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Industry 4.0 and Swedish SMEs:

An assessment of current maturity level and challenges

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Abstract

Title

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Background

In a world where the rate of technological change is constantly accelerating, it is getting more and more important for companies to adopt new technologies and processes to stay competitive. Most recently, the concept of Industry 4.0 has emerged as the newest technological paradigm within industrial management and has its roots in the German government's technological strategy. On a high level, Industry 4.0 is the industrial usage of new technologies, like big data analysis, autonomous robots, cyber-physical infrastructure, simulation, cloud computing, augmented reality and internet of things (IoT) (Ceikcan and Ustundag, 2018). This is enabling machine-to-machine and human-machine interactions and, when implemented successfully, great value creation potential.

Despite that Industry 4.0 is rather new, plenty of papers and consulting reports have been published on the topic. Some of these have indicated that the SME are not quite as well-informed, trained and prepared for this shift in paradigm.

Purpose

The purpose of this project is to assess the current level and challenges for Industry 4.0 adoption among Swedish SMEs by using an Industry 4.0 maturity framework to enable further development of the paradigm in Sweden.

Research questions

The thesis has two main research questions:
1. What is the current level of Industry 4.0 maturity among Swedish SMEs?
2. What challenges are Swedish SMEs experiencing when implementing Industry 4.0?

Methodology

The research methodology can be divided into three steps. Firstly, an Industry 4.0 maturity assessment model was chosen from already existing ones, based on three criteria: comprehensiveness, practicality and proven track-record. The Impuls Industry 4.0 assessment model were chosen, which is survey-based. Secondly, the survey was sent out to companies and the responses were collected. Lastly, the results were analyzed and discussed based on previous research on the topic.

Conclusions

The main conclusion related to RQ 1 is that the maturity level of Swedish SMEs is low, with an average maturity level of 1,17 on a scale from 0 to 5. No strong relationship was found between maturity level and size or revenue.

The main conclusion related to RQ 2 is that the lack of financial resources, business and customer incompatibility together with technological, knowledge and know how issues are the biggest challenges faced by Swedish SMEs when implementing Industry 4.0. Furthermore, the lack of financial resources is SME specific and had not been identified as a main challenge in previous studies.

Keywords

Industry 4.0, Fourth industrial revolution, Automation, Cyber-physical systems, Smart factory Maturity assessment, SME

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1 Introduction

In the first chapter, the problem and context of the problem is outlined, followed by the purpose of the study, the research questions, the delimitations, the project objectives and lastly the disposition of the thesis.

1.1 Context

In a world where the rate of technological change is constantly accelerating, it is getting more and more important for companies to adopt new technologies and processes to stay competitive. Most recently, the concept of Industry 4.0 has emerged as the newest technological paradigm within industrial management and has its roots in the German government's technological strategy. Industry 4.0 doesn't have a clear definition - the German telecommunication association BITKOM has presented over 100 definitions of the concept (Bidet-Mayer, 2016). But on a high level, Industry 4.0 is the industrial usage of new technologies, like big data analysis, autonomous robots, cyber-physical infrastructure, simulation, cloud computing, augmented reality and internet of things (IoT) (Ceikcan and Ustundag, 2018). This is enabling machine-to-machine and human-machine interactions and, when implemented successfully, great value creation potential.

Despite that Industry 4.0 is rather new, plenty of papers and consulting reports have been published on the topic. Some of these have indicated that the SMEs are not quite as well-informed, trained and prepared for this shift in paradigm.

1.2 Problem

Industry 4.0 is in an early development stage, but it has a potential to improve the manufacturing industry by bringing significant benefits. However, studies have shown that the potential is realized mainly for large corporations. The concept of Industry 4.0 was mainly developed around large manufacturing companies in Germany, which suggests it could be difficult to be implemented in the Swedish market that consists of 99.8% of small and medium-sized companies. Research from Germany shows that there are several problems for German SMEs to adopt and utilize Industry 4.0 to its full potential. The same research states that four out of ten SMEs do not have a comprehensive Industry 4.0 strategy compared with two out of ten among large companies (Schröder 2017). Given this, there is a need to evaluate the Industry 4.0 maturity level of Swedish SMEs.

1.3 Purpose and key questions

The purpose of this project is to assess the current level and challenges for Industry 4.0 adoption among Swedish SMEs by using an Industry 4.0 maturity framework to enable further development of the paradigm in Sweden. The thesis has two main research questions, the first having two additional sub-questions. These are the research questions:

1. What is the current level of Industry 4.0 maturity among Swedish SMEs?
   1.1. How does the Swedish maturity level compare to Germany?
   1.2. What is the relationship between maturity and different covariates: revenue, size and industry?
2. What challenges are Swedish SMEs experiencing when implementing Industry 4.0?

1.4 Delimitations

This thesis is delimited to study SMEs registered in Sweden, categorized as manufacturing companies on businessretriever.se. See section 2.3.2 Empirical research, for more specific survey-related delimitation and reasoning behind them.

1.5 Project objectives

There are two objectives of this thesis. Firstly, to conduct a comprehensive assessment of the current Industry 4.0 maturity level of Swedish SMEs, aggregated into a total maturity score. Secondly, to outline what challenges Swedish SMEs currently are facing when implementing Industry 4.0.

1.6 Disposition of thesis

This thesis has eight chapters in total, the first being the introduction and the remaining seven are the core content of the thesis. In this subchapter the content of the following chapters is outlined.

Chapter 2: Methodology. In the second chapter the research strategy, design and methods are described. The main part is the research methods, where the three steps of the projects are described.

Chapter 3: Industry 4.0 maturity models. The third chapter presents the reasoning behind the model and the actual model.

Chapter 4: Previous research: The fourth chapter outlines the previous research related to the research questions. That is the theory platform that will be compared with the results. This chapter is divided into two subchapters, one for each of the main research questions.

Chapter 5: Empirical research and results. In the fifth chapter information about the survey respondents and the results of the survey are presented. The chapter is split up into three subchapters. The first is presenting general respondent information and the following two is connected to the two research questions.

Chapter 6: Analysis. The sixth chapter presents the analyzed results. This chapter is divided into two subchapters, one for each of the main research questions.

Chapter 7: Discussion. In the seventh chapter the results of the analysis are discussed from new perspectives not used in the analysis. The part of the chapter is divided into two parts, one for each of the two main research questions. In addition, a discussion regarding method improvements is found in this chapter.

Chapter 8: Conclusions. Lastly, in the eighth chapter, the conclusions of the report are summarized in two subchapters, one for each of the main research questions. There is also a passage on further research suggestions and presentation of contributions of this study.

2 Methodology

In this chapter, firstly the research strategy is outlined, followed by the research design and lastly the research methods are outlined.

2.1 Research strategy

A research strategy is a general approach of doing research. One can divide research strategies into two groups, qualitative and quantitative. This breakdown is relevant due to its effectiveness in classifying different research methods and consequently is more and more frequently used (Bell and Bryman, 2011).

Quantitative research focuses on quantification of the gathering of data and to do analysis on the data sets. Further, quantitative research has three main characteristics (Bell and Bryman, 2011):

- The relationship between theory and research is deductive and data is collected mainly to test hypotheses.
- The epistemological orientation is based on the Natural science model, especially Positivism.
- The ontological orientation is incorporating the fundamentals of objectivism, i.e. social reality is external.

Qualitative research, on the other hand, is focused on words rather than numbers. It has three main characteristics (Bell and Bryman, 2011):

- The relationship between theory and research is mainly inductive and research is done to generate new theory.
- Rejects positivistic approach and instead supports interpretivism, i.e. the social realm cannot be studied with the scientific method applied to nature, instead it is a matter of subjective interpretation.
- The ontological orientation is constructionistic and views social reality as created by the observing actors.

It should be noted though that the distinction is not always as clear as above and the borders between qualitative and quantitative research can sometimes be blurry. Mixed methodologies, where the researcher combines quantitative and qualitative research are common, where one can enjoy the advantages of both strategies (Bell and Bryman, 2011).

As this research topic is relatively young, unexplored and the dimensions of the research questions are complex and consequently hard to quantify, this study will have mainly have a qualitative research strategy, where theory inductively will be created from the empirical data, but it will be mixed with quantitative assessments of qualitative variables.

2.2 Research design

The design of a research depends heavily on its objective, context and problem. Research can usually have different overall purposes (Höst, Regnell and Runesson 2006):

- Descriptive, the main goal of a study is to find out and describe the way something works or how it is being carried out.
- Exploratory, the goal of a study in this case is to understand in depth how something is done or how it works.
- Explanatory, the goal of a study is to highlight the cause and find explanations for how something is done or how it works.
- Problem-solving, the main goal of a study is to find a solution for an existing problem that has been identified.

The combination of two or three purposes in one study is possible. For example, a problem could be identified in either descriptive or exploratory study which then will be solved in a problem-solving sub-study (Höst, Regnell and Runesson, 2006).

For each of the research designs there are different type of tools for data collection and analysis. The tools are usually surveys, interviews, observations and document analysis. There are four generic research designs for master thesis studies within applied science area (Höst, Regnell and Runesson 2006):

- Survey: compilation and description of the current state of the object studied. Often used for mapping and describing a broad case.
- Case study: studying one or several cases in depth, trying not to affect those.
- Experiment: comparative analysis of two or more alternatives, trying to isolate a few factors and manipulate one of them
- Action research: a supervised and documented study of an activity aimed at solving a problem.

This study is conducted using the survey design with a combination of descriptive and exploratory purposes because of the nature of the topic.

2.3 Research methods

This study is divided into three main parts. An overview of this is presented in Figure 2.1 below.
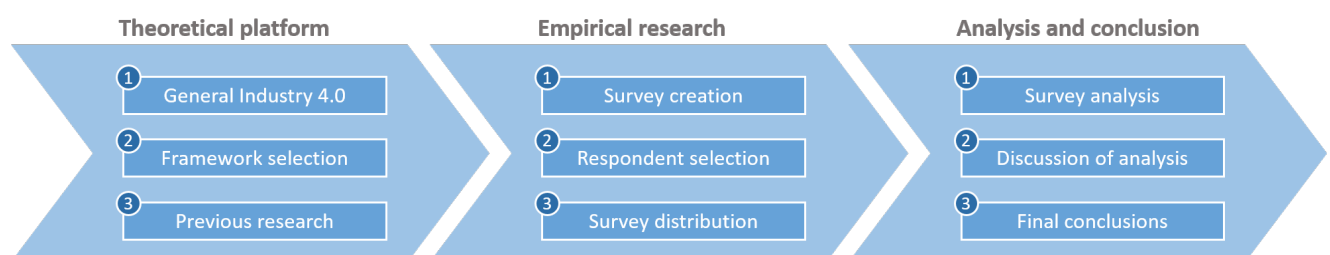

Figure 2.1 Overview of the project methodology.

2.3.1 Literature review and framework selection

The first step of this project was to conduct a literature review, which is described as one of the fundamental methods of research (Höst, Regnell, and Runesson 2006). The literature review had

three different purposes. Firstly, to get a comprehensive understanding of Industry 4.0, the result of this is presented in Appendix A. Secondly, to identify a suitable way of measuring Industry 4.0 maturity for SMEs in Sweden - selecting a maturity assessment framework. This part is presented in Chapter 3, Industry 4.0 maturity models. And lastly, existing studies on the topic of Industry 4.0 maturity was compiled in Chapter 4, Previous research. It is with this the results of the survey will be compared.

Three databases were used when searching for literature, Lubsearch, Scopus and Google Scholar. The search words were:
- Maturity model
- Readiness model
- Assessment
- Framework

The search words were used in combination with "Industry 4.0" and with and without "SME".

In order to fulfill the second purpose of finding a maturity model, a more structured literature review was conducted. After filtering search results for topic relevance, credibility and publication date (only articles published after 2013, due to the novelty of the topic), 15 models were identified. The models come mainly from academic publications, but some consultancy reports were included to get a deeper pool of models.

Models where assessed from three criteria, which were determined after reading the models: comprehensiveness, practicality and proven track record.

2.3.2 Empirical research

The data collection part was conducted through an online survey that was available on a particular server and distributed to the respondents via email (Höst, Regnell and Runesson 2006). The survey tool used was Google forms.

The chosen sampling method is simple random sample, where subset is chosen from a larger set. Each participant is chosen randomly and has the same probability of being chosen as the others. This approach contributes a more representative sampling result (Höst, Regnell and Runesson 2006).

The collection of empirical data was realized by using the survey presented in Appendix D. The survey was delivered to the companies by email. Data collection was held during following period: 9/4/2019-23/4/2019.

Following criteria was used to select the companies included in this study:

Size: The studied companies will be SMEs, defined as having a yearly revenue of between 2 and 50 million euro and having between 10 and 250 employees (European commission, 2019).

Industry: Manufacturing companies will be chosen as objects of study as it was hypothesized that they would in a higher degree have knowledge of Industry 4.0. Previous studies have done the same delimitation (Lichtblau et al. 2015; Saidatul et al. 2018). Furthermore, the products of the chosen companies have to be customizable. The customization enables the possibility of self-optimizing and self-guiding of products through a Smart factory. Additionally, the idea of Data-driven services is applicable on customizable products only.

Respondent: It is important that the respondent has strategic and operational understanding of Industry 4.0, as the model has a comprehensive approach. No constraint is set on respondent position, but the company will be urged to select a respondent that possess both views of the business.

Sub industries: The targeted companies operate within different manufacturing sub-industries and those are presented in Appendix B. Each company was assigned a sub-industry by using a database that can be reached through the website allabolag.se.

286 companies received the survey, whereof answers provided by 28 are included in this study. The names of the companies will not be presented due to the privacy preferences.

2.3.3 Analysis and conclusion

In the analysis the results are processed in order to reach deeper conclusions. After the analysis, the results are discussed, where the data is looked at from other perspectives than the core theory. Finally, the main results are summarized in conclusions. The analysis is split up into two main parts, one for each research question. In the first part the results related to maturity level are analyzed and in the second part the results related to challenges are analyzed.

The first part is further split up into two sub-parts, one part where the total and dimension maturity level is analyzed by comparison with the previous research and one part in which the aim is to identify patterns in the maturity level by plotting against other covariates from the data, specifically revenue, size (small or medium-sized) and sub-industry. The first sub-part is more of qualitative character, whereas the second is of a more quantitative character.

In the second part the companies are categorized based on their maturity level. After that, conclusions are drawn both based on a qualitative analysis of the survey results and a qualitative analysis on the open-end questions, by comparing them to the theory.

3 Industry 4.0 maturity models

In this chapter the result of the maturity model literature review is presented, with emphasize on explaining the chosen model, the Impuls maturity model.

3.1 Assessing Industry 4.0 maturity

Assessing maturity for Industry 4.0 at company level is usually based on self-assessment. Information needed for the assessment is generally collected through internet surveys and sometimes by phone interviews. The surveys target in most cases general information on enterprises, manufacturing and branch specific data (Rajnai and Kocsis, 2018). Similar approach can be observed at global level (The Boston Consulting Group, 2016). The same approach is used in this study.

There are general maturity models, e.g. Project Management Maturity Model (Seesing 2003), not specifically focusing on Industry 4.0. Given the cutting edge nature of Industry 4.0, only models designated for Industry 4.0 have been considered.

3.2 Choice of maturity model

The Impuls maturity model will be used in this study as the maturity assessment model. This decision was made by comparing the different maturity models found through the literature review. In this subchapter, the reasoning behind choosing the Impuls model is presented.

The Impuls model was chosen because of three reasons: it is comprehensive, it is practical and it has been tested.

Several models focus heavily on the operational and technological aspects of Industry 4.0 (Qin, Liu, and Grosvenor, 2016; Weyer et al. 2015; Rockwell Automation 2014; Anderl et al. 2015), thus disregarding the fact that Industry 4.0, like all new strategic paradigms, have to be supported by management and an aligned organization (Paton and McCalman 2008; Schuh et al. 2017). Other models focus heavily on the management and organizational aspects of Industry 4.0 (Schumacher, Erol, and Sihn. 2016; Kannan et al. 2017; Ganzarain and Errasti 2016). As Industry 4.0 fundamentally is driven by technological development (Moeuf et al. 2018) and consequently, the operational applications are an essential way of assessing Industry 4.0 maturity. The Impuls maturity model offers a comprehensive way of assessing Industry 4.0, focusing on both the strategic aspects and the technological. The model is built on six dimensions, three of them being more technological (Smart products, Smart operations and Smart factories), two of them being strategic or organizational (Employees and Strategy and organization) and one lying in the intersection (Data-driven services). There are other maturity models that succeed in doing this (Jung et al. 2016; Geissbauer et al. 2016; Schuh et al. 2017; Scremin et al. 2018; Mittal et al. 2018). The Impuls maturity model was chosen among the 2-dimensional maturity models due to its practicality. The other models are more conceptual (Geissbauer et al. 2016; Schuh et al. 2017; Scremin et al. 2018; Mittal et al. 2018) or statistical (Jung et al. 2016), whilst the Impuls model has clearly defined dimensions and levels within each dimension, making it more suitable for this study. Also, the Impuls model has proven its functionality in two different studies (Lichtblau et al. 2015; Saidatul et al. 2018).

It has been argued that the Impuls maturity model fails to consider the limitations of SMEs when it comes to implementing Industry 4.0 (Mittal et al. 2018). Specifically, it is argued that the Impuls maturity model doesn't take into account limitations regarding technological resources availability, employee participation and organizational culture (Mittal et al. 2018). The model however has successfully been applied on SMEs in previous studies, suggesting it does work in practice when it comes to SMEs (Lichtblau et al. 2015; Saidatul et al. 2018).

3.3 The Impuls model

The Impuls maturity model is created by the Impuls Foundation, a think tank part of the mechanical engineering industry association in Germany, VDMA (VDMA, 2019). Their goal is to support German manufacturing companies, in this case by creating an Industry 4.0 maturity model and assessing the current maturity of German manufacturing corporations, as they have identified Industry 4.0 as a pivotal driver of development in the industry (Lichtblau et al. 2015).

The model was created in two steps. Firstly, an extensive review of existing literature was made. Secondly, interviews and workshops with companies that were experienced within Industry 4.0 were held together with scientists from Cologne Institute for Economic Research. Together they identified success-factors related to Industry 4.0. These factors then constituted the basis for the dimensions of the model.

3.3.1 Model dimensions

As a result of their research, the Industry 4.0 maturity model of the Impuls Foundation of VDMA is based on six dimensions, each dimension being defined by a number of sub-dimensions.

3.3.1.1 Strategy and organization

Industry 4.0 is not only about improving processes and products in companies by using technologies. It encourages the development of entirely new business models (Lichtblau et al. 2015). This is encapsulated in the dimension Strategy and organization. The criteria listed in Figure 3.1 are used to get an understanding of the maturity level inside this dimension.

Dimension	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Strategy and organization						
Degree of strategy	Industry 4.0 is not part of the strategic progress	Industry 4.0 is an issue at the departmental level but is not integrated into the strategy	Industry 4.0 is part of the strategic process, and a strategy is being developed	An Industry 4.0 strategy has been defined	An Industry 4.0 strategy is in implementation	An Industry 4.0 strategy has been implemented enterprise-wide
Definition of indicators	No indicators exist to determine the status of Industry 4.0 implementation	No indicators exist to determine the status of Industry 4.0 implementation	A system of indicators is in place that gives a sense of the status of implementation	A system of indicators is in place that gives a sense of the status of implementation	A system of indicators is in place that gives a sense of the status of implementation	A system of indicators is in place and integrated into the strategic process
Investments	No Industry 4.0 investments	Initial Industry 4.0 investments in one area	Low level of Industry 4.0 investments	Industry 4.0 investments in a few areas	Industry 4.0 investments in several areas	Industry 4.0 investments enterprise-wide
Innovation management	No innovation management	No innovation management	No innovation management	Innovation management in isolated areas	Innovation management implemented in several departments	Uniform, interdepartmental innovation management has been established

Figure 3.1. Maturity Model for the dimension of Strategy and organization – minimum requirements. (Lichtblau et al. 2015).

Smart factory

The concept of the Smart factory implicates a production environment where the production systems and logistics systems are able to organize themselves without any interaction with humans. In this environment the workpieces will autonomously guide themselves throughout the production processes, while simultaneously controlling and monitoring the processes too. One of the most crucial parts of the Smart factory is cyber-physical systems (CPS) which act as a link between the physical and virtual worlds by a communication through an IT infrastructure. Placement of comprehensive sensor technology at strategic data collection points throughout the factory and on the machinery and systems is another key future of the Smart factory. This will enable capturing of all the relevant process- and transaction related data in real time and analyzing it for mapping the order processing. It will also ensure that the resources are used efficiently (Lichtblau et al. 2015).

The maturity within the dimension Smart factory is measured on four criteria: digital modeling, equipment infrastructure, data usage and IT systems. These criteria are broken down into six sub-dimensions, which are illustrated in Figure 3.2.

Dimension	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Equipment infrastructure (current)	Machine and system infrastructure cannot be controlled through IT, no integration (M2M)	Some machines can be controlled through IT, are interoperable, or have M2M capability	Machine and system infrastructure can be controlled to some extent through IT and is integrated	Machine and system infrastructure can be controlled through IT and is partially integrated	Machinery can be controlled completely thorough IT, is partially integrated (M2M) or interoperable	Machines and systems can be controlled almost completely through IT and are fully integrated (M2M).
Equipment infrastructure (target)	Machines and systems cannot be upgraded	Future requirements for machines and systems are relevant	Some machines and systems can be upgraded	All machines and systems can be upgraded	Machines already meet some of the requirements or can be upgraded	Machines and systems already meet all future requirements
Digital modeling	No digital modeling	No digital modeling	Some digital modeling	Some digital modeling	Some digital modeling	Complete digital modeling possible
Data collection	No digital is collected	No digital is collected	Data is collected but for the most part manually	The relevant data is collected digitally in certain areas	Comprehensive digital data collection in multiple areas	Comprehensive automated, digital data collection in all areas
Data usage	No data available for further use	No data available for further use	Data is used for selected purposes (greater transparency, etc.)	Some data used top optimize processes (predictive maintenance, etc.	Data used in several areas for optimization	Data used for comprehensive process optimization
IT systems	No support through IT systems	Main business proves supported by IT systems	Some areas of the business are supported by IT systems and integrated	Some areas of the business are supported by IT systems and integrated with one another	Complete It support of processes, full integration	It systems support all company processes and are integrated

Figure 3.2. Maturity Model for the dimension of Smart factory – minimum requirements. (Lichtblau et al. 2015).

3.3.1.2   Smart Operations

The enterprise-wide and cross-enterprise integration of the physical and virtual worlds is one of the fundamental characteristics of Industry 4.0. The digital transformation and the huge amount of data this integration brought with it have made it possible to develop entirely new supply chain management and production planning approaches. Smart operations imply the technical requirements in production and production planning needed for realizing the self-guided workpieces (Lichtblau et al. 2015).

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Industry 4.0 maturity in the area of Smart operations is determined using the following four criteria: information sharing, cloud usage, IT security and autonomous processes. The details and requirements for each criterion are found in Figure 3.3.

Dimension		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Smart operations	System-integrated information sharing)	No system-integrated information sharing	Beginnings of in-company, system-integrated information sharing	In-company information sharing partially system-integrated	Some in-company and beginnings of external system-integrated information sharing	Predominantly in-company and partially external system-integrated information sharing	Comprehensive in-company and partially external system-integrated information sharing
	Autonomously guided workpieces	Autonomously guided workpieces not in use	Autonomously guided workpieces not in use	Autonomously guided workpieces not in use	Autonomously guided workpieces not in use	Experiments in test and pilot phase	Use in selected areas or even cross-enterprise
	Self-reacting processes	Self-reacting processes not in use	Self-reacting processes not in use	Self-reacting processes not in use	Self-reacting processes not in use	Experiments in test and pilot phase	Use in selected areas or even cross-enterprise
	IT security	No IT security solutions in development or implemented	Initial IT security solutions planned	Multiple IT security solutions are planned or initial solutions are in development	IT security solutions have been partially implemented	Comprehensive IT security solutions have been implemented, existing gaps are being closed	IT security solutions have been implemented for all relevant areas
	Cloud usage	Cloud solutions not in use	Cloud solutions not in use	Cloud solutions not in use	Initial solutions planned for cloud-based software, data storage, and data analysis	Initial solutions implemented	Multiple solutions implemented

Figure 3.3. Maturity Model for the dimension of Smart operations – minimum requirements. (Lichtblau et al. 2015).

3.3.1.3   Smart products

Smart products are physical products equipped with information and communication technology, ICT, components (sensors, RFID, communication interface etc.) which enables data collection on their environment and their own status. Once the products gather the needed data and know their way through the production while simultaneously communicating with a higher-level system, the production processes can be improved and be self-guided in real time. This also adds a possibility of optimizing and monitoring the **status** for a particular product and builds the base for Data-driven services, where customers can communicate with manufacturers (Lichtblau et al. 2015).

The maturity level in this dimension is determined by looking at the ICT add-on functionalities of products of the company and the extent to which data from the usage phase is analyzed at different levels in company e.g. product development, sales support or after-sales (Lichtblau et al. 2015). In Figure 3.4 the sub-dimensions are presented.

Dimension		Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Smart products	ICT add-on functionalities	No add-on functionalities	Products show first signs of add-on functionalities	Products feature initial add-on functionalities	Products feature multiple, interrelated add-on functionalities	Products feature add-on functionalities in different areas	Products feature extensive add-on functionalities
	Use of data	No data collected	No data collected	Data collected but not analyzed/used	Data analyzed/used	Data analyzed/used	Data analyzed/used

Figure 3.4. Maturity Model for the dimension of Smart products – minimum requirements. (Lichtblau et al. 2015).

3.3.1.4 Data-driven services

Data-driven services is about companies evolving from only selling products to providing solutions. One of the most important features of Industry 4.0 is a total reconsideration of existing business models. Companies should focus more on the benefit to the customer and will get an opportunity to both digitize their existing business models and develop new. The after-sales and other services will be based on the evaluation of collected data. To make the data collection possible the sold physical products have to be equipped with sensors so they can send, receive and process the necessary information (Lichtblau et al. 2015). Maturity level in this area of Data-driven services is determined by looking at three criteria demonstrated in Figure 3.5.

Dimension	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Data-driven services	No data-driven services offered	Data-driven services are offered, but without customer integration	Data-driven services are offered, but without customer integration	Data-driven services are offered, but without customer integration	Data-driven services are offered with customer integration	Data-driven services are fully integrated into the business model (integration with the customers)
Share of revenues	No share of revenues	Data-driven services account for an initial share of revenues (< 1%)	Data-driven services account for an initial share of revenues (< 2.5%)	Data-driven services account for an initial share of revenues (< 7.5%)	The share of revenues is significant (<10%)	Data-driven services play an important role in revenues (>10 %)
Level of data usage	Data not used	Data not used	0–20% of collected data is used	20–50% of collected data is used	20–50% of collected data is used	More than 50% of collected data is used

Figure 3.5. Maturity Model for the dimension of Data-driven services – minimum requirements. (Lichtblau et al. 2015).

3.3.1.5 Employees

Changes in the workplace driven by digitalization, highly affect the employees. The working environment that they are used to is changed, making them learn new skills and qualifications. This is the reason why the companies that are going through a digital transformation should prepare their employees for these changes through suitable training and education. The maturity level in this area is determined by looking at the employees existing skills in different fields and the efforts that the company makes in order to acquire new skills and qualifications (Lichtblau et al. 2015), which can be seen in Figure 3.6.

Dimension	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Employee skills	No skills	Employees have low skill levels in one relevant area	Employees have low skill levels in a few relevant areas	Employees have adequate skill levels in some relevant areas	Employees have adequate skill levels in several relevant areas	Employees possess all necessary skills in several relevant areas

Figure 3.6. Maturity Model for the dimension of Employees – minimum requirements. (Lichtblau et al. 2015).

Each of these six dimensions is further decomposed into 18 fields, which in turn groups their respective indicators and constitutes the basis for measuring the Industry 4.0 maturity of the companies (Lichtblau et al. 2015). An overview of this is presented in Figure 3.7.

Figure 3.7. Dimension and associated fields of Industry 4.0. (Lichtblau et al. 2015).

3.3.2 Model maturity levels

Based on the indicator values, a six-level model for measuring Industry 4.0 maturity has been developed. Each of the six maturity levels (0 to 5) includes minimal requirements that companies have to meet in order to complete the level (Lichtblau et al. 2015).

The six levels of the Maturity Model can be described as follows:

Level 0: Outsider. At this level companies do not meet any of the Industry 4.0 requirements.

Level 1: Beginner. Involvement in Industry 4.0 at this level is characterized through pilot initiatives in various departments and investments in a single area. IT systems in the company supports only a few production processes. The future integration and communications requirements are only partially satisfied by the existing equipment infrastructure in the company. The information sharing through the systems in the company is limited to a few areas. IT security solutions are only in planning or implementation phase. At this level companies make first steps in direction of IT-based

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add-on functionalities for their products. The employee skills needed for developing Industry 4.0 are only found in few areas of the company (Lichtblau et al. 2015).

Level 2: Intermediate. At this level companies incorporate Industry 4.0 into their strategic orientation. A strategy for Industry 4.0 implementation and the appropriate indicators for measuring the implementation status are being developed. Investments are only made in a few areas. Some data within production areas is being automatically collected and used to a limited extent. The future expansion is not supported by the equipment infrastructure. Internal information sharing is integrated in the systems to some extent. Even integration of information sharing with business partners are being taken into consideration and first steps are being taken for the realization too. IT security solutions are in place and being expanded. At this level companies are making products with the first IT-based add-on functionalities. The employee skills for expanding Industry 4.0 can be found in some areas (Lichtblau et al. 2015).

Level 3: Experienced. At this level an Industry 4.0 strategy is formulated. The company is making Industry 4.0 related investments in multiple areas and starts to promote the introduction of Industry 4.0 in its departments through innovation management. The linkage between IT systems is supported by an appropriate interface. The IT systems support the production processes too and data is collected automatically in key areas. The equipment infrastructure is upgradable and supports the future expansion. In-company and cross-enterprise information sharing is enabled by and partially integrated into the system. Necessary IT security solutions have been implemented and cloud-based solutions are planned to accommodate further expansion. This environment enables the company to make products with several interconnected IT-based add-on functionalities. These products create the basis of the fundamental Data-driven services, but the company still lacks the integration with the customers. The Data-driven services account for a very small part of revenues. Employees' skill sets are expanded through extensive efforts (Lichtblau et al. 2015).

Level 4: Expert. Expert companies are using a comprehensive Industry 4.0 strategy and monitoring it with appropriate indicators. Industry 4.0 related investments are being made in almost all relevant areas. The investment process is supported by interdepartmental innovation management. The IT systems are used to support most of the production processes and collect large amounts of data for further process optimization. Further expansion in companies are possible due to the existing equipment already satisfying future integration requirements. Both internal and cross-enterprise information is largely integrated into the system. IT security solutions are used in the relevant areas and IT is possible to scale through cloud-based solutions. Autonomously guided workpieces and self-reacting processes are being explored. Both workpieces and the end products feature IT-based add-on functionalities which in turn allow data collection and targeted analysis during the usage phase. The Data-driven services enable direct integration between the customer and producer. The necessary employee skills for the further developing of Industry 4.0 can be found in most of the relevant areas (Lichtblau et al. 2015).

Level 5: Top performer. Top performer companies have successfully implemented Industry 4.0 strategy and are regularly monitoring the implementation status of other projects. This is achieved through investments throughout the company. Enterprise-wide innovation management is established. All the relevant data in production is automatically collected, which is enabled by a

successful implementation of a comprehensive IT system support. All the requirements for integration and system-integrated communications are satisfied by the existing equipment infrastructure, which in turn makes system-integrated information sharing possible, both inside the company and cross-enterprise. Comprehensive IT security solutions have been implemented across all the areas and cloud-based solutions deliver a flexible IT architecture. Autonomously guided workpieces and self-reacting processes are being used in some areas. Both workpieces and products feature extensive IT-based add-on functionalities which in turn allow data collection and usage of this data for functions such as product development, remote maintenance and sales support. The Data-driven services for customers account for a substantial share of revenues and the producer is fully integrated with customer. The company has a well-developed employee skill in all needed areas and can move forward with Industry 4.0 (Lichtblau et al. 2015).

In order to make it possible to better summarize the results and draw conclusions about progress and conditions relating to Industry 4.0, the six maturity levels can be grouped into three types of company (Lichtblau et al. 2015):

- *Newcomers* (level 0 and 1) describe those companies that have done either nothing at all or very little in terms of facing Industry 4.0.
- *Learners* (level 2) are the companies that have taken the first steps towards Industry 4.0 implementation.
- *Leaders* (level 3 and up) are the companies that are well on the way to implementing Industry 4.0.
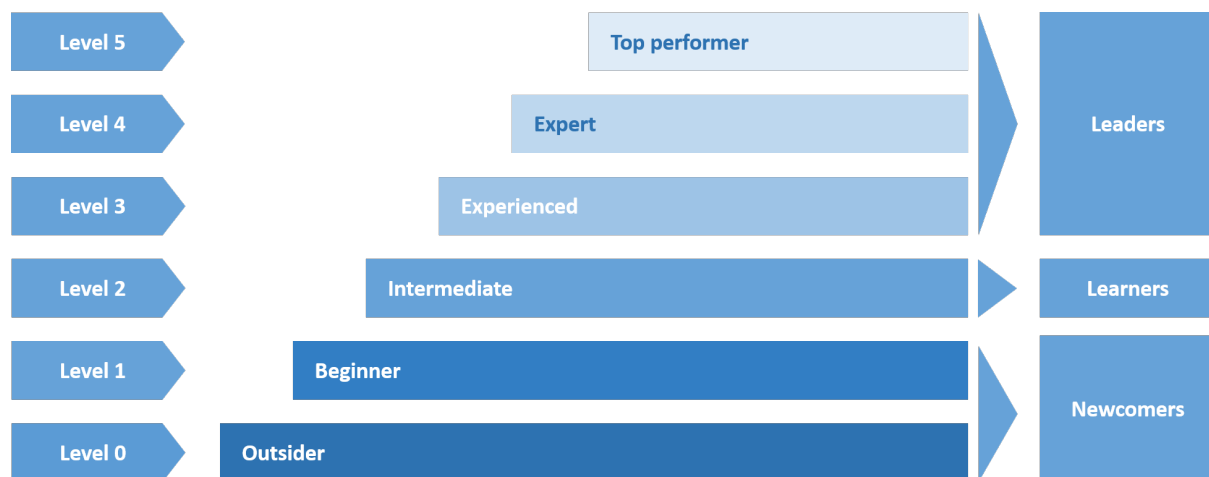
Figure 3.8. Six levels of Industry 4.0 Maturity Model. (Lichtblau et al. 2015)

3.3.3 Total maturity score

The company gets ranked and assigned maturity level in each of the six dimensions based on the lowest score of the sub-dimension within the given dimension. For example, if under Smart factory a company gets the highest level 5 in three fields and level 1 in one field, then the maturity level for the whole dimension is 1(Lichtblau et al. 2015).

The final six dimension-level maturity score is calculated as a weighted average of the maturity scores of the six dimensions. The weights are determined based on the importance assigned by the

respondent companies to that dimension. (Lichtblau et al. 2015). In this study, the same approach was used and an additional estimation question was added to the main questionnaire.

There are totally 100 possible points, and the six dimensions were weighted as follows based on the average survey responses:

- Strategy and organization - 24 points
- Smart factory - 19 points
- Smart products - 17 points
- Data-driven services - 10 points
- Smart operations - 8 points
- Employees - 22 points

3.3.4 Empirical implementation

In order to be able to measure maturity, criteria were defined for each of the areas. To move to the next maturity level a company has to meet these criteria. In Figure 3.9 four different scenarios are presented and what the resulting maturity level would be (Lichtblau et al. 2015):

- Scenario A, if the company meets the criteria for the level 1 but not for levels 2 to 5, it will be assigned the maturity level 1.

- Scenario B, here it is not possible to determine whether the company meets the criteria for level 1, since it did not provide any answer (Missing values). However, if the criteria for the level 2 have been met, the missing values from level 1 are interpreted as fulfilling criteria for level 1. The company is therefore will be assigned the maturity level 1.

- Scenario C, no information is available for level 1 and criteria for level 2 is not met. The missing values at level 1 are interpreted as not meeting criteria for the level 1, the company will therefore be assigned level 0.

- Scenario D, if in any given sub-dimension, some of the levels criteria are the same, then the highest of those levels will be chosen.

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	Result
A	Yes	Yes	No	No	No	No	Level 1
B	Yes	Missing values	Yes	No	No	No	Level 2
C	Yes	Missing values	No	No	No	No	Level 0
D	Yes	Same criterion	Same criterion	No	No	No	Level 2

Figure 3.9. Satisfaction of one or more criteria. (Lichtblau et al. 2015)

3.3.5 Adjustment of model

An additional questionnaire that is mapping fundamental aspects of the company and company representative will be added as a part of the survey sent to companies. The following six questions will be asked:

1. What's the name of your company?
2. What's your position at the company?
3. What was your revenue 2018?
4. What's your employee count?
5. Are your company aware of Industry 4.0?

In addition to the core model suggested by the Impuls Foundation, open-end question for each dimension was added:

What do you experience as the main challenges when it comes to implementing this dimension of Industry 4.0?

This question will add depth and qualitative data to the challenges research question.

4 Previous research

In this section result from previous research related to the research questions are presented.

4.1 Maturity level

In this subsection, the previous research related to RQ 1 is presented.

4.1.1 Overall maturity

Research has indicated that the maturity level of large, Swedish manufacturing companies is low (Antonsson, 2017). However, the same study showed that the implementation of Industry 4.0 indeed has been initiated and that there are some companies that have already achieved high maturity.

In the original Impuls study, the maturity level in Germany was found to be low with a total average maturity level of 0.6 for the manufacturing industry as a whole and 0.9 for the sub-industry mechanical engineering industry (Lichtblau et al. 2015). The maturity is distributed between the different dimensions in accordance with Figure 4.1.
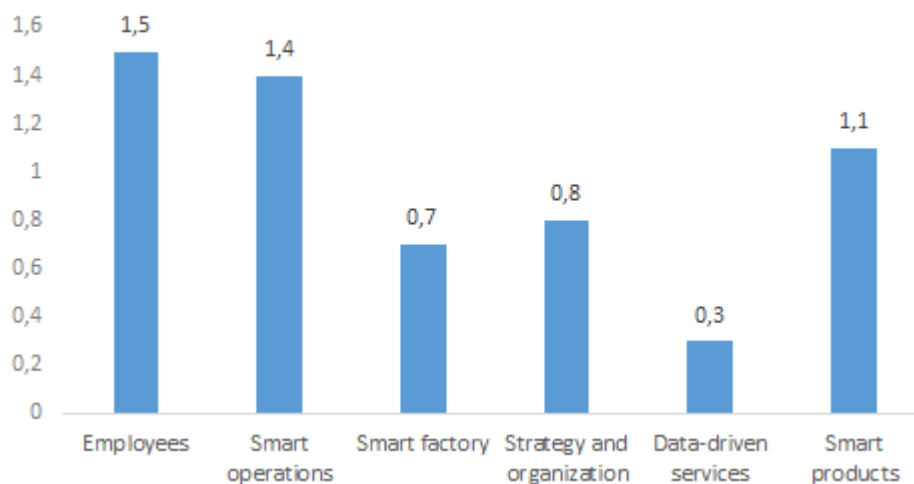
Figure 4.1. Average maturity level in each dimension for German companies. Source: (Lichtblau et al. 2015).

4.1.2 Maturity covariates

As part of RQ1, the maturity level will be compared against three covariates, revenue, size and sub-industry. In this section, the previous research related to this is presented.

4.1.2.1 Revenue

It has been found that there is no correlation between revenue and Industry 4.0 maturity level for manufacturing companies in Sweden (Antonsson, 2017). This study was conducted on only large corporations and the researcher mentions that this could be the reason why no such relationship was identified.

Previous studies have indicated that there is a positive relationship between size of organization, in terms of both revenue and employee count, and Industry 4.0 maturity level. A study in Germany showed that companies with less than 500 employees are more than twice as likely to not be aware of Industry 4.0 as companies with more than 1000 employees (Weiß & Zilch, 2014).

In a systematic review, where nine studies looking at how the Industry 4.0 maturity correlated with employee count, larger corporations were found to be better suited to actively and passively deal with Industry 4.0 (Sommer, 2015).

4.2 Challenges

In this subsection the previous research related to RQ 2 is presented.

4.2.1 Common challenges

Several studies have been made in order to understand the potential challenges with Industry 4.0. There are studies that focus more on the technical aspects of Industry 4.0, while other focus on organizational issues. The main goal of this thesis is to determine the overall Industry 4.0 maturity level of Swedish SMEs and therefore the theory is based on the studies focusing on both technological and organizational issues.

These are the challenges that were found to be recurring in previous studies.

Data challenges. Data in production environments is collected through different machines, sensors, process data, product data, plant data, logistics data, and data from partners and infrastructure data, which all together forms large amounts of data. One study found that the need for new methods for storing, processing and management of such a big size of data arises (Khan and Turowski, 2016). For examples, new algorithms, models, visualization techniques and competent personnel are required in order to gain benefits from such big amounts of data. Another issue found in this area is lack of a standardized approach for data management, which results in different departments using different formats of data and therefore the amount of data redundancy, inconsistency and different interpretations of the same data become a huge problem (Khan and Turowski, 2016). Finally, the integration between different systems would eliminate the above mentioned problems, but is hard to execute because of needed changes in data structure, which was found by another study to be a significant challenge when it comes to data (Abraham et al., 2016).

Training and skill development. Companies face shortage of competent personnel and there are different reasons for it. The first one is the aging population who take all the production knowledge and experience with them when retiring. The second issue is about keeping the skilled staff within the organization, as the younger generation prefers switching jobs more frequently. Finally, it leaves organizations with an older workforce, who refuse to accept changes, learn technologies and change their work routines which results in lack of knowledge and know-how among the personnel (Khan and Turowski, 2016).

Process flexibility. The nature of products is under constant changes by and individualized and customized products become more demanded today. In order to fulfil the demand, flexibility at production level is required which in turn is only possible if the production environment is adaptable at a process level. The issue here is that technology used at the shop floor does not support the process flexibility. The processes and systems at production level are used and managed isolated in various departments, which makes change management at a production level quite challenging. Well-developed change management, process standardization and synchronization between company departments are needed in order to provide the needed process flexibility (Khan and Turowski, 2016). The other issue is when the human is at the core of the value creation, this could make the business incompatible with Industry 4.0, for example with no room for automation (Samuel Nilsen and Eric Nyberg (2016)).

Security. Security has always been and will be a big concern in different industries. The use of smart devices in production sites is increasing and the count of IoT devices will be more than 64 billion by 2025 (Newman, 2019). Monitoring and maintaining both hardware and software of such systems in production sites are challenging and often ignored too. In order to avoid different security threats such as malfunction and viruses, the devices have to be updated on a regular basis (Abraham et al., 2016).

Financial and strategic uncertainties. According to Dennis K. et al. (2017) the companies do not want to invest in Industry 4.0 projects due to the lack of demonstrated business cases, which contributes to uncertainties about financial benefits of the investments. Additionally, there is neither a strategy to coordinate actions across different organizational units nor courage to push through a radical transformation.

4.2.2 Type challenges

In this chapter the challenges presented in the Industrie 4.0 Readiness report for each type of company are outlined (Lichtblau et al. 2015). These challenges were identified in the above mentioned study conducted by VDMA on German manufacturing companies of all sizes.

4.2.2.1 Newcomers
According to Lichtblau et al. (2015), the main challenges for Newcomers are lack of clarity about the economic benefit of Industry 4.0, followed by lack of a general knowledge about Industry 4.0. In addition, German Newcomers are aware that they lack know how in this field and this is therefore another big issue in this area.

4.2.2.2 Learners
Similar to Newcomers, the Learners lack a clear understanding of the economic benefits of Industry 4.0 concepts, followed by lack of general knowledge about Industry 4.0. In addition, nearly half of the companies complain about lack of know-how and a shortage of skilled staff. One third of German Learners are concerned about their employees not being ready for digitalization changes and around 14% fear the market power of large enterprises (Lichtblau et al. 2015).

4.2.2.3 Leaders

When it comes to German Leaders, the biggest challenge is the lack of financial resources for making investments in Industry 4.0. This issue is followed by the lack of forms and standards. Unresolved legal issues relating to Industry 4.0 and a shortage of skilled staff are also major challenges for German Leaders. Some 40 percent of the companies experience unsafety when it comes to data security and 35 percent experience bureaucratic and regulative difficulties in Industry 4.0 implementation (Lichtblau et al. 2015).

5 Empirical research and results

In the section the respondent information and the results of the survey sent out to Swedish SMEs are presented.

5.1 Maturity level

In this subsection, the empirical results related to RQ 1 will be presented.

5.1.1 General

Here the general maturity results of the survey are presented. Firstly, less than half, 44%, of the companies responded that they were aware of the concept Industry 4.0.

In terms of maturity level, which were determined in line with the previously outlined procedure, 18 companies had a maturity level below 1 and were consequently classified as Outsiders, 5 companies had a maturity level between 1 and 2, thus Beginners and 2 companies had a maturity level between 2 and 3, which made them Intermediates. No companies reached a maturity level above 3 and consequently no company were classified as Experienced, Expert or Top Performer. This result is visualized in Table 5.1.

	Count	Percentage
Level 0: Outsiders	12	42,9%
Level 1: Beginners	13	46,4%
Level 2: Intermediates	2	7,1%
Level 3: Experienced	1	3,6%
Level 4: Expert	0	0,0%
Level 5: Top performer	0	0,0%

Table 5.1. Distribution of total maturity level.

The average maturity level of all companies was 1,17, which made Swedish SMEs on average Beginners.

Looking at the maturity level distribution for each dimension, which is stated in Table 5.2, the fact that Smart products have the lowest level is clear. In order to make the results more transparent, the average level for each dimension is calculated and presented too. The total maturity level of the Swedish SMEs is 1,17. Given the results of maturity level for each dimension, the Employees dimension gets the highest level of maturity, followed by Smart Factory, Data-driven services, Strategy organization, Smart operations and finally Smart products.

	Strategy and organization	Smart factory	Smart operations	Smart products	Data-driven services	Employees	Total
Level 0: Outsiders	53,6%	17,9%	28,6%	92,9%	78,6%	7,1%	42,9%
Level 1: Beginners	35,7%	50,0%	7,1%	0,0%	7,1%	32,1%	46,4%
Level 2: Intermediates	3,6%	14,3%	50,0%	3,6%	7,1%	35,7%	7,1%
Level 3: Experienced	3,6%	14,3%	14,3%	3,6%	0,0%	14,3%	3,6%
Level 4: Expert	3,6%	3,6%	0,0%	0,0%	3,6%	7,1%	0,0%
Level 5: Top performer	0,0%	0,0%	0,0%	0,0%	3,6%	3,6%	0,0%
Average maturity	0,68	1,36	1,50	0,18	0,54	1,93	1,17

Table 5.2. Distribution of maturity level for each maturity level, based on survey results.

5.1.2 Strategy and organization

Implementing Industry 4.0 stretches beyond only adopting new information and communication technology, it is a paradigm that requires fundamental changes on all levels of corporations, not least strategically and organizationally.

In the dimension Strategy and organization, Swedish manufacturing SMEs scored a maturity level of 0,68. The companies are predominantly classified as Outsiders 53,6 % and Beginners 35,7 %, which can be seen in Table C.1 in Appendix C. Further, there are 3,6 % Intermediates followed by 3,6 % of the companies being Experienced and 3,6 % being Experts. There are no Top performers in this dimension.

One of the main reasons companies score relatively low in this dimension is lack of Industry 4.0 related investments. More than half of the companies do not have any Industry 4.0 investments currently. The second core reason why companies are underperforming when it comes to Strategy and organization is that the degree of strategic implementation is low. Three out of four companies are Outsiders or Beginners when it comes to strategic implementation of Industry 4.0. Out of these, about half state that Industry 4.0 is not at all part of their strategic process and half state that Industry 4.0 is an issue at department level, but not part of general strategic process.

The strongest sub-dimension within Strategy and organization is innovation management, with an average score of 3,11. Almost half (46,4 %) of the companies are Experienced from an innovation management perspective, which means they do have innovation management in isolated areas of

the organization. Further, 10.7% are Experts and thus have innovation management in several areas. Lastly, 14,3% are Top performers, meaning they have developed an innovation management department that is uniform and stretches over several departments, leading to a consistent approach to innovation management.

The last sub-dimension is definition of indicators. Here, the average maturity level is 1,32. Most of the companies, 89,3%, are Beginners and do not have any indicators to measure the Industry 4.0 implementation. There are 10,7% Experts, with a system of indicators that give a sense of the status of the Industry 4.0 implementation.

5.1.3 Smart factory

The Smart factory is the centerpiece of Industry 4.0, it is here where IT systems connect machines with products, creating an improved production system.

On average, which can be seen in Table C.2 in Appendix C, companies have a maturity level of 1,36 in the Smart factory dimension, making it a dimension with an average maturity relative to the other dimensions. This dimension is dominated by Beginners constituting 50,0% of all companies. Out of the rest of the companies 14,3% are Experienced, 3,6% are Experts and no company is a Top performer.

The equipment infrastructure (current) sub-dimension has the lowest maturity in the Smart factory dimension. Out of all companies, 14,3% have a machines and system infrastructure that cannot be controlled by information technology and do not have any machine-to-machine integration. A bigger group, 46,5%, are at the Beginner level, which means that they have some machines that can be controlled with information technology or that have machine-to-machine integration. Despite this being the lagging sub-dimension 7,1% of the companies are Experts when it comes to current equipment infrastructure. These companies can control their entire machine park with information technology and some machines are integrated with each other.

All three sub-dimensions digital modeling, data collection and IT systems have an average maturity level of 3 or higher, making them on average Experienced. When it comes to digital modeling 67,9% are Experts and some digital modeling is part of their current business. In the data collection sub-dimension 10,7% of the companies are Top performers, which means that they have digital data collection that is comprehensive, automated and active in all areas of the business. The IT system maturity is dividing the companies into two groups. One group containing 32,1% of the companies being either Outsider or Beginners, which means they either have no IT systems for support or some basic IT systems that support the main business processes. The other group contains 67,8% of the companies and is mature with the companies either being Experts or Top performers. The Experts have full, integrated IT support on many of the companies processes and the Top performers have the same performance but for all the companies' processes.

The two remaining sub-dimensions, target equipment infrastructure and data usage, are relative to the other sub-dimensions in the middle in terms of average maturity level. Most of the companies are on the Intermediate maturity level in terms of target equipment infrastructure and thus have

some machines and systems that can be upgraded. The rest of the companies are evenly spread among the maturity levels, except for the Top performer level which is not reached by any company. The maturity distribution of the data usage sub-dimension is similar to the one of target equipment infrastructure, but with a skewness toward Top performers instead of Outsiders. Again, 42,9% of the companies are Intermediates, which means they uses data for a few selected purposes, e.g. transparency. As previously mentioned, in this sub-dimension some companies, 10,7%, reached Top performer level and consequently uses data for comprehensive process optimization.

5.1.4 Smart operations

Smart operations is made up out of the integration of physical and digital systems, both within and between companies. Access to a larger amount of relevant data enables a completely new type of value-chain management, which requires less and less interaction with humans.

An overview of the results is presented in Table C.3 in Appendix C. In this dimension the companies have on average a maturity level of 1,50 which is the third highest scored dimension in this survey. Unlike the previous two dimensions, the Intermediates are dominating here with 50% of the companies. Furthermore, 28,6 % of the companies are classified as Outsiders and remaining 7,1 % are Beginners. Finally, 14,3 % of the companies are classified as Experienced, with no sign of Experts or Top performers.

The sub-dimension for System- integrated information-sharing has the lowest maturity level of 2,0 compared to the other sub-dimension in Smart operations. This sub-dimension is dominated by Intermediates which is 53,6% of all companies, yet Outsiders is the second biggest group and stands for 25%. Intermediates share information in-company, which is also partially system-integrated, whilst the Outsiders do not share any system-integrated information inside the company at all. Experts and Top performers are the minorities and stand for 14,3% respective 7,1% of all the companies in this dimension. At the last-mentioned levels, besides the established in-company system-integrated information sharing, the companies are also partially sharing external system-integrated information.

The sub-dimensions for autonomously guided workpieces, self-reacting processes and cloud usage have an average maturity level above 3 which makes them all on average Experienced. The dominating group within the first two sub-dimensions is Experienced with over 90% of companies. This means that these companies have neither autonomously guided workpieces nor self-reacting processes in their production sites. Only 3,6 % of the companies are classified as Top performers in both dimensions, which means that they have use of autonomously guided workpieces and self-reacting processes in selected areas or even cross-enterprise. The third sub-dimension for cloud usage divides companies into four groups, where the Experienced companies are followed by Intermediates, Experts and finally Top performers. This means that 35,7% of companies are planning initial cloud solutions for data storage and data analysis, whilst 28,6% of companies are not using any cloud solutions at all. Two remaining groups implicate 21,4% of companies that have implemented initial and 14,3% that have implemented multiple cloud-based solutions.

The last sub-dimension for IT-security scores the average maturity level of 2.96. Here the companies are mostly Experienced and Experts, which means that 28,6% of all companies have partially implemented IT security solutions and the other 28,6% are already using comprehensive IT security solutions and closing existing gaps. Outsiders are the fewest and stands for only 3,6% of all companies, where IT security solutions are neither in development nor implemented. Beginner and Intermediates are fairly divided and stand for 14,3% of companies each. Companies that represent these groups are either planning their initial IT security solutions or already developing them and planning for more. The final group is Top performers. They stand for 10,7% and have successfully implemented IT security solutions for all relevant areas.

5.1.5 Smart products

Smart products are equipped with ICT components (sensors, RFID, communication interfaces, etc.) that collect data in the production environment and report their own status. Smart products enable an availability of comprehensive information about a particular product, which is a crucial component of the Smart factory and beneficial for Data-driven services.

Table C.4 in Appendix C summarizes the results for Smart products. The companies in this dimension have an average maturity level of 0,18, making Smart products the lowest scored dimension compared to the others. The majority of the companies here are Outsiders and account for 92,9%. The rest of the companies consist of Intermediates and Experts, who have a share of 3.6% of all companies each.

Smart products consist only of two sub-dimensions: ICT add-on functionalities and use of data. The sub-dimension for ICT add-on functionalities has an average maturity level of 0,18, where the Outsiders stand for the largest group with 92,9 % of the companies. Intermediates and Experienced companies are 3,6 % each. Being an Outsider in this sub-dimension, means that the company has no ICT add-on functionalities, whilst the Intermediates' products feature initial add-on functionalities and the Experts are equipping their products with multiple, interrelated add-on functionalities.

In the next sub-dimension 25% of the companies are both using and analyzing data which makes them Top performers. Intermediates whose data is collected but neither analyzed nor used stand for 10,7% and the rest of the companies are classified as Beginners as they do not collect any data for product development, sales support or after-sales.

5.1.6 Data-driven services

Data-driven services are about transforming companies from selling products to delivering solutions. Industry 4.0 encourages companies to fundamentally rethink their existing business models by either digitalizing traditional business models or developing entirely new ones. Data-driven services enable integration between the manufacturer and the customer, where the smart product collects data and reports the customer's needs through communication between installed sensors and manufacturers' IT systems. In this case, the customer is fully integrated into the company's business model.

Table C.5 in Appendix C presents the distribution of maturity level within the sub-dimension of Data-driven services. The total maturity level in this dimension is 0,54 which makes Data-driven services

second lowest scored dimension. Outsiders and Beginners together account for 85,7 % of all companies, where Outsiders are the majority with 78,6% of all companies. Intermediates are only 7.1% whilst Experts and Top performers stand for 3.6 % each.

Data-driven services sub-dimension consists mostly of Outsiders with 71,4% of the companies. These companies do not offer any Data-driven services to their customers. Experienced companies account for 17,9% and offer Data-driven services but without customer integration. The rest of the companies are Top performers whose Data-driven services are fully integrated into the business model, which means that Data-driven services are offered with customer integration.

Share of revenues is the least mature sub-dimension with an average of 0,68. The companies here are mostly Outsiders, which means that Data-driven services do not account for any share of revenues. There are totally 78,6% of Outsiders in this sub-dimension. Beginners account for 7,1% of the companies and their Data-driven services account for an initial share of revenues (<1%). Intermediates stand for 3,6% and their Data-driven services account for almost equal to Beginners' share of revenues (<2,5%). No companies are classified as either Experienced or Experts in this sub-dimension. However, 10,7% of companies' Data-driven services play an important role in revenues and account for more than 10% share of revenues, which make them to Top performers of the sub-dimension.

Finally, when it comes to the level of data usage, Beginners who stand for 60,7% are not using the data. On the other hand, Intermediates who account for 25% are using either 0% or up to 20% of collected data. Experts in this sub-dimension are equal to Experienced companies who use between 20% and 50% of collected data and account for 7,1% of surveyed companies. Finally, Top performers are the companies who use more than 50% of collected data in their decision-making processes and correspond for 7.1% of all companies.

5.1.7 Employees

The changes that take place at the workplace during the digital transformation have a strong impact on the company's employees who have to adapt to these changes and develop new skills. The companies that go through the digital transformation must make sure to prepare their staff for such changes by offering them an appropriate training.

This dimension has the highest maturity score relative to other dimensions in the survey and its results are presented in Table C.6 in Appendix C. With an average maturity level of 1.93 the Employees dimension consists primarily of Outsiders and Beginners, accounting for 39,2 % of all the companies. Intermediates stand for 35,7% and the rest 25% of the companies consist of Experienced, Experts and Top performers.

Employees dimension consists only of one sub-dimension that evaluates and measures the skills of the employees. Outsiders are the companies that have no Industry 4.0 related skills and account for 7,1% of the surveyed companies. Beginners have low skill levels in one relevant area and stand for 32,1%. Intermediates are the companies, where employees still have low skill levels but in a few relevant areas whilst Experienced have adequate skill levels in some relevant areas. They represent

35,7% respective 14.3% of the companies in the survey. When it comes to the Experts they have the same skill level as Experienced companies but in several relevant areas and stand for 7,1%. The rest of the companies are Top performers whose employees possess all necessary skills in several relevant areas.

5.2 Challenges

In this subsection, the empirical results related to RQ 1 will be presented.

5.2.1 Strategy and organization

When asked to describe the biggest challenge when it comes to implementing the Strategy and organization dimension of Industry 4.0 there were two main themes: lack of knowledge and limited resources. Almost a third of the companies stated that lack of knowledge was their biggest challenge in this dimension. Lack of knowledge means that they either were not aware of the concept Industry 4.0 or that they had very limited knowledge of what it means in practice. It should not be confused with the challenges of finding the right competence or knowhow on how to optimally implement Industry 4.0 - this is a more elementary challenge. When it comes to limited resources, companies did experience two types of limitations: both financial and time-related. The financial limitation is expressed in the previously stated low maturity level within Industry 4.0 investments. The time-related limitation is expressed in companies not having enough manpower to initiate the time-consuming process of implementing Industry 4.0 in their strategy.

5.2.2 Smart factory

The two main challenges that companies experience when implementing the Smart factory dimensions is lack of knowhow and incompatibility with business. The Smart factory is based on several technological features, the companies respond that they currently do not have the knowhow required to implement these features and they have a hard time finding external expertise. Another consequence of this dimension being technological is that it is not compatible with all types of business. One company describe that its manufacturing is heavily dependent on manual labor and that there is no way of automating that process yet.

5.2.3 Smart Operations

The main challenges that companies face when implementing this dimension are lack of knowledge and knowhow. 9 out of 28 surveyed companies experience difficulties in understanding the concept of Smart operations. Knowhow is the second biggest issue and as in previous dimension the companies respond that they currently do not have the knowhow to implement all the features of the targeted dimension. Some of the companies respond that they are limited in resources both financially and time-wise, others experience technological problems, when it comes to using cloud solutions or their equipment being out of date. Other business and customer related issues is about Industry 4.0 not being relevant when it comes to the manufacturing processes as there is too much manual labor involved or because of incompatibility with end customers' desires.

5.2.4 Smart products

As in previous dimensions some of the companies lack knowledge in the area or experience technological problems when it comes to adopting and using new technologies in older production processes. Knowhow is also an issue, the companies do not have enough knowledge and competencies in needed areas in order to benefit from the collected data. When it comes to investing in new technologies, some companies find themselves financially and time-wise limited due to the cost and payoff uncertainty. The rest of the companies experience difficulties in matching the use of Smart products with their business structures or with the end customers' needs.

5.2.5 Data-driven services

Main hurdles in implementing Data-driven services are business and customer incompatibilities. Companies respond that they struggle to see the benefit of using Data-driven services in their businesses or to match it with the end-customer desires. Other companies lack knowledge and knowhow as well as some technological capabilities. One company respond that they are using their own solution, where they can track their orders in real-time by integrating their internal systems.

5.2.6 Employees

The majority of companies in this dimension do not see any problems in implementing this dimension. Some of the companies respond that they have very company specific problems, such as language barriers or mental maturity of their employees before such a transformation. Other companies still lack knowledge, know how or resources when it comes to offering the appropriate training for their staff.

6 Analysis

In this section the results from the survey is analyzed. Firstly, research question 1, maturity level, is analyzed, followed by research question 2, challenges.

6.1 Maturity

In this subsection, the analysis related to RQ 1 will be presented.

6.1.1 General

In this section the general results will be analyzed and compared to results from similar studies. Starting with the total maturity level of Swedish SMEs, it was found to be 1,17 in this study. This makes the average Swedish SME a Newcomer and a consequently has a low Industry 4.0 maturity.

As outlined in Chapter 4, based on their total maturity level the companies can be categorized into three types, which is visualized in Figure 6.1:
- Newcomers: Companies having a maturity level of 0 or 1 are classified as Newcomers and constitute 26 or 89,3% of the companies.
- Learners: Companies having a maturity level 2 are classified as Learners and constitute 2 or 7,1% of the companies.
- Leaders: Companies having a maturity level of 3 or higher are classified as Leaders and constitute 1 or 3,6% of the companies.
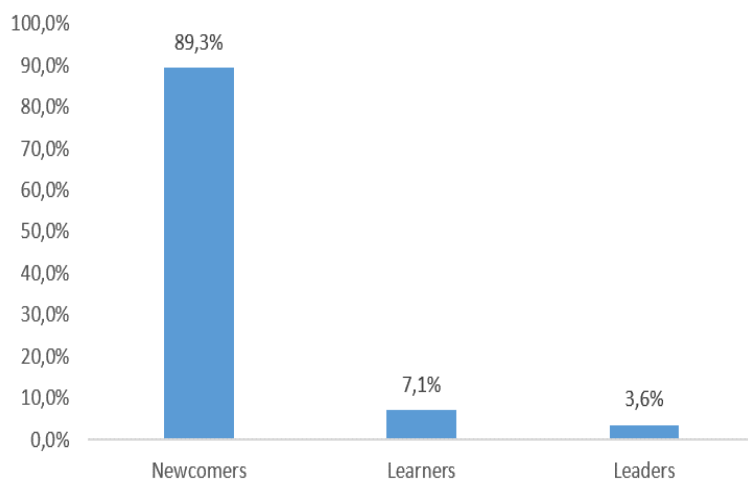
Figure 6.1. Distribution of maturity types amongst Swedish SMEs.

The average maturity level is low, however, the implementation of Industry 4.0 among SMEs in Sweden definitely has begun, which is supported by the result from Antonsson (2017). There are both Learners and Leaders among the companies that have participated in the survey and there is no company that has a maturity level of 0.

Comparing the result to a similar survey conducted in Germany (Lichtblau et al. 2015), where the average maturity level was found to be 0.6 among manufacturing companies, a maturity level of

1.17 is significantly higher. It should also be noted that Lichtblau et al. (2015) included large corporations in their study. A case-study on large Swedish manufacturing companies (Antonsson, 2017), also concludes that the Industry 4.0 maturity is low.

The distribution of types is similar to what was found by Lichtblau et al. (2015). They found that 89,1% of the German manufacturing companies are Newcomers, compared to the 89,3% in this study. Further, they found that 8,6% are Learners, compared to the 7,6% of Sweden. Lastly, they found that 2,3% are Leaders in German, compared to 3,6% in Sweden. In Sweden the distribution of type is slightly relatively skewed towards Leaders, what is explaining the significant difference in average maturity level is the higher maturity level within the types in Sweden, meaning that Sweden is closer to achieving a more mature distribution of maturity types. Antonsson (2017) has also identified a group of companies that had achieved significantly higher maturity level.

In Figure 6.2 the maturity found in study is compared to the maturity of German companies from the study of Lichtblau et al (2015). It should be noted that the following data from Lichtblau et al. is for a subset of the manufacturing industry, the mechanical and plant engineering industry, as that data for the manufacturing industry as a whole is not explicitly stated in their report. The maturity for manufacturing companies in Germany was found to be about 30% lower than for the other companies, thus these figures are relatively high.

The comparison shows the following:

Firstly, overall, the maturity of the dimensions is ordered similarly for Sweden and Germany, with Employees and Smart operations being the two most mature dimensions.

Secondly, the biggest difference is Smart products, being the third most mature dimension for Germany, with a maturity level of 1,1, compared to Sweden where it is the least mature dimension, with a maturity level of 0,18.

Lastly, Swedish companies have a higher maturity level in four out of six dimensions. But it is Employees and Smart operations that primarily drive the higher total maturity level, with maturity levels being 0,43 and 0,66 higher respectively.
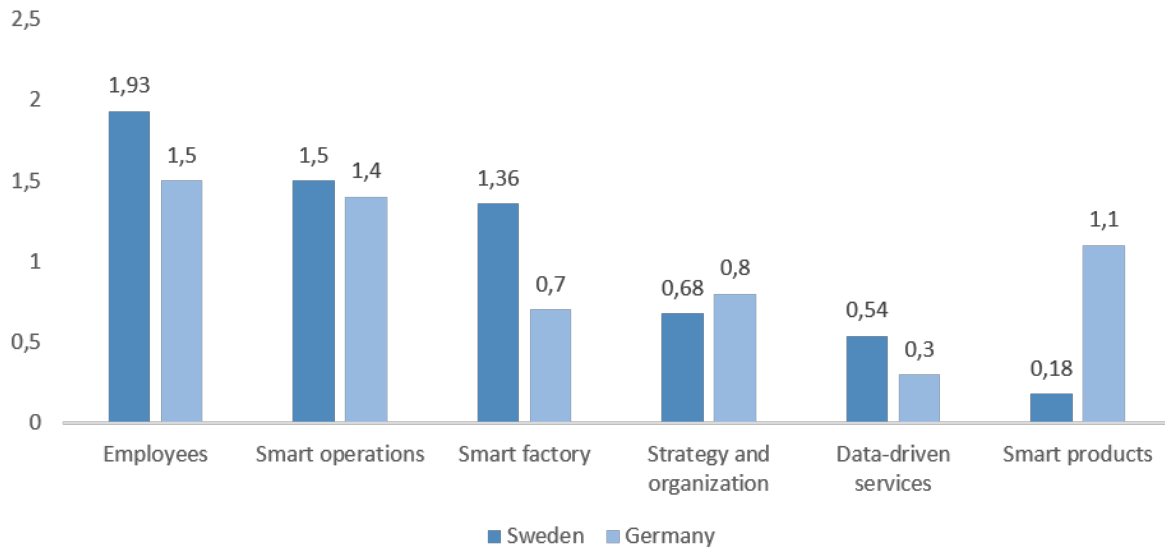
Figure 6.2. Dimension maturity level of Sweden and Germany

6.1.2 Maturity covariates

6.1.2.1 Maturity vs. revenue

The survey results show that revenue does not have a strong relationship with Industry 4.0 maturity levels of the companies, if anything, a slight negative correlation. This goes in line with the result from Antonsson (2017). In some cases, maturity levels of smaller enterprises are much higher than the levels of medium enterprises. See the Figure 6.3.
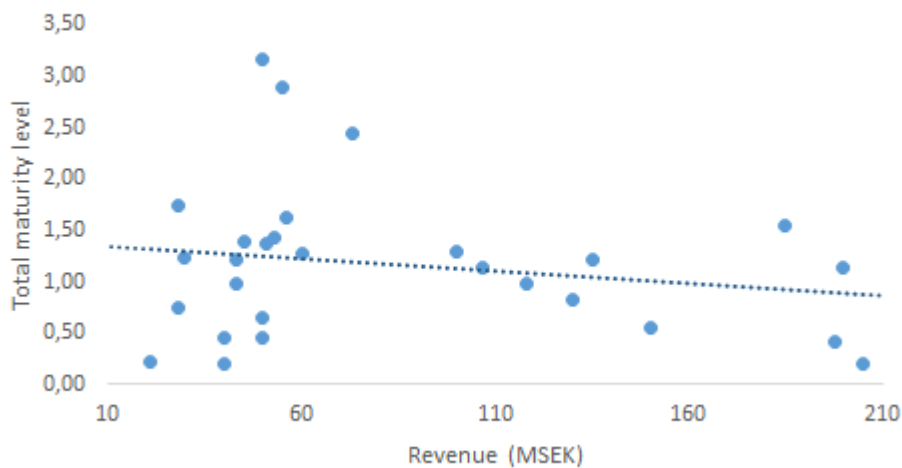
Figure 6.3. Maturity level-revenue relationship.

6.1.2.2 Relationship between maturity and size of company

Here the maturity level between small and medium-sized enterprises is analyzed and compared, which gives an opportunity to see a relationship between maturity and size of a given company.

It was hypothesized that larger companies would be more mature than smaller as this is what previous research is showing. The result of this survey is the opposite, where small companies have

an average maturity level of 1,28 and medium-sized companies 0,90, which can be seen in Figure 6.4.

There is a difference between small and medium-sized enterprises when it comes to maturity levels in different dimensions. In Strategy and organization, small enterprises score a maturity level of 0,85 which is 340% higher than the score for medium-sized enterprises.

The difference in maturity level in the following two dimensions is less than in the former dimension. With an insignificant difference of 1,9% the medium-sized enterprises are ahead in the Smart factory dimension. Furthermore, the medium-sized enterprises are more mature in the dimension Smart operations with an average maturity difference of 12%. The Smart factory and Smart operations are the only two dimensions out of the total six where medium-sized companies have higher maturity levels than small companies, which indicates that companies in this size are more capable in implementing these dimensions compared to the smaller.

The medium-size companies have an average maturity level of 0 in the Smart products dimension. This means that the medium-sized companies are doing very little in terms of implementing Smart products in their production sites. The small companies have a score of 0,25 which shows that the maturity level is still low, but higher than for medium-sized companies. The next dimension is Data-driven services where the small companies are 160% more mature. Lastly, in the Employees dimension, where once again small companies are more mature than medium-sized with a difference of 76%. Thus, the small companies are more mature in 4 of 6 dimensions, which explains the total maturity level being higher for the small companies relative to the medium-sized. It also points to the fact that smaller enterprises have come further in adapting their strategy and business models to Industry 4.0, using more ICT-equipped products and Data-driven services. Finally, the average maturity level being higher in the Employees dimension, speaks for better employee skills amongst small companies when it comes to handling a digital transformation.

Among the medium-sized companies the Smart operations is the highest scored dimension. This means that medium-sized companies have come further in this dimension compared to the other five dimensions. The same goes for the small companies, where the maturity level of Smart operations is slightly lower than for the medium companies but still remains as the highest scored in its own size.
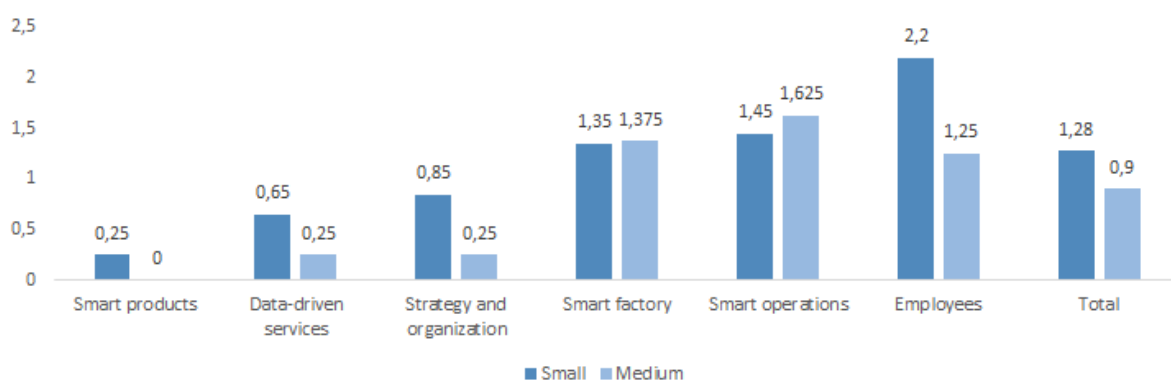

Figure 6.4. Average maturity level of small and medium-sized companies.

6.1.2.3 Relationship between maturity and sub-industry

In this section it will be investigated if there are any sub-industries that are more or less mature in terms of Industry 4.0. Among the companies who took the survey, ten different sub-industries within the manufacturing industry were represented. By categorizing the companies in sub-industry groups, the sub-industries' relative maturity level in total and within each dimension was found. The analysis is summarized in Figure 6.5 and Table 6.1.

Among the sub-industries that the surveyed companies are operating within, medical and boat & ship building industries stand out as more mature compared to other industries. It is worth noting that each of these two industries are represented by one company. The underlying reason for such a high maturity level of these industries might be the nature of the businesses and their end-products, which all together require a higher level of technologies involved in manufacturing process.

One of the surveyed companies is operating within joinery industry and scored a total maturity level of 0,19 which is the lowest maturity level scored among all the industries. This could be explained by the fact that companies within the joinery sub-industry typically do not manufacture the end-product and the design is consequently dictated by some other company, their customer. This gives them fewer degrees of freedom when it comes to implementing new solutions that is not supported by their customers.

Other industries vary on the scale between 0,98 and 1,29 in total maturity level. Except for the joinery industry, the rest of the industries have minimum maturity level of 1 in the sub-dimension Employees which indicates an overall Industry 4.0 awareness among the surveyed companies' employees. The sub-dimension of Smart factory has a minimum level of 0,67 making this sub-dimension the only one with no zeros scored in maturity levels. This indicates that all of the targeted industries are more or less affected by the use of Smart factory in their production environments.
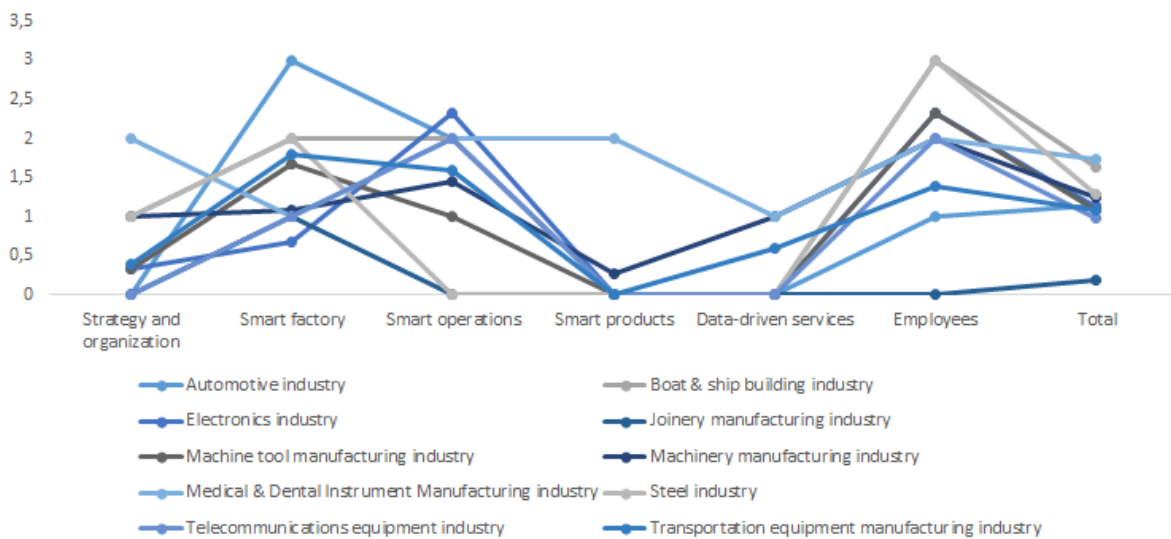
Figure 6.5. Average maturity level for sub-industries

	Strategy and organization	Smart factory	Smart operations	Smart products	Data-driven services	Employees	Total
Automotive industry	0,00	3,00	2,00	0,00	0,00	1,00	1,14
Boat & ship building industry	1,00	2,00	2,00	0,00	0,00	3,00	1,63
Electronics industry	0,33	0,67	2,33	0,00	0,00	2,33	1,12
Joinery manufacturing industry	0,00	1,00	0,00	0,00	0,00	0,00	0,19
Machine tool manufacturing industry	0,33	1,67	1,00	0,00	0,00	2,33	1,09
Machinery manufacturing industry	1,00	1,09	1,45	0,27	1,00	2,00	1,25
Medical & Dental Instrument Manufacturing industry	2,00	1,00	2,00	2,00	1,00	2,00	1,74
Steel industry	1,00	2,00	0,00	0,00	0,00	3,00	1,29
Telecommunications equipment industry	0,00	1,00	2,00	0,00	0,00	2,00	0,98
Transportation equipment manufacturing industry	0,40	1,80	1,60	0,00	0,60	1,40	1,08

Table 6.1. Average maturity level for different sub-industries.

6.2 Challenges

In this subsection, the analysis related to RQ 2 will be presented. In the first part of the analysis, the current maturity level of Swedish SMEs has been analyzed and overall the maturity level was found to be low. A full implementation of Industry 4.0 could have significant positive effects on Swedish manufacturing SMEs, therefore it is relevant to investigate what hurdles there are getting there. This has been done by both looking at the maturity level questions in the survey and identifying the major gaps for Newcomers and Learners to become Learners and Leaders respectively and the major gaps for Leaders to reach level 5 maturity, and by identifying patterns in the replies to the question "What do you experience as the main challenges when it comes to implementing this dimension of Industry 4.0?", which was asked in the end of each dimension in the survey.

6.2.1 Newcomers

For Newcomers the three least mature dimensions are Smart products, Data-driven services and Strategy and organization, all being significantly lower than the other dimensions. The results are shown in Figure 6.6. In order for the Newcomers to become Leaders, these dimensions are going to have to be the main focus.
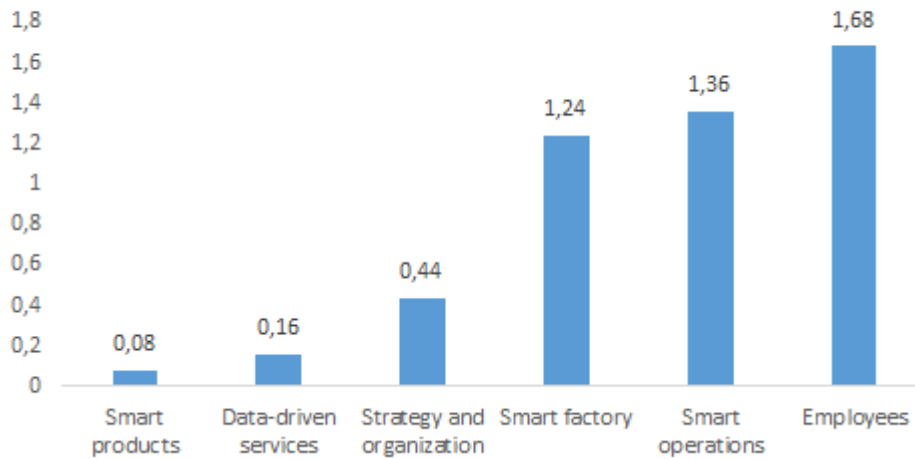
Figure 6.6. Average dimension maturity level for Newcomers.

6.2.1.1 Smart products

The low maturity in Smart products for Newcomers is driven by a lack of ICT add-on functionalities on the products. Only about 4 % show first signs of ICT add-on functionalities and the rest do not have any ICT add-on functionalities. Consequently, this is where the Newcomers should put their focus in order to increase their maturity within Smart products. To reach the Intermediate level, the Newcomer would need to feature initial ICT add-on functionalities on their products, like RFID or basic sensors. See the maturity level distribution for Smart products in Table 6.2.

When asked to describe the biggest challenges with Smart products, the majority of the Newcomers mentioned two things. Firstly, the concept of Smart products, especially ICT add-on functionalities, is experienced as being advanced technology and the Newcomers rarely have the technological knowhow to implement this dimension. The second challenge when it comes to Smart products for Newcomers is that there is a business model incompatibility with Smart products. A large portion of the Newcomers are project-based suppliers to an OEMs or some other company higher up in the value chain. Typically, they are supplying several different companies and not necessarily more than a specific batch, it would be a big transformation of the current business in order to be able to provide specific ICT add-on functionalities.

	ICT add-on functionalities	Use of data	Total
Outsider	96%	0%	96%
Beginner	0%	72%	0%
Intermediate	4%	12%	4%
Experienced	0%	0%	0%
Expert	0%	0%	0%
Top performer	0%	16%	0%
Average maturity level	0,08	1,76	0,08

Table 6.2. Distribution of maturity level for Newcomers within Smart products.

6.2.1.2 Data-driven services

The second driver of the relatively low maturity in the Smart products dimension among Newcomers is that they have, in general, not incorporated Data-driven services in their business model, which can be seen in Table 6.3. More specifically, four out of five Newcomers do not have any Data-driven services. This is reflected in both the share of revenue from Data-driven services and the level of data usage. Among the Newcomers, 68% do use any data in their business model and 88% of them do not have any revenue from Data-driven services. Thus, in order to increase the maturity for the Newcomers in this dimension, effort needs to be put into launching basic Data-driven services. At this stage, there is no customer integration in the service offering.

The Newcomers can be split up into two groups when it comes to Data-driven services, the ones that cannot see Data-driven services as a part of their business model and the ones that experience technological challenges. The first group often see themselves as manufacturers and offering Data-driven services would mean diverging from their core business. Replies like "Not applicable to us" or "Not interesting to us" were common. There exist several examples where manufacturing companies have succeeded in the transition from traditional manufacturing to a more service-driven business model (Short, 2011). This indicates that the knowledge and awareness of implementing Industry 4.0 is low among the Newcomers, which also is reflected in that 48% of the Newcomers responded that they did not have any previous knowledge about Industry 4.0 before responding to this survey. The second group are aware of the potential of Data-driven services, but do not seem to know how. One Newcomer specifically mentioned data standards and how it would be transferred, e.g. Bluetooth, internet, Ethernet or Profibus.

	Data-driven services	Share of revenue	Level of data usage	Total
Outsider	80%	88%	0%	88%
Beginner	0%	8%	68%	8%
Intermediate	0%	0%	28%	4%
Experienced	16%	0%	0%	0%
Expert	0%	0%	4%	0%
Top performer	4%	4%	0%	0%
Average maturity level	0,68	0,28	1,40	0,16

Table 6.3. Distribution of maturity level for Newcomers within Data-driven services

6.2.1.3 Strategy and organization

The last challenge that the Newcomers need to overcome in order to become Learners is developing the Strategy and organization dimension. Here there are two specific steps that need to be taken. Many Newcomers struggle with developing a strategy for Industry 4.0, with 40% not having a strategy at all and 40% discussing Industry 4.0 at department level, but not at a strategic level. To develop into Learners, these companies need to start developing a strategy for Industry 4.0. In combination with developing a strategy, the Newcomers need to invest more in Industry 4.0, 60% not having any investments in Industry 4.0. Of course, these investments need to be preceded by development of a strategy. See the Table 6.4 below.

The challenges experienced by the Newcomers are the same as for the general company, which is lack of knowledge and limited resources, described in the result chapter.

	Degree of strategic implementation	Definition of indicators	Investments	Innovation management	Total
Outsider	40%	0%	60%	0%	60%
Beginner	40%	96%	16%	0%	36%
Intermediate	20%	0%	16%	32%	4%
Experienced	0%	0%	8%	48%	0%
Expert	0%	4%	0%	8%	0%
Top performer	0%	0%	0%	12%	0%
Average maturity level	0,80	1,12	0,72	3,00	0,44

Table 6.4. Distribution of maturity level for Newcomers within Strategy and organization.

6.2.2 Learners

An overview of the result of the analysis for the Learners is presented in Figure 6.7. It should be noted that there were only two Learners identified. For the Learners the Smart products dimension is standing out, with an average maturity of 0. Consequently, that is where the majority of the resources will be needed to be put. Smart factory is also a dimension that needs focus in order for the Learners to reach the Leader type as there are no Learners that yet have a maturity level of 3 or higher in this dimension.
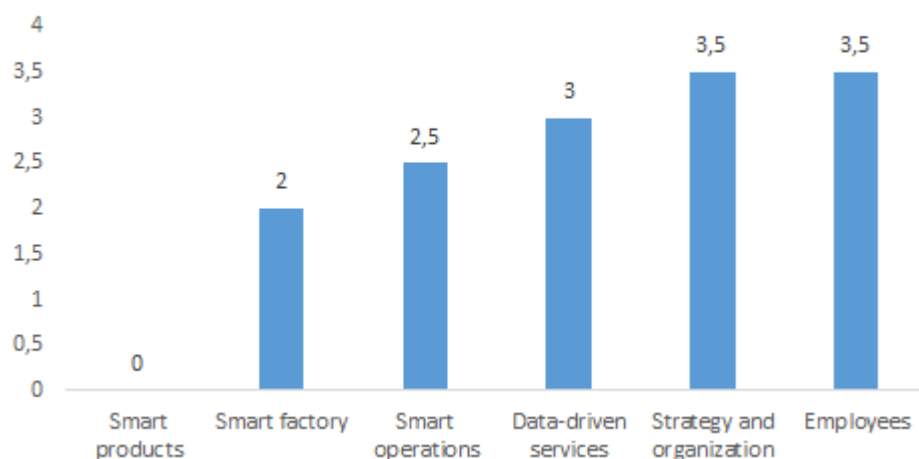
Figure 6.7. Average maturity level for Learners

6.2.2.1 Smart products

Learners are strong in use of data as all of the Learner companies are classified as Top performers in this sub-dimension, which can be seen in Table 6.5. Consequently, ICT add-on functionalities is the reason for such a low maturity level. All of the companies in this sub-dimension are classified as Outsiders. The main focus should therefore lie on starting using basic add-on functionalities on the products which will further evolve in multiple, interrelated add-on functionalities. This will enable the Learners to climb the next maturity level and become Leaders in the sub-dimension of Smart products.

When asked about the biggest challenges that Learners experience in this dimension the most common reason is the incompatibility with their business model, like for the Newcomers. Learners in this dimension are operating as subcontractors for OEMs and therefore using ICT add-on functionalities on not an end-product is complicated and not of big relevance. Consequently, the Learners are simply not focusing enough on implementing the Smart products with ICT add-on functionalities.

	ICT add-on functionalities	Use of data	Total maturity
Outsider	100%	0%	100%
Beginner	0%	0%	0%
Intermediate	0%	0%	0%
Experienced	0%	0%	0%
Expert	0%	0%	0%
Top performer	0%	100%	0%
Average maturity level	0,00	5,00	0,00

Table 6.5. Distribution of maturity level for Learners within Smart products.

6.2.2.2 Smart factory

When it comes to Smart factory, the main driver of the lower maturity level in this sub-dimension among Learners is the targeted equipment infrastructure, which can be seen in Table 6.6. All Learners are classified as Intermediates in this sub-dimension which means that currently some of their machines and systems can be upgraded. The main focus should therefore lie on making all of their machines and systems ready for future upgrade.

When asked about the biggest challenges in implementing this dimension the Learners respond that they mainly experience technological problems and lack of know-how. The problems with system integration and the need for development of relevant skills of their employees in different areas were common hurdles in this dimension. For example, one company states that their employees need to understand the importance and learn the proper execution of time and material withdrawal reporting. The need to address issues like this is therefore very important in order grow in the area of Smart factory.

	Equipment infrastructure (current)	Equipment infrastructure (target)	Digital modeling	Data collection	Data usage	IT systems	Total
Outsider	0%	0%	0%	0%	0%	0%	0%
Beginner	0%	0%	0%	0%	0%	0%	0%
Intermediate	0%	100%	0%	0%	0%	0%	100%
Experienced	100%	0%	0%	0%	0%	0%	0%
Expert	0%	0%	100%	0%	0%	0%	0%
Top performer	0%	0%	0%	100%	100%	100%	0%
Average maturity level	3,00	2,00	4,00	5,00	5,00	5,00	2,00

Table 6.6. Distribution of maturity level of Learners within Smart factory,

6.2.3 Leaders

Like for the Learners, the Leader have one dimension that is significantly less mature than the other dimensions, which in this case is Strategy and organization, which can be seen in Figure 6.8. It should be noted that only one Leader was identified. This dimension should be the main focus for the Leader to reach full Industry 4.0 maturity. But in order to reach Top performer level in all dimensions, the Leader also need to develop within Smart factory, Smart operations and Smart products, but this will not be analyzed in this section as Strategy and organization is the main issue.
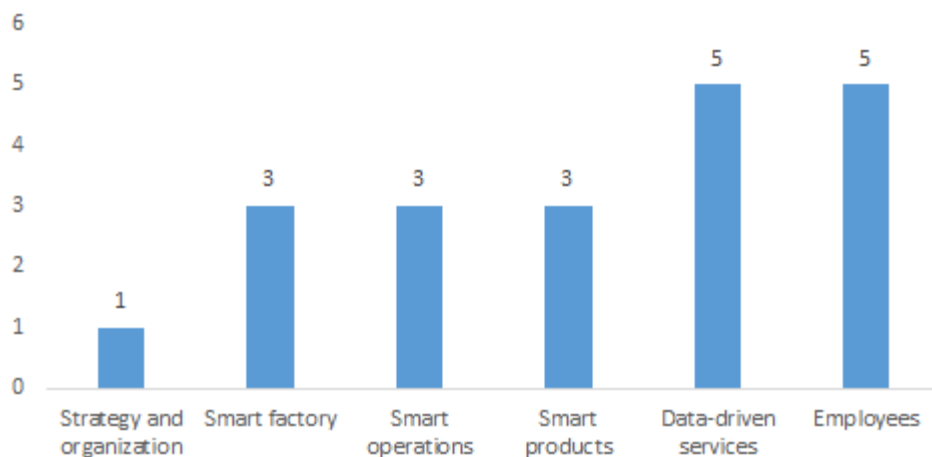
Figure 6.8. Average dimension maturity level for Leaders.

6.2.3.1   Strategy and organization

The main problems in this dimension are low maturity levels in sub-dimensions for degree of strategic implementation, definition of indicators and Industry 4.0 related investments, which can be seen in Table 6.7. Leaders have currently Industry 4.0 as an issue on departmental level and not integrated into the strategy with no indicators to determine the current status of Industry 4.0 implementation. Furthermore, Leaders have a low level of Industry 4.0 investments and innovation management in isolated areas of the company. In order to be a Top performer in this dimension, the Leaders have to address all the above-mentioned issues. They should first of all aim for implementing Industry 4.0 strategy enterprise-wide with a system of status indicators integrated into the strategic process. In addition, the Leaders should consider lifting Industry 4.0 related investments on the enterprise-wide level together with establishing an inter-departmental innovation management.

The Leaders see the lack of resources as a main challenge in this dimension. They say that they have prioritized their resources for other product development projects. This leaves them with no resources left for Industry 4.0 related projects.

	Degree of strategic implementation	Definition of indicators	Investments	Innovation management	Total
Outsider	0%	0%	0%	0%	0%
Beginner	100%	100%	0%	0%	100%
Intermediate	0%	0%	100%	0%	0%
Experienced	0%	0%	0%	100%	0%
Expert	0%	0%	0%	0%	0%
Top performer	0%	0%	0%	0%	0%
Average maturity level	1,00	1,00	2,00	3,00	1,00

Table 6.7. Distribution of maturity level for Learners within Smart factory.

7 Discussion

In this section the results of the analysis for the two research questions, maturity level and challenges, will be discussed, but also the used method and further research suggestions.

7.1 Maturity level

In this subsection the discussion related to RQ 1 is presented.

7.1.1 General

The main result of the survey was that the Industry 4.0 maturity level among Swedish SMEs is low. However, this is not a surprising result considering the novelty of this technology paradigm. As previously mentioned, the term Industry 4.0 was first found 2013 and previous industrial revolutions have taken up to half a century to achieve significant maturity (Geenwood, 1997). But the result also indicated that the implementation begun, albeit slowly, which is positive news to Sweden as quickly adopting new technologies has been found to be a key factor to ensure that a country's workforce remains competitive (Comin and Hobijn, 2008).

The analysis also indicates that Sweden is more mature in terms of Industry 4.0 than Germany. This could be explained by the fact that the German study was conducted in 2015 and as previously discussed, this is a new technology paradigm, consequently some development could have happened the past four years in Germany. However, the difference in maturity between Sweden and Germany were considerable and the German study included large corporations, which were found to have significantly higher maturity than the SMEs. Altogether, this points at a higher maturity in Sweden among manufacturing SMEs. This relatively higher maturity could be explained by the fact that Sweden in general has more highly innovative companies (Business Sweden, 2019) and these could be more prepared to adopt the new technologies that are part of Industry 4.0. This is supported by the result that Sweden has relatively more Leaders than Germany.

Employees were found to be the most mature dimension among Swedish SMEs. Employee skills has been shown to be a key factor when adopting new technologies (Ariss, Raghunathan and Kunnathar, 2000), indicating that Sweden could have a solid platform for future adoption of Industry 4.0.

The survey result indicated that Smart operations are the second most mature dimension, both in Sweden and in Germany. This could be explained by the fact that Smart operations compared to the other operations-related dimensions, Smart factory and Smart products, are more conceptual and dependent on systems. Smart factory and Smart products on the other hand are more heavily dependent on physical, technological solutions, like equipment infrastructure and ICT add-ons. Technological solutions are typically more expensive to invest in and they change the business in a more fundamental way, making the implementation threshold greater for these dimensions, compared to Smart operations.

Turning the previous argument around could explain why Smart products is the least mature dimension, ICT add-ons being a new and expensive technology. Another reason for this could be that

a large share of the Swedish companies are suppliers to other companies and their expertise lies in providing a specialized type of manufacturing, e.g. turning. The organization is typically made up of 10-15 people, most of them being operators or ex-operators and what they know is their type of manufacturing. For these companies to incrementally change their product offering, adding ICT add-ons, would be a disruption maybe too big for an organization like that. But as the demand for these types of components and products will grow, a more probable development would be that new suppliers, specialized in ICT add-ons are created. These will have the mind-set and know-how from the beginning, required to support a business providing add-ons. What is also interesting is that Smart products in fact is one of the more mature dimensions in Germany. This could be explained by the fact that the German study included large corporations, who could be more likely to be OEMs and consequently more likely to have ICT add-ons, than a supplier who is only manufacturing a component.

7.1.2 Maturity covariates

As identified in the analysis, there are no positive correlation between neither revenue nor size and maturity level. On the contrary, smaller companies were found to have a higher maturity level. Studies from Germany have indicated that there is a positive relationship between size and maturity. On the other hand, a study from Sweden did not find any relationship between maturity and revenue. Smaller companies can be more agile and more easily adopt new technologies, but more likely this could be explained by study design. The German studies included several hundred companies, spread over a broader range size-wise, whereas the Swedish study and this thesis included 11 large companies and 28 SMEs respectively. Obviously, the population of the German studies provides a more statistically solid basis for conclusions and before a large-scale study has been made in Sweden, the positive relationship between size and maturity should not be excluded.

7.2 Challenges

In this subsection the discussion related to RQ 2 is presented.

7.2.1 General

Most of the challenges identified in this study are supported by the theory with only one exception. The lack of resources is one of the most common issues among Swedish SMEs which has not been identified in the previous research that has been covered. The reason for this could be that the previous studies did target companies of all sizes. The survey result could therefore indicate that the lack of resources is an SME-specific issue. A similar challenge is identified in the previous research, which concerns the uncertainties related to payback on investments due to the lack of demonstrated business cases. These two challenges are somehow related but differ in an important aspect. The reason for the resource issue being SME-specific is the small size of the SMEs, which typically means financial limitation. Whilst the payback uncertainties related to a specific project do not speak for a company's ability to make investments, but rather about a company's risk aversion.

The issues like business and customer incompatibility together with technological, knowledge and know how identified in this study are confirmed by the previous studies.

7.2.2 Newcomers

The mutual challenges that German and Swedish Newcomers experience are general lack of knowledge of Industry 4.0 and lack of the necessary skills and technological know-how within the field. German Newcomers are more exposed to uncertainties when it comes to financial benefits of Industry 4.0. This can be related to the business or customer incompatibilities and therefore German Newcomers are struggling to see the benefits in investing in Industry 4.0 related projects. This is backed up by the statement in Lichtblau et al. (2015) report Industry 4.0 Readiness about German Newcomers' failure to see any market need for dealing with this topic.

One specific challenge that Swedish Newcomers experience explicitly is lack of financial resources, which in turn can be explained by the focus of this study exclusively on small and medium-sized enterprises.

7.2.3 Learners

The main challenges for Swedish Learners are business incompatibility, technological issues and know-how within the area of Industry 4.0. Nearly half of German Learners experience the same problems with know-how. Additionally, German Learners complain about shortage of skilled labor and openness of their employees for new technological changes. Surprisingly, the general knowledge was a minor issue for Swedish Learners compared to German. On the other hand, German Learners are still uncertain about the economic benefits with Industry 4.0 concepts, which yet again can be explained by either business or customer incompatibilities.

7.2.4 Leaders

The lack of financial resources is the biggest challenge for both Swedish and German Leaders. Swedish Leaders have to prioritize other projects investments, which leaves them with no resources for Industry 4.0 projects. German Leaders have additional challenges, such as lack of norms and standards, unresolved legal issues, shortage of skilled staff, data security and regulations. This shows that German Leaders have come further within Industry 4.0 implementation. But once again this could be a consequence of the objective of this study being exclusively companies of small and medium size.

7.3 Method improvements

Looking back at the method of this thesis, there are several points of improvement. The first one is that the survey was sent out to 286 companies, but only 28 responded to the survey. There could be a bias in the companies that decided to reply to the survey, which could potentially skew the final result. One could imagine that the probability of a company with interest in Industry 4.0 will be more likely to respond to a survey on the topic and a more interested company is likely to also be more mature. One way of removing this bias would be to not flag the topic of the survey beforehand, but this would probably decrease the response rate, on the other hand.

Another issue of the method is that rating process is fully subjective and made by the companies. Consequently, the responses could differ from the reality. On the other hand, many of the question

alternatives are well-defined and should not be subject to subjective estimation. One of the results of the survey was that a big portion of the respondents were not aware of Industry 4.0 before taking the survey, one could imagine that these companies are more likely to misinterpret questions due to lack of knowledge.

Some of the questions in the survey are constructed in a way that despite the company being completely inactive in a sub-dimension, the maturity level might still be above 0. This makes sense on a dimension level as it is the least mature sub-dimension that will determine the dimension maturity, but when studying single sub-dimensions, only looking at the maturity level could be misleading. Creating some indicator, making this more transparent when looking at the survey result, would be a big improvement.

The total number of respondents in this survey was 28, obviously a larger population would yield stronger results. This is especially and issue in the cases where the data is categorized and then analyzed, e.g. in Newcomers, Learners and Leaders. For example, there is only one Leader and generalizing the result based on one observation for that type could be dangerous. Overall, the results of this thesis should be viewed as indications.

The fact that the employee dimension is the top dimensions both in Sweden and in Germany could be explained by two flaws in the model and not necessarily imaging reality. Firstly, it is the only dimension that has one sub-dimension, making more extreme outcomes more likely. Secondly, the question is vague and is up for subjective interpretation. The survey could be improved by rephrasing the question and making the skill requirements more explicit and adding a second sub-dimension to the Employees dimension.

Another point of improvement for the Impulse model is adjusting for the fact that not all companies have the possibility of having Smart products, which makes these companies systematically score lower, even though they might have fully implemented Industry 4.0 given their business. As previously mentioned, many companies who took part in the study were suppliers of steel components like screws – a product that is difficult to imagine having any smartness potential. Consequently, the one could think of an adjustment of the model were Smart products are handled separately or having separate scores for companies were the Smart products dimension were applicable.

8 Conclusions

In this section a summary of the conclusions is presented, and the research questions are directly answered. Also, suggestions for future research are made and contributions of this study are presented.

8.1 RQ 1: Maturity level

The main aim of the thesis was to determine the current Industry 4.0 maturity level of Swedish SMEs. The overall maturity level of Swedish SMEs was found to be 1.17, which is low, which probably can be explained by the novelty of this industrial revolution. However, indications of a starting implementation were found.

In total, Sweden was found to have a significantly higher maturity level than Germany, indicating that Sweden has come further in the implementation. This could be explained by a number of forefronts, highly innovative companies in Sweden, shown in the larger portion of Leaders, driving the maturity. It can also be concluded that the distribution of maturity among the different dimensions of Industry 4.0 are similar between Sweden and Germany, with Employees and Smart operations being the most mature. In the other end of the spectrum, Smart products were found to be the least mature dimension for Swedish SMEs.

The results show that revenue does not have any strong correlation with Industry 4.0 maturity levels of the companies. On the other hand, a negative relationship between size and maturity level was found, which contradicts international research. The authors encourage more research on the topic in Sweden to firmly confirm or reject the result.

8.2 RQ 2: Challenges

By comparing the theory and analysis carried out in this study, the following conclusions can be made. The lack of financial resources is one of the biggest issues and appears to be SME-specific. The other issues like business and customer incompatibility together with technological, knowledge and know how issues identified in this study are confirmed by the previous studies and are applicable on companies of all sizes.

The final comparison between Swedish and German companies of different types (Newcomers, Learners and Leaders) shows that German and Swedish manufacturing companies are experiencing similar challenges with Industry 4.0 implementation. However, some of the facts need to be highlighted such as Swedish Newcomers being more financial insufficient due to the size of the targeted Swedish companies in this study. Furthermore, Swedish Learners prove to be more aware of Industry 4.0 concepts, whilst German Learners experience more difficulties with availability of skilled labor and conservatism. Finally, when it comes to the Leaders, both Swedish and German companies experience financial challenges in investing in Industry 4.0. However, it should be noted that only two Learners and one Leader were identified.

8.3 Further research suggestions

As the results of this thesis should be considered indicative, due to the small population size of the survey, there would lie value in replicating this study, but with a larger population.

In this thesis challenges for implementing Industry 4.0 were identified. Researching how those challenges can be bridged in order to enable Industry 4.0 implementation in Sweden would be a natural next step. This can be done from a company perspective, creating an Industry 4.0 roadmap for Swedish SMEs and it can be done from a government perspective, investigating what can be done to enable Industry 4.0 implementation. This roadmap could be specialized for different company characteristics, e.g. different industries.

As many companies currently are hesitant towards fully engaging in Industry 4.0, comprehensively mapping the benefits of Industry 4.0 for SMEs would be an interesting topic for future research. It has been identified in this study that some companies experience incompatibilities with their business model and Industry 4.0 – how should these companies relate to Industry 4.0?

8.4 Contributions

This is study thesis is the first to specifically study Industry 4.0 in Sweden from a SME-perspective. SMEs are an essential cog in the Swedish business machinery, hence, making sure these companies are competitive is of great importance. A lot of factors indicate that a successful Industry 4.0 implantations being one of the core paths to success for manufacturing companies. This thesis shows that the important company segment, SMEs, still have low maturity when it comes to Industry 4.0 and more specifically, in what way the maturity is low for different sizes of companies, within different sub-industries. In a combined effort of more academic research and the business and public sector, the challenges that are identified in this thesis can be mitigated, leading to an accelerated adoption of Industry 4.0 and ultimately more competitive SMEs. The core contribution of this thesis is raising awareness and providing a platform for the suggested further research.

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Appendix A: Introduction to Industry 4.0

In this appendix a theoretical introduction to the topic of Industry 4.0, with three main topics: core concepts of Industry 4.0, Industry 4.0 supporting technologies and impact of Industry 4.0.

Background

An industrial revolution is driven by "new technologies and novel ways of perceiving the world [that] trigger a profound change in economic systems and social structures" (Schwab, 2016a, p. 11). Consensus is that the world has gone through three technological revolutions. The first being the Industrial Revolution, starting when late-18th century UK went from being an agrarian economy to using mechanical production methods, primarily driven by the introduction of steam power. The second industrial revolution, also known as the Technological revolution, is typically dated between 1870 and 1914 and was driven by the more outspread use of oil, gas and, of course, electricity having enormous implications for both transportation and industries. This was the time when the world was introduced to mass production factories, characterized by the assembly line. In the 1960s the third industrial revolution or the Digital revolution began. The use of electronics and IT lead to a new age of optimized and automated production (Rifkin, 2011). We are now facing the fourth industrial revolution, where the introduction of intelligent manufacturing through Cyber-Physical System, is fundamentally changing the way industries operate. The concept Industry 4.0 comes from the name of the German government's high-tech strategy that was published in 2011 and is now the prevalent term for the fourth industrial revolution (Liu and Zhou, 2015).

Core concepts of Industry 4.0

Industry 4.0 is a widely discussed topic, but does not have a clear, prevalent definition. Business are yet to fully understand how the supporting technologies will be utilized and thus what concrete form Industry 4.0 will take (Cevikcan and Ustundag, 2018). In this section, the most common definitions and aspects of Industry 4.0 are presented.

The final report of the Industrie 4.0 Working Group, a comprehensive recommendation to the German government on how to pursue the strategic initiative Industrie 4.0, could be considered the first source of Industry 4.0 insights. In the report, Kagermann et al. (2013) proposes that the fundamental form of Industry 4.0 is Cyber-Physical Systems (CPS), which 'comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently'. That is, the automated, deep connection of the physical and digital world is the core aspect of Industry 4.0. The supporting technology of the development of CPS are Internet of Things and Services that convert the different parts of the value chain to a network, with the Smart factory in the center (Kagermann 2013).

This definition goes in line with what is suggested by Cevikcan and Ustundag (2018), which is 'Industry 4.0 is comprised of the integration of production facilities, supply chains and service systems to enable the establishment of value-added networks'.

Industry 4.0 supporting technologies

Industry 4.0 is driven by the development of a group of technologies. Researchers suggest fundamentally the same technologies, with some differences. Gerbert et al. (2015) suggest that Industry 4.0 is defined by nine core technologies:

Big data and analytics. The digitalization of production systems will make enormous sets of data available from many different sources. This enables optimization and real-time decision making at every level of the value chain.

Autonomous robots. Enabled by improved performance by AI agents and microprocessors, machines consistently become more intelligent, both in terms of computation and precision, but also in terms of autonomy and comunicativity. The state of art is a system where machines works in perfect sync with each other and humans, communicating and learning. This will drive lower costs and improved manufacturing capabilities.

Simulation. When designing products and machines, simulations are already used to a high degree. The development will go towards including simulation in operations, enabling more intelligent decision making. Using real-time data, simulations of machines, material and human operators could test decisions before actually making them, removing some uncertainty, e.g. when deciding on machine setups.

Horizontal and vertical system integration. Today, many corporations consist of several non-connected silos. The IT systems of engineering, production and service are rarely connected. Even rarer is inter-company connection, where supplier, company and distributor have integrated IT systems. Industry 4.0 will drive connectedness within and between companies, which will lead to fully automated value chains.

Industrial Internet of Things (IoT). By equipping products, completed as well as uncompleted, and machines with sensors and communicative capabilities all moving parts within a plant will be connected and subject to computing capabilities.

Cybersecurity. A consequence of the increased level of connectivity, digital autonomously and amount of sensitive data is an increase in the need for improved cybersecurity to protect against the increased threat of cyber-attacks.

The cloud. Cloud technologies enables data sharing and computational capabilities. Data sharing will increase dramatically with Industry 4.0, both between platforms within companies, but also between companies. Driven by the improved performance of cloud technologies, more and more parts of production systems will be cloud based, e.g. control and monitor systems.

Additive manufacturing. Additive manufacturing is the name of a group of technologies that create 3D structures based on a digital design by adding layers-upon-layer of material. Today there are some limitations to the technology, but as the technology matures the significant advantages will be and more harvestable. Firstly, additive manufacturing allows construction of, by conventional

manufacturing methods, impossible structures. Minimal waste is another advantage additive manufacturing. Included in a network system, additive manufacturing allows high flexibility when and adaptivity when designing parts.

Augmented reality. Augmented reality, where visual, digital elements are merged with graphics of the physical world, could be used in many different applications to improve real-time decision making and procedures for workers. One example would be workers receiving visual information on how to repair a specific machine in their field of sight from augmented reality technology.

Another technology that is not mentioned by Gerbert et al. (20, but is a commonly referenced in other research is embedded systems or Cyber-Physical systems (Cevikcan and Ustundag, 2018); Kagermann et al. 2013). CPS are the networking platform that enables integration between physical and digital world. The following two features generally constitute the requirement for embedded systems:

1. A well-developed network for real-time information exchange between the physical units and the computational units.
2. Intelligent data processing, decision-making and computational capabilities that support the physical system.

To enable this, CPS consist of RTLS technologies, RFID sensors, actuators, controllers and, of course, networked systems connecting the physical and digital infrastructure (Cevikcan and Ustundag, 2018) CPS are consequently more of a meta-technology and a combination of the previously mentioned technologies (Gerbert et al. 2015).

Impact of Industry 4.0

The potential impact of Industry 4.0 is still difficult to fully grasp, but on a conceptual level, one can see eight trends (Kagermann et al. 2013):

Meeting individual customer requirements. Industry 4.0 is capable of handling more customization in the entire value-chain, which will allow customer requirements to be included to a higher degree.

Flexibility. Different dimensions of a business' processes are more dynamic in Industry 4.0, e.g. quality, risk and price. Consequently, the operations can constantly be modified and improved, but also the engineering processes can be more flexible.
Optimized decision-taking. The combination of real-time data access and agility, the value chain can be optimized and changed as a response to disruption in the business climate.

Resource productivity and efficiency. A CPS-based production system allows manufacturing processes to both be optimized over the entire value chain for each specific batch and to continuously adjust during operations, rather than having to stop.

Creating value opportunities through new services. The business potential of Industry 4.0 will itself increase the impact by creating new business opportunities, typically through downstream services.

E.g. using the big data collected from the smart components can though intelligent algorithms create highly valuable services.

Responding to demographic change in the workplace. There is an increasing discrepancy between company demand and supply of labor, driven both by the technological development and diversity of workforce, e.g. in terms of age. If the current workforce skill mismatch is taken care of, Industry 4.0 is opening up for more diverse work and for workers to stay value-creating for longer.

Work-life balance. A large proportion of the global workforce are increasingly valuing a healthy work-life balance, the flexibility and agility of CPS-based organizations are well-organized to offer that, leading to an employer branding advantage.

Gerbert et al. (2015) has quantitatively assessed the potential impact of Industry 4.0, using Germany as their object of study. They identified four areas where areas where Industry 4.0 will drive improvement:

Productivity. Over the course of the coming five to ten years, German manufacturing companies will achieve productivity gains of 5 to 8 percent. The gains will vary between industries, where industrial-component manufacturers are predicted to reach the most significant productivity improvements of 20 to 30 percent.

Revenue growth. Driven by manufacturers increased demand for advanced technology and solutions and customers increased demand for more customized products, revenues will grow. The total revenue growth is projected to be €30 billion a year or approximately one percent of the German GDP.

Employment. Stimulated by the growth in the manufacturing industry, the employment is found to increase by 6 percent during the next 10 years. However, short term there will be issues related to competency transformation as low-skill labor will be displaced by automation solutions.

Investment. Capex related investments of €250 billion during the next 10 years will be needed from manufacturers to update their production systems to facilitate Industry 4.0.

Appendix B: Survey respondent information

In this appendix an overview of the respondents is presented.

Table B.1: Respondent information	
Respondent position	Sub-Industry
CEO	Machinery manufacturing industry
CEO	Transportation equipment manufacturing industry
CEO	Machinery manufacturing industry
CEO	Automotive industry
Head of production	Joinery manufacturing industry
CEO	Boat & ship building industry
CEO	Transportation equipment manufacturing industry
CEO	Machinery manufacturing industry
COO	Machinery manufacturing industry
CEO	Medical & Dental Instrument Manufacturing industry
CEO	Electronics industry
CEO	Transportation equipment manufacturing industry
CEO	Transportation equipment manufacturing industry
Head of production	Machinery manufacturing industry
CEO	Machine tool manufacturing industry
COO	Machinery manufacturing industry
CEO	Machine tool manufacturing industry
CEO	Transportation equipment manufacturing industry
COO	Machinery manufacturing industry
CEO	Electronics industry
Owner	Machinery manufacturing industry
Head of research and development	Electronics industry
CEO	Machinery manufacturing industry
CEO	Telecommunications equipment industry
Head of production	Machine tool manufacturing industry
CTO	Steel industry
Head of production	Machinery manufacturing industry
CEO	Machinery manufacturing industry

Appendix C: Distribution of maturity level within sub-dimensions

Table C.1: Distribution of maturity level within Strategy and organization					
	Degree of strategic implementation	Definition of indicators	Investments	Innovation management	Total
Outsider	35,7%	0,0%	53,6%	0,0%	53,6%
Beginner	39,3%	89,3%	14,3%	0,0%	35,7%
Intermediate	17,9%	0,0%	17,9%	28,6%	3,6%
Experienced	0,0%	0,0%	10,7%	46,4%	3,6%
Expert	3,6%	10,7%	0,0%	10,7%	3,6%
Top performer	3,6%	0,0%	3,6%	14,3%	0,0%
Average maturity level	1,07	1,32	1,00	3,11	0,68

Table C.2: Distribution of maturity level within Smart factory							
	Equipment infrastructure (current)	Equipment infrastructure (target)	Digital modeling	Data collection	Data usage	IT systems	Total
Level 0: Outsiders	14,3%	3,6%	0,0%	0,0%	0,0%	7,1%	17,9%
Level 1: Beginners	46,4%	17,9%	25,0%	7,1%	10,7%	25,0%	50,0%
Level 2: Intermediates	3,6%	42,9%	0,0%	25,0%	42,9%	0,0%	14,3%
Level 3: Experienced	28,6%	17,9%	0,0%	39,3%	14,3%	0,0%	14,3%
Level 4: Expert	7,1%	17,9%	67,9%	17,9%	21,4%	57,1%	3,6%
Level 5: Top performer	0,0%	0,0%	7,1%	10,7%	10,7%	10,7%	0,0%
Average maturity	1,68	2,29	3,32	3,00	2,79	3,07	1,36

Table C.3: Distribution of maturity level within Smart operations						
Level 0: Outsiders	25,0%	0,0%	0,0%	3,6%	0,0%	28,6%
Level 1: Beginners	0,0%	0,0%	0,0%	14,3%	0,0%	7,1%
Level 2: Intermediates	53,6%	0,0%	0,0%	14,3%	28,6%	50,0%
Level 3: Experienced	0,0%	92,9%	96,4%	28,6%	35,7%	14,3%
Level 4: Expert	14,3%	3,6%	0,0%	28,6%	21,4%	0,0%
Level 5: Top performer	7,1%	3,6%	3,6%	10,7%	14,3%	0,0%
Average maturity	2,00	3,11	3,07	2,96	3,21	1,50

Table C.4: Distribution of maturity level within Smart products			
	ICT add-on functionalities	*Use of data*	*Total*
Outsider	92,9%	0,0%	92,9%
Beginner	0,0%	64,3%	0,0%
Intermediate	3,6%	10,7%	3,6%
Experienced	3,6%	0,0%	3,6%
Expert	0,0%	0,0%	0,0%
Top performer	0,0%	25,0%	0,0%
Average maturity level	0,18	2,11	0,18

Table C.5: Distribution of maturity level within Data-driven services				
	Data-driven services	*Share of revenue*	*Level of data usage*	*Total*
Level 0: Outsiders	71,4%	78,6%	0,0%	78,6%
Level 1: Beginners	0,0%	7,1%	60,7%	7,1%
Level 2: Intermediates	0,0%	3,6%	25,0%	7,1%
Level 3: Experienced	17,9%	0,0%	0,0%	0,0%
Level 4: Expert	0,0%	0,0%	7,1%	3,6%
Level 5: Top performer	10,7%	10,7%	7,1%	3,6%
Average maturity	1,07	0,68	1,75	0,54

Table C.6: Distribution of maturity level Employees		
	Employee skills	*Total*
Outsider	7,1%	7,1%
Beginner	32,1%	32,1%
Intermediate	35,7%	35,7%
Experienced	14,3%	14,3%
Expert	7,1%	7,1%
Top performer	3,6%	3,6%
Average maturity level	1,93	1,93

Appendix D: Survey

In this appendix the survey is presented. It is only available in its original language, Swedish.

Företagsinformation

För att analysera resultatet från enkäten behöver vi företagsspecifik information. Företagsnamn kommer inte inkluderas i något publicerat material och era svar kommer därmed vara helt anonyma.

Vilket företag svarar du för? *

Short answer text

Vad är er position? Exempelvis produktionschef eller VD. *

Short answer text

Vad var ert företags omsättning 2018? Vänligen ange svaret i MSEK. *

Short answer text

Hur många heltidsanställda har ert företag i dagsläget? *

Short answer text

Är ni medvetna om Industry 4.0 och/eller arbetar aktivt för att implementera det i er verksamhet? *

○ Ja

○ Nej

Strategi och organisation

Industry 4.0 handlar inte bara om att utveckla processer och produkter genom att använda ny teknologi. Det uppmanar även till att utveckla en helt ny affärsmodell. I det här avsnittet mäts i vilken utsträckning ert företag har anpassat sin strategi och organisation efter Industry 4.0.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

I vilken utsträckning har ni implementerat Industry 4.0 i er strategi? *

1. Nivå 0: Industry 4.0 är inte en del av er strategiska process

2. Nivå 1: Industry 4.0 diskuteras på avdelningsnivå, men är inte en del av den övergripande strategin

3. Nivå 2: En strategi för Industry 4.0 håller på att utvecklas

4. Nivå 3: En strategy för Industry 4.0 har utvecklats

5. Nivå 4: En strategi för Industry 4.0 håller på att implementeras

6. Nivå 5: En strategi för Industry 4.0 har implementerats i hela organisationen

I vilken utsträckning använder ni indikatorer för att mäta status av implementering av Industry 4.0? *

1. Nivå 0: Inga indikatorer finns för att mäta status av implementering av Industry 4.0

2. Nivå 1: (Samma som Nivå 0) Inga indikatorer finns för att mäta status av implementering av Industry 4.0

3. Nivå 2: Ett system av indikatorer finns som ger en uppfattning om status av implementering av Industry 4.0

4. Nivå 3: (Samma som nivå 2) Ett system av indikatorer finns som ger en uppfattning om status av implementering av I...

5. Nivå 4: (Samma som nivå 2) Ett system av indikatorer finns som ger en uppfattning om status av implementering av I...

6. Nivå 5: Ett system av indiktatorer finns och är integrerade i den strategiska processen

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Hur mycket investerar ni i Industry 4.0? *

1. Nivå 0: Inga investeringar i Industry 4.0

2. Nivå 1: Initiala investeringar inom ett område av Industry 4.0

3. Nivå 2: Små investeringar i Industry 4.0

4. Nivå 3: Investeringar i vissa områden av Industry 4.0

5. Nivå 4: Investeringar i flera områden av Industry 4.0

6. Nivå 5: Företagsomspännande investeringar i Industry 4.0

I vilken utsträckning har ni innovation management? *

Innovation management bör tolkas som en kombination ledning av innovationsprocesser och förändringsarbete.

1. Nivå 0: Ingen innovation management

2. Nivå 1: (Samma som nivå 0) Ingen innovation management

3. Nivå 2: (Samma som nivå 0) Ingen innovation management

4. Nivå 3: Innovation management finns i isolerade delar av företaget

5. Nivå 4: Innovation management finns i flera delar av företaget

6. Nivå 5: Uniform, samarbetande innovation management finns i hela företaget

Vad upplever ni som de främsta utmaningarna kopplat till implementering av den här dimensionen av Industry 4.0? *

Long answer text

Smart fabrik

Den smarta fabriken är intelligent och sammankopplad, där produktionssystem kommunicerar med övergripande IT-system och smarta produkter.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

Hur integrerad och kontrollerbar är er nuvarande infrastruktur av verktyg och maskiner? *

1. Nivå 0: Ingen integration mellan maskiner. Maskiner kan inte kontrolleras av IT

2. Nivå 1: Vissa maskiner kan kontrolleras med IT eller är integrerade med varandra

3. Nivå 2: Maskiner och övrig infrastruktur kan i viss utsträckning kontrolleras av IT eller är integrerade med varandra

4. Nivå 3: Maskiner och infrastruktur kan kontrolleras av IT och är delvis integrerade med varandra

5. Nivå 4: Maskiner och infrastruktur kan kontrolleras fullständigt av IT och är delvis integrerade med varandra

6. Nivå 5: Maskiner och infrastruktur kan kontrolleras fullständigt av och helt integrerade med varandra

Vilken utvecklingspotential finns för er infrastruktur av verktyg och maskiner? *

1. Nivå 0: Maskiner och system kan inte uppgraderas

2. Nivå 1: Framtida behov och krav för maskiner och system är relevanta

3. Nivå 2: Vissa maskiner och system kan uppgraderas

4. Nivå 3: Alla maskiner och system kan uppgraderas

5. Nivå 4: Vissa maskiner uppfyller redan framtida krav och behov och resten kan uppgraderas

6. Nivå 5: Alla maskiner uppfyller alla framtida behov och krav

I vilken utsträckning använder ni digital modellering? *

1. Nivå 0: Ingen digital modellering

2. Nivå 1: (Samma som Nivå 0) Ingen digital modellering

3. Nivå 2: Viss digital modellering

4. Nivå 3: (Samma som Nivå 2) Viss digital modellering

5. Nivå 4: (Samma som Nivå 2) Viss digital modellering

6. Nivå 5: Fullständig digital modellering är möjlig

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I vilken utsträckning samlar ni in data från produktion och värdekedjor? *

1. Nivå 0: Ingen data samlas in

2. Nivå 1: (Samma som Nivå 0) Ingen data samlas in

3. Nivå 2: Data samlas in, men framförallt manuellt

4. Nivå 3: Den mest relevanta datan samlas in digitalt inom vissa områden

5. Nivå 4: Omfattande data samlas in digitalt inom flera områden

6. Nivå 5: Omfattande data samlas in automatiskt och digitalt inom alla områden

I vilken utsträckning använder ni data från produktion och värdekedjor? *

Definiera vilken typ av data?

1. Nivå 0: Ingen data används

2. Nivå 1: (Samma som Nivå 0) Ingen data används

3. Nivå 2: Data används inom vissa utvalda områden (exempelvis utökad transparens)

4. Nivå 3: Viss data används för att optimera processer (exempelvis predictive maintainence)

5. Nivå 4: Data används i flera områden för optimering

6. Nivå 5: Data används för omfattande processoptimering

I vilken utsträckning använder ni IT-system inom produktion och värdekedjor? *

1. Nivå 0: Inga IT-system används för att stödja processer

2. Nivå 1: IT-system används för att stödja de viktigaste processerna

3. Nivå 2: IT-system används för att stödja vissa processer och de är integrerade med varandra

4. Nivå 3: (Samma som Nivå 2) IT-system används för att stödja vissa processer och de är integrerade med varandra

5. Nivå 4: (Samma som Nivå 2) IT-system används för att stödja vissa processer och de är integrerade med varandra

6. Nivå 5: IT-system används för att stödja alla processer och de är fullständigt integrerade

Vad upplever ni som de främsta utmaningarna kopplat till implementering av den här dimensionen av Industry 4.0? *

Long answer text

Smart drift

Smart drift utgörs integration av fysiska och digitala system, både inom företag, men också mellan. Tillgång till stora mängder data möjliggör en ny typ av styrning av värdekedjor, som kräver mindre och mindre mänsklig styrning. I det här avsnittet mäts hur smart er generella drift är.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

I vilken utsträckning delar ni information? *

1. Nivå 0: Ingen information delas genom integrerade system

2. Nivå 1: Viss information delas genom interna, integrerade system

3. Nivå 2: (Samma som Nivå 1) Viss information delas genom interna, integrerade system

4. Nivå 3: Viss intern information och inledande till extern information delas genom integrerade system

5. Nivå 4: (Samma som Nivå 3) Viss intern information och inledande till extern information delas genom integrerade sy...

6. Nivå 5: Omfattande intern och viss extern information delas genom integrerade system

I vilken utsträckning använder ni autonomt styrda arbetsstycken? *

1. Nivå 0: Autonomt styrda arbetsstycken används inte

2. Nivå 1: (Samma som Nivå 0) Autonomt styrda arbetsstycken används inte

3. Nivå 2: (Samma som Nivå 0) Autonomt styrda arbetsstycken används inte

4. Nivå 3: (Samma som Nivå 0) Autonomt styrda arbetsstycken används inte

5. Nivå 4: Piloter och tester av autonomt styrda arbetsstycken genomförs

6. Nivå 5: Autonomy styrda arbetsstycken används inom vissa specifika områden eller inom hela företaget

I vilken utsträckning använder ni självreglerande processer? *

1. Nivå 0: Självreglerande processer används inte

2. Nivå 1: (Samma som Nivå 0) Självreglerande processer används inte

3. Nivå 2: (Samma som Nivå 0) Självreglerande processer används inte

4. Nivå 3: (Samma som Nivå 0) Självreglerande processer används inte

5. Nivå 4: Piloter och tester av självreglerande processer genomförs

6. Nivå 5: Självreglerande processer används inom vissa specifika områden eller inom hela företaget

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Hur utvecklad är er IT-säkerhet? *

1. Nivå 0: Inga lösningar för IT-säkerhet är i utveckling eller har implementerats

2. Nivå 1: Grundläggande lösningar för IT-säkerhet är planerade att implementeras

3. Nivå 2: Flera lösningar för IT-säkerhet är i utveckling och grundläggande har implementerats

4. Nivå 3: Lösningar för IT-säkerhet har delvis implementerats

5. Nivå 4: Omfattande lösningar för IT-säkerhet har implementerats och kvarvarande gap håller på att stängas

6. Nivå 5: Lösningar för IT-säkerhet har implementerats inom samtliga relevanta områden

I vilken utsträckning använder ni molnlösningar? *

1. Nivå 0: Molnlösningar används inte

2. Nivå 1: (Samma som Nivå 0) Molnlösningar används inte

3. Nivå 2: (Samma som Nivå 0) Molnlösningar används inte

4. Nivå 3: Grundläggande molnlösningar för datalagring och dataanalys planeras

5. Nivå 4: Grundläggande molnlösningar har implementerats

6. Nivå 5: Flera molnlösningar har implementerats

Vad upplever ni som de främsta utmaningarna kopplat till implementering av den här dimensionen av Industry 4.0? *

Long answer text

Smarta produkter

Smarta produkter är utrustade med ICT-komponenter (sensorer, RFID, kommunikationsgränssnitt osv.) som samlar in data om produktionsmiljön och rapporterar sin egen status. I denna dimension mäts produkternas kommunikationsförmåga under deras livscykels olika skeden, exempelvis tillverkning, användning, återvinning osv.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

I vilken utsträckning använder ni ICT-tillägg? *

1. Nivå 0: Inga ICT-tillägg används

2. Nivå 1: Få ICT-tillägg används

3. Nivå 2: (Samma som Nivå 1) Få ICT-tillägg används

4. Nivå 3: Produkterna är utrustade med flera, sammanlänkade ICT-tillägg, som används inom enskilda skeden i livscykeln

5. Nivå 4: Produkterna är utrustade med flera sammanlänkade ICT-tillägg, som används inom olika skeden av livscykeln

6. Nivå 5: (Samma som Nivå 4) Produkterna är utrustade med flera sammanlänkade ICT-tillägg, som används inom olik…

I vilken utsträckning använder ni er av insamlad data? *

1. Nivå 0: Ingen insamlad data

2. Nivå 1: (Samma som Nivå 0) Ingen insamlad data

3. Nivå 2: Insamlad data är inte analyserad/använd

4. Nivå 3: Insamlad data är analyserad och används

5. Nivå 4: (Samma som Nivå 3) Insamlad data är analyserad och används

6. Nivå 5: (Samma som Nivå 3) Insamlad data är analyserad och används

Datadrivna tjänsteerbjudanden

Datadrivna tjänster handlar om att omvandla företagen från att sälja produkter till att leverera lösningar. Inudstri 4.0 uppmuntrar företag att fundamentalt tänka om sina existerande affärsmodeller och antingen digitalisera traditionella affärsmodeller eller utveckla helt nya. Datadrivna tjänster möjliggör integration mellan tillverkaren och kunden, där den smarta produkten samlar in data och rapporterar kundens behov genom kommunikation mellan installerade sensorer och ett IT system hos tillverkaren. I detta fall är kunden helt integrerad i företagets affärsmodell.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

Hur mycket datadrivna tjänster erbjuder ni era kunder i dagsläget? *

1. Nivå 0: Inga datadrivna tjänster erbjuds i dagsläget

2. Nivå 1: Datadrivna tjänster erbjuds men utan kundintegration

3. Nivå 2: (Samma som Nivå 1) Datadrivna tjänster erbjuds men utan kundintegration

4. Nivå 3: (Samma som Nivå 1) Datadrivna tjänster erbjuds men utan kundintegration

5. Nivå 4: Datadrivna tjänster erbjuds med kundintegration

6. Nivå 5: Datadrivna tjänster är en del av existerande affärsmodell

Hur stor andel av era intäkterna utgörs av datadrivna tjänster i dagsläget? *

1. Nivå 0: Datadrivna tjänster utgör inte någon del av intäkterna

2. Nivå 1: Datadrivna tjänster står för en liten andel av intäkterna (<1%)

3. Nivå 2: Datadrivna tjänster står för en liten andel av intäkterna (<2,5%)

4. Nivå 3: Datadrivna tjänster står för en liten andel av intäkterna (<7,5%)

5. Nivå 4: Datadrivna tjänster utgör en signifikant del av intäkterna (<10%)

6. Nivå 5: Datadrivna tjänster utgör en stor del av intäkterna (>10%)

I vilken utsträckning använder ni er av insamlad data? *

○ Nivå 0: Ingen dataanvändning

○ Nivå 1: (Samma som Nivå 0) Ingen dataanvändning

○ Nivå 2: 0-20% insamlad data används

○ Nivå 3: 20-50% insamlad data används

○ Nivå 4: (Samma som Nivå 3) 20-50% insamlad data används

○ Nivå 5: Mer än 50 % av insamlad data används

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Anställda

Förändringarna som sker på arbetsplatsen under den digitala transformationen har en stark påverkan på företagets anställda som får anpassa sig efter dessa förändringar och utveckla nya kompetenser. Företagen som går igenom den digitala transformationen måste se till att förbereda sin personal för sådan transformation genom att erbjuda dem lämpliga utbildningar.

Vänligen svara på frågor nedan genom att välj den högsta nivå på vilken ni har uppfyllt kraven.

Vilken kompetensnivå besitter era anställda i dagsläget inom digitaliseringsprocesser? *

1. Nivå 0: Anställda har inga relevanta kompetenser

2. Nivå 1: Anställda har en låg kompetensnivå inom ett relevant område

3. Nivå 2: Anställda har en låg kompetensnivå inom ett fåtal relevanta områden

4. Nivå 3: Anställda har en lagom kompetensnivå inom några relevanta områden

5. Nivå 4: Anställda har en lagom kompetensnivå inom flera relevanta områden

6. Nivå 5: Anställda besitter en nödvändig kompetensnivå inom flera relevanta områden

Hur viktiga är dimensionerna?

Vänligen fördela 100 poäng mellan de olika dimensionerna. Ju högre poäng desto viktigare anser ni att dimensionen är för er verksamhet. Vänligen observera att frågan tillåter dig att ange poäng som summerar till något annat än 100. Vi ber dig därför att kontrollera att dina angivna poäng gör detta, då svaret annars inte kan användas.

Strategi och organisation *

Short answer text

Smart fabrik *

Short answer text

Smart drift *

Short answer text

Smarta produkter *

Short answer text

Datadrivna tjänsteerbjudanden *

Short answer text

Anställda *

Short answer text

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