement. Nemoto & Beglar (2014) argue that the idea behind avoiding double-barrelled question is that a question should be designed to measure one idea and not more. In a question that is double-barrelled two ideas are asked in the same questions, resulting in an invitation for respondents to answer two different questions. Resulting into an answer that is probably biased, because it does not measure what it is intended to measure. To avoid questions that are double-barrelled one should avoid words like "and", "or" and "but", because they generally indicate two ideas in one question (Nemoto & Beglar, 2014). Next to this, according to Nemoto & Beglar (2014) it is essential to avoid including positively and negatively worded items to measure one

single construct as this negatively affect uni-dimensionality. Nemoto & Beglar (2014) state that uni-dimensionality is the idea that a question should not measure different constructs, because it is otherwise difficult to interpret the results from the respondent. Measurement questions should be written in one direction, and preferably in a positively worded way. Next to this, Nemoto & Beglar (2014) state that questions should be written in a language that the respondent understands well. For now the questionnaire is written in English, because English is understood by a majority of people. However, in the future it is intended to translate it in Dutch and German as well.

Moreover, according to Martin (2006) and Malhotra (2006) it is necessary to avoid ambiguity and complexity in the measurement questions for a questionnaire. In short, ambiguity is a phrase that indicates that language can have different meanings. Different respondents interpret simple words like "you", "children" and "work" very differently. According to Martin (2006) ambiguity and complexity in measurement questions can lead to cognitive overload, which could results in parts of measurement questions being lost and forgotten. Because of this, measurement questions can be partially understood or misinterpreted leading to biased answers by respondents. Being very specific and consistent in wording measurement questions could avoid these misinterpretations and could significantly increase the reliability and validity of the results. "Simple, ordinary words that match the vocabulary level of the respondents should be used in a questionnaire (Malhotra, p190, 2006)". Fanning (2005) state that questionnaires should be consistent and to ensure consistency, questions should be consistent in appearance, including font, font size, but also in wording. Try to use the same words all over again to reach a higher level of consistency. Next to this, Martin (2006) argues that is essential to exclude presuppositions in the questionnaire. By including presuppositions in the measurement questions, respondents may be led to provide an answer even though the presupposition is false. As an example, Martin (2006) states the question: "what are your usual hours of work". This question presupposes that the respondent works, and that his hours of work are regular and the same most of the time. Try to exclude presuppositions and make the questions accessible for all you respondents by including or excluding parts in the measurement questions (Martin, 2006).

Furthermore, four of the seven papers mention that measurement questions should be simple and clear. Siniscalso & Auriat (2005), taylor-powell (1998) van den Berg & van der Kolk (2014) and Malhotra (2006) all state that simple wording should be used in questionnaire design. Wording should be adapted to the vocabulary and reading skills of the respondents. Letting possible respondents give feedback on the measurement questions can test this. Next to this, Taylor-Powell (1998) states that abbreviations, Jargon and foreign phrases should be avoided. The main problems with these are the misunderstanding of respondents. Most respondents will not understand specific terms of the targeted subject. Measurement questions should be specific and include all necessary information. For example, if a question states "older youth" it should specify from what age onwards is meant in this case (Taylor-Powell, 1998).

Next to this, multiple papers mention the length of measurement questions. Measurement questions should be short and specific in order to get the full attention of respondents. Measurement questions that are too long will distract the attention of respondents and this could cause biased answers. Try to avoid questions that are too time consuming and try to make these questions shorter or split them up into two questions. As a guideline, measurement questions should not be longer than 25 words (Siniscalso & Auriat, 2005) (Taylor-powell, 1998) (van den Berg & van der Kolk, 2014). Moreover, van den Berg & van der Kolk (2014) & Malhotra (2006) mention that a good questionnaire does not contain biased words or phrases. Keep in mind that some words can be emotionally charged and influence the responses from respondents. They provide the example about people that have just gone through a diet program. Words like fat and heavy should be excluded from the measurement questions, because they can have an emotional load to it. However, the topic that is discussed in the extended scan is practical, so this requirement doesn't apply, but it was kept in mind when formulating the measurement questions (van den Berg & van der Kolk, 2014).

Lastly, it is essential to make sure that the answer options are clear, easy to understand and mutually exclusive so only one answer option should be possible (Siniscalso & Auriat, 2005) (Taylor-powell, 1998). This is explained into more detail in the next chapter. As mentioned before table 4 contains a summary of the requirements per paper.

Table 4. The requirements for constructing measurement questions

Papers:	**Requirements:**
Nemoto, T. & Beglar, D. (2014), Taylor-Powell, E. (1998), Siniscalso, M. & Auriat, N. (2005), van den Berg, S. & van der Kolk, H. (2014)	Avoid double-barrelled questions (words like: and, or and but).
Nemoto, T. & Beglar, D. (2014)	Avoid positively and negatively worded items to measure one single construct (negatively affects uni-dimensionality).
Nemoto, T. & Beglar, D. (2014)	Questions should be written in a language that someone understands well.
Martin, E. (2006) Malhotra, N. (2006)	Avoid ambiguity (simple words may have different meanings).
Martin, E. (2006) Malhotra, N. (2006)	Avoid complexity by not making multiple variables in one question.
Martin, E. (2006)	Avoid presuppositions (presuppose something in the question)
Siniscalso, M. & Auriat, N. (2005), Taylor-Powell, E. (1998), van den Berg, S. & van der Kolk, H. (2014)	Use simple and clear wording by avoiding the use of abbreviations, jargon, acronyms, technical terms and foreign phrases.
Taylor-Powell, E. (1998)	Be specific and include all necessary information.
Siniscalso, M. & Auriat, N. (2005), Taylor-Powell, E. (1998), van den Berg, S. & van der Kolk, H. (2014)	Avoid questions that are too time consuming, keep questions short or otherwise break them up (<25 words).
Siniscalso, M. & Auriat, N. (2005), Taylor-Powell, E. (1998).	Make sure that only one answer option is possible and the answer options should be mutually exclusive and clear.
Siniscalso, M. & Auriat, N. (2005) *Fanning, E. (2005)*	Avoid hypothetical questions The questions should be clear, logical and consistent
Taylor-Powell, E. (1998), van den Berg, S. & van der Kolk, H. (2014) Malhotra, N. (2006)	Avoid biased words and phrases

3.2 Using literature to draft the answer options

For the answer options it is chosen to make use of the Likert Scale. The answer options are the same for each measurement question except the measurement questions for aspect 15. The Likert scale is named after Rensis Likert who first used it in 1932. Nemoto & Beglar (2014) state some advantages of using a likert-scale questionnaire. Firstly, data can be gathered rather quickly from a big number or respondents. Next to this, Likert-scale questionnaires can provide highly reliable ability estimates and provide the validity of the interpretations made from the data through different means. The data can easily be compared and combined with qualitative data-gathering techniques, such as open-ended questions. Next to this, according to Malhotra (2006) it is also very easy for a researcher to construct. For the extended scan, a five-point scale is used. "Traditional guidelines suggest that the appropriate number of categories should be seven plus or minus two: between five and nine (Malhotra, p187, 2006)". Next to this a five-point scale happened to be very convenient in combination with radar charts that provide a clear overview of scores. This interval way of scaling the answers gives the researcher the highest possibility of actually using the results. It provided an easier entrance for using powerful statistical techniques such as correlation analysis. Burns & Bush (2005) state on page 280 that by giving the response options on a scale with equal interval in between them a researcher could attain a higher level of measurement than it should have with ratio, ordinal or nominal measurement.

The measurement questions can all be answered by giving an answer by providing a number ranging from 1 to 5. In this case (1) means "not at all" and (5) means "to a very great extent". The questions are drafted in such a way that a score of (1) is always the least favourable option, and obviously a score of (5) is then the most favourable answer.

3.3 Distribution of the measurement questions for the aspects

Figure 5 shows the distribution of the measurement questions amongst the aspects. The measurement questions are not equally distributed amongst the aspects. One can see that eight of the fifteen aspects contain five measurement questions and that there are two aspects that contain ten measurement questions. Some aspects are broader than other aspects when combined with industry 4.0. That is the main reason why the measurement questions are not equally distributed amongst the aspects.

Table 5. Distribution of the measurement questions per aspect

Aspect:	**Number of Measurement Questions:**
Strategy	7
Employees	6
Management & Leadership	5
Organisational Culture & Knowledge Management	5
Marketing & Sales	5
Customer Services	5
Channels	5
Institutional Awareness	5
Inbound Logistics Activities	5
Outbound Logistics Activities	5
Products & Services	7
Production & Process	10
IT Management	10
Industry 4.0 Technologies	1

Step 4: The maturity levels & types

Maturity levels and maturity types were created in order to present respondents a level of maturity based on industry 4.0 implementation. These levels are based on the average score for the all aspects, so in other words, the average score of all 86 measurement questions. Five maturity levels have been drafted and next to them, three maturity types have been added.

4.1 Introducing the maturity levels and providing argumentation for using them

As one can see in table 3 the exploration of literature and existing scans resulted in 37 different maturity levels, which were all analysed in order to construct the maturity levels of this paper. In order to construct the maturity levels, the paper of Leyh et al (2016) was used. They propose different stages of industry 4.0 implementation. To give a general overview, the most important features of the stages are mentioned. The first stage that they propose is the basic digitization level in which the company has not addressed industry 4.0. The second stage is called cross-departmental digitization in which the company is actively engaged in industry 4.0 topics and digitization is implemented across departments. The third stage is called horizontal and vertical digitization in which the company is horizontally and vertically digitized. Stage 4 is called full digitization in which the company has been completely digitized. Stage 5 is called optimized full digitization in which the company is not only digitized itself, but the collaborations with business partners is also digitized (Leyh et al, 2016).

Based on the paper of Leyh et al (2016) the maturity levels for the extended scan also consist of five maturity levels. In the paper of Ungerer (2018) "constructing a multi dimensional smart industry scan" five maturity levels are provided as well. Level 1 is called poor implementation in which the respondents with an average in between 1 and 1.49 were placed. Level 2 is called moderate implementation in which the respondents with an average of in between 1.5 and 2.49 were situated. The next maturity level is called advanced implementation with an average score of in between 2.5 and 3.49. The fourth maturity level is called semi-advanced implementation with an average score of in between 3.5 and 4.49. Lastly, maturity level five is called full implementation with an average score of in between 4.5 and 5.

During the last year, these maturity levels have been updated. During the literature review for the extended scan multiple additional scans were assessed that provided more examples of maturity levels as stated in table 3. Next to this, many people proposed changes to the maturity levels of Ungerer (2018) during the last year. Many specialists gave their honest opinion on these maturity levels. Next to this, four students

used the whole scan including maturity levels for educational purposes at different organisations. A lot of feedback was received, and one of the main points of attention were the maturity levels. The score distribution was very clear, so that is why these haven't been changed. However the maturity levels have changed. In the next paragraph, the maturity levels for the extended scan are shown and the difference between Ungerer (2018) and the proposed maturity levels are provided.

Maturity level 1 was called poor implementation, however it was changed to starting implementation. A specialist in digital transformation proposed this change and stated the negative tone of the word "poor". In his opinion, organisations that see poor implementation can be offended by the word instead of triggered to improve. In his opinion "starting implementation" was a better alternative. The same scenario was also the case for maturity level 2. Maturity level 2 was called moderate implementation, in which the word moderate can easily be seen as a negative word. Therefore, it was changed to "average implementation". For maturity levels 3 and 4 not much has changed. However, maturity levels 3 and 4 are switched around. In the paper of Ungerer (2018), maturity level 3 was called advanced implementation and level 4 was called semi-advanced implementation, however it should be switched. On top of that, both maturity levels are now more closely related to the maturity types proposed by IMPULS (2015). From being called semi-advanced and advanced implementation they are now called semi-advanced and advanced leaders. To finish it off, maturity level 5 has changed from full implementation to "expert leaders". This was a suggestion of one of the specialists that looked through the maturity levels proposed in Ungerer (2018); this specialist proposed expert implementation instead of full implementation. In combination with the previously mentioned switch from implementation to leaders, the maturity level is now called "expert leaders".

4.2 Introducing the maturity types and providing argumentation for using them

The maturity types are constructed in accordance with IMPULS (2015). In their study, three maturity types are proposed and referred to as the following: newcomers, learners and leaders. Newcomers are defined as "companies that have never initialized first projects related to industry 4.0." The learners did initialize some first projects related to industry 4.0. Leaders are ahead of other companies in their industry 4.0 implementation. "Newcomers" are added to maturity level 1, "learners" are added to level 2 and "leaders" are added to maturity levels 3,4 and 5.

The maturity levels, maturity types and the average scores are shown in figure 2**.**

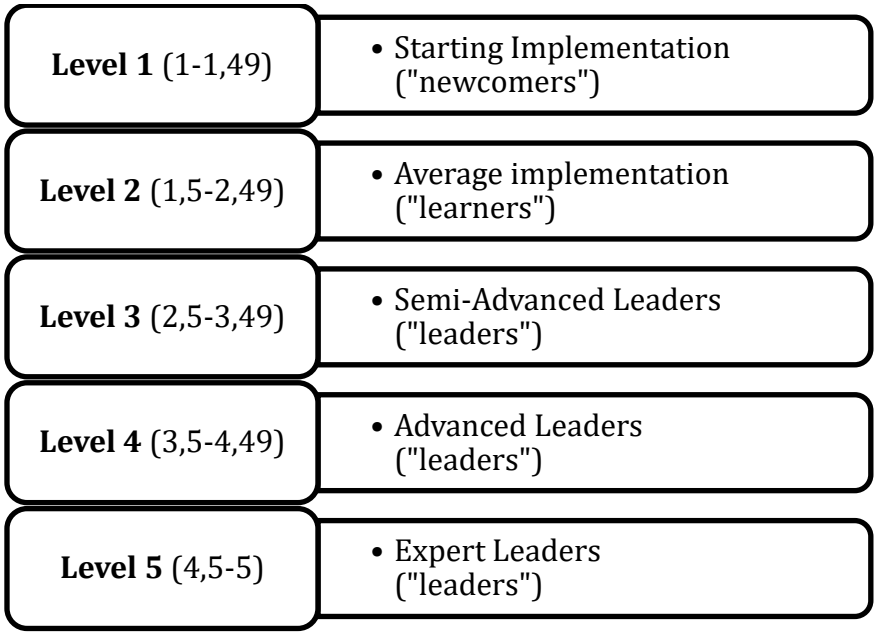

Figure 2. Maturity Levels and Maturity Types

4.3 The added value of implementing Radar Charts

As previously stated, all measurement questions have five possible answer options. These answer options have been drafted in accordance with the ideas of Rensis Likert and reach from (1) not at all to (5) fully. The measurement questions are drawn up in such a way that (1) not at all is always the least favourable outcome and (5) fully is always the most favourable outcome. To give a graphic display of the scores for a respondent, radar charts are set up. A radar chart is a good way to visualize multivariate data to the respondent and it represents an easy visualization of the attributes, including visualisation of comparisons and differences in between aspects and measurement questions (Nowicki & Merenstein, 2016). One respondent will be provided with a radar chart for every aspect showing the average for the measurement questions of that aspect as shown in figure 3. Next to this the respondent will be provided with one radar chart for the average scores of all 14 aspects together as shown in figure 4. Thus a total of 15 radar charts are provided to the respondents that will be generated automatically by a tool that is explained in more detail in chapter 6.

An example is given on how to use the radar charts by using figure 3 and 4. In figure 3 one can see the scores of the measurement questions related to aspect 8. One can directly see that aspect 8 has five measurement questions shown as Q1-Q5. One can also directly see that Q4 is closer to the outside of the radar chart meaning that the respondent scores high on this measurement question. The average score of these five measurement questions is 2,8 ((3+3+1+5+2)/5)) meaning that aspect 8 has an average score of 2.8. The averages for all aspects are shown in figure 4. When we take the average scores of all 14 aspects and add them up one will get to an average of the whole

scan, in other words all measurement questions. This average is used to put the respondent in one of the five maturity levels, which were already discussed previously.

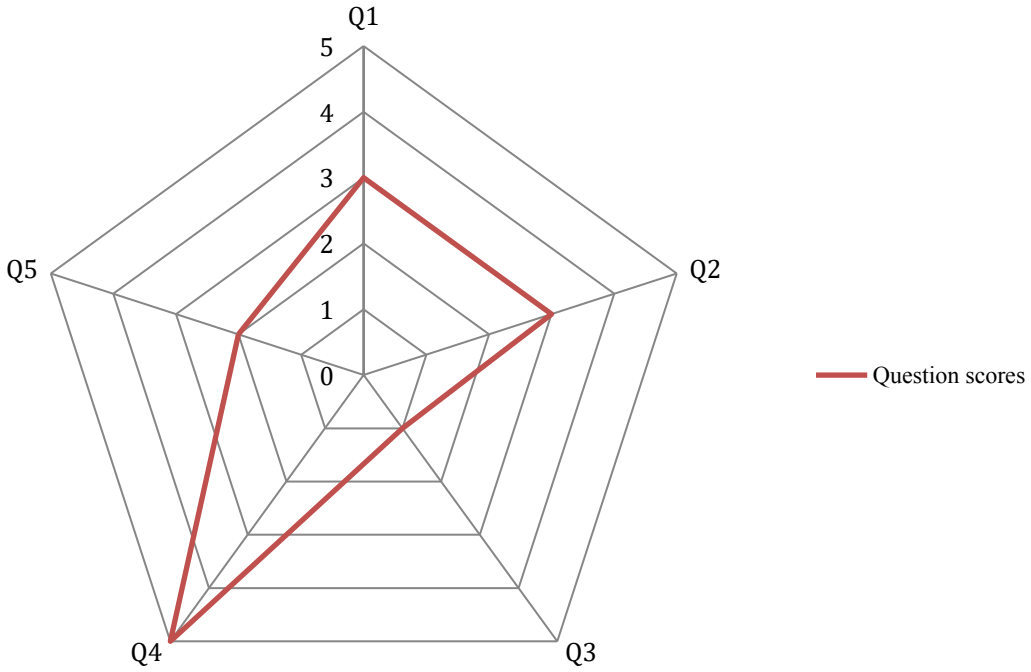

Figure 3. Radar chart of the measurement questions of one aspect

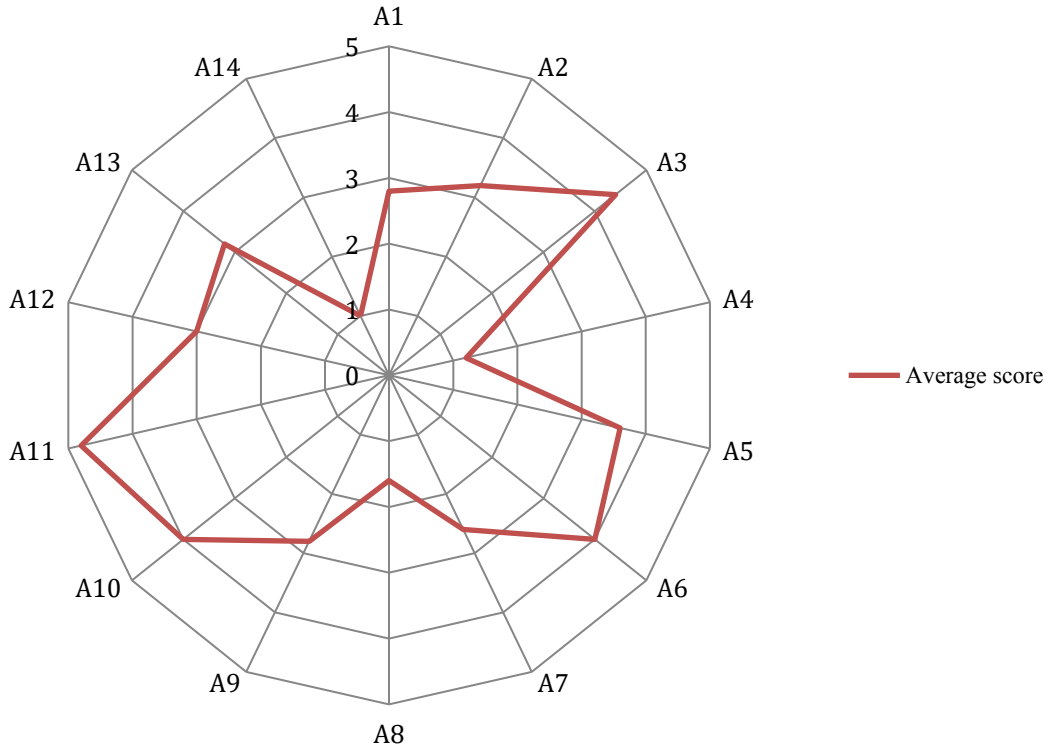

Figure 4. Radar chart for the average score per aspect

Step 5: Assessing the pre-designed scan through the eyes of specialists

5.1 Introduction of the specialists

The following step in drafting the extended scan is to look at the pre-designed scan through the eyes of the experts. Until now, fifteen aspects have been constructed that measure industry 4.0 implementation in a wide range of business aspects. All of these business aspects contain measurement questions, which, if added up, totals 86 measurement questions. As mentioned before, the business aspects were all constructed from literature and an online exploration of existing scans. This means, that the business aspects that were constructed can be seen as reliable and valid to some extent, however a greater validity and reliability is aimed for. The same applies to the measurement questions, the maturity levels and the maturity types. The measurement questions were constructed based on the same exploration of existing scans. In total eleven existing scans were analysed, which had a total of 402 tested measurement questions that were used as inspiration for creating the measurement questions for the extended scan. Next to this, the measurement questions in the extended scan all meet the requirements that were formulated by seven papers that were found. This means that the measurement questions were constructed in the right way, which increases its validity and reliability. The maturity levels and maturity types were also constructed with the help of recognized sources.

In order to improve the reliability and validity of the pre-designed scan the expertise of multiple specialists was used. Multiple specialists were asked to look at parts of the pre-designed scan. A file was created in which an explanation was given of what kind of feedback was expected from them followed up by the aspects that the assessed. One can see the cover sheet with the explanation on it in appendix 2. Next to this, there was also a possibility to provide general feedback. All of this can be found in appendix 1, in which the specific feedback of the specialist per measurement question is written down. Next to this, one can see if the feedback has been implemented, partly implemented or rejected.

As the aspects cover a wide range of business dimensions, so are the measurement questions. Obviously, I needed multiple views from different specialists on the different business dimensions. For example, a process manager could look at production & process and a ICT Lawyer could assess institutional awareness. Next to this, the total amount of measurement questions is 86; so this was also a reason to split up the feedback into smaller parts, so it remains a manageable task for the specialists. That is why the functions of the specialists differ. All specialists were gathered from within my own network, however their names are not provided, because of privacy reasons. In

Table 6 one can see the specialists, their functions and the aspects that they looked at and gave their feedback on.

Table 6. Enumeration of the specialists

Specialist:	Function:	Treated aspects
Specialist 1	Senior lecturer strategic marketing and servitisation	1,2,3,4,10,11
Specialist 2	Consultant new business, transformation & innovation, digital strategy	3,4,5,6,7,8,9,10,11,12,13,14
Specialist 3	Account manager Safety Systems (F&G detection)	2,3,4,5
Specialist 4	Project manager	1,2,3,4,5,6,7
Specialist 5	Content manager E-commerce	5,7
Specialist 6	Consultant value innovation, business models, business strategy, business alignment	1,3
Specialist 7	Product marketing manager	5,7
Specialist 8	Supply chain coordinator	10,11,13
Specialist 9	Certified data protection officer – project manager master data management	1,8,12,13,14
Specialist 10	European supply chain – project management	1,2,8,11,14
Specialist 11	HR Advisor	2,3,4
Specialist 12	Export manager	5,7,11,12
Specialist 13	CEO/Founder manufacturing company	8,9,10,12,13,14
Specialist 14	Manager Information Centre/ former HR Manager	1,2,3,4

Specialist 15:	Consultant strategy, organisation, technology, manufacturing, process improvement, management, coaching, industry 4.0 and smart industry	6,7,8,9,10,11,12,13,14
Specialist 16:	ICT Lawyer	8
Specialist 17:	Technical Online Advisor	6,7,8
Specialist 18:	Process Manager	6,12,13
Specialist 19:	Sales Coordinator	3,4,6
Specialist 20:	Service & Sales Manager	5,6,7,10,11,12
Specialist 21:	Former CEO High-Tech company	6,9,13,14

5.2 The specialists and their feedback

In this part the specialists will be shortly introduced and their feedback will be provided. The function of the specialists is given and the aspects that they looked at are mentioned. The names are not provided because of privacy reasons. For the extended feedback one can have a look at appendix 1**.** In this part only the general feedback that the specialist proposed are discussed and looked at.

Specialist 1 is a senior lecturer on strategic marketing and servitisation. This person proposed to look at aspects 1, 2, 3, 4, 10 & 11. As mentioned before, the extended feedback per measurement question can be seen in appendix 1. Next to the extended feedback, this specialist also proposed some general feedback that has been implemented. One of the things that were proposed was to change the name of the aspect "organizational culture" into "organizational culture & knowledge management", which has been implemented. Next to this, this specialist proposed to give an introduction to every aspect and more specifically the argumentation of using them and the importance of using them. This has been done in chapter 2.2 of this paper. Next to this, the specialist proposed to start every question with "to what extent" for consistency purposes. The measurement questions should be consistent, so that the answer options can be filled in the same way every time. This means that for every measurement question (1) should be the least preferred outcome and (5) should be the most preferable outcome. Lastly, things like "smart practices" should be explained in the scan,

which is now done by using brackets, but in the next chapter a tool will be introduced a that I am already working with. In this online tool an explanation can be added in the measurement question, and the respondent can access this information by clicking on a symbol. Subsequently, a pop-up screen will appear in which the information is shown.

Specialist 2 is a consultant in new business, transformation & innovation and digital strategy. This specialist looked at aspects 2 up to and including 14, so almost the whole scan was analysed by this specialist. This specialist provided a lot of helpful feedback, which one can access in appendix 1. Next to this, the specialist also provided some general feedback, which is discussed in the following. One of the things that was mentioned was the inconsistency between smart industry and industry 4.0. He proposed to choose one and be consistent throughout the scan. Next to this, this person helped to adjust the maturity levels from the ones proposed by Ungerer (2018) into the maturity levels that were shown in the previous chapter. Moreover, the specialist proposed to look at a paper that could help to draft measurement questions for the aspect "strategy". The paper also entailed maturity levels, which could be used as inspiration for purposes of future research, which will be discussed later on in this paper. This person also proposed to make measurement questions related to online marketing channels, such as social media and the Internet.

Specialist 3 is an account manager in safety systems in fire & gas detection. He has gained a lot of experience in previous functions as well, and is also aware of industry 4.0 opportunities in his field. He proposed to look at aspects 2, 3, 4 and 5, because of his experience in the business world. This specialist has provided some strong insights on these aspects that one can see in the extended feedback forms in appendix 1. The general feedback was about the amount of "to what extent" that were used in front of the measurement questions. However, during our meeting I explained that this was used in order to promote consistency, and we both agreed that this was the best way to start the measurement questions.

Specialist 4 is a project manager at an ICT company in the region. He looked at aspects 1, 2, 3, 4, 5, 6 and 7 and gave extended feedback on all measurement questions, which can be seen in appendix 1. The specialist also proposed general feedback, such as to watch grammar mistakes, because it will distract respondents who are filling out the scan. Next to this, this person stated the fact that industry 4.0 is not a very common subject to ask about, so the measurement questions should be very clear. In addition to this, the specialist mentioned that moving your mind into the minds of the respondents in order to see if it is easy to understand what is being asked. Next to this, the aspects should be introduced in his opinion in order to have the complete understanding of the respondents, which is done in chapter 2.2. Lastly, the measurement questions should be consistent it should be tried to use the same words over and over again. Next to this, he also mentioned to use (e.g.) for examples and (i.e.) for explanations.

Specialist 5 is a content manager in E-commerce at a large company in the region. This person is part of the marketing department of the organisation and works on a daily basis with new types of marketing including industry 4.0. That is why this person was asked to look at aspect 5 and 7 in order to provide her opinion. She provided information about the sales process. At her organisation they sell to customers and settle the sells in a digital manner. No face-to-face contact is needed until the moment when the product gets placed. She recommended including a question related to this topic, however she also notified that this wouldn't be the same for every different industry type.

Specialist 6 is a consultant on value innovation, business models, business strategy and business alignment. This specialist is a very experienced consultant with a lot of experience in strategy. That is why this specialist assessed aspects 1 and 3, and his feedback would turn out to be of great value for the measurement questions. As previously mentioned only the general feedback is discussed in detail and the specific feedback per measurement question is in appendix 1. The specialist proposed to introduce the questionnaire with a small text explaining the essence of industry 4.0. In this part, one should get to know the basics of industry 4.0 and how it could contribute to the strategy and achieving a competitive advantage. Next to this, he stated that it is essential to introduce all the topics shortly before the respondent starts with every aspect. This introduction is part of the future research. In the next chapter, the future research will be explained and part of it is to put the whole questionnaire into a tool that was already used for the scan of Ungerer (2018). This tool also allows including a small introduction at the start of every aspect.

Specialist 7 is a product-marketing manager who looked at aspects 5 and 7. This specialist has developed a lot of experience in the marketing world and looked at two of the aspects. This specialist had some specific feedback for some of the measurement questions. He provided the same information as specialist 5 about face-to-face contact. One could say that face-to-face contact is essential for some organisation types and for another organisation type it is not. The measurement questions had been changed to make it more applicable for different organisation types. Furthermore, the specialist liked the measurement questions and had no general feedback to add anymore.

Specialist 8 is a supply chain coordinator, whose daily activities have to do with logistics. That is why this specialist was asked to assess both aspects 10 and 11. Next to his specific feedback per measurement questions he also had some general feedback. Firstly, the measurement questions should be specifically related to the customer. The measurement questions should contain "your organisation" instead of "the organisation" according to this specialist. Next to this, he thinks that "to what extent" is a very broad term and should be specified more, however after explaining him "to what extent" is used to achieve high consistency in between measurement questions, he agreed that every measurement question should start this way.

Specialist 9 is a certified data protection officer and next to this he is also a project manager master in data management. This happened to be a very convenient specialist who knew a lot about institutional awareness and data management. This was one of the reasons to let this specialist assess aspects 1, 8, 12, 13 and 14. The specific feedback for the measurement questions were very convenient and the additional information that was provided to me for aspect 8 contributed to understanding the topic better and confirmed the need for industry 4.0. The general feedback showed that the measurement questions are really good and most importantly relevant for the topics. However, the design of measurement questions should be consistent and specific, so the answers are really the answer that is aimed for. Furthermore, some extra literature was added in order to understand data management better.

Specialist 10 is a European supply chain manager and project manager. This person agreed to look at aspects 1, 4, 8, 11 and 14. Next to the specific feedback, this specialist also proposes some general feedback including proposals for measurement questions of which one was copied into one of the aspects. One of the things that was pointed out was the lack of feedback space in the feedback form, despite this had nothing to do with the scan itself, it was implemented in the feedback forms that were sent afterwards. Next to this, he proposed that some measurement questions should be more general. He stated that some measurement questions had hidden assumptions in them that could lead the respondents to answer the measurement questions in a fixed manner. Moreover, he stated that it should be considered to add a sixth answer option, however there a multiple reasons why it was chosen to have an uneven number of answer options, so this feedback was not implemented.

Specialist 11 is a human resources advisor for an organisation in the region. That is why this specialist looked at aspects 2 and 3. Next to the specific feedback per measurement question, this specialist notified that the order of measurement questions for aspect 2 was incorrect. She proposed to change the measurement question order to the following: Q6 → Q1, Q1→Q2, Q3→Q4, Q5→Q3, Q4→Q5 & Q2→Q6. After looking into this it was agreed and changed to the one that was proposed by this specialist.

Specialist 12 is an export manager for an organisation in the region. His daily business activities involves going to possible clients to sell the product of the organisation. That is why he is involved in outbound logistics a lot. That is why aspect 11 is part of the aspects that he assessed and provided feedback on. The aspects that this specialist assessed were 5, 7, 11 and 12. The person provided a lot of specific feedback on the measurement questions, but not a lot of general feedback. He proposed that more variation should be included in the measurement questions, and not start all measurement questions with “to what extent”. However, during our meeting it was explained why “to what extent” is constantly used and he did agree with me. He was not

the only specialist that proposed this, however consistency is very important in asking measurement questions, especially for the answer options that are the same all the time.

Specialist 13 is a founder and CEO of a manufacturing company in the region that produces Machines upon request of fellow businesses. This specialist agreed to look at aspects 8, 9, 10, 12, 13 and 14. This person did not have a lot of general feedback. He only stated that it might be handy to include some extra explanations for some specific words in the measurement questions. He stated a small explanation should be added for words that might be unclear. This way all respondents will understand what is meant by the measurement question, which will make sure that the answers are filled in the right way. Next to this, he confirmed the measurement questions related to the aspects products and services and production and process. He stated that the machines that they offer to their customers are made as smart as possible, which is of course dependent on the money that the customers wants to spend on the machine. This way, they can log in to machines on distance in order to access data related to for example cycle time. A long cycle time indicates that it is time for maintenance for example. This confirms the feasibility of the measurement questions that are related to this topic, because someone who uses it in practice confirmed the importance of this topic.

Specialist 14 has recently switched from being a human resource manager for a lot of years to being a manager of an information centre and works at an organisation in the region. This specialist agreed to look at aspects 1, 2, 3 and 4. This specialist proposed to introduce the term industry 4.0. This person states that it might not be clear what industry 4.0 entails for all respondents and a small introduction could help to clarify this. Next to this, all the aspects could be introduced individually in order to clarify the different aspects to the respondents. Next to this, he agrees to the measurement questions that are related to human resources. He additionally states that service centre human resources is currently active in a transition, from being a transactional organisation to being a knowledge intensive organisation. In this intended knowledge intensive organisation, simple administrative tasks will be completely automatized, which means a massive change for around 80% of employees in human resources. It is likely that some employees are not capable or willing to make this switch. He points this out, because it outlines the effect of industry 4.0 on a human resource department, which is the case in his organisation, but also the case in many fellow organisations.

Specialist 15 is an experienced consultant in many fields, such as strategy, organisation, technology, manufacturing, process improvement, managing, coaching, and industry 4.0. This specialist agreed to look at aspects 6 up to and including aspect 14. This person provided some specific feedback, which is shown in appendix 1. However, this person also provided general feedback. First of all, he stated that the aspect sustainability should be optional and not always included when assessing an organisation. The respondent should be able to include or exclude this aspect in the overall score, because the concept is very new and not everyone has already

implemented this. Next to this, he states that servitisation should be implemented in the scan, because of the added value that servitisation and digitalisation have to each other. Next to this, he states that the scan is clear to him and he understands what is meant with the measurement questions, however some small manufacturing entrepreneurs might have a different vocabulary. At least from his experience he can confirm that this is the case. These people might not understand all measurement questions. The specialist proposes to add more explanation to the measurement questions to make sure that everyone understands what is meant with the measurement questions.

Specialist 16 is an ICT Lawyer who is specialized in the laws around industry 4.0 and IT. This specialist agreed to look at aspect 8, which is called institutional awareness and has a lot to do with the laws around industry 4.0 implementation. The specialist had only one specific feedback point related to the general feedback. He proposes that I should be consistent in asking the measurement questions.

Specialist 17 is a technical online advisor. He works at a big company in this region and is doing a job that has not been there for many years. It is a job that has been created by the increasing digital world. At his company there are two types of advisors, one that has face-to-face contact with potential customers and one that advises customers online. His working activities consist of making online offers to customers based on the information that is provided to him online. If a customer agrees, this person can sign the offer and this whole process is done online. This specialist agreed to look at aspects 6, 7 and 8. Some specific feedback was provided, however he agreed with most of the measurement questions and did not have a lot of suggestions. One can find the specific feedback in Appendix 1. The only thing that was proposed by this person as general feedback was the amount of explanations. He thinks that there should be more explanations on certain topics that are not obvious. Especially in aspect 8 there are certain words in the measurement questions that need deeper explanations.

Specialist 18 is a process manager for a large organisation. He is in charge of letting the process run smooth. This person has noted that the processes have drastically changed by the digital era. On a daily basis he has to deal with complex issues in the process that include industry 4.0 implementation. This specialist agreed to look at aspects 6, 12 and 13. Especially aspect 13 is essential to be looked at by this specialist. This aspect “production & process” is entirely in his field of work, so this feedback can be of great importance for improving the pre-designed scan. All in all, this person liked the measurement questions and had some minor feedback point, which are added in appendix 1. Next to this, he pointed out to read over all of the measurement questions again in order to achieve consistency and rule out all grammar mistakes, because both will distract respondents. During the meeting, this person pointed out that his organisation is not producing products themselves, however he has worked at a production firm and could confirm the importance of industry 4.0 techniques in production.

Specialist 19 is a sales coordinator at a large organisation in the region. This person is in charge of a department that is responsible for all the sales in a business to customer market. In her department several industry 4.0 techniques are implemented. This person agreed to look at aspects 3, 4 and 6. This specialist had some specific feedback that is mentioned in appendix 1. She had two points of attention as general feedback. First, this person misses a detailed explanation of the term industry 4.0. In order to make sure everyone understands this term it should be introduced according to her. Next to this, the aspects themselves should be introduced as well. What do the aspect entail and what is measured by the measurement questions of these aspects?

Specialist 20 is a service and sales manager at a big company in the region. This company has heavily invested in industry 4.0 practices and has implemented this widely within the firm. It can be said that the company is one of the precursors in the implementation of industry 4.0. Because of this, the feedback can be extremely useful, because it is given by someone who has a lot of practical knowledge of industry implementation within an organisation. This specialist looked at aspects 5, 6, 7, 10, 11 and 12. Generally, it can be said that the specialist misunderstood the task. No specific feedback was provided; only some general remarks were presented bases on the answer options. It was stated that for some measurement questions it is hard to track down if the measurement question is intended to measure what is happening in the market or if it is happening on an organisation level. Next to this, he states that some measurement questions can be interpreted as focussing on the future instead of measuring the status quo of the organisation.

Specialist 21 is a former CEO of a high tech organisation in the region. The organisation develops and manufactures their own products and they are constantly innovating these products to meet customer demands. They widely use industry 4.0 practices throughout their firms and that is why the feedback is based on a lot of practical experience, which makes the feedback very interesting. The specialist agreed to look at aspects 6, 9, 13 and 14 and gave some specific feedback and some general feedback. To see the specific feedback I would like to refer you to appendix 1. This specialist also proposed some general feedback that mainly existed from adding explanations. This person specifically mentioned adding explanations for definitions like technologies, industry 4.0 technologies and new industry 4.0 technologies. The definition could make the terms easier to understand for respondents and would help improve the value of their answers. Next to this, he proposed two new measurement questions. One should be about why people are still not using industry 4.0 technologies and the other one should be about the strategies that are used to implement industry 4.0 technologies. However they don't fit to the answer options that I proposed for the extended scan.

As one can see in appendix 1, a lot of the proposed feedback has been implemented in the end design of the extended scan. The feedback from all the specialists has been proven to be a great tool for improving the pre-designed scan. By using the specific feedback the measurement questions have been changed, adjusted, but most importantly the measurement questions have been significantly improved in comparison to the measurement questions from the pre-designed scan. In table 7 one can see the amount of specialists that each aspect was assessed by. The final design of the extended scan can be seen in appendix 3.

Table 7. Amount of specialist for each aspect

Aspect	Amount of specialists reflected
1	6
2	6
3	8
4	7
5	7
6	7
7	7
8	6
9	4
10	6
11	7
12	7
13	7
14	6

Step 6: Making it fit for use - providing information for consultancy and practitioners

This chapter is dedicated to explain the additional conditions in order to make the scan fit for use. The ones using the scan can be consultancy and other practitioners, such as employees and management representatives. The pre-designed scan has been updated with the feedback from the specialists making it fit for use. However, it is not convenient to send the respondents the scan like it is shown in appendix 3. In this part, the alternative is presented and explained, but first the added value of the scan, and what can be analysed with the results is explained.

6.1 Added value extended scan

The scan is a tool that can be used as a starting point for consultancy or practitioners in order to talk about industry 4.0 implementation within an organisation. The extended scan can be used as a tool for exposing weaknesses, but also strengths in the current status quo on industry 4.0 implementation. Next to this, if filled in by different departments, one can detect possible differences in point of views on industry 4.0 implementation in departments. For example, when the marketing department scores very low on the marketing aspects of the extended scan, and the management scores very high on the same aspects there is a different point of view that should be discussed.

6.2 Conducting the scan using an online tool

The extended scan that is drafted in this research is an extension on the quick scan proposed by Ungerer (2018). During the last year cooperation was entered into with a research company that provided us with an online tool to implement questionnaires. The essential function of this tool is to conduct online questionnaires, however there are many additional options that can be provided by their software. The online tool operates with login codes that the controller can use in order to manage the questionnaire. In this case, my own unique login codes were provided in order to control my own questionnaire. The online tool was already used to add the quick scan into. The landing page shows all the different questionnaires that I already made. Different questions can be added to the questionnaire and a lot of different options to the questions as well, such as the lay out of showing the questions and answer options. After adding the questionnaire to the online tool the questionnaire can be controlled, see the results and share the questionnaire with possible respondents. I can send an email with a unique link that allows them to fill in the questionnaire once. They can open the link and fill out the questionnaire and subsequently their results can looked into, which allows me to see on which aspects they have weak and high scores. An additional feature of the online tool is the possibility of adding an explanation at the end of a measurement questions. I

can add a question mark symbol, and when a respondent clicks on it, they see a pop-up screen with a small explanation of what is meant in case they don't understand. This feature allows making sure that respondent understand the measurement questions the right way.

Now that the basics of the online tool are already explained, an example is provided from the previous year in which bachelor students successfully used the quick scan and the online tool. Last year, there were four bachelor students that were interested in conducting the quick scan at different organisations for their bachelor theses. First, the essentials of the quick scan were explained to them and the thoughts and explanations for using the quick scan. After they understood how the quick scan should be used at the organisation a controller account was created in the online tool for them, so they could control their own results in the online tool. This way, they could share the links by email to the respondents that agreed to fill in the quick scan. Both an English version and a Dutch version were created, so both the English speaking and Dutch-speaking students were able to share the scan. The scan was conducted in two Dutch firms, two Lithuanian firms and one Slovenian firm. A total of 45 scans were conducted scattered across these firms. The students were asked to do a workshop at the firms in order to share the results and provide the firms with some possible advice. These 45 responses provided me with a lot of data and next to this also with a lot of feedback in order to improve the scan. Next to this, the critical view of these four students provided me with new insights as well in order to improve the quick scan. Moreover, it contributed to the extended scan as well. The different employees that filled in the scan and the students that conducted the questionnaire proposed some interesting insights. Especially in relation to things that were missing in the quick scan or things that could be formulated better. Notes were taken and all of the feedback was taken into account during the construction of the extended scan.

Based on the experiences collected earlier, the extended scan that has been designed in this research will be illustrated in the same online tool. The efficacy of the online tool has been thoroughly tested during the last year, and it can be concluded that the online tool works very well in order to conduct the questionnaires.

6.3 The results sheets of the online tool

As previously stated, the online tool has additional features next to inserting and conducting questionnaires. One of these features is an automated results sheet that the respondent get's when finishing the questionnaire. This result sheet is unique and completely tailored to our wishes. The result sheet consists of a small introduction of the importance of industry 4.0 implementation and the contact details if a respondent wishes to get more explanation. For the quick scan its consists of eight radar charts, one for every aspects and one for all aspects combined. However for the extended scan the result sheet will consist of fifteen radar charts, one for every aspects and one for all

aspects combined as one can see in figure 3 and 4. As stated before, a radar chart is a good way to visualize multivariate data to the respondent and it represents an easy visualization of the attributes, including visualisation of comparisons and differences in between aspects and measurement questions (Nowicki & Merenstein, 2016). Next to the radar charts, the result sheet also contains a table in which the averages per aspect are shown and an average of the whole extended scan is shown. This automatically leads to the following part: the maturity levels and types. When an average is known for the whole extended scan, the respondent can be put into one of the maturity levels. This way, the respondent can see what maturity level as it is in now, and how much the respondent needs to improve to get to the next level.

Step 7: Providing limitations and possibilities for future research

Every research has its own limitations, and that is also the case for this research. I want to mention one, which has to do with the amount of specialists that gave their feedback. Personally, I wanted more specialists to provide me with feedback, however this didn't work out like I wanted to. In an ideal situation, I would have more specialists per aspects, because as you can see in table 7, some of the business aspects were assessed by less specialists than other aspects. This is also something that I could assess in a future research to increase the reliability and validity of the measurement questions. Currently, 21 specialists provided specific feedback, however this should be extended in the future to a greater amount in order to get even more insights and feedback on the extended scan.

Next to increasing the amount of specialists that provide feedback a small introduction is also part of the future research. The online tool that I previously discussed provides the possibility to implement a small introduction at the start of every aspect. The introduction can be partly copied from chapter 2.2 in this paper. An introduction will provide the respondent with a small explanation of what the aspect entails and what the importance of assessing this aspect is. Next to adding an introduction to the online tool, I also need to put the extended scan that I designed in this research into the same tool.

The biggest part of possible future research is the explanation of the maturity levels that I designed. I already have plans to further investigate this and try to explain the maturity levels. For now, I only have the names of the maturity levels, so for example: advanced leaders. However, what does this maturity level entail? How do the respondent get to the next level? How can they improve? All of these questions should be assessed in the explanation for the maturity levels. I have already found a lot of literature that can be used in order to explain the maturity levels, such as the theory of Leyh et al (2016) in which their maturity levels have explicit explanations.

8. Summarizing the Design Research

In this design research I created an extended scan called the extended science-based multi-dimensional scan for assessing industry 4.0 maturity. This paper contains the steps that were taken in order to come up with the extended scan. In this part the steps will be shortly summarized.

First of all, an extensive literature review was done that was focussed on the topics related to industry 4.0 and industry 4.0 implementation. Next to this, the effects of industry 4.0 on different business aspects were studied. Thereafter, a big exploration of existing smart industry scan was done. In total, eleven existing scans were selected and used to draft the extended scan. These eleven scans were studied and their features were shared. Based on the knowledge that was gathered in step 1, step 2 could be started. In step 2, the aspects were constructed and the definitions and argumentation for using all of these aspects were given. In total 15 business aspects were constructed that all covered different fields. In the next step, a big literature review was done in order to find out how measurement questions should be constructed. In the end, seven papers were selected that showed different requirement that measurement questions should fulfil. In total 86 measurement questions were drafted that all fulfilled these requirements. Step 4 was all about the construction of the maturity levels and maturity types. In the end five maturity levels and three maturity types were constructed, which were founded in Ungerer (2018), additional feedback and an additional literature review. In step 5 the pre-designed scan was looked at through the eyes of specialists. In total 21 specialists looked at the pre-designed scan and provided me with their feedback, which was then used in order to improve the measurement questions. Different parts of the pre-designed scan were assigned to different specialists who all had different practical experience. All of the 21 specialists had different functions giving a very broad view on all the measurement questions that were constructed. A lot of specific feedback was used to improve the measurement questions, which is shown in appendix 1. The general feedback was also used in order to improve the pre-designed scan. This general feedback is provided in this step in the paper. The next step consisted of suggestions for practitioners and consultancy to make the scan fit for use. In this part, some essentials were discussed in order to use the extended scan as it is intended to. Lastly, some limitations were given and some suggestions for future research were given.

The final extended scan consists of 15 business aspects, 86 measurement questions divided amongst these business aspects, five maturity levels and three maturity types. The extended scan is called the extended science-based multi-dimensional scan for assessing industry 4.0 maturity.

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10: Appendices

Appendix 1: feedback of the specialists

- **Specialist 1: Senior Lecturer strategic marketing and servitisation**

Questions:	Feedback:	Action:
1.2	On investing → to invest	Feedback implemented
1.3	Explain industry 4.0 practices	Feedback implemented
1.4	Remove "from"	Feedback implemented
1.6	Explain smart practices	Feedback implemented
2,1	Rephrase the question	Feedback implemented add "to what extent" and delete "talent"
2.2	Rephrase the questions	add "to what extent" and "facilitated to" also add "to thrive"
2.3	Add "to what extent"	Feedback implemented
2.4	Add explanation of working digitally	Feedback implemented → explanation is information, drawings, instructions etc.
2.5	"Immediately" and change new events to developments	Feedback implemented
3.2	Add "to what extent"	Feedback implemented
3.3	Add "to what extent"	Feedback implemented
4.1	Look at the absorptive capacity literature, maybe you could get more information from here to add to this aspect	Feedback implemented
10.1	Remove "institutionalize" change this to "establish"	Feedback implemented
10.2	Explain smart practices	Feedback implemented
10.4	Change "operative"	Feedback implemented → operative changed to "in place"
11.1	Explain smart practices	Feedback implemented

General feedback:

- Change the name of aspect organizational culture to organizational culture and knowledge management.
- Make a general overview per aspect in which the importance of every aspect is explained.
- Start every question with "to what extent"
- Explain things like smart practices.

❖ **Specialist 2: Consultant new business, transformation & innovation, digital strategy**

Questions:	Feedback:	Action:
2.2	Add an explanation of "switch and "knowledge" what type of knowledge? Enough? Strange word.	Feedback implemented & changed enough to sufficient
2.3	Add developments	Not implemented, development is covered in question 4.6
2.4	Add an explanation of "working digitally"	Feedback implemented, explanation added (information, instructions, drawings etc.)
3.2	Add "related to industry 4.0 techniques"	Feedback implemented
3.3	Add explanation of "ability" to make it clearer	Feedback implemented explanation added: (traits & knowledge)
3.4	Not a good question, make a different questions, preferably related to the decision making process	Feedback implemented new question: To what extent does management use industry 4.0 techniques (data driven, analytics) in decision-making?
4.1	Easily is very subjective, I would leave it out	Feedback implemented
4.2	Does this questions overlap with a question from 3	no it is significantly different, this questions is specifically about trainings and workshops
4.3	Change "does" to "contributes"	Feedback implemented
4.4	Does the "organisation" entail the employees in this question? If so it is a question for aspect 3	No, the organisation entails the whole organisation, so employees, management and especially if the culture in this organisation contributes to the knowledge management of employees
4.5	Is part of aspect 3, you should change it to the organisation in general.	Feedback implemented
5.1	Add examples of online behaviour of target groups	Feedback implemented → automatized feedback, analytics from customer

		behaviour etc.
5.2	Do you only look at leads? I would add conversion rates as well	Feedback implemented
6.1	Add an explanation of smart industry practices/industry 4.0 technologies	Feedback implemented
6.2	Expand the question	Feedback implemented → expanded with "regarding quotations, order, service requests and inquiries
6.5	Add 24/7 and five examples of the channels you mean	Feedback implemented → channels: social media & website
7.1	Add explanation of multi integrated digital channels	Feedback implemented → website, social media and internet
8.1	This question is a bit vague, I can imagine respondent now knowing what digital business policy entails	
8.4	Maybe it is an idea to add international law and tax regulations	
9.3	How the question is formulated right now, it has no relation to industry 4.0	Question completely changed to a sustainability question
9.4/5	Both address emissions, I would reduce it to one question and one question related to sustainability	Feedback not implemented → keep both because they measure two different things, sustainability question added in 9.3
10.2	Add explanation for industry 4.0 technologies	Feedback implemented
10.4	Very vague question, don't get the essentiality of asking this	Question completely changed to: To what extent does industry 4.0 technologies help to et a good overview of the warehouse?
10.5	Add "by suppliers" and "automatically based on data"	Feedback implemented
11	No comments for aspect 11	
12.1	Remove question and make the question related to servitisation	Feedback implemented, question is: to what extent do industry 4.0

		technologies support servitisation (service as a revenue model)?
13.1	The questions as it is now is vague, change the question to something related to automated processes	Feedback implemented: To what extent is the production directed by automated processes?
13.2	Add "and to monitor products produced"	Feedback not implemented: Question is solely meant to be about the well being of the machines used
13.4	Undemanded is not the right word	Feedback implemented → undemand changed to undesired
13.5	There is no relation to industry 4.0 in this question	Feedback implemented
13.9	Add question related to deviations in the product specifications	Feedback implemented → To what extent are machines equipped with technologies that allow them to detect deviations in the product specification during the production process?
13.10	Move this question to aspect 1	Feedback implemented
14.8	Add the link to industry 4.0 in this question	Feedback implemented
14.9	Add question related to IT infrastructure	To what extent does your IT/ICT infrastructure support new innovative industry 4.0 based solutions (processes, product design, simulations, communication, new business models etc.)

General feedback:

1. You are switching between smart industry and industry 4.0, choose one and adjust all to this one.
2. Look at the paper from Appendix (SIMMI 4.0 – Stages | A Maturity Model for Classifying the Enterprise-wide IT and Software Landscape Focusing on Industry 4.0 2016) for the questions of strategy, maybe it could help.
3. Make sure you ask about analytics and the new way of marketing. Make questions about online marketing channels
4. Maybe it is also interesting to ask about the behaviour of online customers
5. And to what extent the offers are provided online/order automatized

❖ **Specialist 3: Account manager Safety Systems (F&G detection)**

Questions:	Feedback:	Action:
2.1	Change "sufficient" for "enough". Delete the part about the "switch" and make the question shorter	Feedback implemented: question is now: "To what extent do your employees have enough knowledge to implement industry 4.0 technologies?"
2.2	Delete "facilitated" and add "the right tools to develop the necessary skills". Delete he part from "to thrive" onwards	Feedback implemented, however decided to keep the part from "to thrive" onwards.
2.3	Turn this question around, and start with the part about being paperless.	Feedback implemented
2.4	Start with "how quickly are developments communicated"	Feedback not implemented → all questions have to start with to what extent
2.5	Provided → offers	Feedback implemented
3.1	Bolster → promote	Feedback not implemented, promote is different that bolster
3.2	"Experimenting with new initiatives related to" → "the use of industry 4.0 technologies"	Feedback implemented, however "the use" → to try out
3.5	Change the question and make it easier. "Do all team members contribute…"	Feedback implemented
4.1	"Newly gained knowledge" → "new ideas and techniques"	Feedback not implemented → its about knowledge
4.2	Change the question → change possibilities to offer	Feedback implemented: "to what extent do you offer your employees trainings/workshops to enable them to understand what a "smart factory" is?
4.3	Add "thinking out of the box"	Feedback implemented
4.4	"What is done to improve the level of digitalisation"	Feedback not implemented → not possible with the answer options
4.5	Spends → puts	Feedback implemented
5.2	"Do you measure" instead of "is measured"	Feedback implemented
5.3	Do you improve instead of	Feedback implemented

	is improved	
5.4	Remove “settled in a digital manner”	Feedback not implemented
5.5	Add “can you rely on your website”	Feedback not implemented

- **Specialist 4: Project Manager**

Questions:	**Feedback:**	**Action:**
1.4	It’s not clear whether you are asking about customer data of production data? Or make it two questions or delete on of the two.	Feedback implemented → customer data deleted
1.6	Be consistent in questions → you are talking about “you” here, but change it to “the organisation” and be consistent in this	Feedback implemented
2.4	I would change “individual working places” to “the workplace” and delete “without paper”	Feedback implemented
2.5	Delete “that happen” and delete “so everyone is up-to-date”	Feedback partly implemented → That happen is deleted, but every… not
2.6	“Opportunities”	Feedback implemented
3.5	Define “the decision” you are talking about → hiring a new employee is something different than when you make a decision about cost cutting	Feedback implemented
4.1	This is a hard question to answer for me. How do I want to measure if my employees adapt new knowledge? Maybe change it to apply new knowledge?	Feedback implemented
4.2	Their → there add i.e.	Feedback implemented
4.5	Explanation of smart?	Feedback not implemented, everyone who fills in this survey will have some basic understanding of the topic.
5.4	Add i.e.	Feedback implemented

5.5	"Your" → of the organisation	Feedback implemented
6.1	Add i.e.	Feedback implemented
6.2	Add e.g. instead of "on for example"	Feedback implemented
6.4	Equipped	Feedback implemented
6.5	Add e.g.	Feedback implemented
7.1	Add "are customers able to access" and add e.g.	Feedback implemented
7.4	Is → are	Feedback implemented

General feedback:

1) Try to move yourself in the minds of the respondents and ask yourself: do I get the questions that are being asked? It's not a very common subject to ask about, so try to introduce the subjects.
2) Watch grammar mistakes, this will distract people.
3) Use (e.g.) for examples and (i.e.) for explanations
4) Be consistent in asking the questions; try to use the same words over and over again.

- **Specialist 5: Content Manager E-commerce**

Questions:	**Feedback:**	**Action:**
5.4	I would add "settle in a digital manner"	Feedback implemented
7.4	Change the question around to: "To what extent are data analyses used as a source in order to improve the channels?"	Feedback implemented
7.5	Up to date with what? Please add explanation	Feedback implemented

General feedback:

- looks good, maybe you can add something related to sending paper briefs automatically.

- **Specialist 6: Consultant Value Innovation, Business Models, Business Strategy, Business Alignment**

Questions:	**Feedback:**	**Action:**
1.3	Change automatisation to automation and organisation's to	Feedback implemented

	organisations'	
1.4	Remove customer and production data and change it to only the general term "data", otherwise you have two questions in one.	Feedback implemented
1.5	The questions are about industry 4.0, so this question should have some relation to industry 4.0, which it has not now.	Feedback implemented → I added the following to the question: "supporting industry 4.0 objectives"
1.6	Remove "digital features"	Feedback implemented
1.7	Make more personal remove "the organisation" and change to "you"	Feedback implemented
3.3	Remove "has the ability" to "feel comfortable" to lead the organisation into new industry 4.0 practices	Feedback not implemented: question is about the ability of the management.
3.5	What team members?? Explain this.	Feedback implemented → to what extent do team members of all departments contribute to the final decision making process when it comes to change management?

General feedback:

- I think it is essential to introduce all the topics shortly at the start of the questionnaire. Next to this, it would be nice to introduce at the start of the questionnaire the essence of industry 4.0 and how it could contribute to the strategy and how it can help to achieve a competitive advantage.

❖ **Specialist 7: Product Marketing Manager**

Questions:	**Feedback:**	**Action:**
5.3	Data analyses → data analysis	Feedback implemented
5.4	I think this a hard question, because it really depends on the organisation. If the organisation has a lot of inside-sales then the question is of course relevant. However, if you have account managers	Feedback implemented → question was: to what extent are sales settled in a digital manner (without face to face contact), changed to: to what extent is the sale process done in a digital manner? (By using

	who visit a lot of customers and in enterprise sales this is mostly the case, the question doesn't have much value. Maybe make the question more general so it can be used for both cases?	industry 4.0 technologies and digital features)
7.5	Example of "up-to-date"	Feedback implemented → up-to-date regarding company information

General feedback:

- I think the questions are really good and very relevant for both topics that I addressed. You could do something with automatized follow up after sending the first message to potential customers. For the rest, not much to add to be honest.

❖ **Specialist 8: Supply Chain Coordinator**

Questions:	**Feedback:**	**Action:**
10.1	Make the question more personal by asking "your organisation" and "your suppliers".	Feedback implemented
10.3	I would change the question to 'is the organisation digitally connected to suppliers"?	Feedback partly implemented: all questions should start with to what extent, however its suppliers is removed and changed to only "suppliers"
10.5	Change the question, because the question is not clear, suggestion: To what extent are the physical actions automated after processing the data of incoming deliveries from your suppliers?	Feedback implemented
11.4	Do you mean you end customer of B2B?	Feedback not implemented: Both are meant, so the questions stays the same

General feedback:

- Try to be specific in every question related to your customer, as in question 10.1. To what extent is a very broad term, so try to be very specific in your questions, because they are sometimes vague to me.

❖ **Specialist 9: Certified data protection officer – project manager master data management**

Questions:	Feedback:	Action:
1.4	Good questions, however, I am curious what the responses will be. In my experience data is not seen as important, it's more something is necessary. Maybe the question should be related to data as an asset?	Feedback implemented: To what extent is data used as an assest in order to create value from?
8.3	Desisions → decisions.. I think this question should change somehow. I would move it more to the privacy and security side. Everyone in the organisation should be aware of these two, so it is applicable for all respondents. If not everyone is aware of these two problems will arise. Being aware of these is not a one-time thing, it should be repeated over and over again.	Feedback implemented: Privacy and security are of great importance for organisations. To what extent are employees of your organization aware of the privacy and security risks concerning the implementation of Industry 4.0 technologies?
8.5	Really good question! Acces → Access. Did you know that these requests should be dealt with within one month, so in big organisation automation of these requests is essential.	Feedback implemented
12.5	Maintanance → maintenance	Feedback not implemented: Both are meant, so the questions stays the same
13.2	Equiped → equipped	Feedback implemented
13.8	Equiped → equipped	Feedback implemented
13.9	Equipped → equipped, specificiation → specification	Feedback implemented
14.1	Do you really need to have ALL data or only relevant data? Storing data costs money, so I would change it to relevant data.	Feedback implemented

14.5	I would also include the storage of data, which should also be secured.	Feedback implemented
14.6	Realtime → real-time	Feedback implemented
14.10	Add question related to security measures applied when building or designing new systems, websites apps etc.	Feedback implemented: new question → To what extent are sufficient ICT security measures taken when designing new systems, website, apps etc.

General feedback:

- The questions look really good and relevant for the topics. Make sure to be consistent in how your questions are asked and be specific so the answers you get are really the answers you want.

❖ **Specialist 10: European supply chain – project management**

Questions:	**Feedback:**	**Action:**
1.3	This question looks like question 1.5, so I would remove it. Add something related to budgets for industry 4.0	Feedback implemented → question is now: To what extent is there a dedicated budget for implementing new digitalisation initiatives?
1.7	I would remove this question and make a question related to the vision of the digital journey.	Feedback implemented: To what extent is there a clear vision for a digital journey?
4	I miss a question related to resistance to change	Feedback not implemented: this is covered in other aspects of the scan.
8.5	I would rephrase the question and make it more related to who gets to see the confidential information within the organisation.	Feedback not implemented: the essence of the questions lies in the GDPR and if the requests are automated.
11.1	I think you should rephrase the question in such a way that the essence lies in if you can see this information in an automated way.	Feedback implemented: To what extent can you automatically keep track on transported products?
14.2	This question is not really	Feedback implemented:

	relevant, I would make a question related to the rapid change that Industry 4.0 has.	To what extent is IT prepared for rapid changes in business requirements caused by the digital journey?

General feedback:

- Look at all the questions and make sure that there are not hidden assumptions in there.

❖ **Specialist 11: HR Advisor**

Questions:	Feedback:	Action:
2.	I don't have any comments on the questions related to this topic, however I would change the order in which the questions are asked: Q6 → Q1, Q1→Q2, Q3→Q4, Q5→Q3, Q4→Q5 & Q2→Q6	Feedback implemented
3.5	In my opinion it is not clear what team members are meant, make this clearer.	Feedback implemented: "all team members of all departments"

❖ **Specialist 12: Export Manager**

Questions:	Feedback:	Action:
5.2	I would change "measure" into "monitor".	Feedback implemented
5.5	I think that you should change sharing to gaining. The website should be the place for customers to gain knowledge about your products	Feedback implemented
7.2	Constantly → continuously	Feedback implemented
11.1	Remove transported and change it to "products in transit"	Feedback implemented
12.2	Provide → offer	Feedback implemented
12.4	Average product → main stream product	Feedback implemented
12.7	Guaranteeing → ensuring	Feedback implemented

General Feedback:

- More variation in your questions, don't always start with to what extent.

❖ Specialist 13: CEO/Founder manufacturing company

Questions:	Feedback:	Action:
8.4	Apllications → applications	Feedback implemented
8.5	Procesing → processing	Feedback implemented
9.4	Delete "the"	Feedback implemented
10.2	Add an example of industry 4.0 technologies	Feedback implemented
10.3	Add "its suppliers"	Feedback implemented
12.5	Add examples	Feedback implemented
12.6	Add E.G.	Feedback implemented
13.2	Optimate →ultimate	Feedback implemented
13.6	Add "for"	Feedback implemented
13.10	Are → is	Feedback implemented
14.1	Provided → available	Feedback implemented

General feedback:

- Try to add more explanations for some words in the measurement questions
- I like the measurement questions related to aspects 12 & 13 that are related to monitoring and maintenance, because we do the same. We implement as much as possible smart things into our machines in order to follow the machines on distance.

❖ Specialist 14: Manager Information centre/former human resource manager

Questions:	Feedback:	Action:
1.1	Add "the"	Feedback implemented
1.2	The organisation → your organisation	Feedback implemented
1.4	The organisation → your organisation	Feedback implemented
2.1	Offers → has to offer	Feedback implemented
3.1	Adaptation → implementation	Feedback implemented
4.2	Make it more general, not your employees	Feedback implemented → to what extent are employees offered
4.4	Offers → offer	Feedback implemented

General feedback:

- Provide an introduction for industry 4.0
- Provide an introduction for all aspects

- Just like in our organisation, industry 4.0 creates a massive switch in tasks for human resources. Most of the jobs will be automatized, which creates different jobs and new jobs for the human resource department employees.

❖ **Specialist 15: Consultant strategy, organisation, technology, manufacturing, process improvement, management, coaching, industry 4.0 and smart industry**

Questions:	Feedback:	Action:
6.1	I would add more example next to sensors, such as connected (IOT), data analytics, AR/VR technologies	Feedback Implemented
6.4	Not only include sensors, but also algorithms, and modelling	Feedback implemented
6.5	Maybe this belongs more to channels?	Feedback not implemented → the question is related to how the channels can contribute to customer services, so it definitely belongs to this aspect
7.	No comments	
8.	No comments	
9.	I think this is an optional aspect, you could skip this for some organisations I guess	
10.	No comments	
11.	No comments	
12.	I would add a question related to servitisation	Feedback implemented
12.	I miss the sales tools like digital marketing in this aspect, maybe include some?	Feedback not implemented, in aspect 5: marketing & sales this is already implemented
13.	No comments	
14.	No comments	

General feedback:

- Sustainability is aspect is optional I think, not a necessary
- Implement servitisation somewhere in the scan
- Most of the scan is clear to me. However for small manufacturing companies maybe you need to add more explanations in order to clarify some things. From my own experience is that they own a different vocabulary.

❖ **Specialist 16: ICT Lawyer**

Questions:	Feedback:	Action:
8.1	No comments	
8.2	Add examples of IP	Feedback implemented → copyrights, trade name rights, domain names, trademarks etc
8.3	No comments	
8.4	No comments	
8.5	Add: the GDPR establishes a number of principles relating to processing of personal data	Feedback implemented

General feedback:

- Be consistent is asking the questions

❖ **Specialist 17:Technical Online Advisor**

Questions:	Feedback:	Action:
6.1	Maintanance → maintenance	Feedback implemented
6.4	Maintanance → maintenance	Feedback implemented
6.5	Access 24/7 → 24/7 access	Feedback implemented
7.3	Automized → automatized	Feedback implemented
8.4	Apliccations → applications	Feedback implemented
8.5	Processig → processing	Feedback implemented

General feedback:

- Add more explanations to some specific words that are not that obvious to understand

❖ **Specialist 18: Process Manager**

Questions:	Feedback:	Action:
6.2	Add e.g.	Feedback implemented
6.4	Examples of different channels	Feedback implemented
12.5	What do you mean with follow and track	Feedback implemented → examples given

13.1	You need to clarify this question, it is not clear if you are asking for the amount of automatized processes or to what extent the processes are automatized	Feedback implemented → "to what extent is the production directed by automated processes"
13.2	How do you want people to score on this, maybe you could split this questions into multiple questions	Feedback not implemented, answer options 1 to 5 give an indication of how many
13.5	Add inside the organisation	Feedback implemented

General feedback:

- Make sure to rule out any possible grammar mistakes

❖ **Specialist 19: Sales coordinator**

Questions:	**Feedback:**	**Action:**
3.2	Add "daily activities"	Feedback implemented
3.1/3.2	I can't really see the difference between questions 3.1 and 3.2	Feedback implemented → difference is better defined
4.5	Examples of effort	Feedback implemented → ("time, money etc)
6.5	I think it is important to mention that a customers should be able to access company information at all time	Feedback implemented → 24/7 added

General feedback:

- Make sure to introduce all aspects and the term industry 4.0

❖ **Specialist 20: Service and Sales Manager**

Questions:	**Feedback:**	**Action:**
No specific feedback		

❖ **Specialist 21: Former CEO High-Tech company**

Questions:	**Feedback:**	**Action:**
6.1	Leave out the last part with	Feedback implemented

	the examples, it is too much	
6.2	Add etc. to the examples, so you don't leave out any examples	Feedback implemented
6.3	What is meant with automatically?	Feedback implemented: automatically is maybe quite vague, changed it to "digitally"
6.4	Can or will, you should add will	Feedback not implemented → I try to avoid the word "or" as much as possible to avoid double barrelled questions.
9.1	Add examples of environmental sustainability	Feedback implemented → renewable resources harvest and pollution creation
9.2	Remove CSR	Feedback not implemented → it is a sustainable management strategy
9.3	By using which industry 4.0 technologies	Feedback not implemented → you won't get a 1 to 5 score and all questions should be answered this way to get to a average score
9.4	Same as 9.3	Same as 9.3
9.5	Same as 9.3/9.4	Same as 9.3/9.4
13.2	To track → tracking	Feedback implemented
13.5	Remove "inside the organisation"	Feedback implemented
13.6	Change the question to "is created"	Feedback implemented
14.1	Remove "all"	Feedback implemented
14.3	"A industry 4.0 organisation" is a bit vague	Feedback implemented → a digital organisation
14.8	Remove "new"	Feedback implemented
14.9	New and innovative is a bit the same, I would remove one	Feedback implemented

General feedback:
Sometimes I miss the definition of industry 4.0 technologies and technologies and other words, I would propose to add more explanations.
You could ask about why people haven't implemented industry 4.0 technologies yet.
You could also ask about what strategies people are following to implement industry 4.0 technologies.

Appendix 2: Cover sheet with explanation for feedback specialists

Validatie VRAGENLIJST Extended SCAN ; onderzoek onder experts

This scan measures the maturity of industry 4.0 technologies and the way of working inside your company.

Each question had to be filled out with: (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

In this scan the term "industry 4.0" is used which is the same as the often used term "smart industry".

De scan bestaat uit 14 aspecten met in totaal 85 vragen op het gebied van Smart Industry. In verband met het Internationale karakter zijn de vragen in het Engels. Voor de beoordeling worden experts benaderd. Deze experts ontvangen een beperkt aantal vragen, zoveel mogelijk aansluitend op de expertise, ter beoordeling.

Dit document bevat de aspecten voor u ter beoordeling.
Opmerkingen, suggesties e.d. kunnen direct onder de betreffende vraag worden genoteerd. Bij voorkeur in een andere kleur.
Het verzoek is voor elke vraag iets in te vullen. Heb je geen opmerkingen vul dan een '-' of 'oké' in.

Graag horen wij onder andere;
Zijn de vragen duidelijk?
Kan ik het een en ander toevoegen aan de onderdelen, zodat het onderdeel breder wordt getest?
Kan ik het een en ander toevoegen om de vragen duidelijker te maken?
Etc.

Om een beeld te krijgen van wat ik ongeveer verwacht heb ik een voorbeeld van de feedback hieronder weergegeven.
Dit voorbeeld betreft een willekeuring gekozen aspect. In dit geval zijn er 9 vragen voor dit speciefieke aspect.

Aspect 13:

I. Ik zou ervan maken: to what extend is the production directed by automated processes?
II. ……and to monitor products produced.
III. oké
IV. dit is meer een strategy vraag; Optie; To restructure product(s) and processes in a smart innovative way?
V. demanded = eiste Wat bedoel je met undemanded? Engelse vertaling nazien…..
VI. link naar data / digitalisering of industry 4.0 ontbreekt in deze vraag…….
VII. wat is de essentie van deze vraag mbt industry 4.0?
VIII. oke
IX. Vraag toevoegen? Gericht op: 'to detect deviations in productspecification during the productionprocess"

Algemene opmerkingen of suggesties zijn ook welkom**.** Deze kunnen onderaan de vragenlijst worden toegevoegd.

Appendix 3: The extended science-based multi-dimensional scan for assessing smart industry maturity

Aspect	Measurement questions	Answers options: (1) Not at all, (2) to some extent, (3) semi-advanced, (4) advanced, (5) fully
1. Strategy	I. To what extent is the implementation of industry 4.0 important for the success of the organisation?	
	II. To what extent does your organisation have plans to invest into industry 4.0 objectives?	
	III. To what extent is there a dedicated budget for implementing new digitalisation initiatives?	
	IV. To what extent is data used as an asset in order to create value from?	
	V. To what extent does your organisation have a coherent digital business strategy supporting industry 4.0 practices (automation, connectivity etc.)?	
	VI. To what extent do industry 4.0 technologies (connected machines, Iot, etc.) contribute to the value creation of the organisation?	
	VII. To what extent is there a clear vision for a digital journey?	
2. Employees	I. To what extent are the employees aware of the opportunities that industry 4.0 has to offer?	
	II. To what extent do your employees have enough knowledge to implement industry 4.0 technologies?	

	III.	To what extent are developments that happen in the business environment communicated immediately within the organisation? (So everyone is up-to-date)	
	IV.	To what extent do employees regularly meet in order to discuss new events?	
	V.	To what extent is your organisation "paperless" (digitalized information, instruction, drawings, administrative acts etc.) in the work place?	
	VI.	To what extent do employees have the right tools to develop the necessary skills in order to thrive in a digital business environment?	
3. Management & Leadership	I.	To what extent does the management bolster the implementation of industry 4.0 practices?	
	II.	To what extent does the management encourage to try out industry 4.0 techniques in daily activities?	
	III.	To what extent does the management has the ability (traits, knowledge etc.) to lead the organisation into new industry 4.0 practices.	
	IV.	To what extent does management use industry 4.0 techniques (data driven, analytics) in decision-making?	
	V.	To what extent do team members of all departments contribute to the final decision making process when it comes to change management?	
4.	I.	To what extent is your organisation	

Organisational Culture & Knowledge Management		(i.e. employees, management etc.) capable to apply gained knowledge?	
	II.	To what extent are employees offered trainings/workshops to enable them to understand what a “smart factory” is?	
	III.	To what extent does the culture support to think out of the box and create new innovative ideas? (not sticking to the "safe" well known processes)	
	IV.	To what extent does the organisation allow employees to improve the knowledge of digitalisation within the organisation?	
	V.	To what extent do you think that your organisation puts enough effort (e.g. time, Money etc.) in making the organisation "smart"?	
5. Marketing & Sales	I.	To what extent does the marketing & sales department know the online behaviour of its target groups (E.G. by making use of automatized feedback, analytics of customer behaviour etc.)?	
	II.	To what extent do you monitor the performance of online marketing techniques (E.G. conversion rates/generated leads etc.)?	
	III.	To what extent do you improve online marketing techniques by measuring their performance (conversion rates)(data analyses)?	
	IV.	To what extent is the sale process done in a digital manner? (By using industry 4.0 technologies and digital features)	
	V.	To what extent is the website of the organization optimally utilized for	

		gaining necessary information about your products/services?	
6. Customer Services	I.	6. To what extent are industry 4.0 technologies involved in customer services (e.g. for maintenance, solving complaints etc.)?	
	II.	6. To what extent are customers automatically notified on information regarding e.g. their orders, quotations, service requests, inquiries etc.?	
	III.	6. To what extent can customers digitally access the performance information of their product?	
	IV.	6. To what extent are machines equipped with sensors/algorithms/modelling, so customers can be automatically notified when maintenance is needed?	
	V.	6. To what extent are different channels available for customers to (24/7) access important information regarding the organisation? (Website, social media etc.)	
7. Channels	I.	To what extent are customers able to access the product/service by multiple integrated digital channels (e.g. website, social media internet etc.)?	
	II.	To what extent are the developments of customer needs per channel continuously monitored?	
	III.	To what extent do automatized processes facilitate the channels?	
	IV.	To what extent are data analyses used as a source in order to improve the channels?	

	V.	To what extent are multiple channels used in order to keep customers up to date regarding company information?	
8. Institutional Awareness	I.	To what extent can you guarantee that the digital business policy is up-to-date and sufficiently developed?	
	II.	To what extent is the intellectual property for products and services of your company protected (for example: copyrights, trade name rights, domain names, trademarks etc.)?	
	III.	Privacy and security are of great importance for organisations. To what extent are employees of your organization aware of the privacy and security risks concerning the implementation of Industry 4.0 technologies?	
	IV.	To what extent are you aware of possible tax effects of new circumstances as a result of Industry 4.0 applications?	
	V.	The new European privacy legislation (GDPR) establishes a number of principles relating to processing of personal data. For example, the GDPR increases the rights of customers with regard to their data. A number of these rights can be summarized in requests for access, namely the right to access, the right to rectification and addition, the right to oblivion and the right to data portability. To what extent are you able to handle such requests for access automatically?	
9. Sustainability	I.	To what extent have industry 4.0 technologies improved the	

		environmental sustainability (renewable resource harvest, pollution creation etc.) of the organization?	
	II.	To what extent has industry 4.0 enabled the implementation of sustainable management strategies (such as, eco-design, circular economy, CSR)?	
	III.	To what extent is the sustainability of your products measured by using industry 4.0 technologies (such as sensors)?	
	IV.	To what extent are the production emissions measured by using industry 4.0 technologies (E.G. sensors)?	
	V.	To what extent are emissions from your products in the field measured by using industry 4.0 technologies (sensors)?	
10. Inbound Logistic Activities	I.	To what extent does your organisation establish collaborations on industry 4.0 topics with your suppliers?	
	II.	To what extent are industry 4.0 technologies (E.G. sensors for deliveries) used in the collaboration with partners/suppliers?	
	III.	To what extent is the organisation digitally connected with its suppliers?	
	IV.	To what extent do industry 4.0 technologies help to get a good overview of the warehouse (E.G. Warehouse management systems)?	
	V.	To what extent are the actions automated after processing the data of incoming deliveries from your suppliers?	

11. Outbound Logistic Activities	I.	To what extent can you automatically keep track on products in transit?	
	II.	To what extent does your organisation institutionalize collaboration on industry 4.0 topics with its customers?	
	III.	To what extent are industry 4.0 technologies used in order to collaborate with the end customers?	
	IV.	To what extent is your organisation digitally connected with your customers?	
	V.	To what extent do you use industry 4.0 technologies in order to optimize the amount of inventories?	
12. Products & Services	I.	To what extent do industry 4.0 technologies support servitisation (service as a revenue model)?	
	II.	To what extent do industry 4.0 technologies help you to offer your services more efficiently?	
	III.	To what extent is data used in order to improve existing products/services?	
	IV.	To what extent is the mainstream product/service in your product portfolio digitized?	
	V.	To what extent can you follow/track your product performance in the field (E.G. when to do maintenance, productivity, emission etc.)?	
	VI.	To what extent is the development of a new product done in a digital way? (E.G. 3d development, digital	

		tests, digital prototypes)	
	VII.	To what extent do industry 4.0 technologies (E.G. sensors) help in ensuring the quality of products?	
13. Production & Process	I.	To what extent is the production directed by automated processes?	
	II.	To what extent are production machines equipped with sensors that allow tracking the condition of these machines? (E.G. to ensure ultimate availability)	
	III.	To what extent do you use industry 4.0 technologies to make processes more efficient/cheaper?	
	IV.	To what extent are industry 4.0 technologies used to recognize undesired variations in the production process?	
	V.	To what extent does the organisation provide you with the possibility to see how industry 4.0 technologies are influencing production processes?	
	VI.	To what extent is a digital model of the factory already created? (For collecting machine and process data during production)	
	VII.	To what extent is the production equipment digitized/enhanced with industry 4.0 technologies?	
	VIII.	To what extent are machines equipped with technologies that allow them to detect deviations in the process?	
	IX.	To what extent are machines equipped with technologies that allow them to detect deviations in the product specification during the production process?	

	X.	To what extent is production related data shared with partners in a manner that is beneficial for all partners in the supply chain?	
14. IT Management	I.	To what extent does your organisation collect relevant data that is available to you?	
	II.	To what extent is IT prepared for rapid changes in business requirements caused by the digital journey?	
	III.	To what extent is the organization able to adjust the IT architecture to a digital organisation?	
	IV.	To what extent is your IT integrated with customers/suppliers?	
	V.	To what extent are sufficient ICT security measures taken for data exchange/storage to protect all company data?	
	VI.	To what extent do you use data from processes/products to make real-time autonomous ERP/MRP decisions?	
	VII.	To what extent is the website operative on all desired platforms (mobile, different browsers)?	
	VIII.	To what extent are industry 4.0 technologies important for enabling (new) business operations?	
	IX.	To what extent does your IT/ICT infrastructure support innovative industry 4.0 based solutions (processes, product design, simulations, communication, new business models etc.)?	
	X.	To what extent are sufficient ICT security measures taken when	

	designing new systems, website, apps etc.?	

15. Industry 4.0 Technologies:

- ❖ Please indicate which industry 4.0 technologies you are 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