The Diffusion of a Diffuse Concept:

The Opportunities and Challenges of Industry 4.0 Diffusion in Swedish Food Manufacturing

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FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2018

MASTER THESIS

Diffusion of a Diffuse Concept

The Opportunities and Challenges of Industry 4.0 Diffusion in Swedish Food Manufacturing

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Published by

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Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

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Abstract

The aim with this thesis is to investigate the diffusion of the fourth industrial revolution in the food manufacturing industry in southern Sweden (FMISS). The interest of the concept Industry 4.0 has increased steadily since the introduction by the German government in 2011. However, the diffusion seems slow. If Industry 4.0 is a revolution, adoption of the new technologies will be crucial for competitiveness. This fact has resulted in the aim of this thesis, investigating how the diffusion of Industry 4.0 can increase.

In this research multiple qualitative research methodologies were applied; descriptive, exploratory and explanatory methodology was performed. Ten in-depth semi-structured interviews were conducted in total, with three experts, two technology suppliers and five production managers within four case companies in the FMISS. A State of the Art review of Industry 4.0 was made in order to give a general understanding of the most recent theory on the theme. The results of the qualitative research were analysed using Roger's theory of Diffusion of Innovations.

The result shows that the adoption of Industry 4.0 in the FMISS is perceived as low, burdened by low knowledge on how to use the innovations. The preconditions for the diffusion are substandard, both when it comes to the perceived innovation characteristics and the selling material. Many opportunities with adoption is seen, but there are barriers such as lack of cyber security and non-existing data standards that further hinders the diffusion, together with many barriers specific for the conservative, low margin food industry. To diffuse the Industry 4.0 solutions, technology suppliers should stop using the confusing term *Industry 4.0* and focus on selling the specific applications and how to use them. Further, the innovations should be diffused bottom-up and from sources with compatible status and credibility, such as *Change Agent Aide*s. In order to manage FMISS's scepticism it is important to be able to communicate the financial viability of the Industry 4.0 investments with the help of quantitative data and reference project.

Keywords: Industry 4.0, Barriers, Opportunities and Challenges, Food Industry, Innovation-Decision process, State of the Art, Everett Rogers

Sammanfattning

Syftet med denna avhandling är att undersöka diffusionen av den fjärde industriella revolutionen inom livsmedelsindustrin i södra Sverige. Intresset för begreppet Industri 4.0 har ökat stadigt sedan det infördes av den tyska regeringen 2011. Men diffusionen verkar låg. Om Industri 4.0 är en revolution är införandet av den nya tekniken avgörande för konkurrenskraften. Detta faktum har resulterat i syftet med denna avhandling – att undersöka hur diffusionen av Industry 4.0 kan öka.

I denna forskning tillämpades flera kvalitativa forskningsmetoder; deskriptiv, explorativ och explanativ metodik utfördes. Totalt genomfördes tio djupgående semistrukturerade intervjuer med tre experter, två teknikleverantörer och fem produktionschefer inom fyra caseföretag inom livsmedelsindustrin i södra Sverige. En State-of-the-Art-undersökning av Industri 4.0 gjordes för att ge en allmän förståelse av den aktuella teorin inom temat. Resultaten av den kvalitativa forskningen analyserades med Rogers teori om innovationsdiffusion.

Resultatet visar att adoptionen av Industri 4.0 i livsmedelsindustrin uppfattas som låg, tyngd av låg kunskapsnivå om hur man använder innovationerna. Förutsättningarna för diffusionen är undermålig, både när det gäller de upplevda innovationsegenskaperna och försäljningsmaterialet. Många möjligheter med adoption ses, men det finns hinder såsom brist på cybersäkerhet och obefintliga datastandarder som ytterligare hindrar diffusionen, tillsammans med många hinder som är specifika för den konservativa livsmedelsindustrin. För att diffusera lösningarna i Industri 4.0 bör teknikleverantörer sluta använda det förvirrande begreppet Industri 4.0 och fokusera på att sälja specifika applikationer och hur man använder dem. Vidare bör innovationerna spridas bottom-up och från personer med kompatibel status och trovärdighet, såsom *Change Agent Aides.* För att hantera skepticismen i livsmedelsindustrin i södra Sverige är det viktigt att kunna kommunicera den ekonomiska bärkraften för Industri 4.0-investeringar med hjälp av kvantitativa data och referensprojekt.

Nyckelord: Industri 4.0, Barriärer, Möjligheter och utmaningar, livsmedelsindustrin, Innovationsbeslutsprocesser, State-of-the-Art, Everett Rogers

Acknowledgments

In this master thesis we have had the opportunity to conduct in-depth interviews with five employees within the food industry, two machine suppliers and three Industry 4.0-experts. We would like to give all of them special thanks - we are really grateful for the time and effort you put into our interviews, and the knowledge, thoughts and insights you shared with us!

We would like to give thanks the two German trainees at Company X, Thomas Schrimpf and David Funke, who helped and inspired us during our meetings there. We would also like to show our deepest gratitude to our fantastic supervisors at Company X - Christoffer Josefsson and John Backe - who supported us and never lost faith in our capabilities and creativity. Also, we take this opportunity to thank our supervisors at Lund University, Lars Bengtsson and Emil Åkesson who worked relentlessly in tandem to support, give us feedback and guide us in the right direction. This boat would have never reached the shore without you.

Lastly, our family and friends who stood by our side, even when it stormed - thank you!

Lund, May 2018

Tove Bolm and Clara Lindsjö

Table of Contents

Overview of Figures and Tables

List of Figures

List of Tables

List of acronyms and abbreviations

AI	Artificial Intelligence
B2B	Business to Business
B2C	Business to Consumer
ERP	Enterprise Resource Planning
FMISS	Food Manufacturing Industry in Southern Sweden
GTAI	Germany Trade and Invest
IoT	Internet of Things
JIT	Just in Time
M2M	Machine to Machine
R&D	Research & Development
SCADA	Supervisory Control and Data Acquisition

List of definitions

Term	*Definition*
Internet of Things	According to some, Internet of Things (IoT) is synonymous to the term Industry 4.0, and is widely used in English speaking countries. IoT defines intelligence and communications between products, processes and services in the computing network (Danish Institute of Industry 4.0, 2016).
Big Data Analytics	Big Data Analytics means mining new and existing data sources for patterns, events and opportunities (Strange & Zucchella, 2017).
Augmented Reality	Augmented Reality combines the view of the real world with images produced by a computer (Cambridge Dictionary, n.d.f).
Advanced Robotics	Advanced Robots, or autonomous robots, are designed to interpret its environment and can work without any human intervention. They can perform a wider and flexible range of work tasks than traditional robots and can interact with humans, other robots and systems (Techopedia, n.d.a).
Additive Manufacturing	Additive Manufacturing, also known as 3D-printing, creates products by building up successive layers of materials, in comparison with traditional manufacturing which mostly rely on the removal of material (Strange & Zucchella, 2017)
Cyber-Physical Systems	A Cyber-Physical System in an integration of physical processes, networking and computation, where the physical processes are controlled via feedback loops who in turn affect computations and vice versa (UC Berkeley EECS Dept, n.d.).
Predictive Maintenance	Predictive Maintenance, in comparison with traditional preventive maintenance, aims to maximize uptime through data driven proactive maintenance. By using different analyses such as oil analysis, vibration analysis, thermal imaging and equipment observations, in combination with expertise about the machine, it is possible to predict when a device or machine failure will occur and prevent this failure with maintenance before the issue manifests (Techopedia, n.d.b).
Digital Twin	A Digital Twin is a virtual replica of a physical object, process or system, making it possible to monitor and optimize the system (Forbes, n.d.).
Cobotics	A Cobot (Collaborative Robot) is a robot that is designed to work closely with humans, and thereby combining the repeatability, precision, and lifting abilities of the robot with the unique cognitive and perceptual capabilities of the human (Law, n.d.).

1 Introduction

This master thesis is written by two students of Industrial Management and Engineering, specializing in Business and Innovation. The first section of this master thesis contains a brief presentation of the background of the research area. It begins with a brief introduction of the concept and characteristics of Industry 4.0, which is followed by an introduction to the food sector in southern Sweden. This is followed by a presentation of the purpose of this thesis, the research questions, delimitations and the potential contributions.

1.1 Background

In 2011 at the Hannover Messe in Germany, the world's biggest technology trade fair, a new expression saw the light of day - *Industrie 4.0* (Drath & Horch, 2014). The term was part of a € 200 million high-tech strategy launched by the German federal government in order to promote digitalisation in the German manufacturing industry, but soon spread to other countries in the name of Industry 4.0, Industrial Internet or Internet of Things (IoT) (Drath & Horch, 2014). In contrast to earlier industrial revolutions, Industry 4.0 has been predicted as a revolution before it has actually happened, and many technology suppliers and consultancies world-wide have caught on, writing optimistic articles and white papers about the benefits of upgrading the factories with the technologies of the fourth industrial revolution (Drath & Horch, 2014).

The first industrial revolution took place at the end of the 18th century when the steam engine, which revolutionized production speed and efficiency, was introduced (Bartodziej, 2017). This famously created a shift from an agricultural to an industrial society. Early in the 20th century the second industrial revolution took place, through the introduction of electricity to the manufacturing plants (Bartodziej, 2017) and through this, the first moving belt conveyor (Siemens, 2013). The third industrial revolution took place in the early 1970s when electronics and information technology enabled automated manufacturing partly replacing manual labour (Bartodziej, 2017).

Trends such as digitalisation and increasing availability of information is nothing new and has been developing since the introduction of the third industrial revolution. But the substantial change now is that the technologies are affordable, accessible and secure, making it possible for firms of all sizes to scale up implementation of digitalised components (Danish Institute of Industry 4.0, 2016). In a consultancy article written by BCG, three major technological developments enabling this shift towards Industry 4.0 are (1) the increasing analytics capabilities, (2) the innovations supporting human-machine interactions and (3) the improved methods of transferring digital into the physical (Lorenz, Küpper, Rüßmann, Heidemann & Bause, 2016).

Since the introduction of the term Industry 4.0, there has been a boom in the interest of the underlying technologies in all sectors of society. On the consumer market, *IoT* or *cyber-physical solutions* have been very popular, with the introduction of connected, "smart home" appliances, apps such as Pokémon Go using augmented reality, and virtual reality glasses being chosen in 2016 as the Christmas gift of the year in Sweden (Svensk Handel, 2016). In academia, there has been a steady increase in the use of the term "Industry 4.0" in articles, more or less doubling in usage for each year[1]. Municipalities are investigating how they can use Industry 4.0-concepts in their cities, as an enabler for the sustainability-focused Smart City initiative in Sweden (Smart City Sweden, n.d.). Among consultancy firms and technology suppliers it is been important to show pioneering expertise and leadership within Industry 4.0 services and technologies. At the same time, the coherency about what technology blocks the concept Industry 4.0 is made out of is low, and the concept is by many seen as just a new buzzword (Lomax, Minturn & Streatfield, 2018). The name states revolutionary tendencies, but is Industry 4.0 diffusing in a way that could potentially make it as revolutionary as the introduction of the steam engine, electricity or IT-system?

Company X is a technology supplier of Industry 4.0 solutions such as real time sensor measurements and visualization, that has recently entered the market. In order to improve their business offer they want to find out what their part could be in increasing the diffusion of Industry 4.0 in manufacturing in Sweden.

According to Rogers (1983), one of the most famous authors on this theme, diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system". In this thesis, Rogers framework will lay ground for the analysis, to find out what is driving and limiting

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[1] From a quantitative search of the number of articles published each year between 2012-2017 on Google Scholar with the term "Industry 4.0" or "Industrie 4.0" in the title.

the degree to which companies adopt the technologies of Industry 4.0 in the Food Manufacturing Industry in southern Sweden (FMISS).

In Sweden, Skåne is the area with the largest proportion of manufacturing companies (Borg, 2005). In addition, its geographical proximity to the European mainland also suggest that German industrial influences might reach Skåne before the rest of Sweden. The food industry contributes with almost a third of the jobs in Skåne (Borg, 2005). This makes the Skåne area, and the food sector, an interesting place and industry to analyse and hence, make up the area of research for this thesis.

1.1.1 The Food Industry in Southern Sweden

The food industry is an industry with many constraints - they produce products that are only good for a certain amount of time, with strict food security control and legislation, tight commercial margins, and deeply affected by the changing tastes and weak loyalty of the consumers (Luque, Estela Peralta, de las Heras & Córdoba, 2017).

1.1.1.1 *Importance in Skåne*

According to Jordbruksverket (2012), the food industry is Sweden's fourth largest industry and Skåne is the region in Sweden with most people employed and the second most production sites in the food industry (Jordbruksverket, 2012). According to Borg (2005) more than 40 % of Skåne's surface consist of farming landscape, which accounts for 17 % of Sweden's total area of farming landscape. The food industry and related industry such as packaging, transporting and subcontractors, are estimated to contribute with 30 % of the jobs in the region (Borg, 2005).

1.1.1.2 *Profitability and Margins*

The food market is a financially pressured sector - the margins are generally very slim (Luque et al., 2017), the profitability in the Swedish food industry is at a relatively constant level (Jordbruksverket, 2012), and many parts of the food sector are labour-intensive in relation to the value added (Borg, 2005). The food sector has a very high proportion of small businesses, but a few large companies account for the majority of the production (Jordbruksverket, 2012). This is amplified by shutdowns and a concentration to fewer locations, often with increased specialisation, which has followed a period of major structural change with larger and fewer actors (Borg, 2005). This is natural in an industry such as the food industry, where the margins are small, which makes vertical integration important, in order to capture as much value from the value chain as possible (Interview 10, 2018). Through a supply chain restructure, the aim is to reduce cost and time-to-market, and to push manufacturers to deliver faster (Beckeman, 2011).

1.1.1.3 *Competition and Globalisation*

Historically, according to Borg (2005), the sector of meat products, dairy, margarine, oil, fat, bread, sugar and soft drinks has been a protected sector with limited or no exposure to international competition, and the market has been national or regional. Some parts of the food sector have now started to see increased imports or production being moved abroad (Borg, 2005). At the same time, Beckeman (2011) sees a trend towards sustainability and locally produced products.

1.1.1.4 *Regulations & Safety*

The food industry is an industry heavily regulated and monitored, both in operations, in final products and in health and safety for their employees. The regulations come from different instances and concerns many parts of the operations. For example, in Skåne the County Administrative Board reviews and authorizes large food companies to operate in a particular location, whereas smaller companies are supervised by the municipalities (Borg, 2005). But food manufacturers also have to answer to the Common Agricultural Policy (CAP) as members of the European Union, which aims to make agriculture more efficient and make sure agricultural products are accessible and affordable for the EU-consumers (Jordbruksverket, 2017). On top of this, the European Commission's General Food Law pushes out a coherent framework for food and feed legislation to ensure protection of human health and consumer interests in food, which affects all stages of the production, processing and distribution of food (European Commission, 2018).

1.1.1.5 *Technology Maturity*

When it comes to innovativeness of the food industry, there are different opinions. According to Jordbruksverket (2012) there seems to be good conditions for the food industry to invest in Research & Development (R&D), but nevertheless it requires that the industry have the capital strength to be able to do so. In 2009 the Swedish food industry invested SEK 377 million in R&D, approximately 0.3 % of the production value, which can be compared with other major production countries in EU, like Germany, Spain, France who invested 0.2 % respectively of their production value in R&D, or other Swedish industries like chemical industry or automotive, who invested 6 % of their production value (Jordbruksverket, 2012). It is important to note that the R&D investments, even though they are likely to be related to product development, have a likely spill-over effect on the innovativeness of the machinery and technology.

According to Larsen (2017), the food and packaging industry are among the slowest industries in the advanced economies to adopt digital technologies, and the level of digitalisation today is very low, as can be seen in the figure below. This goes against the view of Møller (2018) who claims that the level of knowledge among food manufacturers are in fact very high, and that the big companies, at least in Denmark, have launched substantial digitalisation projects. Bremicker & Gates (2017) argue that manufacturing companies often tries to solve a particular issue with isolated projects, siloed into functions, and thereby misses the holistic view needed to improve the production as a whole.

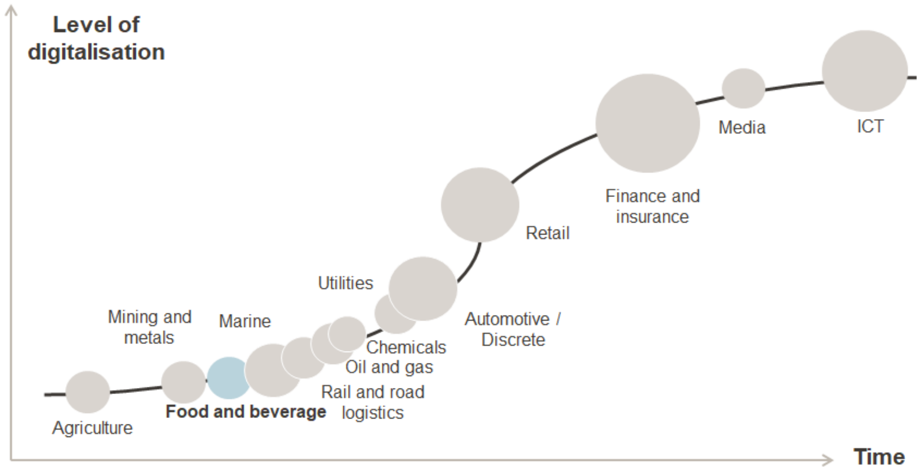

Figure 1. Industrial markets primed to adopt digital technologies, relative size of industry for advanced economies, adapted from Larsen, 2017.

1.2 Problem Definition

There has been a recent surge of interest for Industry 4.0 technologies. Meanwhile, the adoption in the manufacturing industry seems low, and the spread of the technologies does not seem to have reached the expected speed that would be expected of a revolution. The food sector should have many potential gains from adopting Industry 4.0. If it is true that Industry 4.0 will revolutionize the entire manufacturing industry, diffusion will be crucial for competitiveness.

1.3 Purpose of Thesis

The purpose of this thesis is to investigate how the diffusion of the Industry 4.0 concept can be increased in the FMISS, by analysing the perceived potential described by research and practitioners through the Innovation-Decision Process by Rogers. This is done through a comparison of the view of Industry 4.0, in terms of opportunities, barriers and challenges related to adoption of Industry 4.0, between literature and four case companies in the food manufacturing industry, in order to find out where, how and why there are differences and similarities. This will help in gaining a deeper understanding of how this diffuse concept is perceived and adopted in a low-margin and more traditional industry such as the food industry, and what can be done by stakeholders within the social system to facilitate adoption.

1.3.1 Research Question

This study is centred around two main research questions, with four subquestions leading up to the main questions.

The first main question is RQ1:

> *If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS?*

> This will be answered with the help of the subquestions a-c:
>
> *RQ1a: What are the opportunities, barriers and challenges for Industry 4.0 in general?*
>
> *RQ1b: What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?*
>
> *RQ1c: What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS?*

The second main question is RQ2:

> *How can the diffusion of Industry 4.0 increase in the FMISS?*

> This will be answered with the help of the subquestion:
>
> *RQ2a: How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process?*

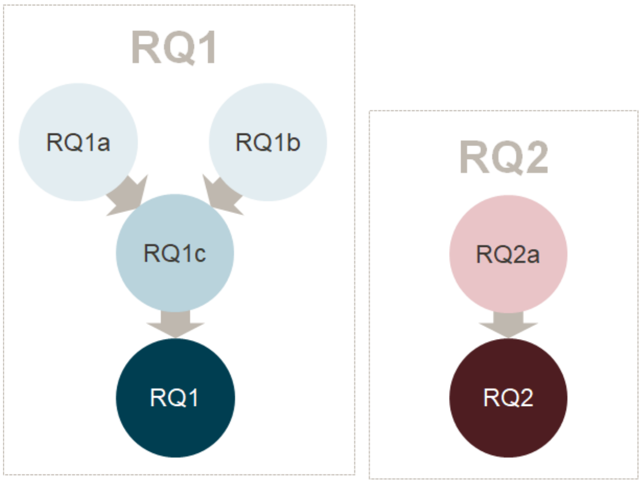

Figure 2. The relationship between the research questions

1.4 Delimitations

This research is delimited to investigating the production within food manufacturing companies in and nearby the Skåne area in Southern Sweden, abbreviated FMISS. In this thesis the term *food manufacturing industry* refers to companies who produce, process and manufacture food and beverage. The case companies within the FMISS are producers who process food, from raw material to a packaged product, either for a B2B- or B2C-market. The respondents in the case companies all have a deep insight into the production, with titles such as plant or production managers, production technicians or automation specialists, which makes this thesis research further delimited to the perception of Industry 4.0 from the production side.

1.5 Suggested Contributions

Industry 4.0 is a fairly new and unexplored concept, with inconsistent explanations of what the term is and contains. A suggested contribution to the academia is the State of the Art research of the Industry 4.0 concept in terms of opportunities, barriers, challenges and definitions of Industry 4.0.

Both a literature study and interviews with practitioners have been made on the theme, through the State of the Art literary research, interviewing four case companies within food manufacturing, two technology suppliers and discussing the result with four experts within the field of Industry 4.0. Hence, the suggested empirical contribution is focused on outlining how the food industry in southern

Sweden is adopting Industry 4.0-technologies, comparing theoretical opportunities, barriers and challenges with what the industry perceives as the most important opportunities, barriers, and challenges, through an analysis of why there are differences and similarities. The result will be a suggestion on how the food sector and their external supply chain should proceed in adopting the Industry 4.0-concept.

Analysing several articles, the authors of this thesis found inconsistency in what was called definitions, enablers, drivers, barriers, opportunities and challenges. A division between these concepts has been made and is presented as a part of the State of the Art research of Industry 4.0. Where the result to each question can be found is presented in table 1 below. Further, the method used to answer the research questions is presented in table 2.

1.6 Outline of the Report

Table 1. The research questions and the chapters in where the result will be presented.

RQs	*Research questions*	*Result*
RQ1a	What are the opportunities, barriers and challenges for Industry 4.0 in general?	Chapter 3
RQ1b	What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?	Chapter 5
RQ1c	What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS?	Chapter 6.1
RQ1	**If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS?**	Chapter 6.2
RQ2a	How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process?	Chapter 7.1
RQ2	**How can the diffusion of Industry 4.0 increase in the FMISS?**	Chapter 7.2

1 Introduction

The introduction chapter aims to present a background of the field in order to help the reader see the relevance of the study and a purpose in order to understand why the study has been conducted. This is followed by the research questions, the delimitations for the research and the potential contributions of this thesis.

2 Methodology

This chapter aims to present and justify the methodology of research that was chosen for this study. First, the research strategy and work process are described, followed by an introduction of the data collection and analysis process. Finally, the credibility of the research is discussed.

3 Industry 4.0 - State of the Art

The State of the Art of Industry 4.0 aims to give the reader an understanding of the current research of the themes and areas that this research touches upon.

4 Theoretical Context

In this chapter the theoretical context for the study is introduced, in order to give the reader an introduction to the field of study and the frameworks that will be used to analyse the collected data.

5 Result: Perceptions of Industry 4.0 in the FMISS

In this chapter follows the empirical findings from the interviews. The case companies' perceived adoption of Industry 4.0 technologies and what opportunities, barriers and challenges they see in the concept will be presented.

6 Analysis: Differences Between Theory and Practice

In this chapter the findings from the State of the Art research of Industry 4.0 and the answers from the interviews will be analysed in order to answer RQ1.

7 Analysis: Adoption and Diffusion of Industry 4.0

In this chapter, the collected data from interviews and from the State of the Arts research will be analysed based on the theoretical frameworks presented in chapter 4, in order to answer RQ2.

8 Experts Comments on the Result

In this chapter, three experts' take on Industry 4.0 will be presented, and used to discuss the result to the research questions of this thesis.

9 Conclusion & Discussion

This closing chapter presents the conclusions from the research, and the limitations and implications of the findings. The research questions will be answered, and the authors will make a critical discussion about the report as well as discuss how the results relates to previous studies and give suggestions for future research on the field of study.

2 Methodology

This chapter aims at explaining the selection of research methodology that has been applied in this study. The research strategy and work process are introduced, as well as a description of the data collection process and an explanation of how the data was analysed. Lastly, the credibility of the chosen research methodology is discussed.

2.1 Work Process

The thesis project started in January, with planning meetings with both supervisors at LTH and at Company X, where expectations and deliverables where discussed, which was then translated into phases and deadlines.

2.1.1 **Iterative Work Process**

When the project was initiated there was no clear picture of the desired outcome, but together with Company X, a wish list of potential contributions was developed. An iterative process was chosen, to be able to form the project over time and redesign the thesis as more information and knowledge was gathered. Weekly or biweekly meetings were held both with the supervisors at LTH and at Company X. An overview of the iterative work process can be viewed in figure 3 below.

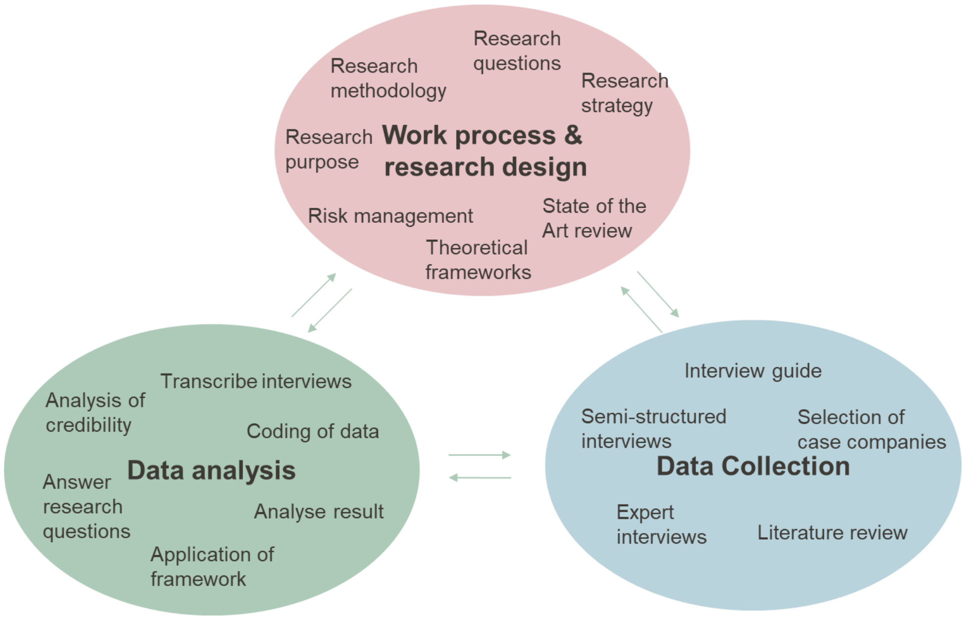

Figure 3. Overview of the iterative master thesis work process

2.1.2 Risk and Stakeholder Management

At the start of the thesis, a meeting was held in order to map out the biggest potential risks of the project and find preventive and reactive action plans for each of them. The stakeholders of the thesis were mapped out in the process, to assess the potential risks connected to the stakeholders. The outcome was the mapping of three primary stakeholder groups; Company X, LTH and the researchers. The meetings with Company X and LTH were always held separately, and therefore the researchers saw themselves as the coordinating link between the interest of these two stakeholders.

2.1.3 Phases of the Thesis

The thesis was divided into four main phases, a pilot study phase, an exploratory phase, a writing phase and a finishing phase. This was done to visualise the process and its milestones, to set up clear deadlines and to get an overview of the 20 weeks at hand to perform the thesis. All phases were planned to overlap and sometimes be run simultaneously, but the main focus of the work was on the main phase of that period. The thesis was mainly written in the facilities of LTH, but a couple of times a month the researchers was located at the Company X office in Malmö, in order to be able to discuss ideas and obstacles.

2.2 Research Strategy

The different research questions had different research methods, as well as qualitative research methods, which will be further explained below.

2.2.1 **Explanatory, Exploratory and Descriptive Approach**

According to Lekvall and Wahlbin (2011) four research strategies can be used, often simultaneously; descriptive, explanatory, predictive and exploratory. In this research the descriptive research method was used, in order to describe the State of the Art of Industry 4.0 in terms of opportunities, barriers and challenges of Industry 4.0 and describe the differences between the found results. An explanatory approach is appropriate when the researchers seek to explain the connection between various factors within a concept, such as Industry 4.0, and the effect they have on each other (Lekvall & Wahlbin, 2011). This approach was used to explain why the views of this concept differs between theory and practice and to explain the adoption through the Innovation-Decision Process by Rogers. Lastly an exploratory approach can be used to gain knowledge in a field with limited amount of prior research, in order to define alternatives for action for the research at hand and future researchers, which was the approach used when exploring the perception and adoption within FMISS, and exploring how the diffusion of Industry 4.0 could be increased. The different research questions and their respective research strategies can be viewed in the table 3 at the end of this chapter.

2.2.2 **Qualitative Research**

The purpose of this thesis is to investigate how the diffusion of the Industry 4.0 concept can be increased, through a thorough study of the FMISS and a State of the Art of Industry 4.0. Through a quantitative research strategy, accessing a larger number of quantifiable data points, more general conclusions on a subject can be made (Rienecker & Jørgensen, 2014), but this was deemed difficult in an area where the concept is new, and the lack of potential respondents in the delimited research area made it difficult to achieve statistical significance. In this thesis, in order to get an in depth understanding of the details and the premises of technology adoption, a qualitative research was decided as appropriate. While a qualitative approach requires fewer data points than a quantitative approach, it goes deeper in order to understand phenomenons in the researched area (Rienecker & Jørgensen, 2014). A qualitative research strategy is also beneficial when the researched area is nascent, with a low amount of prior research, which is the case of Industry 4.0 (Edmondson & McManus, 2007).

2.3 Research Method

Since our research strategy is qualitative, with an exploratory, explanatory and descriptive approach, and there is scarce existing research of Industry 4.0 in the FMISS, performing case studies was deemed an appropriate way to collect the data required, supported by Yin (2003). The methods will be further explained in the following chapters.

2.3.1 **Case Study**

The aim with a case study is to get a deeper understanding of a concept through the usage of multiple data collection methods (Höst, Regnell & Runeson, 2006). In this thesis the methods used are interviews and a State of the Art review. One important factor is to allow the collected data to affect the direction of the study (Höst et al., 2006). Generally, a case study is the preferred method when "how" and "why" questions are being used, when the researcher has little control over events, and when the research is investigating a contemporary phenomenon within its real-life context, where theory is still emerging and is to be used when there are no clear boundaries between the phenomenon and the context (Backman, 2008). This is indeed representative for this thesis and the investigated research questions. Furthermore, this study is explanatory to its nature. An explanatory case study is normally complemented by either a descriptive or an exploratory case study, and all three approaches were used in this study (Backman, 2008).

A case study need to construct both internal and external validity and reliability. This will be described more in 2.6 Credibility of Results. The purpose of this thesis is partly to investigate the perception of Industry 4.0 adoption at food manufacturing companies. To do so, it was deemed relevant to interview several manufacturing companies to then be able to compare the different views from the companies with the State of the Art review. Hence, a multiple case study was performed. Furthermore, a multiple case study and its design is according to Yin (2003) normally stronger than the single case study, since many sources are investigated.

To interview one person with good insight of the unit of analysis, i.e. the production at each case company, seemed like the best approach in order to gain deep insight of their perception and base the result on their view of Industry 4.0 adoption, definitions, opportunities, barriers and challenges. It was decided to be outside of the scope to investigate the difference in perception between different people at the same case company due to the time spent on the literature study just to grasp the subject of Industry 4.0, and the chosen priority of going deeper instead of wider. According to Yin (2003), making a case study might lead to the research changing direction over time, and that the research questions of interest change during the project. The agile work process that was chosen, in combination with this design, made it possible for the direction of the study to change several times during the exploratory phase.

2.3.2 State of the Art Review of Industry 4.0

With a constantly increasing mass of knowledge within a subject, the importance of a literature review is also increasing (Backman, 2008). Studying the current literature on the subject is a good way to realize whether or not the subject is relevant and where the research gaps are (Creswell, 2014). Therefore, the starting point for this research was a review of the latest literature on the subject of Industry 4.0 - a State of the Art review.

As a first attempt, all found definitions, enablers and drivers of Industry 4.0 were researched and described, which is presented in chapter three. After that, the aim with the literature review was to find the barriers, opportunities and challenges that earlier literature has said about Industry 4.0, which is described in chapter three in order to answer RQ1a, as well as used as a basis for RQ1c. In order to get an overview, these findings were also condensed into tables in appendix D. The literature review shed light on inconsistencies in the field, which made this study's contribution even stronger. The literature study also served as a basis to craft the interview guide.

2.3.3 Selection of Theoretical Framework

The Innovation-Decision Process from Rogers Diffusion of Innovation-concept was chosen as a theoretical framework in this thesis. This choice was made based on the knowledge of the researchers and inputs from the supervisors at Company X and LTH. The Innovation-Decision Process framework shaped the literature review concerning Industry 4.0, but was mainly used when analysing the data collected through the interviews to answer research questions 2 and 2a. A thorough description of the Innovation-Decision Process framework can be found in chapter four in this report.

2.3.4 Interviews

The purpose of the interviews was to get a comprehensive understanding of what the perception of the diffusion of Industry 4.0 technologies look like in manufacturing companies in the extended Skåne area, and what the potential opportunities, challenges and barriers are for the adoption of technologies. Manufacturing companies with their production or headquarters in the Skåne-region were contacted by email asking for the opportunity to interview them, in person or over the phone. The email addresses were accessed through their homepages, Company X's client lists or by calling the switchboard at the company of interest.

The result was that five interviews with four different companies within the FMISS was made, complemented with two interviews with technology suppliers to the food manufacturing industry. Towards the end of the thesis, three interviews with experts were conducted, in order to validate and discuss the result found in the case studies and State of the Art review, and to get their input on how they perceived the potential of Industry 4.0 in food manufacturing companies. The experts were found with the help of the supervisors at Company X and LTH. More information about the case companies, the technology suppliers and the experts are found in chapter 2.4 Data collection. Table 3 below is a summary of the research questions, the research strategies and research methods.

Table 3. The research questions and their research strategies and methods.

RQs	***Research questions***	***Research strategy***	***Research method***
RQ1a	What are the opportunities, barriers and challenges for Industry 4.0 in general?	Descriptive	State of the Art review
RQ1b	What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?	Exploratory and descriptive	Semi-structured interviews with case companies and technology suppliers
RQ1c	What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS?	Descriptive	Comparison of results from RQ1a and RQ1b
RQ1	**If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS?**	Explanatory	Analysis of results from RQ1c
RQ2a	How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process?	Explanatory	Analysis of results from RQ1 and other data from interviews through the theoretical frameworks
RQ2	**How can the diffusion of Industry 4.0 increase in the FMISS?**	Exploratory	Analysis and discussion of results from RQ1a, RQ1b, and RQ2a through the theoretical frameworks, together with comments from experts

2.4 Data Collection

In this section the data collection methods will be further explained.

2.4.1 **Selection of Literature for State of the Art Review**

Since Industry 4.0 is a subject younger than a decade, with new emerging technologies and insights expanding the area, there is no consensus within academic research on what it is (Hermann, Pentek & Otto, 2016). For this reason consultancy white papers, which are more consistently updated, were also investigated, as well as management articles and studies from consultancies and research institutes. At the same time consultancy material is commercial material without scientific weight. Therefore, this material was just used to help understand the perimeters of the subject and its business opportunities and challenges, and to facilitate the interview setup. When comparing definitions and perceptions of Industry 4.0, only relevant scholarly articles were used, where the authors themselves had made a study in order to support their definition, or articles from a source of high relevance to the subject, for example the Industrie 4.0 Working Group, chaired by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (Acatech), who coined the term (Elangeswaran, Sanders & Wulfsberg, 2016). For a full list of the articles used in defining Industry 4.0 and why they were chosen, see appendix A.

The sources of literature were found through the following locations:

- LUB Search, Lund University's collective search engine for academic articles, journals, doctoral theses and books
- Google Scholar, Google's search engine for academic articles, journals, doctoral theses and books
- Consulting firm white papers and website articles
- Management articles at Harvard Business Review
- Books at LTH.

In the early phase, more general search words were used, such as Industry 4.0, Industrie 4.0 and Internet of Things, and their respective abbreviations. After studying the found literature, synonyms and sub-parts of the Industry 4.0 sphere was discovered, such as Industrial Internet, Cyber Physical Systems, which were then used as search words to expand the searched field. Lastly the research moved over to the frameworks and theoretical concepts, as well as sub-technologies of Industry 4.0, such as Big Data, automation or Predictive Maintenance.

2.4.2 Semi-Structured Interviews

There are three kinds of interviews that can be chosen, depending on what kind of data that needs to be collected; structured, semi-structured or unstructured interviews (Bryman & Bell, 2005). A semi-structured interview is an interview guided by a loose script with a high degree of improvisation and flexibility on the researchers' part (Myers & Newman, 2006). In order to dig deeper into the viewpoint of the respondents, and be open for unexpected results, a semi-structured interviewing method was used in this thesis.

2.4.3 Interview Guide

According to Harvard University (n.d.) you should not follow the interview guide but follow the respondent and the new information that is brought up during the interview, with the guide as a reminder to bring up all the topics, questions and areas you want to touch upon. To avoid the common pitfall of too little time for the interview (Myers & Newman, 2006), the amount of time dedicated to the interview was established in the beginning of the meetings, and the interview guide was adjusted thereafter in order to avoid having to rush the interview.

As advised by Harvard University (n.d.) the interview guide was tested on a reference group in order to get feedback before conducting the first interview. The areas that were selected to bring up during the interviews were opening questions about the role and the company, with the aim to get familiar with the respondent and set a relaxed tone to the interview. The areas "data collection", "sensors", "automation/interconnection", "pains & gains", "Industry 4.0 knowledge", "future", "new technology", "opportunities", "barriers" and "challenges" were brought up as main areas with sub-questions, in order to get comparable data from each unit of analysis. Thereafter a closing question was asked, to ensure that the respondent didn't think anything of importance had been missed out. The interview guide in its entirety can be found in appendix B.

2.4.4 Unit of Analysis

The unit of analysis is the FMISS, and more specifically the production in this sector. The interviews were held with employees with good insight in and overview of the production at their respective company in the food industry, with people with good insight in automation solutions at the technology suppliers, and experts in the field of Industry 4.0.

2.4.5 **Selection of Case Companies**

There are three methods for sampling; random sampling, purposive sampling and snowball sampling (Yin, 2003). For the first step of the thesis a purposive sampling method was used, where the researchers choose to contact the companies that Company X recommended, in order to get a deep qualitative understanding of how Industry 4.0 technologies are used in Swedish food industry. Since it turned out to be difficult to find respondents interested in being interviewed, due to their lack of time, over 30 companies were contacted, also outside of Skåne, in order to get a satisfying number of interviews.

As the project developed, it was also found to be of interest to interview companies supplying technology to the case companies. Consequently a snowball sampling method was used, since they were identified as data collection units of interest to the thesis during the first set of interviews, where specific contacts were found through advice from the thesis supervisors and respondents (Yin, 2003).

2.4.5.1 *Respondents at Case Companies*

The chosen entry points at the case companies within the food industry were employees with managerial responsibilities who also had insight in the production operations, such as plant managers or automation specialists, or human resource personnel. According to Myers & Newman (2007) it is crucial for the researcher to enter an organisation at the right level, in order not to inhibit access to future subjects within the same organisation, and it was discovered that it was often easier to be redirected to the right person in the organisation through HR than through the wrong employee on the same hierarchical level. The email stated that the person, if he or she didn't consider itself as the most appropriate one in the organisation to interview, should forward the researchers to a more suitable person. In this way, the perception about who is the most suitable person by "the point of entry" was interviewed. The respondents at all case companies except the Industrial Conglomerate were found appropriate and could satisfyingly answer the questions due to sufficient insight in the production. However, at the Industrial Conglomerate, the first respondent was judged as being on a too high level within the company, and the interview was hence complemented with a second interview with a respondent with more specific insight in one of the companies' production facilities. In appendix C, the respondents at the chosen case companies are presented.

2.4.5.2 *Case Companies in Food Industry*

The B2B Producer

The B2B Producer specializes in Business to Business (B2B) ingredients, selling speciality and semi-speciality products for their customers in the fast-moving consumer goods (FMCG) industry. According to their website they have production facilities in around 20 different locations, presence in over 25 countries and 3 000 employees world-wide (The B2B Producer, n.d.).

The Vegan Producer

The Vegan Producer sell their products in over 20 countries and is growing fast in the consumer market. They produce both solid and liquid foods (The Vegan Producer, n.d.).

The Industrial Conglomerate

The Industrial Conglomerate produces packaged food and ready-to-eat dishes for well-known brands in the Nordics, Baltics, countries in Central Europe and in India. According to their website they employ over 8 000 people (The Industrial Conglomerate, n.d.).

The Liquid Producer

According to their website, The Liquid Producer make drinkable fast-moving consumer goods both for their own brand as well as other well-known brands in Sweden. They employ over 600 people in the Skåne region (The Liquid Producer, n.d.).

2.4.5.3 *Technology Suppliers*

The Machine Component Supplier

The Machine Component Supplier (2018) is one of the leaders of drive technology and drive-based automation. They are employing 16 000 people worldwide and have a turnover of more than 2.5 billion euro (The Machine Component Supplier, 2018).

The Production Line Supplier

The Production Line Supplier (n.d.) is a family owned company, producing machinery for the food manufacturing industry. They have 24 000 employees and are present in over 170 countries (The Production Line Supplier, n.d.).

2.4.5.4 *Industry 4.0 Experts*

Johan Lindén, Project Manager at Mobile Heights

Johan Lindén is a project leader at Mobile Heights, a non-profit industry driven networking community aiming to connect and support digital innovation and entrepreneurship in co-creation between business, research and society (Mobile

Heights, n.d.). Mobile Heights arrange, among other things, conferences, workshops, hackathons and multidisciplinary innovation projects for their members (Interview 4, 2018). The member organisations come from different areas - tech companies, law firms, municipalities, universities, consultancies, banking, hospitals - all having some interest in or actively working with digitalisation (Interview 4, 2018).

Charles Møller, Professor in Business Process Innovation at Aalborg University

Charles Møller is a professor in Enterprise Information Systems and Business Process Innovation at Aalborg University (AAU) in Denmark (Aalborg University, n.d.). He's one of the initiators of a so-called Learning Factory at the campus in Aalborg, where academia and industry can meet and innovate around the concept of Smart Production (Nardello, Madsen & Møller, 2017). In an article explaining the idea, Nardello et al. (2017) write that the purpose is to apply the design science approach to address needs from the industry and research concerning production methods, robotics and automation.

Hafsteinn Þór Guðjónsson, Management Consultant at Implement Consulting Group

Hafsteinn Þór Guðjónsson is a management consultant within Operations Strategy at Implement Consulting Group at their office in Copenhagen, specialized in supply chain management, new technologies, cost- and operational optimisation and strategic decision based on analytics. He's a part of a new business unit at Implement Consulting Group currently developing their Industry 4.0 offer to their customers within operations and manufacturing, visiting conferences like the Hannover Messe to learn about the State of the Art (Interview 11, 2018).

2.5 Data Analysis

According to Yin (2003) the data analysis consists of examining, categorizing, tabulating, testing and recombining evidence to connect the findings to the initial propositions, to be able to draw conclusions and answer the research questions. The final analysis was made by categorising the results and applying the Innovation-Decision Process by Rogers.

2.5.1 **The Analysis Process**

The steps (1) compile database, (2) disassemble & (3) reassemble, (4) interpret and (5) conclude data were made, see figure 4 (Yin, 2003). In this thesis, the first step was made through the transcription of the interviews and notes from the literature study. The second step was made through the coding of the data and the third step was made through clustering it, into definitions, opportunities, barriers and challenges. The data was then interpreted continuously via comparisons and the theoretical framework, while iterating through the second and third step. The fifth and last step, conclusion, was made through making conclusions about the whole case study in order to answer the research questions of the thesis.

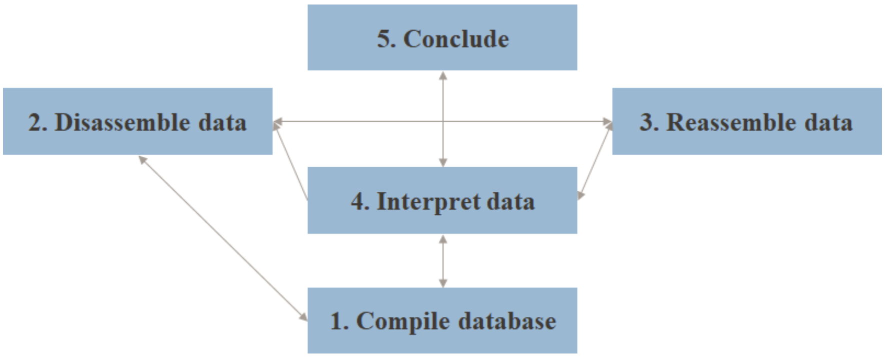

Figure 4. The analysis process of qualitative studies, adapted from Yin (2003)

2.5.2 **Coding of Data**

When coding the collected data, both inductive codes, from concepts brought up by the respondent, and deductive codes, from theoretical concepts, were used. The codes used are shown in table 3 below.

Table 2. Codes used in coding of data

Code areas	*Codes*
Current state	Important factors for the company operations
Current state	Control & Automation systems
Current state	Data Collection Solutions & Sensors
Current state	Automation & Interconnectivity Solutions
Perceived adoption	Perception of the current adoption of Industry 4.0
Perceived potential	Internal opportunities
Perceived potential	Internal challenges
Perceived potential	Internal barriers
Knowledge	Respondents knowledge of the Industry 4.0 concept
Adoption procedures	Procedure for adoption of new technology
Adoption procedures	Important factors when adopting new technology

2.5.3 The Innovation-Decision Process

The collected data and answers to RQ1 and its subquestions was then applied to the Innovation-Decision Process framework from Roger's Diffusion of Innovation-concept (1983), specifically the steps Knowledge, Persuasion, Decision, Implementation and Confirmation. This was also complemented with Gourville's 9 x Effect in Eager Sellers and Stony Buyers (2006) and Tétard and Collan's Switching Cost from their Lazy User Theory (2009). The frameworks are more coherently presented in chapter 4, Theoretical Context.

2.6 Credibility of Results

Höst et al (2006) distinguishes three important subdivision of credibility; reliability, validity and representativeness. These terms are discussed and connected to the research below.

2.6.1 **Validity**

Constructing validity is according to Yin (2003) to establish correct operational measures for all concepts that are being studied, i.e. making sure that the questions of the thesis are answered with data collected through trustworthy methods, that measures what is meant to be measured. This is especially criticized in qualitative researches, since a degree of “subjective judgement” is used to collect data. There are many common pitfalls made with semi-structured interviews, as discussed by Myers & Newman (2007), that are important to be aware of. Some common problems, like lack of time, ambiguity or language were easier to mitigate, whereas some more abstract phenomenons like the Hawthorne effect, where the researchers influence the situation, or lack of trust, are harder to distinguish. In order to mitigate this effect, and ensure overall validity of the study, the methodology and progress of the thesis was regularly discussed with the supervisors at LTH and Company X. Lastly interviews with experts were held, in order to further support or question the results of the study.

2.6.1.1 *Triangulation*

In order to increase validity of the data collection, triangulation was used. Using multiple sources of evidence and establishing a chain of evidence is a way of establishing credibility (Yin, 2003). Either the sources can confirm each other’s statements, or differences between the sources can be observed which might be interesting to analyse (Stake, 2014). The triangulation was three-fold; collecting data from four different case companies within the unit of analysis, collecting data from case companies as well as suppliers of the technology, and through comparing the results from the all interviews with the collected data from the State of the Art review of Industry 4.0.

2.6.2 **Reliability**

According to Stake (2014), the reliability of a study concerns to what extent the result of the study would be the same if the study was repeated in the exact same way and that the conclusions drawn from the study should reflect the reality. To achieve reliability in a qualitative research is difficult, since it cannot be repeated in the exact same way and hence would not give the exact same result (Stake, 2014). One way of approaching this dilemma in case studies is to divide and validate the research in as many sub-steps as possible (Yin, 2003). This has been made through the comprehensive description of the used methodology, and a division of research questions into subquestions, with the aim of making it as easy as possible to follow the work path of the researchers.

2.6.3 Representativeness

Representativeness is according to Höst et al. (2006) the degree to which the results of a research can be generalized to other fields. This is generally not applicable to case studies, which makes it important to set the research in its context. This study pinpoints development in a certain area in a certain industry in a certain point of time. The results of this study could be seen as a derivative of the diffusion of technology implementation in a low-margin industry in a developed country. Even though it might say something about the future technological progress, it’s not a predictive study at its core. The whole study can be deemed representative for the FMISS but also food manufacturing industries in other regions.

3 Industry 4.0 - State of the Art

This chapter presents a State of the Art of Industry 4.0. The focus is on clarifying the concept of Industry 4.0 and aims to provide a common understanding of the concept, the opportunities, challenges and barriers through an extensive literature study. This chapter will answer RQ1a: What are the opportunities, barriers and challenges for Industry 4.0 in general?

3.1 Industry 4.0

In this segment the previous industrial revolutions will be introduced, followed by an introduction of various definitions of Industry 4.0. The enablers behind this revolution, as well as the drivers and the barriers for its success will be introduced, along with the opportunities for usage and value creation, and the challenges that comes along.

3.1.1 A historical Overview of the First Three Industrial Revolutions

The industrialisation started with the first industrial revolution, in the end of the 18th century, when James Watt introduced the steam engine which increased production speed and efficiency (Bartodziej, 2017). The efficiency improvements in the agricultural sector lead to avoidance of food shortage, which lead to an explosive population growth (Bartodziej, 2017). This also affected the education system, the governmental system and the housing situation in major cities (Blinder, 2006). Social changes such as increased international trade, political shifts, the growth of cities, the division and specialisation of labour and the development of the working-class, has also been attributed to the first industrial revolution (Encyclopaedia Britannica, 2018).

The second industrial revolution started in the beginning of the 20th century, through the introduction of electricity to manufacturing plants, which enabled mass production and organisational changes such as scientific management procedures, notably Taylorism by Frederick W. Taylor (Bartodziej, 2017) and also introduced the moving belt conveyor (Siemens, 2013). The first two revolutions brought more than technical innovations, they also induced socioeconomic and cultural change.

After the second industrial revolution, between 1810 and 1960 the agricultural sector went from employing 84 % to 8 % of the workforce in the US, while manufacturing increased from 3 % to 25 % (Blinder, 2006).

The third industrial revolution took place in the early 1970s when electronics and information technology, such as computers, lean production, internet and biotechnology led to major innovations like factory automation and telecommunications (Bartodziej, 2017; Taalbi, 2017). The automated manufacturing, replacing manual labour to a high degree, led to rationalisations as well as a higher productivity and versatile serial productions (Bartodziej, 2017). There's been a shift from manufacturing jobs to the service sector, and as production efficiency has increased, people have been able to afford more for less, and thereby spending more of their money on services (Blinder, 2006). Taalbi (2017) claims that the third revolution is still in action today, but that we are now in the second wave; the first wave focused on the computerization and automation of factories, and the second on communication and internet infrastructure. In table 4, a conclusion of the revolutions is presented.

Table 4. Industrial revolutions, innovations and developments adapted from Taalbi, 2017.

Industrial revolution	***Technological revolutions***	***General-purpose technologies***	***Major innovations***
1st	Water-powered mechanisation of industry Steam powered mechanisation of industry and transport	Steam engine, Factory system Railways, Iron steamship	Cotton spinning, Coal Steam engines, Railway infrastructure, Machine tools
2nd	Electrification of industry, transport and the home Motorisation of transport, civil economy and war	Internal combustion engine, electricity Automobile, Airplane, Mass production	Electrification Automotive vehicles and transportation
3rd	Computerisation of entire economy	Computer, Lean production, Internet, Biotechnology	Factory automation, Telecommunication, Biotechnology

The first three revolutions were not defined as revolutions until after they had taken place. (Drath & Horch, 2014) One reason to why these technological shifts have been seen as revolutions, in comparison with other technological introductions, is because they induced a substantial increase of productivity which in turn led to higher growth (Blinder, 2006).

3.1.2 Definitions of Industry 4.0

The term Industry 4.0, or Industrie 4.0 in German, became widely used after the 2011 Hannover Messe (Lundström & Porat, 2016). In the United States of America, the corresponding phrase is “Industrial Internet” or “Factories of the Future”, while it is called “Internet Plus” in China (Schlaepfer, Koch & Merkofer, 2015; Hermann et al., 2016; Keqiang, 2017; Mrugalska & Wyrwicka, 2017; Industrial Internet Consortium, n.d.). IoT is mostly seen as a technology of Industry 4.0 instead of a synonym (Mrugalska & Wyrwicka, 2017; Strange & Zucchella, 2017; Elangeswaran et al., 2016; Seliger & Stock, 2016;). Even though the term Industry 4.0 was introduced seven years ago, it has no established universal definition by relevant literature, but many different definitions has been proposed (Brettel, Friederichsen, Keller, Rosenberg, 2014; Hermann et al., 2016). Many definitions appear broad and vague, making it possible to include almost any technical innovation to the Industry 4.0 spectra. After a literature study made by the authors of this thesis, exclusively based on academic studies researching the categorisation, principles or base of Industry 4.0, table 5 shows the most common terms used to describe Industry 4.0. Moreover, some other authors’ view of Industry 4.0 that is not included in table 5 will be presented in this section. For an entire display of the authors definitions, see appendix C.

Maybe the most ambitious attempt to define Industry 4.0 was made in a study by Pfohl, Yahsi & Kurnazet (2017) where they made a structured review of 152 published articles and reached the following conclusion: “*Industry 4.0 is the sum of all innovations derived and implemented in a value chain to address the trends of digitalisation, autonomization, transparency, collaboration and the availability of real-time information of products and processes”* (Pfohl et al., 2017). However, even though this covers important areas of Industry 4.0, this definition leaves it open to include almost any new digital technology to the Industry 4.0 term.

Buckley and O’Sullivan (2015) define the fourth Industrial Revolution in a rather inclusive but easy-to-understand manner, as “*the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes*”. Similarly, Germany Trade and Invest (GTAI) (2014) use the definition “*a paradigm shift [...] [which] means that industrial production machinery no longer simply "processes" the product, but that the product communicates with the machinery to tell it exactly what to do”*, which takes the concept further and makes a somewhat more describing definition, including the possibilities. Hermann et al. (2016) defines it more frankly, as “*the IoT, cyber-physical systems and Smart Factories*”, where the term "Smart

Factory" in itself could be argued to make this definition even more inclusive than GTAI and Buckley and O'Sullivan's definition.

Hermann et al. (2016) aren't the only authors to mention the "smart"-dimension of Industry 4.0. Mrugalska and Wyrwicka (2017), Elangeswaran et al. (2016), Hermann et al. (2016), Kagermann, Anderl, Gausemeier, Schuh & Wahlster (2016), Feld, Fettke, Hoffmann & Lasi (2014) and Kagermann, Wahlster & Helbig (2013) all mention the smartness in some way when defining the concept, see table 5. But even though the introduction of smart products, smart services, smart machines or implementation of smart factories seem to be seen as an integral part of the concept, there is no coherent definition of the term "smart" in relation to manufacturing facilities (Bilberg, Bogers, Madsen & Radzivon, 2014, Kagermann et al., 2013). The Smart Factory is both defined as technologies, an approach or a paradigm (Bilberg et al., 2014). Concluding their view of the potential of The Smart Factory, Industry 4.0 could potentially change the isolated activities within the manufacturing environment of today to automated, optimized and integrated data flows and products within the global value chain (Strange & Zucchella, 2017). Mrugalska and Wyrwicka (2017) say that smart products will help with their own production by storing operational data and coordinating the production process, smart machines will use an integrated network of manufacturing units in order to self-organize and -optimize, while augmented operators will make strategic decisions on his or her mobile context-sensitive assistance systems (Mrugalska & Wyrwicka, 2017). This is a clearer, yet more limited way, to define the smart dimension of Industry 4.0.

How the concepts within Industry 4.0 are categorised also differ between the different authors. Feld et al. (2014) list seven "current concepts" that are a part of Industry 4.0: "the smart factory", "cyber-physical systems", "self-organisation", "new systems in distribution and procurement", "new systems in the development of products and services", "adaptation to human needs" and "Corporate Social Responsibility". Their concepts are both micro and macro, on highly different abstraction levels. Furthermore, Herman et.al. (2016) made a qualitative literature review and a quantitative text analysis of relevant publications, which helped them identify four design principles for implementation of the Industry 4.0-concept; interconnection, information transparency, decentralized decisions, and technical assistance. These design principles are said to "[guide] practitioners and scientists on 'how to do' Industrie 4.0" (Hermann et al., 2016). But how these broad concepts will be made into action plans seems like it is yet to be established. Industry 4.0 can also be defined as a set of "new digital industrial technologies", such as embedded sensors, autonomous robots, additive manufacturing and devices that can communicate and interact (Strange & Zucchella, 2017). This definition is more focused on the technology building blocks of Industry 4.0 and less on benefits and usage, which makes it more concrete and lowers the abstraction level, but with the limitation that new technologies emerge rapidly making the definition obsolete. See figure 5 for some of the technologies mentioned by literature as part of Industry 4.0.

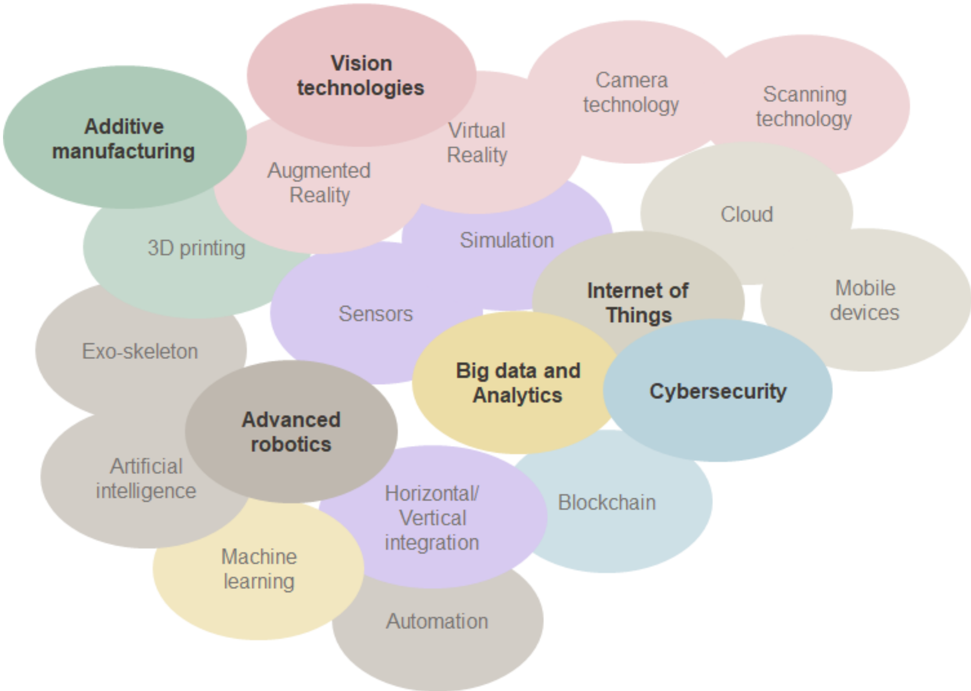

Figure 5. Some of the technologies often proposed to be part of Industry 4.0 according to different academic and business sources, colour clustered by the authors.

Lomax et al. (2018) see Industry 4.0 as an umbrella term, covering all technologies that deliver new customer requirements such as better quality, lower cost and quicker availability. They are one of few authors mentioning the customer perspective when defining Industry 4.0. Most of the technologies of Industry 4.0 have been available for a long period of time, without any extensive adoption, but Strange & Zucchella (2017) mean that it is with a recent cost reduction and improvement in reliability that they are now more commercially viable. Even with this in mind, Larsen (2017) claim that full deployment is still 15-20 years away. This supports the proposition made by several authors that Industry 4.0 isn't a revolution, but an *evolution* and a logical extension of the third industrial revolution. In table 5, a conclusion of the definitions used for Industry 4.0 is presented.

Table 5. Descriptions of Industry 4.0 and their subsequent authors

Descriptions	*Authors*
introduction of cyber-physical systems	Elangeswaran et al., 2016; Hermann et al. (2016), Kagermann et al. (2016), Feld et al. (2014), Kagermann et al. (2013)
IT-enabled networking	Elangeswaran et al. (2016), Kagermann et al., 2016, Buckley & O'Sullivan (2015), Germany Trade and Invest (2014), Kagermann et al. (2013)
a change that affects the whole value chain involved in manufacturing	Kagermann et al. (2013), Elangeswaran et al. (2016)
a new paradigm	Elangeswaran et al. (2016), Feld et al. (2014), Germany Trade and Invest (2014)
based on digitalisation of processes, products and systems	Pfohl et al. (2017), Elangeswaran et al. (2016), Feld et al. (2014)
introduction of the Internet to manufacturing facilities	Elangeswaran et al. (2016), Hermann et al. (2016) Kagermann et al. (2016), Feld et al. (2014)
communication, collaboration and interaction between devices	Pfohl et al (2017), Kagermann et al. (2016), Elangeswaran et al. (2016), Germany Trade and Invest (2014), Kagermann et al. (2013)
self-organized machines and devices	Kagermann et al. (2016), Feld et al. (2014), Kagermann et al. (2013)
smart factories; smart products; smart services; smart machines; smart systems	Elangeswaran et al. (2016), Hermann et al. (2016), Kagermann et al. (2016), Feld et al. (2014), Kagermann et al. (2013)

3.1.3 Enablers of Industry 4.0

In consultancy articles written by BCG and McKinsey, the major technological developments that are enabling this shift are said to be the increased computational power, the increasing analytics capabilities, the innovations supporting human-machine interactions, the improved methods of transferring digital into the physical (Lorenz et al, 2016; Baur & Wee, 2015) and the rise in data volumes and connectivity (Baur & Wee, 2015). In general, consultancies seem to be agreeing on the enabling factors. The Danish Institute of Industry 4.0 (2016) sees the exponentially decreasing cost of technology as an enabler, since the cost level now is sufficiently low for a widespread adoption of Industry 4.0. Also, the quality and accessibility of internet is better than ever, and is decreasing in price, and the cloud is getting more cost efficient and accessible and allows data storage and sharing, which makes the shift possible (Danish Institute of Industry 4.0, 2016). Further, the global direct networking of smart objects is supported by IPv6, the new Internet protocol that was introduced in 2012, which means that there is now a sufficient amount of available Internet addresses (Kagermann et al., 2013).

3.1.4 Drivers & Supporting Trends of Industry 4.0

In order to meet the new demands of society, it is said to be integral to integrate horizontally and vertically in the supply chain of processes and operations, which enables efficiency and flexibility as well as innovation and reactiveness (Danish Institute of Industry 4.0, 2016). According to Feld et al. (2014), the demand for Industry 4.0 can be divided in two different directions, one pulled by societal demand and one pushed by technology suppliers. The first direction is triggered by general social, economic, and political changes, as the need for short development periods, individualisation on demand, flexibility, decentralisation and increased resource efficiency. The second direction is triggered by the technological advancements in creating "smart" objects (Feld et al., 2014). According to i-SCOOP (2017), the society is changing as new business models in the service-economy are sought, and there is increasing human talent development.

Supporting Feld et al., other driving forces on a macro-level is, according to Prause & Weiga (2016), the big concerns in society today; climate change, resource scarcity, globalisation, changing demographics as well as innovation of dynamic technologies and mass customisation. They mention both an aspect of treat and potential gains as drivers. The Danish Institute of Industry 4.0 (2016) say that drivers that speed up adoption are the increased pace of technological change, increased technological complexity and more disruption. When it comes to technological drivers, the development is also driven by the sophisticated tech innovations, for example sophistication of camera and scanning technology, sensors, artificial intelligence (AI) and machine learning, enabled by higher computational power. The fact that mobile devices are increasing in use allows for flexible access and control (Danish Institute of Industry 4.0, 2016).

One factor that could affect the speed and extent to which Industry 4.0 solutions are being implemented is how big the importance of the manufacturing industry is to the economy of the country. In Germany, where the manufacturing industry make up nearly one fourth of the GDP[2], measures have been taken to facilitate the implementation and to make up guidelines for the implementation (Industry Today, n.d.). According to GTAI (2014), the German government see Industry 4.0 as a

[2] GDP = Gross Domestic Product, the monetary value of all goods and services produced within a country's borders in a specific time period, usually annually.

major possibility to establish themselves as a leading industry nation. They want to take a pioneer role and see the implementation of Industry 4.0 as a strategy to stay globally competitive (Germany Trade and Invest, 2014). Larsson (2017) states that the concept of Industry 4.0 was developed as an idea in Europe on how to increase profitability in the production and to win back ground from the low-wage countries. This is seen as one of the big motivators for western countries to make Industry 4.0 investments (Larsson, 2017). The Swedish government have a mission to strengthen investment promotions with the purpose of increasing the number of companies that are choosing Sweden as the base for their production (Regeringen, 2016).

According to Burke, Hartigan, Laaper, Mussomeli & Sniderman, (2017), the initiative to develop a Smart Factory will rise from the specific needs an organisation experiences, hence, the expansion will start from widely spread areas in the company and the features that are seen as most relevant will be prioritized (Burke et.al, 2017). This way, the smart factory will look different for each company. Even though the authors mention that it is not possible to generalize the reason for companies to start building up the "smartness" of their factories, the drivers normally address asset efficiency, quality, costs, safety and sustainability (Burke et.al, 2017).

Authors of earlier research and white papers mention several other drivers of the development of the fourth industrial revolution. After a literature study from relevant articles, table 6 concludes the most common drivers mentioned in accordance to Industry 4.0 found by the researchers.

Table 6. Drivers of Industry 4.0 and their authors

Drivers	***Authors***
Increasing uncertainty/unpredictability of geopolitical and macroeconomic picture, due to; climate change; globalisation; changing demographics	i-SCOOP (2017), Prause & Weiga (2016), Kagermann et al. (2013)
Increasing uncertainty/unpredictability regarding consumer spending/confidence, due to; mobile devices is increasing in use; a changing customer	i-SCOOP (2017), Danish Institute of Industry 4.0 (2016)
Customers' increasing desire for customisation, hence; need for individualisation on demand	Kagermann et al. (2016), Prause & Weiga (2016), Feld et al. (2014)
More disruption, due to; highly competitive landscape; need to diversify and tap into new revenue sources	i-SCOOP (2017), Danish Institute of Industry 4.0 (2016)

Need for resource efficiency, due to; resource scarcity	Prause & Weiga (2016), Feld et al. (2014), Kagermann et al. (2013)
Manufacturing industry in advanced economies seeking to maintain global market leadership; desire of nations to become leading supplier of smart manufacturing technologies	Larsson (2017), Kagermann et al. (2016), Kagermann et al. (2013), Industry Today (n.d.)
Innovation of dynamic technologies, through; the increased pace of technological change; analytics, software and algorithm developments; increased mechanisation and automation; sophisticated technology innovations (ex. AI)	Danish Institute of Industry 4.0 (2016), Prause & Weiga (2016), Feld et al. (2014)

3.1.5 Opportunities of Industry 4.0

The biggest opportunities seen with Industry 4.0 seem to be increasing productivity within manufacturing, cost improvements, improved product quality and more agile operations (Kiel, Müller & Voigt, 2018; i-SCOOP, 2017; Lorenz et al, 2016; Morgan Stanley, 2016). The new technologies can further lead to maximizing asset utilisation, optimised decision making, business processes which can be adjusted according to breakdowns in the value chain and reduced downtime (Mrugalska & Wyrwicka, 2017; Morgan Stanley, 2016). Creating new business opportunities through new business models is also seen as an opportunity with Industry 4.0 (Kiel et al., 2018; Bremicker & Gates, 2017; Mrugalska & Wyrwicka, 2017; Kagermann et al., 2016; Morgan Stanley, 2016; Wortmann & Flüchter, 2015). Connected to this, Bremicker and Gates (2017) mean that the real value of Industry 4.0 is running the manufacturing to enhance the delivery of competitive advantage. The possibility of mass customisation is mentioned as a part of Industry 4.0 by several authors, made possible by automation, self-organizing and cyber-physical systems in the production facilities that give an improved flexibility in meeting individual customer requirements while still being profitable (Kiel et al., 2018, Mrugalska & Wyrwicka, 2017, Elangeswaran et al, 2016 Feld et al., 2014).

Strongly connected to the driver of making manufacturing in developed economies more attractive, according to Larsson (2017) it is further seen as a possibility to win back work opportunities from low-wage countries through Industry 4.0. Change will also reach beyond the factories and economic benefits. Improved resource and energy efficiency, a work organisation fit for the demographic changes and the shift towards a better work-life balance are just some of the societal benefits that goes hand-in-hand with Industry 4.0 (Kagermann et al., 2013), which is in line with Buckley and O'Sullivan's (2015) view of Industry 4.0 as leading to better "societal outcomes", and Feld et al. (2014) who includes Corporate Social Responsibility as a concept in the term Industry 4.0. According to Seliger and Stock (2016) Industry 4.0 also represents huge possibilities for sustainable manufacturing. One of the improvements in working conditions are the higher levels of safety for employees, not in the least with heavy weight automated systems making decisions based on sensor input. (Kiel et al., 2018; Lorenz et al, 2016; Kagermann et al., 2013) With the automation of repetitive and manual tasks comes the possibility of more flexible career path for the employees, who can be productive longer and get higher wages, at the same time as the company can cut cost on energy and personnel (Mrugalska & Wyrwicka, 2017). An overview of the opportunities found in the State of the Art research is presented in appendix D.2.

3.1.6 **Barriers to Industry 4.0**

The pace of adopting Industry 4.0 innovations has proven to be slower in industrial and manufacturing settings than in the consumer market, which according to a McKinsey report based on interviews with managers of over 50 manufacturing companies in large is due to the difficulty for companies to know where to begin their Industry 4.0 efforts (Baur & Wee, 2015). A big barrier for companies in getting started with Industry 4.0 lies in defining a strategy, but when it comes to implementation, the company culture and organisational change are limiting the adoption, where existing values and ways of working has to be adapted (The Danish Institute of Industry 4.0, 2016; Lorenz et al, 2016). Senior management can constitute a barrier, if they are lacking the necessary capabilities or are not fully committed to changing the organisation (The Danish Institute of Industry 4.0, 2016). Furthermore, manufacturing technology is quite capital intensive and the installation cost is also a significant upfront investment (Danish Institute of Industry 4.0, 2016; Morgan Stanley, 2016). The complexity of Industry 4.0, both in terms of actual and perceived complexity, will in general increase the need for technical skills, either by retraining existing workforce, or recruiting new talent since in-house competence often is too limited (Kiel et al., 2018; Danish Institute of Industry 4.0, 2016; Hannover Messe, n.d.; Lomax et al., 2018). The automation of manual work will mean a higher demand for IT, engineering, data science and HR activities (Danish Institute of Industry 4.0, 2016).

Another key barrier today is connected to the integration of different kinds of data and consequently, the lack of standards in systems and data formats (i-SCOOP, 2017; Kim, Kwak & Lee, 2017; Danish Institute of Industry 4.0, 2016; Kagermann et al., 2016; Morgan Stanley, 2016; Davenport & Sarma, 2014, Kagermann et al., 2013). In a study made by Kim et.al (2017) they found that there is a leading standard today; the 3GPP standards, but that there are several strategic groups lobbying for other preferred standards. They mean that a clear standard would boost the importance of IoT technologies on the expense of the diversity of solutions (Kim et al., 2017). Further explained, according to Kagermann et al. (2016) one big hold up for Industry 4.0 implementation is that manufacturing systems need horizontal integration into value networks, and vertical connection with companies' internal business processes requires an end-to-end digitalisation of the whole value chain, Industry 4.0 platforms and a digital ecosystem. This implies the importance of developing standards as well as reference architecture to provide a technical description of how to implement solutions. The technology is of a highly dynamic nature which requires the norms and standards to be very flexible and adaptable (Kagermann et.al, 2016). Standards would build trust between stakeholders, avoid technology lock-in and lead to a more secure investment environment (Kagermann et al., 2016; i-SCOOP, 2017). Today, without clear standards, there is no consensus between stakeholders (Kim et al., 2017). One reason for the difficulty in agreeing might be the fact that Industry 4.0 is a preannounced revolution, where all players want a slice of the pie, lobbying for their preferred standard.

Kagermann et.al. (2016) mean that Industry 4.0 is breaking new ground, not only technologically but also legally. This means that existing legislation needs to be adapted to include the new concepts of Industry 4.0, for example in terms of data protection, cyber security, liability issues and restrictions of trade. This also affects the guidelines, contracts, agreements and audits internally in the companies (Kagermann et al., 2016). With an enormous number of embedded sensors and devices communicating, there is a great risk of systematic breaches (Strange & Zucchella, 2017). A lot of data has to be shared between a large number of actors in the value chain, and in order to interconnect in the supply chain, it is important that a reliable, high quality and comprehensive broadband infrastructure is available in all the locations where the partnering organisations are put (Kagermann et al., 2013). It is important that the suppliers of Industry 4.0-technologies can offer secure digital processes and thereby demand a high level of security from their own suppliers. In addition to this it is also imperative to establish who in the value chain owns the data (Danish Institute of Industry 4.0, 2016). This is still viewed as a barrier to further implementation today. An overview of the barriers found in the State of the Art research is presented in appendix D.1.

3.1.7 Challenges of Industry 4.0

According to Kagermann et al. (2016) Industry 4.0 is estimated to favour cooperation, but to find suitable partner companies in the development and implementation of new, data-driven business models is seen as a challenge, without the partnering firm undermining the competitive advantage with their own solution. Hence, it is seen as a risk to collaborate with external partners and loss of know-how, product piracy and a general loss of control is feared. Furthermore, Kagermann et al. (2016) argue that there is a lot of promising potential technology, but it is difficult to make ideas into actual technology and getting investors to recognize potential benefits. Managers experience a fear of developing solutions that lack market relevance (Kagermann et al., 2016). There's also a risk for siloed and ad hoc projects, and thus it is important to have a holistic approach to Industry 4.0 implementation and strategy (i-SCOOP, 2017).

A strong national focus and a short-term focus on return on investment in companies make them fail to see the potential and importance of upgrading to Industry 4.0 (Kagermann et al., 2016). Lomax et al. (2018) argue against other authors on this theme and stress the benefits of a step-by-step approach in the implementation, and that a limited budget should not be an issue. However, they mean that the over-excitement about the concept has become problematic. This is because an "all-or-nothing"-mentality has been established that puts companies off starting the implementation in the first place - thinking that only the big fish that can afford a total transformation of their factory has a shot at reaping benefits from Industry 4.0. Many consultancy white papers create a sense of urgency and panic - which might disfavour the adoption. Today, Lomax et al. (2018) mean that digitalisation of the infrastructure can be implemented step-by-step without replacing existing equipment, which is not fully understood in the industry. There are some doubts remaining regarding the affordability of Industry 4.0 solutions, and cost for training and hiring competence to use it. Companies must convince stakeholders about the validity of an investment, which is found challenging, since there is little data existing regarding the return on investment (ROI) of Industry 4.0 implementation (Lomax et al., 2018).

Contradictory to Lomax. et al (2018), Bremicker and Gates (2017) mean that larger scale, disruptive implementation is crucial to gain benefits from Industry 4.0. They say that there is a significant gap between the high ambition of executives and the minimal actions taken to transform the status quo (Bremicker & Gates, 2017). In an article by Pfohl et al. (2017) they say that there seems to be a positive correlation with the diffusion of digitalisation and with the ROI of digitalised products and processes. This basically means that there's a network effect seen in Industry 4.0 diffusion, where it is more profitable to invest in Industry 4.0 technologies with every implemented unit (i-SCOOP, 2017; Pfohl et al., 2017; Kagermann et al., 2016), which supports Bremicker and Gates thesis.

In Kiel et al's study (2018) of 746 German manufacturing companies, factors related to "competitiveness & future viability" and "organisational & product fit" were found to create challenges for the implementation of Industry 4.0 through "existing business models being endangered", "loss of flexibility", "standardisation", "need for transparency" and "high implementation efforts" regarding, e.g., costs and standardisation. An overview of the challenges found in the State of the Art research is presented in appendix D.3.

3.2 Summary of Chapter 3

Chapter 3 aims at answering the subquestion RQ1a: *What are the opportunities, barriers and challenges for Industry 4.0 in general?* In order to make Industry 4.0 more comprehensive, enablers, drivers and the definition of the concept has been investigated. In order to provide a full overview of the result from chapter three, a summary has been made in the following table:

Table 7. Definitions, drivers and the opportunities, barriers and challenges of Industry 4.0 in general

Definitions of Industry 4.0	***Opportunities for Industry 4.0 diffusion***
• Introduction of cyber-physical systems • IT-enabled networking • A change that affects the whole value chain involved in manufacturing • A new paradigm • Based on digitalisation of processes, products and systems • Introduction of the Internet to manufacturing facilities • Communication, collaboration and interaction between devices • Self-organized machines and devices • Smart factories; smart products; smart services; smart machines; smart systems	• Creating new business opportunities • Optimised decision making, through increased understanding of production • Optimisation of processes, production and systems • Reduction of environmental impact • Higher level of automation that self-organises and self-synchronise • Mitigating risks associated with breakdowns • Better working conditions in terms of safety and career paths • Better production overview • Improved product quality • Increased flexibility and speed • Cost benefits • Improved JIT-production

Drivers of Industry 4.0	*Barriers for Industry 4.0 diffusion*
• Increasing uncertainty/unpredictability of geopolitical and macroeconomic picture • Need for resource efficiency • Manufacturing equipment industry in advanced economies seeking to maintain global market leadership • Innovation of dynamic technologies • More disruption • Customers" increasing desire for customisation • Increasing uncertainty/unpredictability regarding consumer spending/confidence • New business models in an "as a service" economy are sought • Human talent development	• Resistance against manual work being automated • Lack of comprehensive broadband infrastructure • Lack of standards and norms of data ownership • Hype of Industry 4.0 • Low technical competences in the industry • Data and cyber security

Challenges for Industry 4.0 diffusion
• Emotions and mindsets • Strong national focus • Business related challenges • Avoiding ad hoc implementation • Transparency in the supply chain • Workforce challenges, related to competencies and organisation structure • Investment challenges • Integration of systems and machines • Management does not prioritise or see the value • Flexibility challenges

On the matter of finding a clear definition of what Industry 4.0 is, this was found to be a mission impossible, since authors use their own definitions, either very broad and vague or technology specific. There were many opportunities seen with Industry 4.0, where the potential of disrupting and transforming the entire way of doing things today was made clear. However, there are several barriers and challenges with Industry 4.0, since enablers like standards are missing, and big potential change brings large uncertainty.

4 Theoretical context

This chapter presents the theoretical frameworks that make up the base for the research. This includes Roger's Diffusion of Innovation (1983), Tétard and Collan's Lazy User of Solution Selection methodology (2007), and Eager Sellers and Stony buyers by Gourville (2006). The theory is based on Business to Consumer (B2C) Diffusion of Innovation, but is applicable for B2B diffusion with the constraint that the characteristics of the decision-making unit of the organisations will affect the adoption more and are more complex than those of a single consumer (Rogers, 1983).

4.1 Five Stages of Diffusion in the Innovation-Decision Process

An important aspect in Rogers (1983) theory is the Innovation-Decision Process, which deals with the process from first hearing about an innovation until having it implemented and seeking confirmation. The five steps of this process are shown in figure 6 below.

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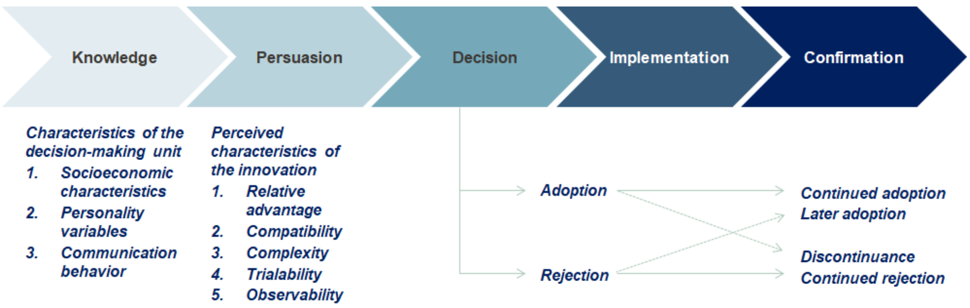


Figure 6. Rogers' five stages of diffusion in the Innovation-Decision Process

Rogers defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system". He considers the main elements as the innovation, the communication channels, time, and the social system. In this thesis communication channels will not be discussed in depth.

4.1.1 Rate of Adoption

The rate of adoption is with what relative speed the innovation is adopted by the members of a certain social system (Rogers, 1983). When this is plotted over time on a cumulative frequency basis, it distributes as an S-shaped curve. Early on there are only some who adopt the innovation per time unit, they are called *innovators*. Soon the diffusion speeds up and the curve begins to steepen, until the diffusion speed starts to level off, since less and less units remain who haven't adopted the innovation. When the S-curve reaches its asymptote, the process is completed. According to Rogers (1983) the S-curve varies for each innovation depending on the speed of adoption, from being more "gradual" to more "lazy". Why the steepness differs is connected to the characteristics of the innovation, such as perceived *relative advantage* or *compatibility* etc. Furthermore, the S-curve for an innovation differs in different social systems (Rogers, 1983).

Opinion leaders are informal leaders in a social system (Rogers, 1983). The leadership is based on the opinion leader's ability to influence others within the system in their desired way, while they also provide information and advice about innovations to the system members (Rogers, 1983). The opinion leader is chosen based on their technical competence, social accessibility and conformity to the norms of the system.

4.1.1.1 *Change Agents and Change Agent Aides*

The concept of *change agents* is introduced by Rogers (1983) as, often technical, professionals with higher education. This gives them social status and differentiates the change agents from the average system member, which creates problems when they communicate about and promote innovations. *Change agent aides*, who are less formal than the change agent, intensively communicate with system members to influence their innovation decisions, bridging the gap between the change agent and the average system member (Rogers, 1983).

Innovations can be adopted or rejected by individual units, or by the entire social system by a collective or authority decision, according to Rogers (1983). *Optional innovation-decisions* are made by a unit without a basis of the decision of other system units, even though it might be influenced by norms and of interpersonal networks. Still, the individual is the unit of decision making, rather than the entire social system. *Collective innovation-decisions* is adoption based on consensus among the system members, where all system members have to conform. *Authority innovation-decisions* are choices to adopt or reject an innovation made by few system members with high power, status or technical knowledge. Other members of the system have limited or no influence and have to implement the decision.

Collective and authority decisions are much more common than optional decisions in formal organisations as factories in comparison with other fields like agriculture and consumer behaviour. Naturally, authority decisions generally creates higher speed of adoption, and optional decisions are normally more rapid than collective decisions (Rogers, 1983).

4.1.2 **Adopter Categories**

According to Rogers (1983) the different groups within the social system are divided into five subgroups; *innovators*, *early adopters*, *early majority*, *late majority* and *laggards*, based on their willingness and speed to adopt innovations. They have different attributes (venturesome, respectful, deliberate, sceptical and traditional respectively), different socioeconomic status, different personality variables and different communication behaviour, and this can be used in audience segmentation and marketing strategies. The innovator has an interest in new ideas and this interest takes them out of their local circle. The early adopter has a higher degree of opinion leadership in most systems than the other adopter categories. The early majority has a frequent interaction with their peers meanwhile the late majority answers to peer pressure, economic necessity and the necessity to be cautious. Laggards are in possession of no opinion leadership, they are normally isolated and very suspicious of innovations in general (Rogers, 1983).

4.1.3 **Prior Conditions**

The prior conditions to the Innovation Decision Process are according to Rogers (1983) "previous practice”, "felt needs or problem”, "innovativeness" and "norms of the social systems”. These prior conditions should be fulfilled before the Innovation Decision Process even starts.

4.1.4 **Step 1: Knowledge**

The Innovation-Decision Process can only begin when *knowledge* is attained (Rogers, 1983). Throughout the Innovation-Decision Process, information is sought and processed in order to decrease experienced uncertainty about an innovation. In the first step, knowledge about what the innovation is, how it works and why it works is sought, while the decision-making unit looks for information to establish the cause-effect relationships involved when using the innovation, and if it will create benefits or solve a problem (Rogers, 1983).

4.1.4.1 *Finding Out About an Innovation*

According to Rogers (1983), some prior authors on the theme of diffusion mean that units find out about an innovation by accident, that it is not possible to actively search up an innovation before you know that it exists. Others say that a unit can only get awareness through active behaviour. There is no clear answer to whether awareness of a need or awareness of an innovation comes first (Rogers, 1983).

Selective exposure is a term that Rogers (1983) says means that units normally expose themselves to ideas that are in accordance with their already existing interests, needs, or views, and that they consciously or subconsciously, avoid messages that are in conflict with these. Hence, a unit won't expose itself to innovations they don't feel a need for, and exposure will not have much effect if the innovation is not perceived as relevant to an existing need, attitudes and beliefs. Hence, experienced need for an innovation must usually precede awareness-knowledge of the innovation (Rogers, 1983).

According to Rogers (1983), a need, or dissatisfaction or frustration about something, can develop when someone gets to know that an innovation exists. Hence, an innovation can create a need and a need can create an innovation. Thus, solely knowing about the existence of an innovation can motivate adoption. Perceived needs or problems are far from a complete explanation of why the Innovation-Decision Process gets started. Units don't always notice when they have a problem, and needs aren't always in line with what experts might think. As an example, "we may want food but not need it. And we may need vitamins and minerals and fail to want them" (Rogers, 1983).

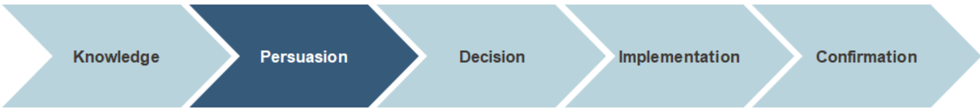
4.1.4.2 *Knowledge Types*

There are three types of knowledge according to Rogers (1983); (1) *awareness-knowledge*, the basic knowledge about the existence of the innovation which awakens questions about how and why the innovation works, (2) *how-to knowledge*, the knowledge about how the innovation is used and how it works, which increases with the complexity of the innovation and (3) *principles knowledge*, which deals with the principles underlying the functionality of an innovation, often learned at academic institutions. Later in the Innovation-Decision Process, the principles knowledge is not as essential as the how-to knowledge, but when an understanding of the underlying principles is missing, the danger of misusing the innovation is greater (Rogers, 1983).

4.1.4.3 *Hype*

Hype is a phenomenon that has been coined as the First Law of Technology, which says that "we invariably overestimate the short-term impact of a truly transformational discovery, while underestimating its longer-term effects" (Collins, 2010). The nature of the over-optimistic hype peak is based on the human attraction to new things, the social contagious spread of new ideas and the heuristic attitude to decision-making. The exaggerated perceived potential decreases after hand, due to the disappointment of first results of bad and early applications. After some time, some adopters start to profit on the technology and investors regain interest. As the understanding of the technology context and possibilities grow, methodologies and best practices are being developed, and the innovation starts to be socialized until the value of the technology is finally realistic, business and reference cases exist and the technology spreads in an accelerating speed (Dedehayir & Steinert, 2015). It can be argued that hype distorts the shape of the S-curve and the rate of adoption in the innovation diffusion.

4.1.5 Step 2: Persuasion



Persuasion is the second step of Rogers' (1983) model and happens when a decision-making unit starts attaining a favourable or unfavourable attitude toward the innovation, and seek information to evaluate the innovation. The social system's view on consequences and the changes that will occur to the entirety or members of the system when adopting or rejecting an innovation are strong influences (Rogers, 1983).

Even though many units know about innovations, they haven't chosen to adopt them. This might be because they don't view it as relevant or useful to their specific situation. Consideration does not start if the information seems irrelevant or if sufficient knowledge is not obtained (Rogers, 1983).

At this stage, according to Rogers (1983), the unit becomes more psychologically involved with the innovation by actively searching for information. What is important is where information is sought, what messages are received, and how the received information is interpreted. *Selective perception* plays an important role, and the perceived attributes of an innovation, connected to its relative advantage, compatibility, and complexity are especially important here. The decision-making unit starts to mentally project the innovation into their future plans. Innovation-evaluation information is sought, to reduce uncertainty about the consequences of an adoption and the innovation's advantages and disadvantages. This could be scientific evaluations, but the subjective opinion by near-peers is more important (Rogers, 1983).

Rogers (1983) means that there might exist a discrepancy between favourable attitudes and actual adoption, and a favourable or unfavourable attitude does not guarantee that adoption or rejection will occur. For example, *preventive innovations*, such as car seat belts, insurances or disaster preparations, lessening the effect from an undesired event that may or may not occur, tend to have a slower rate of adoption. The motivation of the decision-making unit to adopt is low but can be spurred by a *cue-to-action*, an event that transforms a favourable attitude to actually adopting the innovation (Rogers, 1983). For example, a car crash by a family member can be a cue-to-action for the rest of the family to start using seat belts.

Carter, Gupta, Jambulingam & Melone (2001) studied the impact of the institutional aspects on the adoption of innovations and the success specifically concerning the success in the implementation of IT solutions. They found that advocacy by middle management does not have a positive effect on the success of implementation. The study shows that innovations that imply large investments might have to be adopted through a top-down process with top management involvement. They also found that smaller scale innovations, tangible as well as intangible, or innovations that require a high degree of learning, had a great potential for adoption through a *bottom-up process*. The bottom-up process contributes with a broad-based support for the innovation in comparison to a top-down process where single proponents are to advocate something (Carter et al, 2001).

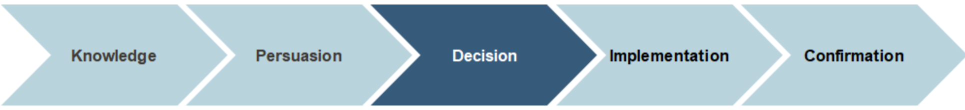
4.1.5.1 *Perceived Characteristics of the Innovations*

Whether or not an innovation is adopted is highly dependent on how individuals perceive the characteristics of the innovation, and Rogers (1983) introduce five attributes that greatly affects the attractiveness of an innovation: *Relative advantage*, *Compatibility*, *Complexity*, *Trialability* and *Observability.* Rogers (1983) describes the concepts as follows: Relative advantage concerns to what extent the new technology is perceived as better than the ones it is aimed at replacing. Compatibility means whether or not the new technology is compatible with the current system it will be a part of, or if a change in the current infrastructure is required, and if it is compatible with the existing needs and values of the adopter. The longer the time horizon, the less compatibility is required with existing solutions. Complexity concerns the perception of how easy it is to understand and use the innovation. Trialability concerns the possibility to try the innovation before deciding on whether or not to buy it. Observability concerns to what extent it is possible to observe the benefits an implementation of the innovation would result in (Rogers, 1983).

4.1.5.2 *Relative Advantage in the Light of the 9 x Effect*

Gourville’s (2006) theory about *the 9 x Effect* stresses that the consumers subjective perception of value and attractiveness of an alternative will make the basis of the decision on whether to adopt new products or not, and that consumers, when evaluating the new product, base the value in relation to their current solution to the problem they want the product to fix. The shortcomings of the old solution have a much greater impact on the decision than the gains of the new. Furthermore, consumers strongly avoid having to learn how to use new products, and value sticking with their current solution. This leads consumers to "over value" what they already possess which explains why consumers tend to stick with the solution they already have. Meanwhile, suppliers think that their innovation works great and find need for it everywhere they look, they find problems with current solutions and view their own solution as the benchmark, hence, end up overvaluing their product. Both parts overvalue their favoured solution by a factor of three, which creates a gap in the perceived value by a factor of nine called *the 9 x Effect.* To measure, manage and minimize potential consumer resistance are ways to mitigate this effect. This can be done through making more behaviourally compatible products, through finding consumers who have no current solution or who would benefit more strongly from your particular solution than others (Gourville, 2006). This theory is an extension to Rogers "relative advantage”, and with the 9 x Effect in mind it is extra important to acknowledge the meaning of "relative" in relative advantage.

4.1.6 **Step 3: Decision**



The decision step is when a decision-making unit starts doing things that lead up to making a choice on whether to adopt or reject the innovation. Peer to peer-diffusion is especially effective when spreading evaluative information about the innovation. This subjective form of evaluations of the innovation influence more strongly at this stage (Rogers, 1983).

One common way of starting to adopt an innovation, according to Rogers (1983) is to try it during a shorter period or in small-scale, in order to determine whether or not it is useful for their specific settings, and to reduce the uncertainty of the outcomes of the decision. If the trial period shows that the innovation has some degree of relative advantage in comparison to the existing solution, it will probably be adopted. Some innovations cannot be tried out, they have to be adopted in full, but they can also be observed through a similar organisation that has already adopted the innovation, which partly caters to the need of trialability (Rogers, 1983).

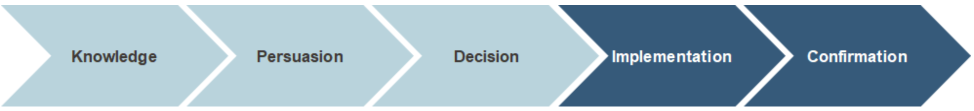
The possibility of rejection is not only possible at the decision step but can be reached at all of the steps in the Innovation-Decision Process. There are two kinds of rejection; (1) *active rejection*, considering and then deciding not to adopt the innovation and (2) *passive rejection*, never even considering the adoption (Roger, 1983). There is also a possibility for innovations to be adopted before the organisation is convinced about the relative advantage, for whatever reason. In that case the sequence is knowledge, decision, persuasion (Roger, 1983).

4.1.6.1 *Switching Costs*

According to Tétard and Collan (2009), *Switching Costs* are a part of the *Lazy User Theory* that was developed as an extension to "the Physical Law of Path of Least Resistance”, saying that the user will use the possible solution that requires the lowest level of effort from the user’s perspective, that still fulfils their need. The theory suggests that if a user has a multiple equally apt solutions to fulfil a need, the user will choose the solution which requires the least effort. Effort can be measured by amount of time, money or energy, or a combination of the three, and is often a perceived estimation from the user's perspective (Tétard & Collan, 2009). Switching costs are defined as "the cost associated with switching suppliers" (Thompson & Cats-Baril, 2002) and includes a multitude of underlying costs, such as relationship, learning and training, search cost, network, trust, risk of failure, information management or cost of switching back (Tétard & Collan, 2009).

Tétard & Collan (2009) argue that these costs are dynamic, for example learning cost which decreases when knowledge is accumulated over time. The users will assess the trade-off between previous investments and future possible investments and prefer solutions where parts of previous investments can be transferred and avoid lock-in that affects potential future switching costs. The authors implicate that if there is a solution that demands the least effort, it will always be chosen, but when that's not the case, e.g. when an individual does not use e-services even though it is more convenient, or choses to go to the grocery store instead of getting groceries home delivered, the transaction cost of changing from traditional methods is considered too big (Tétard & Collan, 2009).

4.1.7 **Step 4 & 5: Implementation & Confirmation**



Implementation happens when a decision-making unit starts using an innovation. Confirmation is established when a decision-making unit reinforces an innovation decision it has already made. The decision can be reversed; for example, through discontinuance - a decision to reject it after having adopted it, due to dissatisfaction or replacement with an improved idea. Vice versa, innovations can be adopted after a first rejection, through later adoption (Rogers, 1983).

As mentioned, Rogers' theory is mainly focused on end customers and it is of importance to remember that the adoption of innovations in organisations is more complex. It is argued that the diffusion of innovations of a more complex nature, for example innovations that are a part of a complex network like many information technology (IT) innovations, cannot fully be explained with the Diffusion of Innovation theory (Lyytinen & Damsgaard, 2011). Lyytinen & Damsgaard (2011) suggest that IT solutions are socially constructed and learning intensive which makes the diffusion harder to predict.

4.2 Summary of Chapter 4

This chapter has presented the Innovation-Decision Process from Rogers' Diffusion of Innovation framework, dealing with all stages from gaining knowledge, being persuaded, deciding on whether to adopt, implementing and confirming an adoption. Together with the Switching Costs phenomenon from Lazy User Theory, and the 9 x Effect from Eager Sellers and Stony Buyers, this will be the framework for analysing the second main research questions of this thesis and its subquestion; RQ2: *How can the diffusion of Industry 4.0 increase in the FMISS?* & RQ2a: *How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process?*

5 Perceptions of Industry 4.0 in the FMISS

In this chapter the empirical findings from the interviews are presented, from four case studies within the FMISS, as well as findings from two technology suppliers to the FMISS. The perceived adoption at the case companies will be presented, as well as perceived opportunities, barriers and challenges of Industry 4.0. This chapter will answer RQ1b: What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?

5.1 The Perception of Industry 4.0

Apart from one respondent not knowing what the fourth industrial revolution is, the definition of Industry 4.0 did not differ that much between the case companies. Three of them mentioned some version of IoT-interconnectability between devices. The respondent from the Vegan Producer was the one who felt most confident in their description of Industry 4.0, and mentioned several of the often-associated technologies, whereas the respondent from the Industrial Conglomerate sceptically called Industry 4.0 a diffuse concept and a bundle of small innovations. In the table below are quotes from the interviews with the case companies, translated from Swedish by the authors of this thesis.

Table 8. Definition of Industry 4.0 and the case companies

Definition	*Company*
"I have no knowledge of the concept"	The Liquid Producer
"I associate Industry 4.0 with the fact that everything will talk to everything."	The Industrial Conglomerate
"Industry 4.0 is nothing new, it is some small innovations that someone suddenly has chosen to bundle into a concept. It is a diffuse concept." "The B2B Producer has not come far in the implementation - since we don't have the solutions everywhere & linked."	The B2B Producer
"IoT in the industry is what Industry 4.0 is to me. I associate industry 4.0 with data, data collection, used to create more efficient processes, machines, AI and smarter robots."	The Vegan Producer

5.1.1 Case Company 1: The Liquid Producer

The first case company was The Liquid Producer and the interview was held with their Head of Production at their production site in southern Sweden. According to the Head of Production at The Liquid Producer, to have functional machines, which results in efficiency and cost effectiveness, is the main priority in their production. Product quality, hygiene and safety are other important factors (Interview 1, 2018).

Industry 4.0 Implementation

Today the Liquid Producer is using a Supervisory Control and Data Acquisition (SCADA)-system to control the production. Data is collected from the majority of the machines and is used to visualize the production through the SCADA-system. The system was introduced in the factory in 2012 and will be fully implemented approximately in 2022. There is a big amount of points of measurement, where sensors measure vents, objects and the temperature. According to the Head of Production, about three quarters of the production is fully automated (Interview 1, 2018).

Opportunities, Barriers & Challenges

The opportunities seen at The Liquid Producer is to further optimize the production and to increase the profitability. Moreover, they see big potential in getting better quality assurance and to increase the automation in the packaging department. To better meet legal demands and decrease their environmental impact are possibilities, and they see this happening through decreasing the amount of wastage, water- and energy consumption. Further, this might lead to good publicity concerning their focus on environmental improvement (Interview 1, 2018).

Some barriers that limit the adoption is the fear for lack of cyber security in cloud-solutions within management, especially from the older generation, according to the Head of Production (2018). There also exists a disbelief in sensors, through the opinion that they do not always show the truth since they can be programmed incorrectly and hence cannot be fully trusted. There's also a disbelief in automation, AI and machine learning and the Head of Production states that the plant is only as good as the person who built it (Interview 1, 2018).

According to The Liquid Producer (2018), the old machines are their biggest challenge today. Another big challenge is the difficulty to justify big investments related to the implementation of new systems. It is problematic to prove that the investment will be worth it before it is installed in the production, and the inability to try out solutions before the installation limits the adoption of new solutions. High costs for reprogramming in current systems is another challenge. Moreover, since the suppliers of the packaging material do not deliver it in such a way that automation is possible, it is a challenge to find other ways to make this part of the production more efficient. It is a challenge to find better solutions for filling the machine with packages and weighing the packages, to ensure that the right product batch enters the production in the right order and to perform quality assurance using new technology instead of people (Interview 1, 2018).

5.1.2 **Case Company 2: The Industrial Conglomerate**

The first interview (Interview 3, 2018) at Case Company 2 was held over telephone with the Plant Manager at one of The Industrial Conglomerate's production facilities in southern Sweden. This was later complemented with a phone interview with a Production Technician at the same site (Interview 8, 2018). According to the Plant Manager, management capabilities are the most important factor that distinguishes the company from other actors within the industry. The most important factors for the food industry in general is having a healthy and safe work environment. The second most important factor is quality followed by the production economy that can be summoned as cost, flexibility and time-to-market (Interview 3, 2018). According to the Production Technician at The Industrial Conglomerate, the most important factors are firstly quality, secondly productivity and thereafter, lean production (Interview 8, 2018).

Industry 4.0 Implementation

According to The Industrial Conglomerate, they have come far in the implementations of technologies from the third industrial revolution, but not far at all in the implementation of Industry 4.0. The production is fairly digitalised, the Plant Manager considers the collection of data and measuring points through sensors as extensive, but they lack the ability to optimize the production through smart usage and analytics of the collected data which can lead to real time actions. Today they measure overfilled tanks, rate for loading of machines, temperature, quality and leakages etc. The data is mainly used for alarms and is not visualized in graphs to much extent. The production is automated in constant flows, but not interconnected via internet through the entire lines. Therefore, the machine to machine (M2M) interface is not as intelligent as it could be, and no real time action in response to unforeseen incidents is taken (Interview 3, 2018).

Opportunities, Barriers & Challenges

The Industrial Conglomerate sees opportunities in implementing a real time data based measuring system of the food processing, instead of their current random sampling method. They see opportunities for implementation of more sensors for the internet interconnection of the entire production lines, according to the Plant manager (2018). They see an opportunity in an entire, connected system for overview and control of the production system. Better M2M communication could lead to a Just in Time (JIT)-production where intelligent machines could control the production. As a more futuristic opportunity, The Industrial Conglomerate sees value in a completely integrated, smart factory. Lately, there have been more initiatives from top management to automate more within the company, which acts as an internal driver for change. According to the Production Technician, Predictive Maintenance is seen as an opportunity. Furthermore, specific parts in the factory could be improved by further automation, for example, raw crop refining is partly performed manually which is inefficient and leads to more wastage. Another opportunity is to decrease the amount of freshwater that goes down the drain (Interview 8, 2018).

A barrier is that the experience of IoT and the technical development is low at the Industrial Conglomerate and in the food industry in general, according to the Plant Manager. The lack of action from competing companies does not justify investments, and thereby does not drive the development in the food industry in the way it could have.

The Plant Manager explains that management prioritizes other areas, and more urgent projects. The Industrial Conglomerate has gone through a process of mergers and acquisitions for nearly 30 years and is now in the process of merging factories and consolidating software. A challenge is old machinery that is not considered profitable to upgrade. Also, the incompatibility of Enterprise Resource Planning

(ERP) systems throughout The Industrial Conglomerate is a challenge. One internal barrier for the diffusion of Industry 4.0 is the difficulty to prove profitability of investments created by the economic system and procedure for investment decisions (Interview 3, 2018).

5.1.3 Case Company 3: The B2B Producer

The third case company of the study was The B2B Producer and an interview was performed over phone with the Team Leader of Automation at one of the production facilities in southern Sweden. At the production facility of the Team Leader of Automation, the most important factors for the production are flexibility and quality. Since different customers have very specific demands on the products, there is a high requirement of flexibility in the production. An important factor for competitiveness is the high quality of their produced goods (Interview 6, 2018).

Industry 4.0 Implementation

According to the Team Leader of Automation, the implementation of Industry 4.0 has not come that far, since technological solutions are not applied everywhere in the production, and the concept of Industry 4.0 aims at complete automation and total integration. Today, they have four control systems that they want to integrate into one system, the ABB 800xa, but the current systems are not compatible with each other. The Team Leader approximates that data is collected from almost all of the machinery, but not from the old machines which still has local panels. They are using a big number of sensors, on all valves to see if they are open or closed, on the pumps to see if they are on or off and on engines, to measure the temperature and pressure. The temperature is measured on the boilers to predict stops, something they have done since 2005. The Team Leader of Automation assesses the production to be almost completely automated and approximately half of the machine park to be interconnected. They started automating the production in the 1970s and interconnecting the machines in the 1990s.

The incentive to implement new technology normally comes from an internal technician that has found out about something they consider of interest to the production at The B2B Producer. This is then presented to management for approval and gradually implemented, first in small scale in less vital systems, to be upscaled eventually if the first implementation works well. This takes time, and the Team Leader of Automation believes that the process would be speedier and easier to implement if the first incentive was to come from management instead of the technicians. The factors that are investigated while choosing new technology is the safety of operation, investment cost and life cycle cost (Interview 6, 2018).

Opportunities, Barriers & Challenges

Today, far from all the data that could be used is taken advantage of. An opportunity would be to reduce waiting times in connection to sampling of product quality through in-line analysis with UV-sensors and Near InfraRed-sensors. Another opportunity is Predictive Maintenance, which would require less operator intervention, and less down time for the production. The Team Leader means that through more use of data, safer production could be obtained. Better interconnectivity between different parts in the production is another potential opportunity, which would enable quicker feedback loops. The biggest potential seen by the Team Leader of Automation lies in optimizing the energy consumption. Intelligent sensors and the introduction of AI are technologies he believes will be implemented in the future. Another opportunity is to create useful, working alarms out of the real time data and automatic responses to alarms from the machinery. Also, visual graphs of the factory throughput and the ability to access the information outside of the control room are potential opportunities (Interview 6, 2018).

Many suppliers have their own specific system that is not compatible with the systems of other suppliers, and the integration is a technical barrier. Another barrier is to find an external partner to perform the implementation. Other internal barriers considered by the Team Leader of Automation are lack of IT-security and knowledge about the new technologies within management and among technicians. Another barrier is that the industry is conservative to its nature and changes happen slowly (Interview 6, 2018).

Among the challenges of implementing new technologies are the associated high costs and time consumption of implementation. It is hard to see the value of further automation when The B2B Producer is only implementing small parts at a time, and a big challenge today is the inability to prove that the investment is profitable. There is a challenge in finding a good starting point in the production for the implementation. Another challenge is implementing solutions for old machinery. Historically the system has not been able to handle all the data and today someone still has to take care of and analyse the data, which is seen as problematic. Today the B2B Producer's plant facility experiences an abundance of unnecessary alarms that are not actionable or does not lead to something operators can or should do, which creates mistrust in Industry 4.0.

5.1.4 Case Company 4: The Vegan Producer

The forth case company of the study was The Vegan Producer and an interview was performed over the phone with the Plant Manager at one of the production facilities in southern Sweden. Since development of new products is the core activity at The Vegan Producer, flexibility and time-to-market are the most important factors in their production, according to the Plant Manager (Interview 7, 2018).

Industry 4.0 Implementation

The Plant Manager has heard of the concept Industry 4.0, but express not being fully familiar with the definition. He mentions IoT, smart robots and AI as important parts and has read about it in "Ny Teknik”, a Swedish technology magazine, but no machine supplier is selling the concept to The Vegan Producer to his knowledge. The Vegan Producer has not noticed any revolution and considers their implementation of Industry 4.0 to be very limited. However, they do collect a lot of data in their processes, according to him, the basic conditions for further Industry 4.0 implementation. The incentive to buy new technology often comes in connection to new product development which requires new machinery or processes. According to the Plant Manager they then set up a project organisation with a technical project leader to select the machinery and hire consultants to help with implementation and installation. The most important factors in the selection of new technology is food safety, hygiene, food quality and stability in the process (Interview 7, 2018).

The Plant Manager assesses that data is collected in the majority of the factory, mainly in filling machines where data is collected for follow up on stops and speed and real time data is presented in visual graphs in an interface developed by Qlik. This is already a built in feature in the machinery they buy. Data is not collected to the same extent in the processing part of the production since it is self-constructed - but has been extended with data collection. The Plant Manager does not consider there to be enough data collection on energy consumption. Data from machines is discussed in the morning meeting the following day - not in real time. Focus is on growth, therefore data collection and understanding of the current situation better in order to make improvements is not a priority, there isn’t enough time to focus on this right now. There is already a lot of sensors and data collection - the problem is the inability to do something with the data. The Plant Manager assesses about three quarters of the production to be automated, where the remaining fourth is kept manually operated in order to not lose flexibility or because the ROI is too small. For example, quality control is still performed manually. The Plant Manager does not see much potential in eliminating manual tasks - this has already been done with the "low hanging fruits" and further improvements should be on a system level (Interview 7, 2018).

Opportunities, Barriers & Challenges

Opportunities seen in Industry 4.0 are using data to understand the production better in general - in order to make improvements you need to understand the current situation. Another opportunity is seen in real time measurement on water and energy consumption in machinery in the entire factory. Being able to check the filters of wastage leaving the factory could help to meet legal requirements and in limiting the environmental impact. Predictive Maintenance, today performed through The

Production Line Supplier to some extent, could be further developed. Real time quality control, and control of products' pH-value and viscosity throughout the process, would also improve the production at The Vegan Producer (Interview 7, 2018).

The Vegan Producer sees a barrier in the fact that they have many systems that are incompatible today and no interface that is easy to use and understand for everyone. They have limited time and lack knowledge. According to the Plant Manager, the food industry is conservative - historically there has been no drive for production innovation through competition and limits for exportation has made global competitiveness less substantial. The suppliers of machinery or consultancies have to drive the development of more high tech production plants (Interview 7, 2018).

5.2 The Perceived Potential of Industry 4.0 in the Food Industry in Southern Sweden

5.2.1 **Industry 4.0 Implementation**

Table 9. Overview of Industry 4.0 implementation at the food manufacturing companies

Company	***The Liquid Producer***	***The Industrial Conglomerate***	***The B2B Producer***	***The Vegan Producer***
Industry 4.0 implementation	No knowledge of the concept	Not far	Not far	Not far
Driver for implementation of new technology	Increased volumes, often through new customer	Need for renovation in the factory	Discovery of new relevant technology by Production Technician	New product introduction
Important factors for implementation of new technology	Pay back-time Life cycle analysis focused on economical values	Profitability of investment Cost/benefit ratio Compatibility Technical reliability	Safety of operations Investment cost Life cycle cost	Food safety Hygiene Food quality Stability in processes

5.2.2 **Perceived Opportunities**

The opportunities seen in the manufacturing companies are mostly related to higher levels of automation, reduction of their environmental impact and improved product quality, but also other benefits such as optimisation, better working conditions and an improved overview of the production are mentioned by the respondents. In the following table all the opportunities, categorised in themes, can be seen.

Table 10. Opportunities of Industry 4.0 at the case companies

Opportunity	***Company***
Optimisation, through:	
Increased profitability; Effective cleaning; Cost reductions	The Liquid Producer
Decreased waiting times in connection to sampling of product quality; Avoiding of downtime through Predictive Maintenance	The Industrial Conglomerate
Quicker feedback loops; Better planning of production; Energy optimisation	The B2B Producer
Reduction of environmental impact, through:	
Decreased product wastage	The Liquid Producer, The Industrial Conglomerate
Decreased fresh water wastage; Improved water usage	The Liquid Producer, The Industrial Conglomerate
Decreased energy consumption	The Liquid Producer
Measurements of energy consumption	The Vegan Producer
Keeping water wastage within legal boundaries	The Vegan Producer
Mitigating risks associated with breakdowns, through:	
Predictive Maintenance	The B2B Producer, The Vegan Producer
Higher levels of automation, through:	
Automation of packaging	The Liquid Producer
M2M communication & Increased interconnectivity	The Industrial Conglomerate, The B2B Producer
Less manual interaction	The Industrial Conglomerate, The B2B Producer
More advanced sensors in production lines; Automated machine maintenance; Automated product (beetroot) handling	The Industrial Conglomerate
Use of more data; In-line analysis; Intelligent sensors / AI; Useful, working alarms; Automatic response to alarms;	The B2B Producer
Better working conditions, through:	
Increased safety for workers in the production (through sensors that stops machines if someone is too close)	The B2B Producer, The Industrial Conglomerate
Automation to unburden workers	The Industrial Conglomerate
Improved product quality, through:	
Improved quality assurance	The Liquid Producer, The B2B Producer

Real time quality control	The Liquid Producer, The Industrial Conglomerate, The B2B Producer, The Vegan Producer
Better production overview, through:	
Entire connected system for overview of production system; a common ERP system	The Industrial Conglomerate
Real time production overview/ control	The Industrial Conglomerate, The B2B Producer
Better understanding	The Vegan Producer
Increased speed and flexibility, through:	
Automatic production orders	The B2B Producer
JIT-production	The Industrial Conglomerate
Publicity in connection with environmental improvements	The Liquid Producer

5.2.3 **Perceived Barriers**

The barriers viewed by the respondents were mostly related to their specific industry, the food industry, and often related to the conservativeness and slowness of the industry. Two companies also mentioned cyber security as a big barrier and the lack of external partners that could help with the implementation of Industry 4.0. The perceived barriers are presented in detail below.

Table 11. Barriers of Industry 4.0 and the case companies

Barrier	***Company***
Data and cyber security	The Liquid Producer, The B2B Producer
Conservative industry	
The industry is conservative to its nature	The B2B Producer, The Vegan Producer
Low technical competences	
Speed of technology development experienced as too high to cope with	The Liquid Producer
Disbelief in sensors & automation	The Liquid Producer
Low experience of IoT/technical development in the industry	The Industrial Conglomerate
Competition	
Historical lack of competitive drivers; Mainly local markets; Overcapacity in production in Europe	The Industrial Conglomerate, The Vegan Producer
Strong competition, limited growth due to limited profit	The Liquid Producer
Vague "Industry 4.0"-name	The Vegan Producer
Rethink current business	The Vegan Producer

Lack of external partner for implementation; Lack of external drive through supplier	The B2B Producer, The Vegan Producer
Integration barriers, such as:	
Incompatible systems between/with suppliers	The B2B Producer, The Vegan Producer
Incompatible ERP/SCADA systems	The Industrial Conglomerate, The Liquid Producer

5.2.4 Perceived Challenges

When the respondents are asked about what the biggest challenges are for them with Industry 4.0 implementation, the answers differed from challenges related to human resources, such as workforce competence and management challenges, to technological challenges such as integrating machinery and systems. But everyone agreed that the investment in money and time, both directly and indirectly associated with Industry 4.0, was the biggest challenge for them. The challenges are presented in the table below.

Table 12. Challenges of Industry 4.0 and the company mentioning it

Challenge	***Company***
Workforce challenges, such as:	
Lack of the technical competences/knowledge within the company	The B2B Producer, The Vegan Producer, The Industrial Conglomerate
Lack of trust in technical capability	The Liquid Producer
Management challenges, such as:	
Lack of knowledge about the new technology within management	The B2B Producer
Managements prioritizes other areas; Lack of incentives for top management to automate more	The Industrial Conglomerate
Industry 4.0 not a priority	The Vegan Producer, The Industrial Conglomerate
Investments challenges, such as:	
Costs of changing an entire system; big up-front investments	The Industrial Conglomerate, The Liquid Producer
Costs of storing data	The Liquid Producer
Cost of implementing new technology; Cost of Predictive Maintenance solutions	The B2B Producer, The Vegan Producer
Profitability of investment; To see that the new technology delivers what it has promised	The Industrial Conglomerate, The Liquid Producer
Economic justification when implementing small parts at a time; Hard to find a good starting point for implementation	The B2B Producer

Time of implementing new technology	The B2B Producer
Time to implement changes; Too much data, too little time to analyse it	The Vegan Producer
Integration challenges, such as:	
To integrate the new machines in the plant successfully	The Industrial Conglomerate
Integration of different technologies/systems	The B2B Producer
Old machinery not profitable to upgrade	The B2B Producer, The Industrial Conglomerate, The Liquid Producer
Interface that is easy to understand	The Vegan Producer
Inability challenges, such as:	
Historical inability of system to handle data; Current inability of system to take care of and analyse data; tables/graphs that make sense and are usable	The B2B Producer, The Vegan Producer
Factory not built for the demands of today (straighter lines)	The Industrial Conglomerate
Flexibility challenges, such as:	
Loss of flexibility because of advanced reprogramming needed when changing flows	The Vegan Producer

5.3 Technology Suppliers

5.3.1 **The Machine Component Supplier**

The Machine Component Supplier is a global company with the Swedish headquarters in Jönköping. The respondent from the company is a part of the sales crew for automated solutions in the southern Sweden region. The Machine Component Supplier sells physical robots and the intelligence needed to operate them, including the safety routines and other services required, and they have customers such as The Production Line Supplier. Moreover, they sell mechanically driven assembly lines connected to the robots. The Machine Component Supplier has customers within a broad variety of industries. In the south of Sweden their customers consist of a high representation of companies within the food & beverage industry, whereas the highest concentration globally is within the automotive industry (Interview 2, 2018).

Opportunities, Barriers & Challenges

According to The Machine Component Supplier, one of the main drivers for the adoption of Industry 4.0 solutions is a trend for business model innovation. The biggest internal driver today in companies is economic incentives in relation to automation. Interconnection is not of interest from a market perspective in manufacturing companies. Today there is still a lot of “easy” jobs performed by humans that the companies find incentives in removing, such as loading finished products into boxes etc. The Machine Component Supplier is currently not collecting and analysing data to a big extent, except the local data collection at the customers’ facility in order to run the robots and assembly lines but see a large potential in doing so in the future.

The biggest potential with a centralized collection and analysis of data is seen as the possibility for Predictive Maintenance. Collection of data concerning the current, vibrations, heat etc. could be analysed centrally and send out an alarm or message to the customers’ factory on when measures has to be made concerning the machine. According to The Machine Component Supplier, the technique to perform Predictive Maintenance has existed for some time, but the incentive to do so is created by the insight about an opportunity to change business models and the way you charge for your products or services. Further, The Machine Component Supplier sees a potential in mitigating the energy consumption through further automatization and interconnection as well as predicting production stops. (Interview 2, 2018)

A mentioned barrier is the general conservative mindset in the manufacturing industry. The Machine Component Supplier believes that another barrier is the lack of reference projects, which still makes Industry 4.0 solutions into buzzwords that are easy to ignore. The Machine Component Supplier does not look at Industry 4.0 as a revolution - but when there is a different openness with sharing of data this might change. There are third parties that can collect data from all sources through cloud solutions. But a barrier for further adoption exists due to the reluctance to share data between organisations, and the data is collected through various different, non-compatible protocols. Since a factory has machinery from dozens of organisations, there still does not exist one integrated platform for data collection, analysation and visualisation in use in a factory. According to The Machine Component Supplier, the machine producer would be the one acting on the Predictive Maintenance alarms- collecting alarms from machinery from various organisations. For this to happened, the machine producer must understand the value in a business model based on this service offer or the possibility not to sell the machinery but the actions the machinery performs. In this way they would become the problem owner of production down time and the incentives for Predictive Maintenance would increase (Interview 2, 1018).

The Machine Component Supplier does not think Industry 4.0 is substantial enough as a concept today, and that one challenge is the difficulty to explain the quantitative gains but rather focuses on qualitative measures such as flexibility and quality. Today it is hard to promise a ROI. But in five years’ time The Machine Component Supplier thinks that the existence of more reference projects will facilitate and that a market pull attitude will exist. They see a problem in convincing both top management and production management about the value of the solutions in order to legitimate an investment. Another problem is the demand for integration over departmental boundaries when IT and production have to cooperate (Interview 2, 2018).

The maturity for implementation of Industry 4.0 solutions within the food industry is pretty low today. The automotive industry is more mature - since they have a higher demand for flexibility with a high variety of modules to satisfy a broader product portfolio. Today Industry 4.0 solutions are sold through technology push. The end customer, for example The Liquid Producer, has yet not seen the value in Industry 4.0 solutions. Solutions from The Machine Component Supplier make up a disappearing part of the end customers' purchasing, while they have a bigger impact with their direct customers, like The Production Line Supplier. The machine producers, for example The Production Line Supplier, are more mature (Interview 2, 2018).

5.3.2 The Production Line Supplier (Services)

The Production Line Supplier has three parts, processing machines, packaging machines & materials and after sales services. The respondent is from the aftersale service department. When the Production Line Supplier started their business, the competitive landscape looked very different. They were the only ones with their idea and with a patent. Today, there are many other companies with a similar offer. This is one reason that has inspired The Production Line Supplier to focus more on competing with the services related to their machines. Historically, the service in relation to the machines was something The Production Line Supplier included when selling the machinery, and the services were not that complicated to perform. Nowadays, with more advanced machinery, and a huge variety of machine types in different customers machine parks, it is no longer possible to perform service in the same fashion (Interview 5, 2018).

Opportunities, Barriers & Challenges

The Production Line Supplier needs experts to perform the service, but since it is not an option to have enough people with specific knowledge of each machine, an interface has been created where the service engineers can get help to perform service through a mobile application. This means that global communication is possible, where knowledge is spread easily and efficiently, and no expert has to be on site to help fixing problems. The Production Line Supplier believes that there is more value to gain from their current investment in better service, for example through Predictive Maintenance. When they are visiting customers to install the machinery they have noticed that finding out where to place the machinery is an issue that is fixed with manual work. A potential spin off is to make a cad drawing of the factory and see how to optimize the positioning of the machines, that is enabled by the connectivity aspect of Industry 4.0 (Interview 5, 2018).

A barrier is the lack of reference cases. Today, the solution is to work with more progressive customers in order to create reference cases that hopefully will inspire more conservative customers to demand the new solution. One driver for The Production Line Supplier to invest in Industry 4.0 solutions is to create a value offer to their customers where The Production Line Supplier is their customers' most desirable partner. The trust from customers is an important factor in order for this to work. An external barrier is the political question about who will own the data. The Production Line Supplier sees as one of the biggest barriers to further adoption in the food- and beverage industry as the aspect that these are generally very slow moving industries. A line in a factory can work for decades, and there are a lot of lines in operation where more modern solutions are available, but the investment made in the old line rules out investment in the new technology. This makes the implementation of changes slow in comparison to other industries (Interview 5, 2018).

A challenge for The Production Line Supplier is to justify investment for solutions when the potential future spin offs are what will create the biggest value. Since the technology development is happening so fast, there is no way of knowing what the leading technologies in five years will be. These aspects make it a big risk being a leader of the development. The acceleration into the more digitized age has to happen "in the right way", with the right partners and investments in the right technology. It is very hard to foresee whom and what this will be.

Another challenge is for The Production Line Supplier's customers to see the value in a new service offer. The service and the investment in new service systems is costly. Since the productivity can increase with less down time and optimized production, The Production Line Supplier will charge more for each unit produced. On paper this would be a win-win for the customer. But there is still an unwillingness from the customers to change the business model and payment, especially when no reference cases exist (Interview 5, 2018).

5.4 The Perceived Potential of Industry 4.0 in the FMISS According to the Technology Suppliers

5.4.1 **Perceived Opportunities**

The opportunities seen in the FMISS by the technology suppliers are related to creating new business opportunities, higher levels of automation, reduction of their environmental impact, optimisation, and mitigating risks associated with breakdowns. In the following table all the opportunities, categorised in themes, can be seen.

Table 13. Opportunities of Industry 4.0 and the company mentioning it, from the supplier perspective

Opportunities	***Company***
Creating new business opportunities, through: *Business model innovation*	The Machine Component Supplier
Reduction of environmental impact, through*: Mitigating the energy consumption*	The Machine Component Supplier
Higher level of Automation, through; *Automation of manual tasks*	The Machine Component Supplier
Mitigating risks associated with breakdowns, through: *Predictive Maintenance, Predicting production stops*	The Machine Component Supplier, The Production Line Supplier
Optimisation, through: *Optimizing the positioning of the machines, Predicting production stops, Global communication*	The Production Line Supplier, The Machine Component Supplier

5.4.2 **Perceived Barriers**

Some barriers identified by the technology suppliers were related to the food industry, but also macro-barriers such as cyber security. All mentioned barriers are presented in detail in the table below.

Table 14. Barriers of Industry 4.0 and the company mentioning it, from the supplier perspective

Barrier	***Company***
Data and cyber security; *Establishing who will own the data, Non compatible protocols, No existence of one integrated platform*	The Machine Component Supplier, The Production Line Supplier
Conservative industry; *The food manufacturing industry is very slow moving to its nature/ Conservative mindset in the manufacturing industry*	The Machine Component Supplier, The Production Line Supplier
Technical challenges; *Inability to predict future technology*	The Production Line Supplier
Vague "Industry 4.0"-name; *Buzzword*	The Machine Component Supplier
Rethink current business; *The food manufacturing industry does not see the value in a new service offer; The food manufacturing industry is unwilling to change their business models*	The Production Line Supplier

5.4.3 Perceived Challenges

Workforce challenges, business challenges and lack of external partners for integration was mentioned by the Machine Component Supplier. Both technology suppliers agreed that the investment challenges, management challenges and integration challenges exist. The challenges are presented in the table below.

Table 15. Challenges of Industry 4.0 and the company mentioning it, from the supplier perspective

Challenge	***Company***
Workforce challenges, such as:	
Shift in workforce from manual work to IT; need for more IT knowledge	The Machine Component Supplier
Investments challenges, such as:	
Lack of reference projects	The Machine Component Supplier, The Production Line Supplier
Difficulty in communicating the value of investments; to exactly determine a return of investment; for customers to understand the benefits of Industry 4.0; difficulty to explain the quantitative gains of Industry 4.0	The Machine Component Supplier, The Production Line Supplier
Companies does not want to be first mover; need for reference cases	The Machine Component Supplier
Lower value in doing the transition step by step	The Machine Component Supplier
Long-term focus on investments	The Production Line Supplier
Management challenges, such as:	
Convincing management of the value	The Machine Component Supplier, The Production Line Supplier
Integration challenges, such as:	
Demand for integration over departmental boundaries	The Machine Component Supplier
Reluctance to share data between organisations	
Too many platforms/systems	The Machine Component Supplier

Technology lock-in	The Machine Component Supplier
Unwilling to exchange functioning machines	The Production Line Supplier
Business challenges, such as:	
Getting machine supplier to sell the output instead of the machine	The Machine Component Supplier
Lack of external partner for implementation: No external party understanding the value in a business model of being an integrator	The Machine Component Supplier

5.5 Summary of Chapter 5

This chapter aims at answering the subquestion RQ1b*: What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?* Moreover, in order to better understand the perception at the case companies, two technology suppliers in the external value chain of the food manufacturing companies has given their view of the opportunities, barriers and challenges. In order to provide a full overview of the result from chapter five, a summary has been made in the following table:

Table 16. The opportunities, barriers and challenges for Industry 4.0 diffusion in the FMISS, according to the case companies and the technology suppliers

	According to case companies	***According to technology suppliers***
Opportunities for Industry 4.0 diffusion in the FMISS	• Good publicity, connected to decreased environmental impact • Optimisation of processes, production and systems • Reduction of environmental impact • Higher level of automation that self-organises and self-synchronise • Mitigating risks associated with breakdowns • Better working conditions in terms of safety and career paths • Better production overview • Improved product quality • Increased flexibility and speed	• Business model innovation • Automation of manual tasks • Mitigating energy consumption • Predicting production stops • Global communication • Predictive Maintenance • Optimizing the positioning of the machines

	• Cost benefits • Improved JIT-production	
Barriers for Industry 4.0 diffusion in the FMISS	• The food industry is a conservative industry • Lack of competition to drive change in the industry • Vague “Industry 4.0” name • Rethinking of current business • Lack of external partner for implementation • Low technical competences in the industry • Data and cyber security • Integration	• Conservative mindset in the manufacturing industry • Lack of reference projects • Industry 4.0 - buzzwords • Reluctance to share data between organisations • Non-compatible protocols • No existence of one integrated platform • Lack of reference projects • Inability to predict future technology • Establishing who will own the data • Big investments required • The food manufacturing industry: • is a very slow moving industry • does not see the value in a new service offer • is unwilling to change their business models
Challenges for Industry 4.0 diffusion in the FMISS	• Inability to handle data or technology • Workforce challenges related to competencies and organisation structure • Investment challenges • Integration of systems and machines • Management does not prioritise or see the value • Flexibility challenges	• No external party understanding the value in a business model of being an integrator • The difficulty to explain the quantitative gains of Industry 4.0 • Convincing management of the value • demand for integration over departmental boundaries • Justify investments

Two key takeaways from this chapter is that the abstraction level of mentioned opportunities, challenges and barriers is low and that improving business as usual is what the food manufacturing companies have in mind with Industry 4.0. The technology suppliers see value in changing the structure of how business is made today, but see this mindset of keeping business as usual in the food manufacturing as a barrier to change.

6 Differences Between Theory and Practice

In this chapter the empirically collected data will be compared to the findings in literature, and the differences will be analysed. The first part of this chapter, 6.1, will answer the subquestion RQ1c: What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS? The result from 6.1 will then be analysed in 6.2 in order to answer RQ1: If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS? The chapter ends with a summary where the findings are displayed.

6.1 Differences and Similarities

In this chapter the differences and similarities in answers between the respondents at the case companies and the researched literature are presented.

6.1.1 **Opportunities for Industry 4.0 in the FMISS**

6.1.1.1 *Commonly Expressed Opportunities*

Optimisation

One of the most mentioned opportunities in literature and by the case companies was optimisation of processes, production and systems. The optimisation, based on big data, better analysis and automation, will lead to a higher efficiency, a maximisation of resource utilisation, decreasing costs and an increased profitability in the production. Some of the respondents also mentioned that the planning of the production would be improved and that there would be a decrease of downtime. Optimisation is perhaps the highest abstraction of opportunities, and can be viewed as an umbrella for the rest of the opportunities.

Reduction of Environmental Impact

On the topic of optimisation and reduction of environmental impact as opportunities of Industry 4.0, both academia and practice are agreeing, even though the case companies bring up some opportunities on a lower abstraction level, as effective cleaning, reduction of waiting times in connection to sampling of product quality and less fresh water wastage. Meanwhile the academia is focusing more on “increased resource productivity” or “better resource allocation” and concepts such as “dynamic self-optimisation” and “sustainable value creation”, that might include the above mentioned practical opportunities.

Higher Level of Automation

In both academia and practice, higher level of automation is seen as an opportunity, except for one of the respondents that does not trust automation. The third industrial revolution introduced automation and digitalisation. In Industry 4.0, the revolutionary factor is *autonomous* automation, driven by cognitive data, and both empirically and theoretically the integration of automation, interoperability and intelligent machines are mentioned as opportunities. Furthermore, theoretically, the new opportunities are through self-synchronisation, synchronisation of the entire value chain, products controlling their own manufacturing process, item tagging and machine learning. Many of the respondents refer to automation as the possibility of sensor driven alarms and automatic responses to alarms. There is also a hope for further automation to cover for a limited and expensive workforce. Interestingly enough the respondents only mention that automation will cover for the workforce they are unable to hire, not that it will lead to downsizing the operational staff. This possibility is however mentioned by both literature and The Machine Component Suppliers.

Mitigating Risks Associated with Breakdown

In theory, there are opportunities of mitigating risks associated with breakdowns, through business processes adjusted according to breakdowns in the value chain, autonomation (automating the manual processes to include inspection) and Predictive Maintenance. Three out of four case companies mentioned Predictive Maintenance on this theme, and quite a lot of their confidence in Industry 4.0 was connected to this theme, as something revolutionizing for the industry. This was also what the two machine suppliers saw as the biggest chance for new profitable business models, since breakdowns are very costly for their customers.

> *"[Increased interconnectivity] would help to measure the media use of one department, for quicker feedback loops when something is wrong, as a higher usage of steam might indicate a fault etc". [own translation] The B2B Producer*

The quotation of The B2B Producer explains how an opportunity of interconnectivity creates a “chain reaction” of optimisation and mitigation of risks associated with breakdowns.

Better Working Conditions

A higher level of safety for employees and less monotonous work through improved man-machine interfaces are lifted both theoretically and in practise on the theme of better working conditions. But the theoretical opportunities go beyond this, painting a picture where workers are productive longer with flexible career paths, a better work-life-balance, higher wages, and a transformation of the traditional industry and value chain roles, with age-appropriate workplaces and virtual organisations. This sounds very promising, the question is of course *how* it will happen, considering the conservative mindset and culture in most organisations.

Improved quality assurance, through improved product quality, optimised quality of production and through real time quality control, are things mentioned by all case companies. For example, the B2B Producer mentions that it would be great to analyse the products in the production lines, since it would make it easier to ensure quality.

> *"Real time data about the food processing instead of random sampling would save time and make it easier to meet legal requirements" [own translation] The Industrial Conglomerate*

Better Production Overview

The real time control would also lead to a better production overview, another stated opportunity by both literature and practitioners, through simulation of processes or an entire connected system overviewing the production system. The latter is exemplified with a scenario of having a common ERP system, real time production overview and real time controls - with the hope of gaining better understanding of how their production works in order to make improvements.

> *“You can't improve without understanding, and you can’t understand without measuring.” [own translation] The Vegan Producer*

Earlier research and white papers believe the increased understanding to be best gained by applications of simulations, such as digital twins, a virtual replica of a physical machine, process or even a full plant where settings or events can be tested. In this way the overview is not only of the present but also of the future.

Improved Product Quality

Through the use of real time quality control and improved methods of quality assurance a higher level of product quality can be achieved, something mentioned by both literature and case companies.

Increased flexibility and speed

Increased speed and flexibility will, according to literature, be achieved through modular production, making operations agile, flexibility in business processes and production, distribution efficiency and smart reallocation of orders. Automatic production orders are something mentioned by one case company. JIT-production was mentioned in literature and by The Industrial Conglomerate, which can be matched with load balancing and stock reduction which are opportunities found in the literature research.

> *"Automatic production orders from the production system with information about origin and content would be helpful". [own translation] The B2B Producer*

Cost Benefits

Cost benefits lie in the base of almost all other opportunities mentioned by both literature and the respondents, but are explicitly mentioned through cost cuts on energy, personnel and operations. The short or long term financial benefits of an investment is always the foundation of a choice to invest (Investopedia, n.d.).

JIT-production

Both literature and one of the case companies saw a possibility to improve the processes behind JIT-production (Just in Time) in a more seamless way with the help of the Industry 4.0 technologies.

On Demand Production

An opportunity mentioned by several sources is on-demand production, through customer specific production, produced to the same cost as mass production, but with business processes adjusted according to demand. This concept is sometimes called Batch Size One or Mass Customisation and is enabled by several of the technologies included in the fourth industrial revolution, such as Big Data, modular production and vertical and horizontal integration. No one from the case companies discussed this, but it was mentioned by The Production Line Supplier, perhaps because this is something covering the whole production and business process, and thereby it is an opportunity that employees close to production does not think about or consider.

6.1.1.2 *Opportunities only found in earlier research*

Creating new business opportunities

A lot of value of Industry 4.0 is seen in the ability to create new business opportunities, through new value opportunities, enhancement of the delivery of competitive advantage, gaining access to new business and operating models as value-adding cooperation, R&D projects & training, more innovation and better cooperation between employees and business partners is introduced. No respondent mentioned this an opportunity, but one company mentioned this as a barrier, which is probably, once again, due to the fact that it also covers the business part of the value chain.

Optimised Decision Making

Another opportunity by earlier research is seen in optimised decision making. This goes hand in hand with increased understanding but is different in the way that the decisions mentioned are more business-oriented and high-level, than the day-to-day operational decisions mentioned by the practitioners and literature when they discussed increased understanding. Optimised decision making might lead to decisions regarding the whole production chain, and are, according to literature, built upon Big Data and algorithms, which optimises the decisions.

6.1.1.3 *Opportunities Only Mentioned in Interviews*

Publicity

Publicity in connection with environmental improvements is seen as an opportunity by one of the case companies.

> *"The possibilities I see [with new technologies] is publicity through reduction of our environmental impact, energy savings, which will also show in our financial result, through social media and commercials." [Own translation] The Liquid Producer*

Together with stronger customer opinions that also have a way of resonating and spreading through social media and influencers, the importance of a strong brand is increasing. Especially in the Swedish market, a big trend towards environmental consciousness is seen, and a low environmental impact is a selling point. One example of this is Max Hamburgare, a Swedish fast food chain who have a certain symbol for their menu options with low carbon dioxide emissions (Max, n.d.). To be able to save energy or water would be a great publicity opportunity for the food manufacturing companies. The publicity aspect is not mentioned by literature, who do recognise that environmental winnings can be made, maybe because it differs from each industry how big this impact would be, or maybe because it could be seen as Greenwashing, i.e. promoting a company as eco-friendly because they have green initiatives even though the company's main operations are bad for the environment.

6.1.2 **Barriers for Industry 4.0 Diffusion in the FMISS**

6.1.2.1 *Commonly Expressed Barriers*

Low Technical Competences

A low experience of IoT and technical development in the industry in general might correlate with that the speed of technology development is experienced as too high to cope with, and that there is a disbelief in sensors and automation in the case companies.

> *"Sensors does not always show the truth, they can be programmed wrong". [own translation] The Liquid Producer*
>
> *"The plant is only as good as the person who built it". [own translation] The Liquid Producer*

In earlier research it is often commented that there is generally a low competence level of workers in the industries, but this is seen more as a challenge that is frustrating but can be overcome, than a barrier preventing Industry 4.0 technologies to be adopted at all.

Data and Cyber Security

Cyber security is a concern both in practice and research, and in a consultancy survey of managers it is lifted as the biggest concern with implementation of Industry 4.0. Cyber security as a term is as mentioned interpreted to cover multiple things; the reliability of transferring data through a cloud instead of in servers, the risk of an outsider hacking into your data connection and shutting it down or interfering with the manufacturing processes, or the risk of an outside company being able to steal your data through the internet. The first fear is connected to the barrier of comprehensive broadband infrastructure mentioned above. The two latter ones are more related to the distrust of the security solutions technological stability and the suspicion of others. The Machine Component Supplier mentioned that data sensitivity is one of the big barriers, and many companies are reluctant to share their data with other parties even though it could create a lot of value for them, for example by sharing orders with a supplier’s supplier so that they have time to produce accordingly. The concern of data security and sharing data is also voiced by two of the companies. This could probably be because of the traditional way of doing business where concepts such as company secrets or secret ingredients still exist. This is a mindset that will take time for the industries to change. At the same time, technology is moving at such speed that it is difficult to keep up, and most of the decision-making positions are held by older people. The Liquid Producer on the topic of Management's Cybersecurity fear [own translation]:

"Old people don't trust new technology that much"

6.1.2.2 *Barriers Only Mentioned in Earlier Research*

Resistance Against Manual Work Being Automated

Resistance against traditional manual work being automated is lifted as a barrier but wasn't mentioned by any of the respondents at the case companies. This might have several reasons; many of the respondents mention that they don't see the Industry 4.0-technologies such as AI or big data as taking over the jobs of the employees, even if they might take over some of their more repetitive tasks. Another reason is that they do not see a 100 % Industry 4.0-implementation as realistic, even though a factory where you put in the raw material in one end and get the finished product in the other is mentioned as a dream scenario by The Industrial Conglomerate.

Lack of Comprehensive Broadband Infrastructure

Comprehensive broadband infrastructure is important since that in order for the interconnection of Industry 4.0 to happen the broadband has to be reliable, not only in the plant facility but also in all other locations that need to retrieve or send data to the plant. In many parts of the world, internet connections are still shaky or object to disturbances, making this a barrier for full Industry 4.0 roll-out. In a Smart factory, a short broadband cut could mean very costly downtime. This barrier was mentioned by the scholarly literature, but not by the respondents. This could be because of the fact that internet connections are usually very good in Sweden, or that the food manufacturing industry is mainly locally based with little or no global partners, which means that they might not perceive this as a barrier.

Lack of Standards and Norms of Data Ownership

The lack of standards and norms within Industry 4.0 is a barrier for the development and diffusion of Industry 4.0 technologies and applications, mentioned by literature. This is also in connection to the ownership of data in the supply chain, especially when it comes to integrated value chain where more than one company are sharing data about customers, products or processes. This area is only mentioned by literature.

Hype of Industry 4.0

There is a hype of Industry 4.0 as a whole but also for each of the technologies which can create a barrier for Industry 4.0 adoption, according to earlier research. This is mainly because hype makes it difficult to see the true value of a technology, and makes companies adopt them with far too high expectations of the investment return, which then leads to bad reputation of the technology when it does not deliver the result that was expected.

6.1.2.3 *Barriers Only Mentioned in Interviews*

Conservative Industry

The respondents mentioned several industry specific barriers to Industry 4.0, and especially the conservatism of the food industry was mentioned by several respondents which disfavours development. The technology suppliers also mentioned the conservatism of the industry as the biggest obstacle for the diffusion of Industry 4.0 in the food manufacturing industry.

Competition

> *"The lack of action from competing companies does not justify investments or drives development". [own translation] The Industrial Conglomerate*

The low competition and lack of competitive drivers are mentioned as barriers from two of the case companies, that mean that the business landscape is made out of mainly local markets without the effects of globalisation. Contrary to other respondents' opinions, one respondent claimed that there actually was strong competition in their industry, which was limiting growth due to the limited profit in the industry. The expression of high competition in one of the case interviews might indicate that some changes have already happened and that a major change is due so that the food industry companies will have to develop at a higher rate than historically. It could also refer to different kinds of competition, where high competition leaves small margins but does not drive high tech implementation.

Vague "Industry 4.0" Name

The vagueness of the name "Industry 4.0" was considered a barrier for one of the companies, since it is difficult to adopt a concept when you don't know what it entails.

Rethink Current Business

People and companies have to rethink their current business in order to get the value of Industry 4.0, and this is mentioned as a barrier by case companies, meanwhile the access to new business models is seen as an opportunity in research. However, the scholarly research is unambiguous and also mentions the risk of endangering existing business models and the fear of developing solutions that lack market relevance. The only company mentioning the potential in Industry 4.0 regarding changes to the business plan was The Production Line Supplier, as they are planning to move from a product focused to a service focused value offering.

Lack of External Partner for Implementation

Many of the respondents expressed a need for external help with implementation of Industry 4.0 applications, especially since they experienced insufficient technical competence within the companies and that the concept was vague. One of the barriers of Industry 4.0 implementation was therefore to find external partners to help with driving the transformation.

6.1.3 Challenges for Industry 4.0 Diffusion in the FMISS

6.1.3.1 *Commonly Expressed Challenges*

Workforce Challenges

One worry shared by both literature and the respondents is that the current workforce does not have enough qualification or technical competencies to support the complexity of Industry 4.0-solutions. There's also a concern that the job market will suffer from a shortage of technical know-how in general, when all companies are looking to in-house the knowledge.

Moreover, according to some of the respondents it is also important that all system interfaces in the Industry 4.0-setting are easy to understand for everyone, no matter the educational background or experience. In the factories of today, most ERP- or control systems are handled by a select few, with deep insight into how the programmes work, and thereby the ease-of-use of the interface design does not have to be that high. In a Smart Factory every employee should be able to utilise the system interfaces.

The changing tasks at the companies, and thereby restructuring of organisations, is also mentioned as a challenge. The Machine Component Supplier exemplifies this with the IT-department having to change role and also working with and supporting production to a larger extent. This will require a lot of transparency in systems, but also a retraining of the existing workforce as well as a change of mindset throughout the organisations.

Investment Challenges

Beyond the cost, the profitability of an investment is something respondents raise as problematic. There seems to be a general disbelief in Industry 4.0-solutions concerning whether or not they will deliver the financial benefits that is promised.

In literature it is seen in another way - where the focus instead is on the issue that companies generally have a deceptive short-term focus on investments, hindering them from investing in Industry 4.0. At the same time, research also acknowledges that it is a problem that the efforts needed for implementing Industry 4.0 are too big, both in terms of time, money and standardisation.

> *"It is cheaper to move a pallet from A to B with a truck, than to buy a robot to do it" [own translation] The Vegan Producer*

When it comes to investments, it is also a challenge for companies to know where to start with Industry 4.0, something that the respondents and earlier research agrees on. According to the Machine Component Supplier it is difficult to sell or explain the concept when there's nothing concrete to exemplify with, and it takes a lot of convincing to get all of the different forces within a company, the C-suite, IT-manager, production manager and so on, on board and wanting to invest.

> *"Yesterday: Wine & Dine. Today: Quantitation. You have to support the profitability claim with data." [own translation] The Production Line Supplier*

The slowness of adopting the technologies in the food industry is mentioned by the respondent at the Production Line Supplier, who means that the culture of choosing a supplier has developed from a more relationship-based interaction to a more data-driven sell-pitch. Their customers want to know how many percent more effective their product is in comparison to the existing solution, or even better exactly what the return of investment will be. This means that reference cases are gaining importance in the machine supplier sector, a view shared by The Machine Component Supplier, which further pushes the importance of quick-win projects, i.e. small investments with a big relative return, rather than projects that would help the companies in the best way. The Production Line Supplier sees an increase in firm sizes in the food industry where the big players keep on growing and therefore can have higher demands on their suppliers.

Integration Challenges

After the interviews it also became apparent that there is a want to integrate the new technologies with the existing machinery in the plants, which can be problematic. Making the integration successful and economically profitable are mentioned as challenges, but also being ready to exchange existing machinery. The Production Line Supplier mentioned a case where they had developed a machine that was producing cheap, sustainable and easy-to-ship packaging, much better than the existing tin cans, but no one wanted to buy it since they already had installed lines of tin cans in their factories (Interview 5, 2018). The investments in manufacturing machinery are huge, long term and usually affects a big part of the plant, and there is no incentive big enough to exchange something that is still working.

Apart from the reluctance of exchanging machinery, there is also sometimes a problem to integrate the technology with existing machinery. Some respondents answered that the new systems or technology add-ons would not be possible to introduce into their older machinery, especially when it came to interconnectability or cloud solutions. Further, the systems can be incompatible which makes it even more difficult to integrate. Literature mentions that there is a challenge in working out a viable plan for coordination and integration of the multitude of technologies.

Management Challenges

Both literature and the case companies mention challenges related to management. The respondents at the case companies acknowledged that there is a tendency from management to prioritize other areas than Industry 4.0-initiatives, and that hence there is a lack of incentives from top management downwards in the organisation for adoption. The case companies also mentioned a lack of knowledge within management as a challenge for Industry 4.0 diffusion, which was echoed by literature who sees a lack of commitment and capabilities in order to make necessary transformation and define appropriate strategies.

Flexibility Challenges

Challenges in connection to flexibility were discussed both in literature and in the interviews. The respondents expressed a concern with integrating too much technology into the operations that then needed to be reprogrammed when for example flows were to be changed. In literature, the flexibility loss that comes with standardisation was argued to be a challenge.

6.1.3.2 *Challenges Only Mentioned in interviews*

Inability Challenges

There is a historical inability to handle and analyse data within the systems at the case companies, as well as making it useful and actionable, which several of the respondents discussed. The issue of the factories not being built for the perceived demands of Industry 4.0 technologies was lifted as a concern.

6.1.3.3 *Challenges Only Mentioned in Earlier Research*

Emotions and Mindset Challenges

An interesting challenge only mentioned by earlier research was that there are strong emotions connected to the concept Industry 4.0. The hype and over-excitement of the concept was considered problematic and could also result in an exaggerated sense of urgency and panic about getting onboard on the Industry 4.0-train. These mindset challenges were not mentioned by any of the respondents.

Strong National Focus

In one of the research literature a strong national focus was mentioned as a challenge, since it prevents companies from thinking in integrated globalised value chains.

Business Challenges

One challenge that literature lifts is related to whether current business models might be endangered and cannibalised by newer Industry 4.0-enabled business ideas. At the same time there is a fear of developing solutions that are too high tech and lack market relevance. To make research into actual technology is also a challenge for industries that provide Industry 4.0 technologies.

Ad Hoc Challenges

By literature it was emphasised that there is a correlation between having a larger part of the plant connected and getting more value out of Industry 4.0. This means that not only is it difficult to predict the value of an investment, because of the network effect, but also that it is important to think holistically about the implementation, and to avoid ad hoc efforts. Ad hoc efforts don’t only lead to a disorganised integration with unreached potential, but perhaps also to system lock-ins and clashes since there are no standards. Therefore, it is very important to have a unified approach to Industry 4.0 integrations.

Required Transparency

Finding suitable external partners for implementation and external drive through suppliers is a big challenge today, both in literature and at the case companies, though seen as a barrier at the case companies. More specifically, in literature, it is seen as a challenge of required transparency, difficulty to find suitable partner companies, a risk of loss of know-how, product piracy and a general loss of control, and, furthermore, the difficulty in the creation of new regulations for intellectual property protection.

6.2 Why the Differences Exist Between Theory and Perception in Practice

6.2.1 Different Abstraction Levels

The discussions by the literature and the case companies were on different abstraction level. The answers from the production managers within the FMISS regarding the potential of Industry 4.0 were straightforward, connected to savings and efficiency on a low abstraction level, mentioning increased water and material usage as examples. Meanwhile, in academia, gains are seen through “the smart factory”, entire connected systems and entirely new business models. Why this difference exist could be explained by the background of the respondents at the case companies and the one of the authors of academic publications. Another possible explanation is the earlier mentioned push from a higher level in the social system, that is not compatible with the FMISS, from politicians to machine technicians and production managers. The high abstraction level might not serve its purpose in convincing the users of the massive potential but miss the point completely in easily explaining how Industry 4.0 could benefit the business as usual.

6.2.2 Lack of Knowledge of Industry 4.0 in FMISS

Even though there is an interest in Industry 4.0 expressed by the food manufacturing companies, the low knowledge level of Industry 4.0 was apparent. The respondent at The Liquid Company had no knowledge of the concept Industry 4.0, and another respondent said that he couldn’t really say what Industry 4.0 was.

Except for the one respondent having no idea about what Industry 4.0 was, others said to be confused about the meaning of the term, but then had a long list of technologies that they associated with it, in line with what is usually claimed to be the technological building blocks. The confusion about the term seemed to create annoyance and disbelief in Industry 4.0. One respondent views Industry 4.0 as a holistic solution where everything is connected, but still considers the concept Industry 4.0 as something insignificant. There is a discrepancy between how respondents defined Industry 4.0 and the possibilities they see in the technology. The difference in seen potential between the positive literature and the sceptical FMISS could be explained by the annoyance and confusion with the term Industry 4.0. Calling the new technologies “Industry 4.0” does not seem to help the development, but on the contrary, make companies sceptical. Further, consultancies and machine suppliers “make the term into what fits them the best” which further undermines its meaning. The confusion of what actually is the base of Industry 4.0 makes it more inclusive, and this current limitlessness of the concept might be a reason to why the FMISS feels like Industry 4.0 isn't for them, or something that is just a hype and without meaning.

The lack of a clear definition is supported by the experts and the technology suppliers. A lower abstraction level, like a list of the technologies covered by Industry 4.0, could lead to an easier access to the concept and avoid the vague, ambiguous inclusiveness mentioned above. But both the food manufacturing respondents and earlier researchers say that the high pace of development of new technologies make it hard to know what solutions will exist even in a few years' time.

> *"Defining Industry 4.0 is a mission impossible. It is an interpretation differing from company to company. "[Own translation] The Machine Component Supplier*

6.2.3 **Business Focus**

No respondent mentioned new business models as an opportunity, but rather as a barrier, which is probably due to the fact that they have little to do with extension of current business within the company value chain. The researched literature focused much more on business, as some of them also were consultancy white papers or from state organisations wanting to help companies invest in Industry 4.0 technologies, thus they naturally had a more business focused approach.

A business model is a complex issue, and changes that are good for business, e.g. the introduction of a new product, or new unit sizes, are often pushed down from R&D or the business executives onto production, who will need to adapt and make the necessary process changes. Bearing this in mind, it isn't strange if respondents within the production sphere are negatively oriented towards changes in business models, and do not see them as an opportunity, but as something that just would require a lot of work.

Another explanation is that they, as leaders within production in their plants, often have to execute the decisions made further up in the hierarchy, and thereby having to handle their employees distrust and convince them of the feasibility of a decision they did not make themselves. This is not an easy task, and they know that mindset and culture can pose as barriers.

6.2.4 **Micro & Macro Perspectives**

As mentioned, finding suitable external partners for implementation is seen as a big challenge today, both in literature and at the case companies. However, some case companies seem to see it more as a barrier, as a type of partner they would need to find that does not exist today or in the near future while literature see it as a challenge to find the right match. This difference in perception feels strongly connected to the positive attitude towards Industry 4.0 effects in literature in general, and the general scepticism at food manufacturing companies. Further, the difference in abstraction levels might lead authors on the theme towards looking for potential partners in the entire future potential value chain, meanwhile plant managers at the case companies have a micro perspective, and don't look outside of the box. Hence, they only see the partners they have today or have had in the past as potential future partners.

6.3 Summary of Chapter 6

The first part of this chapter aimed to answer the question RQ1c: *What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS?* In order to provide a full overview of the findings, a summary has been made in table 17.

Table 17. The opportunities, barriers and challenges related to Industry 4.0 in FMISS

Opportunities with Industry 4.0 in the FMISS		
Mentioned by earlier research	***Mentioned by case companies***	***Mentioned by both***
• Creating new business opportunities • Optimised decision making, through increased understanding of production	• Good publicity, connected to decreased environmental impact	• Optimisation of processes, production and systems • Reduction of environmental impact • Higher level of automation that self-organises and self-synchronise • Mitigating risks associated with breakdowns • Better working conditions in terms of safety and career paths • Better production overview • Improved product quality • Increased flexibility and speed • Cost benefits • Improved JIT-production

Barriers for Industry 4.0 diffusion in the FMISS		
Mentioned by earlier research	***Mentioned by case companies***	***Mentioned by both***
• Resistance against manual work being automated • Lack of comprehensive broadband infrastructure • Lack of standards and norms of data ownership • Hype of Industry 4.0	• The food industry is a conservative industry • Lack of competition to drive change in the industry • Vague "Industry 4.0" name • Rethinking of current business • Lack of external partner for implementation	• Low technical competences in the industry • Data and cyber security

Challenges for Industry 4.0 diffusion in the FMISS		
Mentioned by earlier research	***Mentioned by case companies***	***Mentioned by both***
• Emotions and mindsets • Strong national focus • Business related challenges • Avoiding ad hoc implementation • Transparency in the supply chain	• Inability to handle data or technology	• Workforce challenges related to competencies and organisation structure • Investment challenges • Integration of systems and machines • Management does not prioritise or see the value • Flexibility challenges

Furthermore, the end of the chapter attempts to give an explanation to RQ1: *If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS?* The reason behind the differences in themes mentioned by literature and the respondents was mainly due to the different abstraction levels discussed, where research applied a more macro perspective on the transformation, together with the lower knowledge level of the respondents. Moreover, it was clear that literature also discussed pure business and product opportunities, where the respondents focused on process improvements. Lastly there was a tendency for the research literature to be optimistic about the change, whereas the respondents were more sceptical, which could be explained by their micro-perspective of things.

7 Adoption and Diffusion of Industry 4.0

The first part of this chapter, 7.1, aims at answering the subquestion RQ2a: How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process? The second part of the chapter, 7.2, aims at answering the second main question RQ2: How can the diffusion of Industry 4.0 increase in the FMISS? The data will be analysed based on the theoretical frameworks presented in chapter 4. This is done with the purpose of drawing general conclusions on the topic of Industry 4.0 and pave way for further studies.

7.1 The Perceived Adoption of Industry 4.0 in the FMISS Through the Innovation-Decision Process

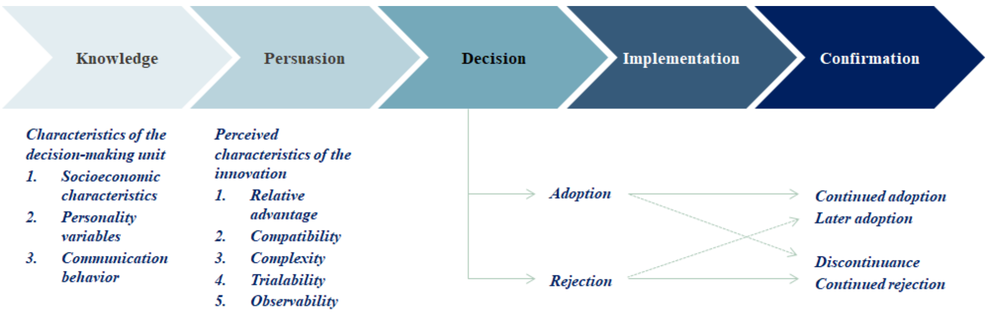


Figure 6. Rogers' five stages of diffusion in the Innovation-Decision Process

7.1.1 **Rate of Adoption**

7.1.1.1 *Actors Affecting the Adoption*

In line with Rogers' DOI theory, the German government could be seen as a change agent, pushing the Industry 4.0 concept towards the entire manufacturing industry. Another actor with incentives to increase adoption is The Machine Component Supplier. They consider themselves innovative technology-wise, for example say that they have had the technology required to perform Predictive Maintenance for a long time. Their interest and gains in further development takes them out of their local circle, pushing other actors in the system. There is an incentive from companies like The Machine Component Supplier in encouraging actors like The Production Line Supplier to take on the role as a system integrator. The system integrator is said to be a missing link today and would be an external part who could handle data from technology suppliers further up in the external value chain in order to overcome the obstacle in using data from different sources in manufacturing facilities. Moreover, The Production Line Supplier could be viewed as a potential change agent aide. The Production Line Supplier could be argued to have a higher degree of opinion leadership in the system than other actors - hence, The Production Line Supplier is viewed as an actor of great importance to the plausibility of Industry 4.0 breakthrough. They might also be on an equal level education wise as the person in equal roles within the FMISS.

7.1.1.2 *Revolution or Evolution?*

> *"To me Industry 4.0 is no revolution [...]" [own translation] The Vegan Producer*

Industry 4.0 is the first preannounced industrial revolution, and the term seems to have been chosen by the German Government just because the aim was to surpass the slow evolution, to push German manufacturers into adopting the future technology, and give them a head start. A revolution is defined as "a sudden radical, or complete change" or in a technological application "a changeover in use or preference" (Merriam-Webster, n.d.). In academia, the consensus is that technological change is an inert process that takes time, because of the amount of coordination, institutional arrangements and implementation of complementary technologies needed. Many researchers and technology suppliers argue that Industry 4.0 is, in fact, an evolution, that has been growing through natural development.

> *"I don't see it as a revolution, not yet. Packaging things that already exist in new ways is not a revolution, and automation has been around for a long time. Only when there's an openness regarding data things can happen[...]" [Own translation] The Machine Component Supplier*

At the same time, according to the Machine Component Supplier, there seems to be a reason to call it a revolution:

> *"There is a difference between actors in different parts of the value chain in whether [Industry 4.0] is seen as step-by-step implementation or a revolution. If taking a step-by-step approach, you don't get the additional value of Industry 4.0." [Own translation]*

7.1.2 **Adopter Categories**

The food industry is lagging behind due to limited competition and lacking knowledge about technology innovations. They don't seem to have a frequent interaction with their peers as is significant for the early majority, neither do all of the case companies seem to answer to peer pressure, economic necessity and the necessity to be cautious. Generally, the FMISS seems to have no opinion leadership, being isolated with low knowledge of the Industry 4.0 concept, suspicious of its potential innovations and how it could help them in their production. This makes them late majority or laggards, which also fits with their own assertion that the food industry is conservative.

7.1.3 **Prior Conditions**

The limited diffusion of Industry 4.0 in the food manufacturing industry, and even more, the limited belief in and enthusiasm about the concept in food manufacturing companies, indicates that the companies are in an early stage of the Innovation Decision Process - or some might not even have entered at all. Previous practice, felt needs or problems, innovativeness and norms of the social systems are prior conditions to entering. The low competition has contributed to the norms of the social system not promoting innovativeness and not requiring food manufacturing companies to be on the forefront of implementing new technologies. Working proactively to improve the business is not a part of the conservative food manufacturing industry, hence the big opportunity seen in literature in improving and innovating business models is not seen at the case companies. Hence, one might argue that the prior conditions for entering the process of innovation diffusion are not fulfilled. However, the case companies' current implementation of automation and information collection through sensors, alarms acting on data etc. could be said to be a way of practicing Industry 4.0. They also express a need for better usage of data and information in real time, due to problems with long waiting times for results on the quality of a product etc. But according to the FMISS, this implementation is at an "Industry 3.0"-level, and they express that they haven't come far in the Industry 4.0 adoption. Not fulfilling the prior conditions might explain the low and even misleading, confused knowledge of Industry 4.0 at the case companies.

7.1.4 **Knowledge**

As mentioned earlier, the respondents in this study seem to lean more towards a somewhat basic knowledge of the technologies and concept of Industry 4.0. This might, as said, be because of the hype of the concept and applications like AI and machine learning. The knowledge seems to be at the *awareness-level*, and lacking at the *how-to knowledge* and *principles level*, with insufficient awareness of how to actually use and get value out of the Industry 4.0 technologies. The Production Line Supplier and The Machine component supplier have better knowledge than the food industry and still they see Predictive Maintenance, in literature seen as a small part of Industry 4.0, as a main potential. This might be explained by Rogers' concept *selective exposure*, and show that there is a misuse, or wrong focus, on how to apply Industry 4.0.

7.1.4.1 *Lack of Knowledge and Persuasion Due to the Term "Industry 4.0"*

> *"Defining Industry 4.0 is a mission impossible. It is an interpretation differing from company to company. "[Own translation] The Machine Component Supplier*

Even though there is an interest in Industry 4.0 expressed by the case companies, the low knowledge level of Industry 4.0 was apparent among the case companies in the FMISS, while academia discusses it like something revolutionizing that everyone in the industry knows about. This supports the already mentioned discrepancy between how respondents defined Industry 4.0 (read: something diffuse) and what they then associated with Industry 4.0 (read: in line with literature definitions), see below. The quotes are made by the same respondent within each company and can explain why it is hard to tell if the Innovation-Decision Process has reached the knowledge phase or not.

> *"I associate Industry 4.0 with the fact that everything will talk to everything."*

> *"There's a lot of talk about the revolutions, mainly the three first ones though, what the fourth industrial revolution really is, is a bit unclear." [own translation] The Industrial Conglomerate*

> *"IoT in the industry is what Industry 4.0 is to me. I associate Industry 4.0 with data, data collection, used to create more efficient processes, machines, AI and smarter robots."*

> *"Industry 4.0 is a diffuse concept without much substance." [own translation] The Vegan Producer*

This might mean that the term Industry 4.0 isn't something helping the development, but on the contrary, something that makes companies sceptical, confused and something that delays the adoption, explaining why companies say that they perceive their adoption as low.

The confusion of what actually is the base of Industry 4.0 makes it more inclusive - one example of this is Blockchain technology, which is presented as a part of Industry 4.0 by ABB (Larsen, 2017), but is by Frankfurt School Blockchain Centre seen as an outside solution that is not a part of Industry 4.0 but can support it and help with some of the cyber security issues posed by the new revolution (Dieterich et al., 2017). The current limitlessness of the concept might be a reason why the case companies feel like Industry 4.0 isn't for them, or something that is just a hype or without meaning.

Most definitions by earlier research seem to cover one part of Industry 4.0 but don't capture the essence of the concept. A higher abstraction level, such as the definition made my Pfohl et al. (2017), could lead to a sustainable, long-term comprehensiveness, since it does not point out what exact technologies are part of the revolution, thus avoiding being obsolete in a few years. At the same time, a lower abstraction level, like a list of the technologies covered by Industry 4.0, could lead to an easier access to the concept and avoid the vague, ambiguous inclusiveness mentioned above. But both the FMISS respondents and earlier researchers say that the high pace of development of new technologies make it hard to know what solutions will exist even in a few years' time.

Furthermore, the concept of having a numerical term such as Industry 4.0, seem to tempt people into defining parts of the concept that seem futuristic, overly complex or high tech as a part of the might-be-coming Industry 5.0. One of the interview subjects, when discussing a very high-tech smart factory, said that it was so high tech it was "almost Industry 5.0" (Interview 4, 2018) and another respondent suggested that Industry 4.0 probably won't be completely rolled out until the fifth revolution (Interview 2, 2018).

7.1.4.2 *Hype*

> *"We invariably overestimate the short-term impact of a truly transformational discovery, while underestimating its longer-term effects" (Collins, 2010).*

The knowledge level also seems to be connected to the hype of the concept and its technologies, since it prevents companies from assessing the potential value of Industry 4.0. When the hype goes down, the understanding of the technology context and possibilities grow, methodologies and best practices are being developed, and the innovation starts to be socialized, with the creation of business and reference cases. This should enable the technology to be diffused at a faster speed. In some sectors, as the automotive industry mentioned as progressive by many case companies, true value seems to be extracted. But today, reference cases are still missing in the food manufacturing industry- which puts off food producers from investing and limits the speed in which the innovations can spread.

7.1.5 **Persuasion**

> *"In my opinion, [another liquid producer at the Swedish market] are not very mature. The suppliers that sell equipment to the machine builders are more mature, but the end users of the technology are not ready and have not understood the value yet. It requires more capital to make something out of Industry 4.0, machine parks have machine parts from a huge number of different suppliers, and today Industry 4.0*

solutions are sold more through push than pull. To make the end user understand the value, a system integrator is needed, since The Machine Component Supplier and companies like us have a negligible part and hence, cannot sell straight to the end user." [Own translation] The Machine Component Supplier

At the persuasion stage, the unit is said to become more psychologically involved with the innovation, and hence, starts to actively search for information. According to the information collected at the case companies, they are not seeking information at all, but find people trying to give information annoying. This might indicate that they have not yet reached the persuasion phase. This also means that innovation-evaluation information is not sought by food manufacturing companies yet and will not have effect. The question is not about uncertainty about the expected consequences, but what Industry 4.0 is, and whether it is useful for the company.

Even when a positive attitude towards something is adopted, there might be a discrepancy between favourable attitudes and actual adoption. Most case companies see value connected to Industry 4.0 as a whole. Still, they have a hard time to picture how this value could be transferred to business opportunities in their own manufacturing facilities. The information spread about the innovations might be to abstract - missing the how aspect of implementation. Or, even though viewed as somewhat valuable, the perceived characteristics of the innovations are not seen as valuable enough.

7.1.5.1 *Perceived Characteristics of the Innovations*

Compatibility & Complexity

The compatibility is one of the areas where Industry 4.0 lacks the most, both according to research, the respondents and the experts. One of the biggest barriers to Industry 4.0 concepts being used in manufacturing settings is that the software for different brands of machines, ERP-systems and so on are incompatible, and no standard seems to be in sight. This is strongly connected to the complexity, since there are many different machine components in each machine in the machine park that would need to be integrated, different types of data, and a fear of sharing information between companies, which makes is hard to reach standards and use existing data. The complexity is also related to the fear of lack of know-how that many case companies mention. The new Industry 4.0 applications seem too complex for their current staff to handle and properly use.

Observability & Trialability

The low amount of reference cases with relevant Industry 4.0 implementation in the food manufacturing industry, and the low ability to try out the technologies make this area very weak. Uncertainty and the importance of being in line with your peers is highly affecting adoption. The social system's view on consequences and the changes that will occur to members or the entire system is highly impacting the decision to adopt or reject something. Subjective opinion by near-peers is more important than facts - and the fact that no reference cases exist makes it hard for sales reps to sell the concept through telling about peer implementation. Further, in the persuasion phase, the decision-making unit starts to mentally project the innovation into their future plans - something which is much harder without reference cases - enabling observability and trialability to a degree.

Relative Advantage

A very likely explanation of the slow adoption of Industry 4.0 in the food manufacturing is that attractiveness of the inventions is too low, limiting the diffusion. Relative advantage of the new innovations in comparison with the existing solutions is probably something everyone agrees on. The concerns are of the profitability of making the huge investments in the first place.

An explanation connected to the relative advantage concerns *the 9 x Effect*, that consumers "over value" what they already possess and tend to stick with the solution they have, while technology producers overvalue their product. Even though Industry 4.0 brings improvements, they might not be perceived as being ten times better than the solutions the food manufacturers have today. This could explain the ambiguity between literature and the actual perception at the case companies, since academia tends to see the "real" advantage and customers prefer to stick with their existing solutions.

Preventive innovations, innovations that prevent something bad, but unlikely, to happen, such as extensive safe measures, tend to have a slower rate of adoption. The motivation of the decision making unit to adopt is low but can be spurred by a *cue-to-action*, an event that transforms a favourable attitude to actually adopting the innovation. Many of the respondents within the case companies seem positive to Industry 4.0 concepts, but this does not seem to be enough for them to actually adopt them. This could be explained that there are too few or to insignificant *Cues-to-actions* in order to make the companies feel a need to adopt.

7.1.6 Decision

When it comes to the rejection of Industry 4.0 technologies at the case companies, it is apparent that the rejection is mostly passive, i.e. the companies never really consider adopting the innovations due to general scepticism and lack of knowledge. With an insufficient relative advantage, it is not surprising that few food industry companies have made the decision to exchange existing, functioning machinery to new Industry 4.0-solutions. This corresponds to the theory of switching costs, where the monetary cost of a new solution is complemented by psychological and organisational costs, and the idea that companies prefer new solutions where parts of the old solution are transferable into the new. Moreover, the switching cost and the lazy user theory indicate that a user will choose the solution with the lowest level of effort needed. This is probably an explanation to why the already conservative food industry sees a slow diffusion of Industry 4.0 technologies.

7.1.7 **Implementation & Confirmation**

None of the food manufacturing companies interviewed in this thesis has managed to implement a full-scale Industry 4.0 project in their manufacturing facilities. Thereby it is more difficult to say anything about this step in the Innovation-Decision Process from the practitioner point of view. Industry 4.0 sounds very promising when reading consultancy reports. But one problem is that small scale implementation does not benefit from the network effects from full scale implementation and adopting technology in such a big scale will require a change of mindset and culture in most traditional organisations.

Whether or not there are examples in the food manufacturing industry and specifically FMISS regarding implementation of Industry 4.0 at all is a topic of discussion. The case companies themselves consider their current automation solutions to be interconnected, with a sufficient number of sensors, but still say that they have not come far in the implementation of Industry 4.0. An important factor to look at is how the implementation of new technology normally looks at the food manufacturing companies in this thesis, see table 9. By looking at how new technology normally is implemented, it is clear that cost, profitability and payback time is important. One major barrier mentioned with Industry 4.0 is proving the profitability and return on big investments - something that could explain the low adoption.

7.2 How to Improve Future Diffusion

7.2.1 **Rate of Adoption**

As mentioned, there is a consensus in literature that technological change is an inert process that *takes time*, with a margin between when innovations emerge and when they actually start to have an economic breakthrough. Hence, Industry 4.0 might only need some more time to develop and grow strong, and the slow adoption might be natural and something without need for change.

7.2.2 **Knowledge**

This study shows that the knowledge, especially on how and why the technology works, seem low in food manufacturing companies, and that the hype and diffuse name makes them sceptical of the value of the concept Industry 4.0. For technology suppliers there seems to be two options concerning the hype; waiting for the hype to settle and the evaluation to be more accurate or making it clear that the hyped version of Industry 4.0 is not what you are trying to sell. When selling, focus should be put on spreading the more advanced knowledge; the principles and how-to knowledge. Principles knowledge is, according to Rogers, most important in the knowledge stage and not as important for adoption further along the Innovation Decision Process as the how-to knowledge. However, if there is no understanding of the underlying principles, misuse of the innovation can damage the adoption.

Rogers means that the social system spreads awareness and influences others to adopt the best. However, in the conservative food manufacturing industry, no one of the case companies in the industry has taken a lead in implementation. Therefore, to implement reference cases are of utmost importance for the technology suppliers.

7.2.2.1 *Introduction of "Change Agent Aides"*

Even though needs and problems in the manufacturing at food companies aren't experienced as high today - due to Rogers' theory that the knowledge of a need does not always exist even though adoption would be very beneficial, further pushing of potential gains of adoption of Industry 4.0 could be crucial. But this needs to be done by a trustworthy source. Consultants could be seen as "change agent aides" that help the government in communicating the message to companies. An issue with this approach is that consultants often have high educations, and within the wrong social systems compared to the food industry - they might have the same disadvantages as a change agent.

Also, the consultancy white papers generally bring up concerns on a higher abstraction level than the things the production managers mention as their hopes for Industry 4.0. Someone who can make Industry 4.0 more applicable to the food manufacturing companies might be what is needed for further adoption, who is trustworthy and part of the same social system.

The Production Line Supplier could work as a better change agent aid, being in the supply chain of the food companies, having knowledge but still being seen as equally educated as the employees of the food companies, and having the needed trust. What earlier research as well as practise say is missing for further implementation of Industry 4.0 is a system integrator, someone seeing value in changing their business model to capture the value of being the coordinating link in the value chain. This actor could also be equal to the change agent aide required to spread knowledge about and speed up the rate of adoption of the Industry 4.0 innovations.

7.2.2.2 *Not Using the Term Industry 4.0*

Industry 4.0 is difficult to define in a way that is abstract enough to include all future relevant technologies, and concrete enough to make it tangible for practitioners in the manufacturing plants. If the high abstraction level does not really explain what technological building blocks that are part of the concept, then maybe most stakeholders would benefit from breaking up of the concept into its integral parts and components. From a consultant's or technology supplier's point of view it is easier to speak of the benefits and functionalities of e.g. a self-organising robot, a sensor or a 3D-printer than Industry 4.0 as a whole. It also makes it easier for the manufacturing companies to understand and visualise the products, and to mentally project them into their plant. It could help the food manufacturing companies move their knowledge from the current awareness-level, to the principles-level, seeing that most of the respondents have a technical education behind them, and have some idea about how the different technologies function. As mentioned earlier, having a principle knowledge helps with making the adoption long-term and successful.

Another way of clearing the fuzziness is to further focus on the applications of Industry 4.0. This is already done with Blockchain, although it is unclear whether it is granted a place within the Industry 4.0-concept, and to some degree with Predictive Maintenance and Digital Twins. The applications are often a mix of several Industry 4.0 technologies, but serve a certain purpose or outcome, which also makes them easier to gain awareness and knowledge about.

7.2.3 **Persuasion**

Consideration will not even start if the information seems irrelevant. Food manufacturing companies, as discussed earlier, might know what Industry 4.0 is but experience confusion that clouds their view. A more straightforward definition could help mitigating this confusion and improve the persuasion.

As mentioned, *preventive innovations* tend to have a slower rate of adoption, and some of the Industry 4.0 applications can be seen as preventive, but a *cue-to-action* could push the adopter so that they actually adopt the innovation. Creating more, and relevant, cues-to-action could ignite the diffusion.

The way that information is given has to change, to even reach the persuasion phase. At the same time, the perceived characteristics of the innovations have to be emphasised in some way, to make the information about the consequences of adoption seem more worthwhile. This, through strengthening the relative advantage, compatibility, observability and trialability and mitigate the complexity.

Complexity

The complexity is strongly connected to not having a standard and compatibility to the barrier of incompatible data. This is hard to do much about without a legal restriction or decision from high up in the hierarchy.

> *"First when reaching an openness regarding data things can happen - if a third party could access sensitive data this would work - but people don't want to. Hence, sensitive data is a big barrier today." [Own translation] The Machine Component Supplier*

Perceived complexity can also be lowered through education and training.

Compatibility

The compatibility is lacking for Industry 4.0 solutions, both according to research and the respondents. Finding common ground on the subject of sharing data is crucial for further implementation, as well as introducing standards in data format and systems. There might also be necessary, through a *collective decision* on a global level, to introduce regulations in order to avoid technological lock-in.

Observability

Data driven selling proposals is one way to deal with observability. Since subjective opinion by near-peers is more important than facts, creating more reference cases would make it easier to sell the concept through telling about peer implementation. According to the 9 x Effect theory, technology suppliers could find a suitable entry point in the social systems through finding companies without a current solution or companies who would benefit more strongly from the particular solution.

Trialability

Aalborg University has understood the need for trialability and established a Learning Factory. Trying out the concepts and learning about how to use them will also lower the Switching Cost, especially when it comes to solutions where parts of the learning from previous investments can be transferred.

Trial periods is expressed to already be an option available by some technology suppliers, and the respondents expressed it as something they need. But since the network effect of Industry 4.0 is said to be hard to see without a full scale implementation, this might not be enough. Trialability through data simulation could be an option, where financial factors are included.

Relative Advantage

Relative advantage is said to be the most important characteristic for adoption, and although everyone seems to agree that Industry 4.0 applications are better to some degree, it does not seem to be enough. How to make the Industry 4.0-solutions seem relatively more advantageous than other or already existing solutions could be a matter connected to the network effect, that trialability and observability before implementation could help with. The high implementation costs and the inability to justify the investments with the financial system in organisations today could possibly be mitigated through focusing on quantified outcomes from simulations and reference cases in selling material. As mentioned by the Production Line Supplier, most companies seek quantitative data to support their investment decisions. Having the 9 x Effect in mind can also help, as well as the making the products more behaviourally compatible with the current company culture.

As said before, Lyytinen & Damsgaard (2011) suggest that IT solutions are socially constructed and learning intensive which makes the diffusion harder to predict. Carter et.al (2001) say that innovations implying large investments will favourably be adopted through a top-down process with top management involvement. Further, for smaller scale innovations or innovations involving a high extent of learning - like IT solutions - adoption is better through a bottom-up process which contributes with a broader-based support for the innovation in the organisation. This is a factor worthy of consideration when trying to communicate the relative advantage of the innovations. More than considering who should deliver the information - who to contact might be an equally important factor. This should according to Carter et.al's finding, be done differently depending on the scale and features of the innovation.

7.2.4 Decision

Small-scale adoption is often a way of taking an early decision without committing fully which organisations tend to like, but as argued this might lower the network effect value of Industry 4.0 interconnection.

Making Industry 4.0 not just an authority initiative but an *authority decision*, could create a higher speed of adoption and make solutions diffuse faster in the industry. With regulations and incentives pushing the adoption it wouldn't be up to each actor to take a stand on how to react, whether to adopt or dismiss Industry 4.0. This could be done by setting up goals of where the industry should be, with plausible time frames, that would be legally binding and regulated by the governments of each country. However, this could force non profitable decisions, being bad for the economy as a whole.

Active rejection, considering and then deciding not to adopt the innovation, seems more fair than passive rejection, where units are not even considering the adoption. There seemed to be a trend between seeing Industry 4.0 as a buzzword, and not considering adopting Industry 4.0 solutions at the case companies. Hence, even at the decision stage, it is of importance to consider how the concept Industry 4.0 is used.

It is also important for the technology suppliers to make the transgression as convenient as possible and adapt their solution to all aspects of Switching Costs, such as included learning and training, making it possible for previous investments and training to be transferred and avoid technology lock-in with their proposed Industry 4.0 solution.

7.2.5 **Implementation & Confirmation**

It seems like many food manufacturing companies might still be at the knowledge and persuasion stage. In order to further reach implementation, these steps have to be overcome first, according to the Diffusion of Innovation-theory. Hence, time and patience might be the two factors that need to be applied before a full-scale implementation can start.

In table 9, important factors for technology implementation are presented, where cost, profitability and payback time are important. One major barrier mentioned with Industry 4.0 is proving the profitability and return on big investments - something that could explain the low adoption, and increased adoption could be reached by being able to visualize the technology and quantify savings.

That some case companies seem to see the lack of a suitable partner for implementation as a barrier, believing that this potential partner does not exist today or in the near future feels strongly connected to the general scepticism at food manufacturing companies and plant managers at the case companies thinking of potential partners as the ones they have today. To better communicate the potential in looking for partners in the entire future value chain, could be a way of changing this negative attitude.

Other manufacturing industries are said to have come much further in the implementation of Industry 4.0. Further research on success factors for the implementation and making up a “how-to guide”, could be a way to reach further adoption of Industry 4.0 in food manufacturing industries and other industries lagging behind.

7.3 Summary of Chapter 7

In this chapter the second main question, RQ2, and its subquestion RQ2a has been answered. RQ2a: *How can the perceived adoption of Industry 4.0 in the FMISS be* *explained through the Innovation-Decision Process?* & RQ2: *How can the diffusion of Industry 4.0 increase in the FMISS?*

Some main takeaways is that it seems like the majority of food manufacturing companies are late majority or laggards, and might still be at the knowledge stage of the Innovation-Decision Process, lacking knowledge on *how to use* Industry 4.0. In general the complexity of Industry 4.0 is too high, the compatibility, observability and trialability are low, and the relative advantage isn't high enough to cover for the other characteristics. The hype of the concept, the lack of a clear definition and the name *Industry 4.0* seem to confuse more than it helps in the diffusion process. Further, the government and consultancies seem to be unable to spread knowledge on an abstraction level that is comprehensible by the food manufacturing companies but focus on societal or larger transformational possibilities that the food manufacturing companies can't relate to.

Most of the actions needed in order to diffuse the Industry 4.0 concept, based on Rogers' theory on Diffusion of Innovations, are directed towards technology suppliers, but some are more general. Through following these mentioned steps, the diffusion of Industry 4.0 could increase in the food manufacturing companies in southern Sweden:

Table 18. Actions to take in order to diffuse Industry 4.0 in food manufacturing companies in southern Sweden

Steps in the Innovation-Decision Process	***Actions to take for further diffusion***
Knowledge	• Market the individual Industry 4.0 technologies • Introducing a "change agent aid" through a technology supplier or someone else in the external value chain • Wait for the hype to settle, or make it clear that it's not the hype of Industry 4.0 that is being sold • Spread principles knowledge and how-to knowledge • Create relevant cues-to-action
Persuasion	• Introduce standards and norms • Introduce training • Data driven proposals • Reference cases with companies without current solutions, or benefit from your solution. • Virtual reference cases • Learning Factories • Simulations of Industry 4.0 investments • Trial periods • Marketing of quantified data • Solutions that are behaviour compatible

	• Marketing with the 9 x Effect in mind • Selling and marketing with a bottom-up approach
Decision	• Make it possible for small-scale adoption • Push the transformation from authority level • Not use the term Industry 4.0 • Lower the switching costs
Implementation & Confirmation	• Suitable partner to drive the implementation • Introduction of system integrators • Creation of how-to guides • Apply learnings from other industries
General	• Wait for the revolution or evolution to progress • Don't use the term Industry 4.0

8 Experts Comments on the Result

In this chapter, three experts' take on Industry 4.0 will be presented, and used to discuss the results to the research questions of this thesis. One professor, one business coordinator and one management consultant working with Industry 4.0 in the food manufacturing industry have been interviewed with the result as a benchmark.

8.1 The Experts' Perception of Industry 4.0

Lindén (2018) is not too familiar with the term Industry 4.0, but he believes it to be equal with what they call *digitalisation* at Mobile Heights. He believes that the knowledge and interest of digitalisation is growing, but one of the most important things today is to understand and capture the true value of digitalisation, without just creating another app that does not actually help people (Interview 4, 2018). Both Møller (2018) and Guðjónsson (2018) see Industry 4.0 as a buzzword, hyped up by the German industry sector, and as something confusing since there is no coherent definition of the concept.

According to Møller (2018) the interesting part of the concept, whatever you choose to call it, is that it is an intersection of functional disciplines, but with the substantial part in software engineering rather than computer engineering and a developed smartness in machines and devices. Other larger trends that Møller (2018) sees as a part of what we call Industry 4.0 is the change from a product orientation to a service orientation, supporting the findings of the State of the Art research, and the shift from offshoring to a more local production, especially since additive manufacturing is becoming cheaper. This also puts the pressure on previous low-wage countries such as China, who are now investing more on quality and technology in their "Made in China"- government campaign (Interview 10 2018).

The management consultant, Guðjónsson (2018), believes Industry 4.0 to be a natural progression of the lean methodology, or similar methodologies like Agile and Six Sigma, something that will optimize and make processes more efficient. The larger part of Industry 4.0 means digitalisation of almost everything. Digitalizing all the systems that we know, for example Kanban, and utilizing data to further optimize processes is an extension of this. Technology-wise, there are a lot of technologies within the concept. Robotics is nothing new per say, but cheaper, more efficient and easier to program now. Even AI is nothing new, but fast computers make it possible to use AI in real time, and it is the same with IoT. Cobotics, autonomous drones and cars and platform services are technologies of Industry 4.0. But generally, it enables technology to talk and act on this (Interview 11, 2018). His view supports both the State of the Art research and what is expressed at the FMISS, even though the FMISS present this aspect of not presenting anything new in a more critical manner.

8.2 Opportunities, Barriers and Challenges for Industry 4.0 in General and in the FMISS

8.2.1 **Opportunities**

Opportunity wise - the mentioned opportunities at the food manufacturing companies are quite similar to the ones mentioned in literature, even though the abstraction level in literature is much higher. Common opportunities are optimisation, reduction of environmental impact, mitigating risks associated with breakdowns, higher level of automation, better working conditions, improved quality assurance, better production overview, increased speed and flexibility and JIT-production. Opportunities only mentioned in literature is on demand production, the ability to create new business models and optimised decision making. One case company in food manufacturing mentioned publicity in connection with environmental improvements as an opportunity of industry 4.0. The technology suppliers saw business model innovation, automation of manual tasks, mitigating energy consumption, predicting production stops, global communication, Predictive Maintenance and optimizing the positioning of the machines as the biggest opportunities of Industry 4.0.

Guðjónsson (2018) believes that there are a lot of possibilities with going away from manual data handling, and get strong real time data of machinery such as Predictive Maintenance, that can increase the uptime of the plants. The efficiency aspect of Industry 4.0 means that job profiles will change a lot over the next ten years - it will be very easy to program a robot which means that you only need one instead of four employees to perform the same jobs as today. Hence, the spend on salary will decrease and more talented employees can be offered more exciting jobs (Interview 11, 2018). Møller acknowledges that many see Predictive Maintenance as the star application of Industry 4.0, since it is easy to sell. This supports the result in this thesis, since both technology suppliers and FMISS mention this as a big potential. But according to Møller implementation is not that easy, with incompatible formats of data and closed systems. To him, individualisation and transparency in the supply chain are the biggest opportunities of Industry 4.0. The individualisation means getting control of the processes, and with the collected data you can optimize the production (Interview 10, 2018).

Lindén (2018) and Møller (2018) see tracking of food through the entire value chain as an opportunity, to make sure that the products are kept and transported at the correct levels of temperature, moisture etc, in order to ensure food security and avoid food having to be thrown away.

Through tagging and information processing you can guarantee a controlled processing and food security for the customer, to the degree that you can even see for example when and where the ingredients you are about to eat comes from (Interview 10, 2018). This isn't mentioned by any of the case companies, where they mainly focus on the production isolated from the value chain and reduction of costs in already existing activities. This difference could be explained through the fact that all the respondents at the case companies are working in and with the production and does not see the value chain opportunities as the biggest opportunities of Industry 4.0, but are limited to production improvements in their mindset.

Lindén (2018) also believes that fully automated production is within the near future. Already, he knows there's one automotive producer who will soon have a "blind factory" keeping their lights off, since almost no one have to work within the factory and everything is automated. He also believes that Predictive Maintenance is a must in the future factory (Interview 4, 2018).

8.2.2 **Barriers**

Cyber security and integration barriers are commonly mentioned by the FMISS and literature. However, there are many industry specific barriers mentioned at the food manufacturing companies and by the technology suppliers, such as that speed of technology development is experienced as too high to cope with, the conservativity of the industry, disbelief in sensors & automation in general, historical lack of competitive drivers due to the fact that mainly local markets exist and an overcapacity in production in Europe, and a low experience of IoT/technical development in the industry. Somewhat contradictory, strong competition and due to this, limited growth from a limited profit, are also mentioned and limiting factors. That people and companies have to rethink their business was mentioned as a barrier in the food manufacturing companies, something they don't want to do, which in literature is seen as a possibility to create new business opportunities. Other barriers only mentioned in literature and by experts are lack of norms and standards and lack of a comprehensive broadband infrastructure. Today, the contact between the parties in the food manufacturing value chain is characterized by being transactional, cost focused and non-relational, and the relationship suffers from lack of trust and transparency (Beckeman, 2011). This lack of trust and transparency that is characteristic for the food industry might be a reason for the scepticism.

What both the case companies and literature have in common is the cyber security issue, and lack of partnering companies is seen as a barrier at case companies while this is seen as a challenge of finding the right match between companies to create new business models in literature. However, barriers only mentioned in literature, such as establishing who in the value chain owns the data, is strongly connected to barriers mentioned by the FMISS, such as their scepticism towards the possibility of finding suitable partners. The problem of data ownership is further something mentioned by the technology suppliers and the experts interviewed in this thesis. Resistance against traditional manual work being automated is something mentioned in literature, that the case companies in general didn't worry much about but saw as a possibility to reduce costs, a view shared with the experts.

According to all the experts, a difficult barrier to overcome with Industry 4.0 is the cyber security, also mentioned by FMISS and literature. The problem, according to Lindén (2018) is not only building safe systems, but also changing the mindset of the organisations and getting them to trust the data in the system, like the scepticism from management at The Liquid Company. Another mentioned barrier is the amount of systems and standards in data, and creating a platform or a steering system that multiple organisations can use (Interview 4, 2018). This means that the different organisations have to collaborate in creating this platform, and Lindén (2018) believes that a test arena for this would be a way to support collaboration.

Even though the food manufacturing is not an area of expertise for Guðjónsson (2018), he thinks that everybody can use the new technologies but that, as soon as the users see it as something that would solve all their problems, it gets tricky. Today, nobody really knows what Industry 4.0 is, and there is a hype about the concept. In short, Industry 4.0 is just already existing technology that is improving. Germany has a big part in hyping up the concept - but even if the name seems useless, the technologies are relevant and will improve the entire industry. But today, companies don't know what they want or what Industry 4.0 is, due to miscommunication. We are only in a pilot phase, since identifying technologies is hard and takes time (Interview 11, 2018).

Guðjónsson (2018) says that at the Hannover Messe in April 2018 the focus was on making already existing technologies tangible and usable. His impression is that it is relatively easy to buy and install IoT or sensors, that can provide real-time data and communicate. More than the hype, right now the issue is the knowledge gap. Everybody can get a robot and/or IoT sensors, they just have to figure out how to use it. When considering Industry 4.0, it is important that organisations have a fully functional IT-platform, since a large amount of the Industry 4.0 technologies rely on the IT-platform and knowledge. This is largely in line with the concerns with Industry 4.0 implementation expressed by the technology suppliers. The manufacturing companies have to have someone on the floor with insight in both operations and IT to be able to successfully implement the solutions. In general, in low margin companies, there is a tendency to have workers with low education levels which could be a problem due to lack of knowledge in regards to IT, technology and operational improvements (Interview 11, 2018).

The knowledge gap makes it hard to define what technologies make sense for a certain type of company, to pivot, and to know how to get the technologies up and running. In industries in general, there is a low degree of employees with masters in engineering in the plants. As Guðjónsson (2018) sees it, even the academic profiles of today are not enough, and for example, Industrial Engineers or engineers with operational focus, often don't know enough about IT. The gap has to be closed in order to use the technologies of Industry 4.0. Help is needed and can be obtained for the implementation, but usage requires knowledge inside the company, where knowledge of operations and IT has to be combined. However, this knowledge gap is slowly growing smaller (Interview 11, 2018). Møller (2018) does not agree that the food manufacturing companies lack the knowledge of Industry 4.0, at least not in Denmark where they are used to having large IT and automation projects, and where the concept is on the agenda of almost every conference. Despite this, he believes it will be the suppliers that are pushing the technology on the conservative manufacturing companies (Interview 10, 2018).

8.2.3 Challenges

Commonly expressed challenges of Industry 4.0 were workforce challenges, related to competencies and organisation structure, investment challenges, integration of systems and machines, management does not prioritise or see the value and flexibility challenges. Inability to handle data or technology was a challenge only mentioned at the case companies, whereas required transparency in the supply chain, avoiding ad hoc implementation, emotions and mindset challenges, strong national focus and business challenges were only mentioned in literature.

According to Lindén (2018), a solution like food tagging has the challenge of getting the different parties to cooperate and getting someone in the supply chain to make the financial investment, even though the business case is strong. This further emphasises the need for communication and collaboration between organisations, where one important factor in order for this to happen is the participation of large companies in the project (Interview 4, 2018). Agreeing with Lindén, as Møller (2018) sees it, the biggest challenges with the Industry 4.0 diffusion is the organisation mindset and workforce competences. Most companies are comfortable with upgrading machines and software, but Industry 4.0 also affects the ways of collaborating between supplier, manufacturer and customer, and the organisation of the company. This means, among other things, that it is very important that this is driven by management level. Furthermore, in order to get the full value of the concepts, some companies will need to make their value offer more service-based, which will pose a huge challenge for many companies. This is in line with the system integrator The Machine Component Supplier said is missing. Add to this, different company sizes face different challenges, according to Møller (2018). The large corporations struggle to push change projects through the organisational levels and bureaucracy, while the smaller companies lack the variety of competences needed for the transformation (Interview 10, 2018).

Lindén (2018) sees an increased interest in Industry 4.0, and they no longer need to chase members since, as they view it, the members are starting to understand the benefits and value of Industry 4.0. Supporting the expressed challenge of justifying investments, simultaneously Lindén expresses the challenge to get companies to invest in the new technologies. In one case concerning food tagging where multiple stakeholders were involved, no one wanted to make the IoT-investment of approximately 100 000 SEK despite a clear business case where the saving would be approximately 1 million SEK each month.

Small margins are something specific for the food industry, which according to Møller (2018) means that the companies will have to reorganise and integrate their value chain in order to capture the value from Industry 4.0. Further, many producers are operating with old machinery, which will not be exchanged that quickly, slowing down the transformation (Interview 10, 2018).

8.3 Why is There a Difference?

All experts agree that Industry 4.0 isn't defined well. Møller (2018) sees the term "the fourth industrial revolution" as confusing since it is unclear what it includes, and the inconsistency in definitions makes it useless from an academic perspective (Interview 10, 2018). This view seems to be supported by the case companies' confusion when Industry 4.0 was brought up during the interviews. There are other terms such as cyber-physical systems, Systems of Systems and IIoT (Industrial Internet of Things) which has gained traction and are more explanatory, but Møller (2018) also understand the marketing power of the term Industry 4.0. He states that, regardless of whether Industry 4.0 is a revolution or an evolution, he agrees with the economics who call it "Industry 3.0 with Computers", and he is convinced people will consider what we call Industry 4.0 as a part of the third industrial revolution in the future.

Guðjónsson (2018) supports the findings of this thesis regarding the definition of Industry 4.0, that it differs from author to author what it actually means, which creates an inconsistency in literature. When he has read literature he also found that papers are either on a super specific, theoretical and "nerdy" level, or very general, explaining what Industry 4.0 means to the entire society. Something that he finds is missing in literature is how to actually use Industry 4.0. This supports the conclusion that how-to knowledge is lacking and has to be spread in order to further diffuse Industry 4.0. It also supports the finding that literature is on a macro level meanwhile the FMISS see Industry 4.0 from a micro perspective - which affects the optimism and scepticism of the parties. Further, he finds that Industry 4.0 is treated a little bit like Big Data was a couple of years ago, which was hyped up as the newest coolest thing that nobody really knew what it meant despite that it was good with a lot of data - but as with Big Data, how you use it is the most relevant with Industry 4.0 (Interview 11, 2018).

The difference in business focus, where there was no interest of the business aspects found in FMISS cannot be explained by the expert interviews but are rather viewed as a potential effect of the choice of respondents and further discussed in chapter 9.2 Critical Discussion.

8.4 How Can the Diffusion of Industry 4.0 Increase?

One conclusion from this thesis is that the term Industry 4.0 might confuse more than it helps and hence, shouldn’t be used when selling Industry 4.0. According to Møller (2018) Industry 4.0 as a name might be alright, but the term is probably not solving anything or adding value. It is the usage of the specific technologies in the right combination that is tangible, and this technology combination will differ from company to company. Hence, it would be more useful to talk about the technology than Industry 4.0 to see what could or couldn't be used (Interview 11, 2018). To prevent the confusion about the term, Aalborg University has chosen to use the term *Smart Production* when they talk about Industry 4.0 in manufacturing perspective (Interview 10, 2018). This supports the advice to market the individual Industry 4.0 technologies, to use physical and virtual reference cases and learning factories.

In order for Industry 4.0 technologies to diffuse faster Guðjónsson (2018) believes it to be important to focus on the problems they are meant to solve, not just on wanting to implement Industry 4.0 - supporting focus on spreading how-to knowledge to the food manufacturing companies. Many of the technologies have been there for more than 20-30 years but are now cheap and smart enough to use in daily operations. One reason for this going slower than it should, is that the computing power needed is not strong enough, and that the current situation is not bad enough to demand change. One way to move forward on the latter is to share knowledge between companies on how to use and get the full value out of the technologies. But the time aspect of diffusion of all new things is worth considering. (Interview 11, 2018).

On the matter of Introducing a “change agent aide” through a technology supplier or someone else in the external value chain - this is supported by the experts saying that literature and marketing of Industry 4.0 is on a too high abstraction level. Introduction of a *system integrator* is further mentioned by the experts as an important aspect.

Selling and marketing with a bottom-up approach is not mentioned as an important solution by the experts, nor is making it possible for small-scale adoption or pushing the transformation from authority level. Application of learnings from other industries was not exclusively mentioned, but could be interpreted as a part of the Learning Factory.

8.5 Summary of Chapter 8

In this chapter, the input from three experts of Industry 4.0 has been used to analyse, add to and verify the result of this thesis. This has been done for each question, and the expert opinions are in general in line with the findings of this thesis. However, they disagree on Predictive Maintenance as the main value and presses the importance of food tagging in the food industry. This is interesting and further shows the micro-focus of the FMISS. The barriers vary the most between the case companies and literature, a difference supported by the experts' perception. All of the case companies believe that Industry 4.0 is a vague name, something that is supported by the experts, meanwhile literature is very optimistic, and few criticises the name. Hype of the concept is mentioned by all parties.

One thing not supported by the experts concerning the result of existing differences, was the lack of business focus within the FMISS, potentially explained by the lack of business insight of the respondents. The explanation to why differences exist (the answer to RQ1) was supported by experts, as was the suggestions to how to further increase diffusion of Industry 4.0 (the answer to RQ2), except on the themes of selling and marketing with a bottom-up approach, making it possible for small-scale adoption and pushing the transformation from authority level. One reason why some solutions weren't brought up by experts could be their limited knowledge of Rogers' DOI-theory that was used to find suggested improvements. Further, a limited time to hold interviews made it impossible to bring up everything of interest.

9 Conclusion & Discussion

The conclusion will consist of the key takeaways found when answering the research questions. Furthermore, a critical discussion about the choice of methodology and its impact on the outcome and credibility of the result of the thesis will be performed.

9.1 Conclusion of Results

9.1.1 Answers to the Research Questions

RQ1a: What are the opportunities, barriers and challenges for Industry 4.0 in general?

The general opportunities mentioned by literature are related to cost, flexibility and efficiency benefits as a result of optimisation of processes and systems. This optimisation is in turn made possible by automation, interconnectability and big data analytics. Many also see big opportunities in improving the working conditions in Industry 4.0 settings, and creating new business models and opportunities.

The barriers are connected both to technology, societal or individual factors. On the technology side there is a lack of comprehensive broadband infrastructure, and too low data security to make it attractive for companies to commit. In society, there's a resistance towards automating manual work since it could lead to unemployment in some sectors, and there are also no standards on how to decide data ownership in an integrated supply chain. From the perspective of the individual, there's a hype of Industry 4.0, making it difficult to assess the value, as well as insufficient technical competencies in general to support the transformation.

The most mentioned challenges are related to the workforce and the return of investments. Most companies lack the skills to service and uphold the technology, and their recruitment and training efforts are not enough for their needs. Both convincing stakeholders about the validity of an investment, the current short-term return focus in organisation and the actual cost of the investment, are seen as challenging.

RQ1b: What are the perceived opportunities, barriers and challenges of Industry 4.0 in the FMISS and what is the perceived adoption?

The case companies see a lot of opportunities in reducing the environmental impact and decreasing resource consumption through real-time measurements and sensors. An overall improved product quality by controlling quality in the factory line is also mentioned, as well as higher degrees of automated processes and interconnectivity. An overall optimisation of the processes and a better production overview are expected as outcomes of Industry 4.0 adoption. The potential of the application Predictive Maintenance was emphasised by the technology suppliers.

The barriers mentioned by the case companies are related to the low technical competencies and experiences in the industry, the lack of competition, and the lack of external partners to drive the implementation. The conservatism of the food sector was also mentioned several times by both the case companies, and the technology suppliers. The technology suppliers saw the lack of reference projects as problematic from a selling perspective.

The investment in money and time associated both directly and indirectly to Industry 4.0, was the biggest challenge for the case companies. But challenges in integration of machines and systems was also considered difficult, by both case companies and technology suppliers. All of the case companies mentioned workforce and management related challenges, such as lack of technical competences in both operative and strategic parts of the company. On the other side, the technology suppliers saw difficulties in convincing companies about the validity of the investments.

The case companies self-assess that they haven’t come far with the Industry 4.0 adoption, and this view was agreed upon by the technology suppliers.

RQ1c: What are the differences and similarities in the perceived potential of Industry 4.0 between literature and the FMISS?

When it came to opportunities, the majority of the mentioned opportunities were lifted by both case companies and literature, where the opportunities from management and business perspective were completely disregarded by the case companies.

The view of the barriers differed the most. The case companies mentioned mostly barriers related to the industry they’re in, and its conservatism, while the literature described societal and overarching barriers that also affect the food manufacturing industry even if they are not aware of them. This implies that barriers might be specific for all industries, or that there are more barriers for Industry 4.0 diffusion in the FMISS than in general.

Even though the case companies saw a lot of challenges, the literature had identified several more, mainly on higher abstraction levels, or including the business perspective. The case companies agreed on challenges related to investment, integration, management and workforce, as well as flexibility, but also lifted their companies' specific inabilities to handle data or integrate technology.

Overall, there were a lot of factors of perceived potential that was mentioned by both practitioners and literature. The factors that were only mentioned by practitioners were mostly industry-specific. The opportunities, challenges and barriers only lifted by literature were generally of a higher abstraction level, and more business-oriented. The perceived potential seemed generally much higher by literature than by the case companies, which is supported by the number of barriers that they discussed. See the similarities and differences in following table:

Table 19. Tendencies of differences and similarities in perception of Industry 4.0 between literature and case companies

Differences, similarities and tendencies in perception	***Literature***	***Case companies in FMISS***
Abstraction level	High/Macro	Low/Micro
Knowledge level	High	Low
Perspective	Technological, economical, workforce, management, business, societal, individual	Technological, economical, workforce, management, food industry

RQ1: If there is a difference, why does the view of Industry 4.0 differ between literature and the FMISS?

The biggest differences were in abstraction levels, knowledge levels and perspective. Generally, researchers have a high abstraction level, and the respondents, working with operations and production, are bound to focus on a micro-level. Considering that the respondents at the case companies were mostly process-oriented, it is also not that odd that they did not consider the perspectives of business, the society and the individual when talking about opportunities, barriers and challenges. Furthermore, in a conservative industry, such as the food manufacturing industry, there can't be an expectation for a high knowledge level of the latest technological advances. And as seen in the Knowledge-step of the Innovation-Decision Process, the knowledge step seems to be where most companies get stuck. Lastly the literature was usually very optimistic about the possibilities, whereas the respondents were more sceptical.

RQ2a: How can the perceived adoption of Industry 4.0 in the FMISS be explained through the Innovation-Decision Process?

The perceived adoption in the FMISS is low. According to this study, the FMISS belongs to the adopter categories late majority or laggards, which is supported by their suspicion of new technology, the emphasis put on competition as a driver for investments, and the weight they put on the economic necessity of a decision. Late majority and laggards are among the last to adopt new technologies.

In addition to this, the important *how-to knowledge* is missing in the industry, preventing them from knowing how to use the technologies and to retrieve value from them in their own settings. Looking at the Industry 4.0 applications as the innovations to be diffused, they have high complexity, low compatibility, observability and trialability and not-high-enough relative advantage - bad preconditions for the diffusion.

RQ2: How can the diffusion of Industry 4.0 increase in the FMISS?

The knowledge step in the Innovation-Decision Process seems to be where the food industry in southern Sweden gets stuck. Because of this, an introduction of change agent aides is recommended, possibly in the form of a technology supplier. Technology suppliers should have a bottom-up approach in trying to persuade the company to adopt. Further on, a system integrator, to integrate the different technologies completely, would also facilitate implementation.

Since the financial viability of investments is one of the major challenges for Industry 4.0 diffusion in the FMISS, technology suppliers should prioritise to create reference projects, make their proposals quantified or create a possibility to simulate virtually how implementation would look like in a specific plant setting. Spreading how-to knowledge can be done through reference projects, but further by focusing on explaining the specifics of usage in a manufacturing company. Avoiding explaining the hyped up version of Industry 4.0 and the macro level of benefits and focusing on specific customer value and implementation in the production is a way of spreading how-to knowledge.

Finally, the diffusion of Industry 4.0 technologies or applications would benefit from being marketed and sold under their specific name, since the term Industry 4.0 only confuses, and beshadows the potential value. For all the actions recommended for increased diffusion, see table 18 in 7.3 Summary of Chapter 7.

9.1.2 Concluding Remark

The actions suggested by this research are mainly aimed towards technology suppliers or consultants, since earlier research shows that *change agent aides* or *system integrators* are successful in increasing the diffusion of knowledge-intensive innovations. Companies within the FMISS are not without responsibility – it is up to them to embrace the change, and dare to move from the slow to the faster side of the adopter category-span.

Technological change *takes time*, from innovations emerging until an economic breakthrough. Hence, Industry 4.0 might need some more time to develop and grow strong, and the slow adoption might be natural and something that will naturally speed up with time. In time, we will see whether or not Industry 4.0, and its applications, is a revolution, evolution or just a hype.

If Industry 4.0 should exist as a concept, which the authors doubt, and there therefor is a need for a definition, the conclusion from this study is that it is a "collection of technologies that help factories become automated, interconnected and optimised".

9.2 Critical Discussion

The results found in this thesis are partly based on interviews with four companies in the south of Sweden, and it is thereby important to keep in mind that they do not, and cannot, represent the whole unit of analysis (FMISS). The results of a qualitative research cannot be exactly repeated, since the research cannot be performed in the exact same way. What the interviews can contribute with are hints of trends, and samples of how employees with *production-proximity* reason about the fourth industrial revolution. Moreover, it is important to keep in mind that the result would probably look different if the interviews had been conducted with more *product-focused* respondents, since they probably would have seen completely other kinds of opportunities and challenges with the Industry 4.0 technologies. The *production-proximity* of the respondents in this thesis could further explain for example why tagging of food was mentioned as one of the biggest opportunities by experts, but not even brought up by any of the case companies. The choice of respondents might also explain why opportunities are on a less abstract level then what is mentioned theoretically, and if general management had been interviewed the responses might have been more similar to the theoretical findings.

The triangulation of this thesis was made by interviewing multiple companies within the unit of analysis, as well as interviewing two technology suppliers and three experts within Industry 4.0, and comparing this with data from scientific articles and business white papers. To be able to confirm or question the answers from the case company interviews it could have been beneficial to make at least one more interview with other employees at the case companies in order to verify the answers received during the case company interviews. This was not prioritised by the authors of this thesis, since the focus is on the FMISS and not specific companies, and the received answers were instead verified through respondents at other case companies within the industry.

It is important to remember that this thesis focuses on perception, where subjective opinions of the respondents during the interviews have shaped the result of this thesis. An objective analysis of the responses is however the base of the conclusions. Since it is only the perception of the production manager that lays ground for the thesis, it is hard to say if the adoption of Industry 4.0 really is as low as expressed by the respondents. The case companies themselves consider their current automation solutions to be interconnected, with automation to some degree and a sufficient number of sensors, but still say that they have not come far in the implementation of Industry 4.0. Performing observations would have been a way of finding out how the perception and reality corresponds.

In making a division between drivers, barriers, opportunities and challenges, the thesis authors themselves shaped this division and sorted the factors. Both challenges and barriers contain micro and macro perspectives, something that could have been further divided but wasn't judged as valuable enough. As mentioned, the meetings with Company X and LTH were always held separately, and if there was a chance to redo the thesis, coordination through common meetings would be considered, to better synchronise the academical contribution with the wishes of Company X.

Lastly, it can be discussed whether or not Rogers' Diffusion of Innovation theory is the best framework to describe and assess the diffusion of Industry 4.0, since it is mainly designed for B2C-products and individuals, as well as for clearly defined innovations. When choosing the framework a multitude of frameworks were investigated, and Rogers' theory was deemed to be the most suitable among the considered selection, but its relevant to remember that the results might have looked differently if this study was structured from a different framework.

9.3 Suggestion for Future Research

One thing the authors of this thesis quickly realised was the micro focus of the respondents close to the production in the case companies. Many of the opportunities mentioned were related to cost optimisation and making current processes even better and more efficient. A suggestion for future research is investigating the perceived barriers, challenges and opportunities from other points of views in the food manufacturing industry, or other low-margin industries, in Sweden. For example, if investigating the perception of Industry 4.0 by product-focused employees at the same case companies, such as R&D, or customer-centric business units such as sales or marketing, it would be of interest to see if they would highlight very different opportunities and challenges, more linked to improvement of the customer offer and echo the trend of service-based customer offers. It would also be of interest to study management's perception of how a successful implementation of Industry 4.0 could be accomplished.

Since this thesis is based on qualitative interviews, further suggestions for future studies is to base a survey on the result to verify the results and quantify the study. This study was limited to the food industry with manufacturing companies as case examples, where comparison was made between case companies and literature. Future studies could include more industries in order to make a comparison between firms within different sectors. During our work process about Industry 4.0 we also came in contact with different national initiatives aiming to strengthen the technological development in their respective country. To further investigate how this is impacting the diffusion of Industry 4.0 is a further suggestion for future research.

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Appendix A - Author List for Definitions

Table C1. List of authors used for collected definition of Industry 4.0, and work the definition is found in, and why the work/author is relevant.

Author	***Title***	***Why it is relevant***
Buckley & O'Sullivan (2015)	*IIC Testbeds – A Blueprint for Delivering Innovation and Ecosystems*	An article in the journal by the Industrial Internet Consortium, a global, not-for-profit organisation with 210 member organisations. The authors are Donagh Buckley, Senior Director, EMC Research Europe & John P. O'Sullivan, Senior Researcher, Cork Institute of Technology. The article is about *IIC testbed,* aiming to facilitate IoT implementation, but describes the current situation as an introduction, mentioning enablers, barriers, challenges and opportunities.
Elangeswaran et al. (2016)	*Industry 4.0 Implies Lean Manufacturing: Research Activities in Industry 4.0 - Function as Enablers for Lean Manufacturing*	Academic article in the Journal of Industrial Engineering and Management about lean manufacturing and Industry 4.0's indications for the area. The authors define industry 4.0.
Feld et al. (2014)	*Industry 4.0*	Academic article by Dr. Heiner Lasi, Prof. Dr. Hans-Georg Kemper, Privatdozent Dr. Peter Fettke, Dipl.-Inf. Thomas Feld, Dipl.-Hdl. Michael Hoffmann
Germany Trade and Invest (2014)	*INDUSTRIE 4.0—Smart manufacturing for the future*	Document with a "Germany Market Report and Outlook" made by GTAI, the economic development agency of the Federal Republic of Germany
Hermann et al. (2016)	*Design Principles for Industrie 4.0 Scenarios*	Material to the Hawaii International Conference on System Sciences (HICSS), Conference Date(s):5-8 Jan. 2016, Conference Location: Koloa, HI, USA, an annual conference for Information Systems and Information Technology academics and professionals sponsored by the University of Hawaii at Manoa.
Kagermann et al. (2016)	*Industrie 4.0 in a Global Context: Strategies for*	The report is presenting the results of projects carried out by the National Academy of Science and Engineering. The studies are intended to

	Cooperating with International Partners	provide informed assessments and future-oriented advice for policymakers and society. Copyright – National Academy of Science and Engineering
Kagermann et al. (2013)	*Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group*	Final report of the Industrie 4.0 Working Group, copyright acatech – National Academy of Science and Engineering, sponsored by the Federal Ministry of Education and Research, Germany.
Pfohl et al. (2017)	*Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies*	This report includes a structured literature review of 152 scientific papers, books and articles from high-rated international journals within the topics Management Science, Operations Research, Journal of Management Studies, Organisation Science, M&SOM, Transportation Science and Information Systems Research, in order to map what trends characterise the Industry 4.0-concept and how they contribute to its diffusion within the supply chain.

Appendix B - Interview Guides

Opening questions

Name and position?
Tell us about your organisation and industry?
What type of products and services does your segment offer?
What features in production is most important for your success as a company? (e.g. time to market, flexibility, quality, ergonomics, safety, cost etc)

Industry 4.0

Data Collection

To what extent is data collected from machines, tools etc.?
What and where do you collect data? What do you do with the data?
What opportunities do you see in collecting data today? What challenges?

Sensors

To what extent are sensors used in the manufacturing process?
Where and why do you use sensors? What do you do with the sensor data?
What opportunities do you see in using sensors today? What challenges?

Automation/Interconnection

To what degree is your production automated/interconnected today?
What and where do you automate/connect? Do you use cloud services?
What opportunities do you see in automating/connecting processes today? What challenges?

Pains and gains

Where do you see the biggest potential for improvements in your production today?
Where are the main issues in you assembly today?
What problems in your production are most urgent to be solved?
Which problems do you need external help solving?
Do you find any value in being able to access the following functions through a web-based interface?

- Visualised graphs showing throughput of your production line in real time and historically?
- Visualised real time graphs on measured air quality?
- Alerts based on real time data? On what for example?
- Help to analyse graphs and act on alarm?
- Do you have any other ideas of features or functions that you would like to have visualized in real time that have not been mentioned here? (e.g. Air pressure, electricity, heat, vibrations…)

Would you be interested in testing the features and functions described above if you were offered a trial-period?

Future

Is there any other technology that you consider relevant in the future for your manufacturing?
How well do you know Industry 4.0?
What do you associate with Industry 4.0?
Tell us about the first time you came in contact with Industry 4.0?
How far have you come in implementing Industry 4.0, in your opinion?

New technology

What does your procedure for integrating new technology look like?
What elements are most important to you when choosing what new technology to invest in?

Opportunities

What main opportunities do you see in incorporating the mentioned technologies in your company?
What main opportunities do you see in incorporating the mentioned technologies in general?

Challenges & Barriers

What main challenges do you see in incorporating the mentioned technologies in your company?
What main challenges do you see in incorporating the mentioned technologies in general?
What, in your opinion, are the external barriers of this technological change in your industry?
What, in your opinion, are the drivers of this technological change in your industry?

Closing question

Is there anything you'd like to add that we haven't covered so far?

An adapted version with focus on the technology suppliers' customers was used when interviewing the Machine Component Supplier and the Machine Line Supplier.

Appendix C - Reference List from Interviews

Table A.1 List of respondents, interview method, referral number and date of interview.

Role, company	***Interview method***	***Interview number***	***Date of interview***
Head of Production, The Liquid Producer	Personal meeting	Interview 1	2018-02-06
Strategic Key Account Automation, The Machine Component Supplier	Personal meeting	Interview 2	2018-02-09
Plant Manager, The Industrial Conglomerate	Telephone meeting	Interview 3	2018-02-12
Johan Lindén, Project Manager, Mobile Heights	Personal meeting	Interview 4	2018-02-13
Digitalisation Project Manager, The Production Line Supplier Services	Telephone meeting	Interview 5	2018-02-15
Team Leader of Automation, The B2B Producer	Telephone meeting	Interview 6	2018-02-21
Plant Manager, The Vegan Producer	Telephone meeting	Interview 7	2018-03-05
Management Consultant, Implement Consulting Group	Personal meeting	Interview 8	2018-03-07
Production Technician, The Industrial Conglomerate	Telephone meeting	Interview 9	2018-03-20
Charles Møller, Professor in Enterprise Information Systems and Business Process Innovation, Aalborg University	Personal meeting	Interview 10	2018-04-26
Hafsteinn Þór Guðjónsson, Management Consultant within Operations Strategy at Implement Consulting Group	Telephone meeting	Interview 11	2018-05-15

Appendix D - Thematic Overview from the Literature Study

D.1 The Barriers of Industry 4.0 Found in Literature Research

After a literature study from relevant articles the following table shows the most common barriers mentioned in accordance to Industry 4.0:

Table D.1 Barriers for Industry 4.0 diffusion, and the cited authors.

Barrier	***Authors***
Data and cyber security	i-SCOOP (2017), Danish Institute of Industry 4.0 (2016), Morgan Stanley (2016), Buckley & O'Sullivan (2015)
Lack of standards and norms of data ownership	i-SCOOP (2017), Danish Institute of Industry 4.0 (2016) Kagermann et.al. (2016), Morgan Stanley (2016), Kagermann et al. (2013)
Lack of comprehensive broadband infrastructure	Kagermann et al. (2013)
Resistance against manual work being automated	Danish Institute of Industry 4.0 (2016)
Hype of Industry 4.0	Lomax et al. (2018)

D.2 The Opportunities of Industry 4.0 Found in Literature Research

After a literature study from relevant articles the following table shows the most common opportunities described in accordance to Industry 4.0:

Table D.2 Opportunities for Industry 4.0 diffusion, and the cited authors.

Opportunities	***Author(s)***
Optimisation, through: increased profitability in the production; efficient production; optimized processes; improving operational efficiency; improving productivity; reduced downtime; increased efficiency; create simpler processes; maximizing asset utilisation; increased resource productivity; dynamic self-optimisation;	Kiel et al. (2018), Bremicker & Gates (2017), e-SCOOP (2017), Larsson (2017), Mrugalska & Wyrwicka (2017), Elangeswaran et al. (2016), Lorenz et al (2016), Morgan Stanley (2016), Feld et al. (2014)
Reduction of environmental impact, through: reduced waste; resource efficiency; better resource allocation; sustainable value creation	Kiel et al. (2018), Seliger & Stock (2016), Schlaepfer et al. (2015)
Mitigating risks associated with breakdowns, through: business processes adjusted according to breakdowns in the value chain; *autonomation* (automating the manual processes to include inspection); Predictive Maintenance	Mrugalska & Wyrwicka (2017), Elangeswaran et al. (2016), Lorenz et al (2016), Feld et al. (2014)
Higher level of automation, through: integration of automation; interoperability; self-synchronisation; synchronisation of entire value chain; intelligent machines; products controlling their own manufacturing process; item tagging, machine learning	Bremicker & Gates (2017), Elangeswaran et al. (2016), Lorenz et al (2016), Kagermann et al. (2016), Feld et al. (2014)
Better working conditions, through: higher levels of safety for employees; flexible career paths; better work-life-balance; higher wages; transform traditional industry; value chain roles; age-appropriate workplaces; virtual organisations; less monotonous work through improved man-machine interfaces	Kiel et al. (2018), Bremicker & Gates (2017), Larsson (2017), Mrugalska & Wyrwicka (2017), Elangeswaran et al. (2016), Lorenz et al. (2016), Feld et al. (2014)
Improved product quality; improved quality assurance, and optimised quality of production	Kiel et al. (2018), Strange & Zucchella (2017), Lorenz et al. (2016)
Better production overview, through; simulation of processes	Elangeswaran et al. (2016)

Increased speed and flexibility, through: modular production; making operations agile; flexibility in business processes; production and distribution efficiency; smart reallocation of orders	Kiel et al. (2018), Mrugalska & Wyrwicka (2017), Strange & Zucchella (2017) Lorenz et al. (2016), Schlaepfer et al. (2015), Feld et al. (2014)
JIT-production, through; load balancing and stock reduction	Kiel et al. (2018)
On demand production, through: customer specific production; produced to economics of mass production; business processes adjusted according to demand;	Kiel et al. (2018), Mrugalska & Wyrwicka (2017), Feld et al. (2014)
Cost benefits, through: costs cut on energy; costs cut on personnel; general costs decreased	Kiel et al. (2018), e-SCOOP (2017), Mrugalska & Wyrwicka (2017), Strange & Zucchella, 2017, Kagermann et al. (2016), Lorenz et al (2016), Schlaepfer et al. (2015)
Creating new business opportunities, through: new value opportunities; enhance the delivery of competitive advantage; gain access to new business and operating models; value-adding cooperation; cooperation in creation of new business models, R&D projects & training; innovation; better cooperation between employees and business partners	Kiel et al. (2018), Bremicker & Gates (2017), Mrugalska & Wyrwicka (2017), Elangeswaran et al. (2016), Kagermann et al. (2016), Morgan Stanley (2016), Seliger & Stock (2016), Wortmann & Flüchter (2015)
Optimised decision making	Mrugalska & Wyrwicka (2017)

D.3 The Challenges of Industry 4.0 Found in literature Research

After a literature study from relevant articles the following table shows the most common challenges described in accordance to Industry 4.0:

Table D.3 Challenges for Industry 4.0 diffusion, and the cited authors.

Challenges	***Authors***
Integration challenges, such as: horizontal integration into value networks; vertical connection with companies' internal business processes; end-to-end digitalisation of the whole value chain; Industry 4.0 platforms and a digital ecosystem that creates networks and lock-in effects; work out a viable plan for coordination and integration of multitude of technologies	Lomax et al. (2018), Kagermann et al. (2016)
Workforce challenges, such as: existing workforce lacking skills of digital interface; lack of engineers in new workforce; employee fear and concerns; lack of expertise; safety and security of the environment and of the workforce; adapt existing culture & values/ways of working; need for workforce shift; increasing need for need IT, engineering, data science competences; insufficient recruiting & training	Kiel et al. (2018), Lomax et al. (2018), i-SCOOP (2017), Danish Institute of Industry 4.0 (2016), Kagermann et al. (2013), Hannover messe (n.d.),
Management challenges, such as: gap between ambition of executives and required actions to transform the status quo; Senior management not fully committed/lack necessary capabilities; defining strategy	Bremicker & Gates (2017), Danish Institute of Industry 4.0 (2016), Lorenz et al (2016)
Investment challenges, such as: Short-term return focus on investment in companies; high implementation efforts regarding e.g., costs and standardisation; getting investors to recognize potential benefits; seeing the potential and importance of upgrading to Industry 4.0; convince stakeholders about the validity of an investment, Capital intensive to replace technology; legacy-installed base; major barrier-to-entry; significant upfront investments required	Kiel et al. (2018), Lomax et al. (2018), Danish Institute of Industry 4.0 (2016), Kagermann et al. (2016), Morgan Stanley (2016), Buckley & O'Sullivan (2015)
Flexibility challenges, such as: standardisation	Kiel et al. (2018)
Required transparency: difficulty to find suitable partner companies loss of know-how; product piracy; general loss of control; creation of new regulations for intellectual property protection	Kiel et al. (2018), Kagermann et al. (2016),

Emotions and mindset challenges: sense of urgency and panic; over-excitement about the concept	Lomax et al. (2018)
Ad hoc challenges, such as: siloed and ad hoc efforts; holistic approach; “all-or-nothing”-mentality; network effect required to get return of investment; knowing where to begin with Industry 4.0	Lomax et al. (2018), i-SCOOP (2017), Pfohl et al. (2017), Baur & Wee (2015)
Strong national focus	Kagermann et al. (2016)
Business challenges, such as: existing business models endangered; fear of developing solutions that lack market relevance; make research into actual technology	Kiel et al. (2018), Kagermann et al. (2016)