Utilizing Big Data and Internet of Things in a Manufacturing Company

- A case study of using technological advances in the production process of Swedish Match

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Abstract

Title Utilizing Big Data and Internet of Things in a Manufacturing Company - A case study of using technological advances in the production process of Swedish Match

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Studied case Swedish Match experiences a changing business environment with increased competition. In this business environment, the ability to successfully utilizing technological advances, such as big data and IoT, is becoming more important to remain competitive. In addition, a limited number of studies have been conducted on the theme big data and IoT in a manufacturing firm. Thus, this master's thesis is an initiative to increase the knowledge, both within the company as well as in the overall industry.

Purpose The purpose of this master's thesis is to investigate how the manufacturing company Swedish Match can optimize their production process by utilizing big data and IoT.

Methodology To answer the research questions and the purpose presented in this master's thesis, a single qualitative case study with an inductive reasoning approach is initiated. To gain insights in the case organization, in-depth interviews and observations are conducted. These methods, in combination with a literature study, provide an understanding of how big data and IoT can be utilized in a production process. Thus, the research questions and the purpose of the master's thesis are also answered.

Conclusions

Four fundamental gaps between the current situation and the desired situation emerge when studying the production process of Swedish Match. These gaps are *(1)* a lack of internal process integration, *(2)* a reactive approach instead of a proactive, *(3)* that high pressure is put on employees, and *(4)* that much data is stored without being available, combined or visualized at the right place.

Furthermore, it is clear that there are two main application areas of big data and IoT that are feasible when manufacturing functional and mature products. More specifically, these applications are in manufacturing optimization as well as in preventive and predictive maintenance. The applications in these two areas can contribute to attaining increased efficiency in the production process while minimizing costs. Ultimately, this can result in increased quality of the finished products.

In addition, when considering a utilization of the two technological advances, it is of high importance that the company knows what their actual goal is with the adoption. Furthermore, it is of high importance that the organization realizes what big data and IoT can accomplish as well as its limitations, all to assure reasonable expectations.

When considering utilization, it is also important to consider the associated risks. Here, the critical risks should be managed first to mitigate the potential issues. There are two critical risks in this case, namely the risk of the required investment being too large and it being hard to find the needed competencies.

Keywords

Industry 4.0, Big Data, Internet of Things, Industrial Internet of Things, Product Life Cycle, Functional product, Innovative product, Supply Chain Strategy

Preface

This master's thesis is the final part of the degree Master of Science, Industrial Engineering and Management, Faculty of Engineering, Lund University. It is written for the Division of Engineering Logistics at the university during the spring of 2016.

First and foremost, we would like to thank Swedish Match for the opportunity to conduct the master's thesis at the company as well as for initiating the study on the subject of big data and IoT, which we find very interesting. In addition, we would like to extend our gratitude to our supervisor, Mattias Wermé, Business Engagement Liaison Scandinavian Division, for his engagement and support throughout the process. Also, for sharing his experience and insights. Furthermore, we would also like to give a thank you to everyone else at Swedish Match who shared his or her knowledge with us.

Finally, we would like to express our gratitude to Malin Johansson, our supervisor at the Division of Engineering Logistics at the Faculty of Engineering, for her assistance and time throughout the learning process. You have challenged the way we think, which continuously improved the thesis. We also hope that you have learnt as much as we have throughout the process.

Gothenburg, May 2016
Hanna Karlberg & Sofia Pettersson

List of Acronyms

This list displays the acronyms used in this master's thesis and is provided to simplify the reading.

DC	Distribution Center
DMZ	Demilitarized zone
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product
IoT	Internet of Things
KPI	Key Performance Indicator
PLC	Product Life Cycle
PSO	Portioned Packed Snus Original
RFID	Radio Frequency Identification
SKU	Stock Keeping Unit
SM	Swedish Match
SMD	Swedish Match Distribution
WLAN	Wireless Local Area Network

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1 Introduction

In this chapter, an introduction to the research field as well as a brief problem description of the case organization is presented to the reader. Furthermore, the research questions and the purpose of the master's thesis are provided. Lastly, the scope, delimitations and outline of the report are presented.

1.1 Background

Recent technological development has changed the working conditions of the manufacturing industry (Accenture, 2014). Today's Digital Industry 4.0 is described as the fourth industrial revolution enabling a digitized value chain (PwC, 2015). The revolution makes it possible for production sites to be connected through smart information systems. As a result, machines can communicate with other machines and products. In addition, more accurate data can be delivered and information can be processed to give real time updates (Accenture, 2014). However, history tells that technological development takes time (Rüssmann et al., 2015). A complete shift to adoption of Industry 4.0 is likely to require about 20 years before the full potential can be realized. On the other hand, Rüssmann et al. (2015) estimate that important progress will be made during the next five to ten years, which will result in the rise of winning and losing firms.

Industry 4.0 is expected to have a deep impact as well as the capability to change manufacturing, design, operations, and service of production systems and products. A shift is expected towards plants that are connected to each other. This can be seen as a significant alteration compared to the previous situation with single automated cells. Results include increased levels of flexibility, productivity, quality and speed. For example, the complex manufacturing landscape in Germany can realize productivity gains up to eight percent on the total manufacturing costs over ten years. In monetary terms this would result in over 90 billion EUR. If considering Germany separately, the shift can contribute with one percent to the gross domestic product (GDP) each year over ten years, increase the manufacturers' revenues with over one percent, and generate close to 400,000 jobs (Rüssmann et al., 2015).

Improved efficiency and lowered costs are two feasible results of digitizing products and the value chain. Furthermore, digitization is an essential factor to remain competitive or increase the competitiveness of a company in the manufacturing industry. Here, it is of high importance to digitize the services and products that already are in the company's portfolio, but also to work with the development of novel digital services. This means that the business models of manufacturing firms are challenged by the major and fast progress of digital development. Clearly, the industrial digitization results in several opportunities, but it also results in a number of new challenges and risks. These challenges need to be considered when considering the potential of Industry 4.0 (PwC, 2015).

The changes in industrial production associated with Industry 4.0 are driven by nine key advancements of technology. Two of the included technological developments are big data and Internet of Things (IoT) (Rüssmann et al., 2015), see Figure 1.1 for further details. Big data and IoT are both facilitating information sharing and are making the value chain more flexible (Accenture, 2014).

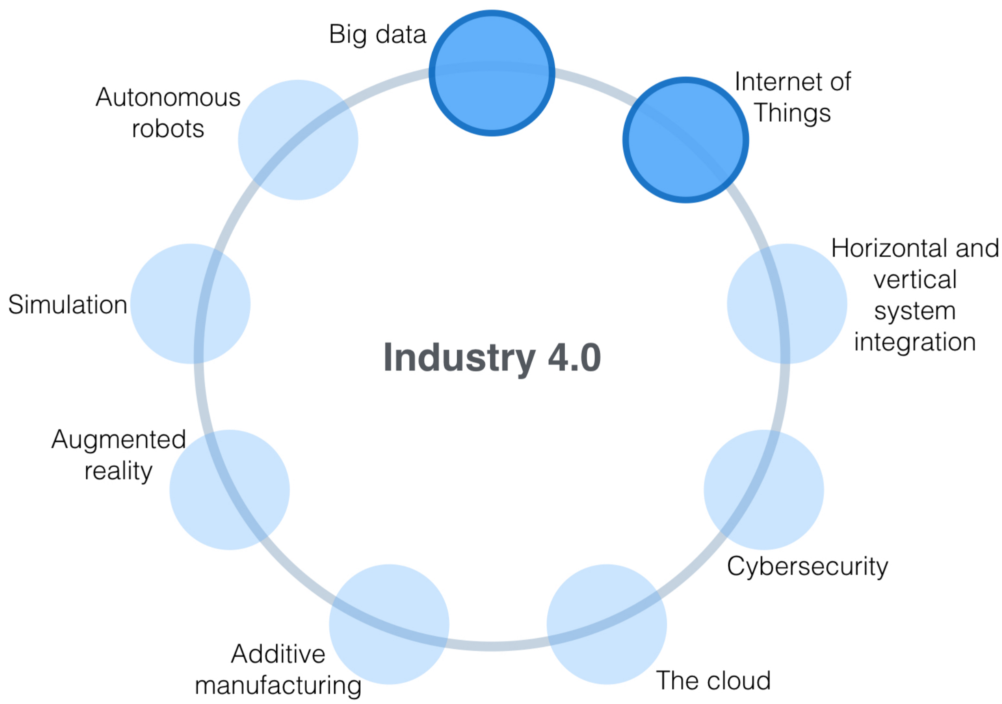


Figure 1.1 The nine technologies that are changing the industrial production (Rüssmann et al., 2015)

Big data is explained as a massive collection and understanding of data, which is made possible through strong analytic capabilities that monitor and analyze various digital streams (Davenport, 2014). IoT, on the other hand, is made up of a number of connected data sources that both generate data and communicate with each other in efficient ways (Chase, 2013). When implementing IoT, a company must first have a big data strategy to handle the massive amounts of data that are generated (Aberle, 2015). Thus, big data and IoT are closely related and do both contribute to transforming the industrial production. This is also why both technologies will be investigated further in this master's thesis. In addition, both technologies are rather new advances (Rüssmann et al., 2015) and currently it is hard for companies to realize what potential that actually exist. Furthermore, it is hard to foresee the degree of threat from new players who are able to compete with fully digitized business instead of the traditional physical products (PwC, 2015).

To understand the potential of big data and IoT in manufacturing companies, the production process of Swedish Match (SM) is investigated. SM is an experienced company within both the tobacco and match industry. The tobacco product portfolio has its roots in AB Svenska Tobaksmonopolet, a company founded by the Swedish government over a hundred years ago (Swedish Match, 2013).

1.2 Problem Description

The competitive landscape of SM has changed during recent years, much due to the entry of price-pressuring competitors on the snus market. To remain competitive, SM has differentiated their product portfolio by increasing the number of stock keeping units (SKUs). Currently, more than 200 SKUs are included in SM's product portfolio. This means that the company's product portfolio has become more complex, with a reduction in the individual batch sizes and an increase in the number of different batches. The large number of batches results in longer changeover times and less efficient usage of machinery. As the current production process of SM is standardized, it is not adapted to the flexibility that is required to meet the increased complexity (Project managers at SM, 2016).

As the complexity in the production increases, more data needs to be handled. Currently, data is collected both manually and automatically. For example, quality controls are performed regularly to reassure the quality of the snus. The results of the controls are documented manually on paper. This documentation is put in a folder that is stored in a separate room. In contrast, there are other types of data that are recorded automatically into an information system. Depending on where in the production process the data is collected, the data is registered and processed in different systems (Project managers at SM, 2016). Collecting data in different ways and locations can result in information islands. These information islands prevent efficient data sharing and credible decision-making (Bi, Xu, & Wang, 2014). The digital transformation where big data and IoT is utilized could potentially lead to an opportunity to eliminate information islands.

This all add up to the fact that SM is an appropriate company to consider in this master's thesis. The issues described provide new motives to transform the company's production process. In this study, big data and IoT are explored as options for a digital transformation to improve the performance in the production process of SM. The overall research question (RQ1) is constructed and stated in below.

RQ1. How can big data and IoT be utilized to optimize the production process at Swedish Match?

Here, optimization of the production process relates to an uninterrupted flow of finished goods and avoidance of defects. In addition, three sub-questions (RQ2 - RQ4) are formed to support the overall research question in a systematic way.

RQ2. Why should Swedish Match utilize big data and IoT?
RQ3. What are suitable applications of big data and IoT at Swedish Match?
RQ4. In which parts of the production process is it most appropriate to start?

RQ2 is constructed to understand the current production process and its improvement opportunities. Furthermore, it is formed to gain an understanding of the internal drivers at SM. RQ3 is constructed to gain insights in the literature and the external environment. Suitable applications are studied to understand if the new technologies can be implemented, and if so, which prerequisites are required in the factories of SM. RQ4 relates to evaluating where and how big data and IoT can be implemented at SM.

1.3 Purpose

The purpose of this master's thesis is to investigate how the manufacturing company Swedish Match can optimize their production process by utilizing big data and IoT.

1.4 Focus and Delimitations

Based on the initiative of SM, the focus of this master's thesis is limited to the manufacturing process in SM's factory located in Gothenburg. This production process includes three sub processes, namely the mill, pasteurization and packaging. Therefore, the topics of warehousing and distribution are both excluded from this study.

In addition, the scope of this study includes conducting an examination of the production process of a specific product of SM, all to investigate what opportunities that can be realized through big data and IoT. The studied product is portioned packed snus original (PSO), more specifically General, which is one of SM's the strongest brands (Swedish Match, 2015a). By understanding the potential of big data and IoT in this specific case, the principles can be applied and scaled to fit other products' production processes. This can be done both within the company and in other manufacturing corporations. However, the testing of the theory developed through this specific case study is up to others to investigate further.

The focus of this master's thesis is on big data and IoT, not on the remaining seven technologies included in industry 4.0. This delimitation is motivated by directives provided by SM. However, some of the remaining ones are briefly mentioned in this study as the nine technologies are related to each other. Finally, the results of this master's thesis are not presented in monetary terms, as this study is a qualitative report with more of a strategic focus.

1.5 Outline of the Report

This section provides a short summary of the outline of the report. Furthermore, it includes key topics discussed in the different chapters.

Chapter 1 Introduction

In this chapter, an introduction to the research field as well as a brief problem description of the case organization is presented to the reader. Furthermore, the research questions and the purpose of the master's thesis are provided. Lastly, the scope, delimitations and outline of the report are presented.

Chapter 2 Methodology

The purpose of this chapter is to present the overall methodological approach of this master's thesis. It describes the strategy and approach of the research as well as how the data is collected and analyzed. Lastly, discussions regarding the credibility of the study are presented.

Chapter 3 Frame of Reference

In this chapter, a background of earlier research in the field and a theoretical framework are presented. A detailed introduction to supply chain strategies, Industry 4.0, big data, and IoT is provided. In addition, big data and IoT is further elaborated on in terms of potential challenges and possible applications. Lastly, the required IT landscape and key success factors when implementing big data and IoT are described.

Chapter 4 Empirical Data

Several elements from the single case study are presented in this chapter. First, a general background of the company, the changing business environment and the chosen product are discussed. Then, the production process is presented, in terms of the actual steps, data collection, and improvement opportunities. In addition to the production process, the general IT landscape is elaborated on. Finally, key findings from the case study are discussed.

Chapter 5 Analysis

This chapter begins with an analysis of the characteristics of the studied product and a matching supply chain strategy is suggested. Then, a gap analysis is conducted to find possible applications of big data and IoT in the production process of SM. In addition, a risk analysis is conducted to point out critical risks that need to be accounted for when utilizing the two technological advances. Lastly, the analysis is summarized and suitable applications are suggested.

Chapter 6 Discussion

This chapter elaborates on aspects that have the potential to affect the analysis and results of this master's thesis. Included factors are the choices of the studied product as well as the considered factory. Finally, the choice of studying the production process of Swedish Match and how this specific choice of company can affect the findings are discussed.

Chapter 7 Conclusion and Final Remarks

This chapter provides answers to the research questions presented in the first chapter. In addition, a recommendation to the studied case organization is provided. The recommendation is based on the findings in this master's thesis. Lastly, suggestions for future research in the studied field are presented.

2 Methodology

The purpose of this chapter is to present the overall methodological approach of this master's thesis. It describes the strategy and approach of the research as well as how the data is collected and analyzed. Lastly, discussions regarding the credibility of the study are presented.

2.1 Research Theory

Before describing the strategy and the approach of this master's thesis, the philosophy of science is discussed and established. Briefly put, the philosophy of science describes how science is constructed and tested in the social environment. There are different traditions on which research can be based, namely positivism, system theory, hermeneutic and lastly, phenomenology. First, positivism implies that if a theory is true, it corresponds to the surrounding environment. Key aspects include that the theory should be empirically verified and that the authors are objective in order for the theory to be successful. Second, system theory is the study of a limited system. Here, the focus is on understanding the function of the system as well as its inter- and intra-relations. Third, the hermeneutic philosophy is related to the interpretation of various phenomena. Often, it is the interpretation of the underlying factors or the explanation of the observed phenomenon. Fourth, phenomenology is related to how individuals experience certain theories or ideas (Wallén, 1993).

The overall research approach in this master's theory is based on the system theory. The scope of the study is limited to a production process at SM, which clearly indicates a system. To further motivate the choice of theory, typical characteristics of system theory are presented and identify the similarities with this study. First, there are clear limitations of the system. In this study, the system is clearly limited to the production process of SM. Second, the flows of physical elements and information as well as human integration are studied. Here, the authors investigate the flow of snus, how data is handled, and how operators add value throughout the process. Third, each subsystem is defined in a specific way. However, the value of the whole system is larger than of the sum of the individual subsystems (Wallén, 1993). In this study, the whole system contains three subsystems, namely the mill, pasteurization and packaging process. The three parts depend on each other, section 4.3 elaborates further regarding this system.

2.2 Research Strategy

When conducting this master's thesis, a qualitative research strategy with an inductive reasoning approach is applied. The authors' choice of research strategy is based on understanding the nature of the study, its purpose, and the research questions. Depending on the characteristics of the study, either a quantitative or qualitative strategy is more appropriate. Quantitative research focuses on quantification, both when collecting and analyzing data. In a quantitative research strategy, it is common to use a deductive approach. The main purpose of this is to test existing theories. In contrast, qualitative research focuses on words and descriptions, both during collection and analysis of data. In qualitative research, an inductive approach is more suitable as its purpose is to generate theories. Moreover, the inductive approach implies that a theory is formed based on findings in interviews and observations (Bryman & Bell, 2015).

There are two main factors motivating a qualitative research strategy for this master's thesis. First, this strategy addresses the matters of understanding and interpreting to develop a holistic comprehension of the actual case studied. This is well aligned with both the purpose and the research questions of this study. The overall research question and its sub-questions are of an exploratory nature and to answer them, a holistic response is needed. Second, a qualitative research strategy is appropriate when investigating a novel research area with low or moderate prior insights (Eriksson & Kovalainen, 2008), which is the case for big data and IoT in the manufacturing industry. When applying an inductive reasoning approach, an interpretation of the qualitative Grounded Theory analysis is appropriate (Bryman & Bell, 2015). The Grounded Theory is further described in section 2.7.

In addition to the qualitative strategy, this study is of an exploratory character. A study can either be of an exploratory, descriptive or explanatory character. The choice of character is based on the current research level of the phenomenon. Exploratory studies are appropriate when gaining elementary knowledge of where, when and how the phenomenon is applicable (Wallén, 1993). In this study, big data and IoT are a novel research subjects, therefore gaining elementary knowledge of the phenomenon is appropriate.

2.3 Research Approach

In order to carry out the research strategy and complete the master's thesis, a description of the research approach applied is presented. The approach is based on the qualitative research cycle of Hennink et al. (2011), see Figure 2.1. The cycle is divided into three sub cycles, namely the design cycle, the ethnographic cycle and the analytic cycle. First, the design cycle includes formulating research questions, reviewing previous research and establishing theoretical frameworks. Second, the ethnographic cycle is described as the basis of the data collection, which includes constructing the data collection methods, identifying what data to collect and execution of data collection. Third, the analytic cycle consists of coding as well as categorizing data and theories. All sub cycles are closely related and since the cycle is based on a qualitative research strategy, it follows an iterative process. In other words, the sub cycles do not follow a linear order. As a result, the design cycle can change depending on which data is collected in the ethnographic cycle (Hennink, Hutter, & Bailey, 2011).

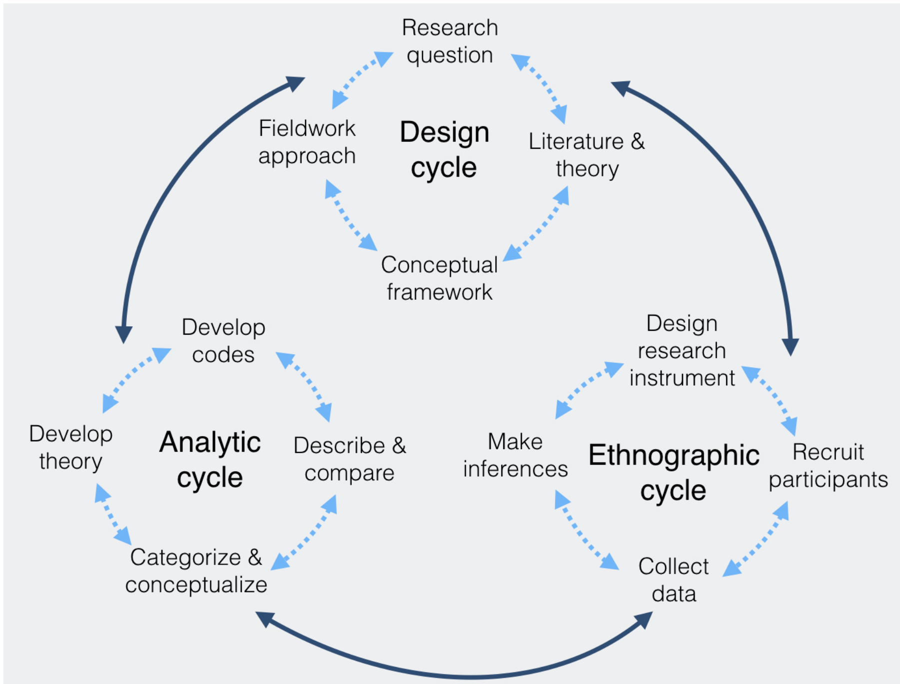


Figure 2.1 The Qualitative Research Cycle (Hennink, Hutter, & Bailey, 2011)

Similar to the qualitative research cycle, the authors of this master's thesis begin the study in the design phase. Here, an initial literature review is performed, research questions are formulated and the fieldwork approach is selected. The literature review and the design of the research is described in sections 2.4 and 2.5. After the initial review of literature is completed, the ethnographic cycle or the data collection is initiated. As further described in section 2.6, data is collected in the setting of a single case, where appropriate participants are recruited. As the collection is completed, the analytic cycle begins. The purpose of the analytical cycle is to understand why big data and IoT should be utilized (RQ2) and where it is most appropriate to start (RQ4). The analytical process is further described in section 2.7. As it is an iterative process, the authors continuously investigate previous research to understand the possible applications of big data and IoT in a manufacturing company (RQ3).

2.4 Literature Review

To gain an in-depth understanding of the phenomenon and to identify gaps in previous research, the first step includes conducting a literature review. The purpose of performing the literature review is partly to gain an understanding of the terminology (Rowley & Slack, 2004). In addition, there are two fundamental reasons to include a literature review in the early stages of a study. First, the literature review enables the authors to construct the research questions and design in a proper manner. Second, a research review facilitates the data collection and gives an idea of how the data can be analyzed (Bryman & Bell, 2011). As big data and IoT are novel, broad topics with multiple usage areas, it is also necessary to find key themes (Rowley & Slack, 2004).

The process of the literature review begins with a literature search. Keywords are identified and form the basis of the search, see Table 2.1 for the used keywords. The search is completed through usage of online bibliographic databases, such as Web of Science, Emerald and ScienceDirect. The databases are accessed through LUBsearch, the online library of Lund University. In addition, Google Scholar is used as a complement. The findings from the literature search are then used to formulate the frame of reference and to understand the possible applications of big data and IoT (RQ3).

Keywords used in literature search
Industry 4.0, Big Data, Internet of Things, Industrial Internet of Things, Product Life Cycle, Functional product, Innovative product, Supply Chain Strategy

Table 2.1 Keywords used in the search during the literature review

2.5 Case Study

A case study design is applied during the process of this study to describe and understand the potential of big data and IoT at SM (Yin, 2013). More specifically, Yin (2014, p. 16) provides a basic definition of the scope of a case study.

> *"(i) Investigates a contemporary phenomenon in depth and within its real-world context, especially when (ii) the boundaries between the phenomenon and the context may not be clearly evident."*

The real-world context is usually a limited group such as an organization, group of individuals or situation. A case study can also be expanded to both investigating social contexts and operational links. To gain an in-depth understanding of the phenomenon, a holistic perspective is applied during the case study (Patel & Davidson, 2011). In addition, Voss, Tsikriktsis and Frohlich (2002) discuss that a case study generates answers to the questions why, what and how.

The way in which the purpose and the research questions are defined in this master's thesis motivates the choice of research design in two ways. First, the purpose of the research questions is partly to explain the current circumstances, how and why the phenomenon works. RQ1 asks the question of how, RQ2 asks why and RQ4 asks where it is most appropriate to start. Second, the questions need an extensive descriptive answer to complete the study. Both elements prove the relevance of the case design in the study (Yin, 2014). In addition to the formulation of the research questions, a case study is suitable for an early, not fully developed phenomenon or an exploratory investigation (Voss, Tsikriktsis, & Frohlich, 2002). The research on big data and IoT is still in an early stage or even in a hype phase, where a clear application of the phenomenon is to be defined (Gartner Inc., 2014).

Even if there are several factors motivating the choice of case study in this master's thesis, there are also challenges with the method. As the data collection is mostly limited to the specific case, the result and analysis is company specific and therefore limited (Petersen & Plenborg, 2010). The method is also time consuming and well-prepared interviewers are necessary. In addition, the risk of observer being bias must be considered. When a researcher enters the specified field, a strong interest can influence the result of what is seen, heard or recorded. To reduce the risk of the observer being bias, multiple interviewers can participate, interview guides can be prepared, and the interviews can be recorded (Voss, Tsikriktsis, & Frohlich, 2002). In this study, two interviewers participate during all interviews, interview guides are constructed, and lastly the interviews are recorded.

This study primarily focuses on a specific case, namely the production process of SM's Gothenburg factory and its opportunities to exploit big data and IoT. The specific case is chosen through a strategic selection. The selection is based on several criteria that are fulfilled by SM. First, is the increased complexity in the product portfolio that creates new motives to overlook the digitization in the production process. Second, is the shift in the business environment and its conditions that is caused by the increased competition from price-pressuring companies. Here big data and IoT could potentially enable SM to stay competitive. Third, is the fact that SM owns the production process, from raw material to finished product, which results in a clear case definition and scope. Lastly, there is a large interest in big data and IoT from the management at the company who initiated this master's thesis.

2.6 Data Collection

When conducting this study, data is primarily collected through semi-structured interviews, observations and conversations. The choice of data collection techniques is correlated to the qualitative characteristics of the study. As the study applies a qualitative research strategy to answer the exploratory research questions, interviews and observations are suitable methods (Yin, 2013). A brief comparative description of these two methods provided by Yin (2013) is displayed in Table 2.2.

Data Collection Method	Type of Data	Examples of Collected Data
Interviews	Language, both verbal and body language	Description from a person's point of view
Observations	Scene, processes or physical environment	The coordination between people and/or machines

Table 2.2 Comparison between interviews and observations (Yin, 2013)

The purpose of conducting semi-structured interviews as a primary data collection method is to gain a deep understanding of the studied case. These interviews differ from structured interviews as they are based on themes of questions that are answered rather than following a strict interview guide. The interviews mainly include open questions and the interviewers can ask subsequent questions more freely than in structured interviews. Both the opinions of the participants and detailed answers are encouraged (Bryman & Bell, 2011).

Semi-structured interviews are conducted with SM employees to complete a comprehensive data collection and to answer two of the three research sub-questions, RQ2 and RQ4. Observations are conducted as a supplementary research method to the interviews in order to collect additional qualitative data (Bryman & Bell, 2011). Conversations with external resources are conducted to further validate the collected information. These three data collections methods are further discussed in the three following sections of this chapter.

2.6.1 Semi-Structured Interviews

The purpose of conducting semi-structured interviews with SM's employees is to answer RQ2 and partly RQ4. These research questions are related to understanding the different parts of the current production process, their improvement opportunities, and what consequences that are related to them. As this study consists of one specific case, it is necessary to collect various types of data in order to gain a holistic view of the case (Patel & Davidson, 2011). As a result, people in various positions at SM are interviewed.

The selection of interviewees is based on an assessment of their influence in the production process or projects related to the production process. Overall, the interviewees are divided into three groups, namely operators, project managers and managers. Operators are interviewed to understand the day-to-day activities in the production. Project managers are interviewed to understand current and previous projects performed in the production process, such as IT projects. Managers are interviewed to understand the strategic decisions within the company and its production process. This group includes both members of the management team and area managers. Further information regarding these three groups is presented in Table 2.3.

Number of Interviews	**Interviewee group**	**Description of Position**
4	Operators	Day-to-day activities in the production process
3	Project managers	Responsible for projects related to the production process, such as IT projects
5	Managers	Includes management team members and area managers responsible for strategic decisions within the company and its production process

Table 2.3 The number of interviews with interviewees grouped in three different groups as well as a description of the positions

An interview guide is constructed prior to the execution of the interviews. It is used to support the interviewers and to assure that the required information is collected. After a general research of the studied subject and formulation of the interview guide's topics and questions, the supervisor at SM and the authors review the interview guide. When the interview guide has been approved, it is finalized (Bryman & Bell, 2015). An example of the final interview guide is presented in Appendix A. The interview guides are not distributed to the participants in advance to keep the interviewees as neutral and open minded as possible. As a result, biased opinions and preconceptions are avoided.

The interviews are held in Swedish and last between 40 minutes and 1.5 hour. In addition, continuous interviews were held with one of the interviewees throughout the progression of this study. All interviewees are open, engaged and answered the questions willingly. With the permission of the interviewees, the interviews are recorded. More information regarding the interviewees and their positions at SM is displayed in Table 2.4. This table does also present information regarding the date and lengths of the interviews.

Interviewee group	Specific Position	Date	Length
Operators	Operator Mill	2016-03-10	1h 10 min
Operators	Operator Pasteurization	2016-03-08	40 min
Operators	Operator Packaging	2016-03-10	50 min
Operators	Production Technician	2016-02-10	1h
Project Managers	Project Manager	2016-02-11	1h 3 min
Project Managers	Engineer	2016-02-05	1h 28 min
Project Managers	Business Engagement Liaison	Continuous	Continuous
Managers	Supply Chain Manager	2016-03-03	57 min
Managers	Factory Manager Gothenburg	2016-02-08	44 min
Managers	Factory Manager Kungälv	2016-02-29	50 min
Managers	Area Manager Mill and Pasteurization	2016-03-01	46 min
Managers	Area Manager Packaging	2016-03-03	1h 12 min

Table 2.4 Information about the interviewees' positions at SM, the interview dates and lengths

2.6.2 Observations

As previously mentioned, observations are performed as a supplementary data collection method to the interviews. An advantage with observations, compared to interviews, is that the issue is studied through the eyes of the observer and is not filtered through the opinions of others. During a qualitative research, the observer has a passive role (Yin, 2013), which also applies to this study.

Two types of observations are applied in order to further complete the answering of RQ2 and more specifically to develop an understanding of why SM needs big data and IoT. First, each part of the production facility is observed to improve the understanding of the flows in the production process. Second, meetings held by the production management and the IT department are attended to gain insights in the business and its way of working. The authors document the observations through written notes. The fundamental purpose of the observations is to unfold current improvement opportunities in the production process and to verify the motives for an adoption of big data and IoT.

2.6.3 Conversations

Together with the literature review, the external conversations are conducted to partly answer RQ3. The purpose of the research question is to understand the possible applications of big data and IoT as well as their technological requisites. In other words, the interviews with external resources are completed to gain a holistic picture of the recent research regarding the two technological advances. The interviewees are professors within the field and representatives of other companies. The interviews are more informal than the internal interviews and are treated as a supplement to the literature review. Due to the informality, there is not a formal interview guide for the conversations. Furthermore, these interviews are held at seminars and are not recorded.

2.7 Data Analysis

To analyze the empirical data, an approach inspired by the qualitative analysis method, the Grounded Theory, is applied. The theory was developed in the 1960s as a response to the so-called Grand Theories. Unlike Grand Theories, the Grounded Theory bases the analysis on the empirical data to form a theory applicable to a specific case. In other words, the Grounded Theory is an approach used to perform an inductive, qualitative research with the goal to discover and generate a theory that is grounded in empirical data (Bryman & Bell, 2015; Patel & Davidson, 2011). Similar to the Grounded Theory, an inductive approach is applied in this study to discover concepts and theories in the empirical data. Contrary to the Grounded Theory, previous knowledge gained during the literature review is included in the analysis of this master's thesis.

The collected data from the interviews with employees at SM are recorded and transcribed. When the interviews are transcribed, the authors code the material by identifying main concepts or categories. Coding consists of three steps. First, open coding is performed meaning that the data collected is broken down into different sub-concepts. Concepts are the foundation of the theory. Open coding is the analytical process used in order to identify the concepts by their properties and dimensions. The concepts can consist of individual observations, ideas or specific events. Second, the sub-concepts are analyzed to find linkages between the sub-concepts and to group them together. Finally, selective coding is performed during which core concepts or categories are selected and compared to the other categories (Voss, Tsikriktsis, & Frohlich, 2002). As it is an iterative approach, the coding is continuously reviewed, further analyzed, and in this final stage theoretical concepts are generated to answer the purpose and research questions of the study (Bryman & Bell, 2015).

In this master's thesis, the coding mainly includes identified issues that potentially weaken the production process and improvement opportunities. After each interview is listened to and transcribed, the coding process of this master's thesis results in four major issues. The coding process is finalized by ranking commonly discussed key themes based on their frequency of occurring, see Appendix B. These main improvement opportunities are used as a foundation to understand how big data and IoT is used to optimize a production process in a more detailed manner. In other words, a comparison of the current situation, where the issues weakening the production process exist, and the desired situation, where the issues are solved, is conducted. The process to reach the desired situation is also described as a part of the final analysis. This includes a description of how various applications of big data and IoT can be implemented to reach the desired situation and optimize the production process.

Furthermore, to mitigate any failures associated with utilizing big data and IoT, a number of risks are identified and assessed. By assessing the identified risks, the company understands what risks to focus on. Therefore, the authors of this master's thesis assess the risks based on the probability of the risk happening and its potential impact faced by SM. The grading range of the risks is developed by the authors and consists of low, medium and high. The choice to exclude a numerical grading scale is motivated by the qualitative character of the master's thesis.

Prior to the analysis, the results from the empirical data are illustrated through a process mapping of the manufacturing of the specific product, the PSO General. The map is constructed to support the understanding of the current production process. This enables further identification of how big data and IoT be utilized to optimize the production process at SM, which is the purpose of this study. The map is made as generic as possible to enable upscaling to fit the entire factory in Gothenburg, other products as well as SM's factory in Kungälv.

2.8 Credibility of the Study

When conducting a case study, it is of great importance to pay attention to validity and reliability (Voss, Tsikriktsis, & Frohlich, 2002). To establish a feasible quality and credibility of the empirical research, three elements are discussed. These elements include validity, reliability and transferability.

2.8.1 Validity

Validity refers to what extent the study mirrors the reality (Bloor & Wood, 2006). In this study, the validity aspect applies throughout the entire research process. Validity is not only associated with data analysis, but also with how the participants are chosen and how the interviews are presented and discussed (Patel & Davidson, 2011). To verify the validity of this study, external validity, internal validity and triangulation is discussed.

External validity partly refers to validity of the data selection represented in the case (Gibbert, Ruigrok, & Wicki, 2008). In this study, the interviewees are chosen based on their relevance in the production process or IT projects. The different positions of the interviewees provide diverse perspectives, thus gaining a realistic understanding and avoiding bias information. In addition, external validity refers to whether the result of the study can be transferred to another case setting (Voss, Tsikriktsis, & Frohlich, 2002).

In contrast, internal validity refers to the extent to which casual relationships can be established between variables and results. For example, this concerns that the questions are asked in a correct way when completing the interviews and how the data is analyzed (Gibbert, Ruigrok, & Wicki, 2008). As semi-structured interviews are conducted in this study, open questions are asked to decrease the risk of the participants being misguided in their responses. In addition, subsequent questions are asked to validate the meaning of the previous answer to avoid any misunderstandings. All interviews are transcribed and analyzed following the same systematic steps. Thus, avoidance of premature conclusions is secured.

To further increase the validity of the study, triangulation is applied. Triangulation is explained by the usage of numerous perspectives to gain a more in-depth perspective of a phenomenon. In other words, triangulation is implemented when both multiple data collection methods and multiple data sources are used (Patel & Davidson, 2011). In this study, triangulation is used in these two ways. First, interviews, conversations and observations are three methods to collect empirical data. The observations increase the validity of the study since they are excluded from personal opinions of the interviewees

(Yin, 2013). Second, the interviews are held with many participants at different times and places.

2.8.2 Reliability

Reliability concerns to the extent the study would result in the same outcome, if the same procedure would be repeated (Bloor & Wood, 2006). However, unlike a quantitative research approach, asking the same question twice and receiving the same answer do not equal reaching a high reliability. During a qualitative approach, the background of the interview plays a larger role and can affect the collected data. For example, the perception of the interviewees might not be the same today as three months ago. Compared to a quantitate research approach, the reliability during the qualitative one is closer related to validity. As previously mentioned, to reach validity and therefore also a high credibility, a structured way of working is required throughout the research process (Patel & Davidson, 2011).

2.8.3 Transferability

Transferability, or generalizability, is closely related to external validity and refers to what extent the findings of the study can be transferred beyond the specific case study (Voss, Tsikriktsis, & Frohlich, 2002). The purpose of this study is to investigate how a manufacturing company can optimize their production process by using big data and IoT. Even though this case study is based on one specific company with an adapted production process, similar issues can be found in other manufacturing companies. This indicates that the studied phenomenon can be applied elsewhere. To further enable transferability, the findings are studied from a higher level, rather than a detailed one.

3 Frame of Reference

In this chapter, a background of earlier research in the field and a theoretical framework are presented. A detailed introduction to supply chain strategies, Industry 4.0, big data, and IoT is provided. In addition, big data and IoT is further elaborated on in terms of potential challenges and possible applications. Lastly, the required IT landscape and key success factors when implementing big data and IoT are described.

3.1 Introduction to Concepts

As this master's thesis concerns aspects in the field of supply chain management, it is important to first provide a common understanding through definitions of the supply chain as well as of supply chain management.

3.1.1 Definition of Supply Chain

There are various definitions of what a supply chain is, but many are quite similar and incorporate the same aspects. Goetschalckx (2011, p. 3) provides a definition that accounts for several of the other definitions.

> *"A supply chain is an integrated network of resources and processes that is responsible for the acquisition of raw materials, the transformation of these materials into intermediate and finished products, and the distribution of the finished products to the final customers."*

Basically, this means that a supply chain is a group of firms that move goods forward to the subsequent company. Usually a set of firms acting on their own is included in the production and distribution of a good to the end customer (Mentzer et al., 2001). In addition, there are both upstream and downstream connections between the included organizations and value are generated to the end consumer in the shape of products or services (Goetschalckx, 2011).

3.1.2 Definition of Supply Chain Management

Historically, the literature has provided a great spectrum of contrary definitions of supply chain management. A definition of this matter, which also combines many of those opposing definitions is suggested by Mentzer et al. (2001, p. 18).

> *"... supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole."*

The various definitions of supply chain management can be considered as a root cause of confusion in the field, thus a joint definition is needed (Mentzer et al., 2001). Furthermore, this is also the reason for why this definition is used in this master's thesis.

3.2 Introduction to Supply Chain Strategies

To develop a well-functioning and effective strategy of its supply chain, a company should start by studying the characteristics of the demand of its products. Here, there are several important factors to keep in mind, such as the product lifecycle (PLC), variety of goods, how well the demand can be foreseen, and the market's standard levels regarding both service and lead times (Fisher, 1997).

This section elaborates further on the importance for a company to understand its product and which implications it has on what is a suitable supply chain strategy. Moreover, this section elaborates on the PLC, the nature of different products, different supply chain strategies, mapping of a production process as a tool to understand a company's current situation, and finally on how a firm can achieve strategic fit and why this is important.

3.2.1 The Product Life Cycle

The company needs to identify where the product is in its PLC in order to understand the actual product, its requirements, and the implications on the supply chain strategy. Previous research discusses the PLC in terms of two definitions. The first definition of the PLC refers to the progress of a product from raw material to final disposal. The second definition is associated with the evolution of a product. Here, the product is evaluated depending on its sales volume over time. In this study, the second definition is applied. The PLC can be divided into four stages, namely introduction, growth, maturity and decline (Sundin, Östlin, & Björkman, 2008), see Figure 3.1 for further details.

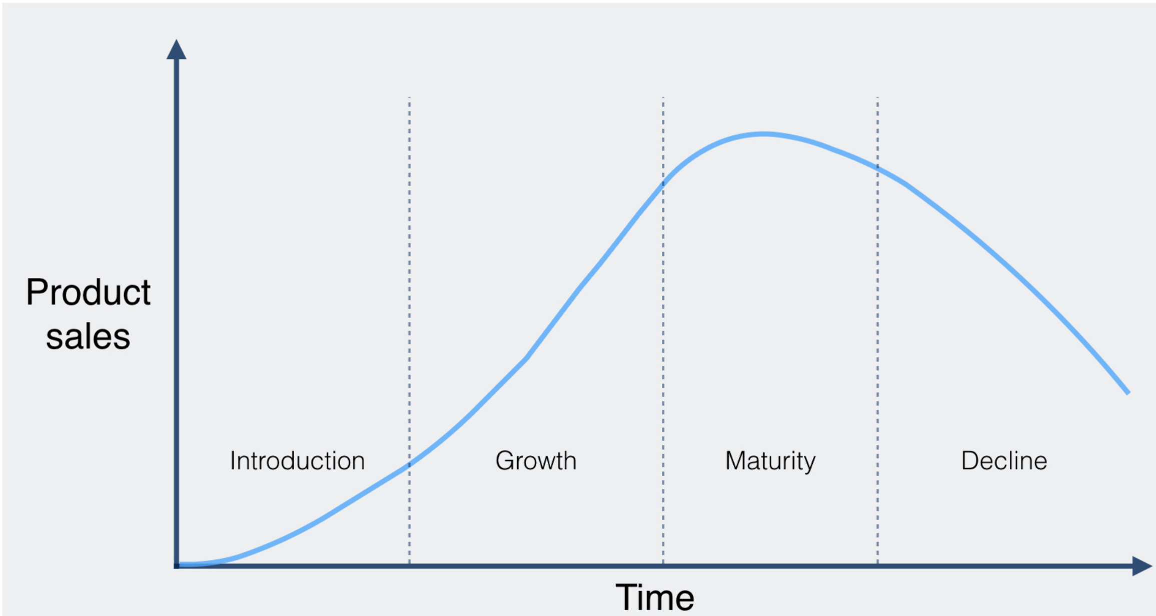


Figure 3.1 The four general phases of the product life cycle (BBC, 2014).

The introduction stage focuses on informing the customer of the product. The demand is low and the product is continuously changed to meet the customer needs. The manufacturing of a product in this phase should be quick and flexible to enable adaption to the uncertain demand. In other words, the time-to-market should be as short as possible. During the growth stage, the product sales volume starts to increase and the potential demand is high. Flexibility in the manufacturing is an important factor as the uncertainties in the demand and production process continue to exist (Sundin, Östlin, & Björkman, 2008). In the maturity phase, the number of competitors increase, thus it is crucial to have a strong brand, quality and service compared to competitors (Andersson & Zeithami, 1984). In addition, the sales volume is stabilized and the focus is on a lean and efficient production process. Lastly, in the declining stage, the sales volume decreases. Here, the focus of the company shifts from efficient manufacturing, quality and service towards optimizing the inventory and production equipment for the time when the product is not produced anymore. All this is done to avoid obsolete inventory or machines (Sundin, Östlin, & Björkman, 2008). Clearly, a company has different focus depending on the maturity of the product.

3.2.2 Functional or Innovative Product

Products can be classified as either mainly innovative or mainly functional based on the nature of their demand. These two product categories require significantly different supply chains and strategies. The mismatch occurring if the company does not understand what strategy fits their products, is a common underlying reason for poorly functioning supply chains in the industry (Fisher, 1997).

Functional products meet fundamental needs, usually have long lifecycles, correspond to few alterations over time, and imply an even and foreseeable demand level. These products do also tend to imply low profit margins as a result of the fact that many competitors have similar products. To avoid the low margins companies can try to find innovative solutions. An example in the food industry is specific designer flavors (Fisher, 1997).

In contrast, the margins of innovative products tend to be higher. On the other hand, the demand is usually more volatile for new products compared to the functional ones. Due to the competition that arise when the product is developed, companies need to constantly provide new innovations. This results in the fact that the lifecycle tends to be shorter for innovative products when compared to functional ones (Fisher, 1997). Table 3.1 provides further details regarding the differences in demand and other aspects between functional and innovative products.

Aspect	Functional product	Innovative product
Characteristics of demand	Predictable	Unpredictable
PLC	> 2 years	3 months – 1 year
Contribution to margin*	5 – 20%	20 – 60 %
Product variety	Low (10 – 20 variants per category)	High (commonly millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40 – 100%
Average stockout rate	1 – 2 %	10 – 40%
Average forced end-of-season markdown as percentage of full price	0%	10 – 25%
Lead time required for made-to-order products	6 months – 1 year	1 day – 2 weeks
** The contribution margin is expressed as a percentage. It is calculated by subtracting the variable cost from the price and then dividing it by price*		

Table 3.1 Differences in demand between functional and innovative products (Fisher, 1997)

3.2.3 Physically Efficient or Market-Responsive Supply Chain Strategy

A supply chain strategy determines what the supply chain of a company is designed to do especially well. For example, it defines how purchasing of material is handled, production of goods, and distribution of the manufactured products to the customers. In contrast, the customer requirements that a firm strives to fulfill by offering products and services are described by the corporation's competitive strategy (Chopra & Meindl, 2007).

There are two fundamental supply chain strategies, namely the physically efficient and the market-responsive. The main purpose when applying a physically efficient strategy is to ensure to supply the demand that is predictable, while imposing minimal costs. In contrast, when considering the market-responsive strategy, the main purpose is to answer fast to unpredictable demand. This is done to attain the lowest possible levels of stockouts, obsolete products as well as being forced to do markdowns (Fisher, 1997). See Table 3.2 for further details regarding the differences between a physically efficient supply chain strategy and a market-responsive one.

Aspect	Physically efficient	Market-responsive
Primary purpose	Supply predictable demand efficiently at the lowest possible cost	Respond quickly to unpredictable demand in order to minimize stockouts, forced markdowns, and obsolete inventory
Manufacturing focus	Maintain high average utilization rate	Deploy excess buffer capacity
Inventory strategy	Generate high turns and minimize inventory throughout the chain	Deploy significant buffer stock of parts or finished goods
Lead-time focus	Shorten lead time as long as it does not increase cost	Invent aggressively in ways to reduce lead-time
Approach to choosing suppliers	Select primarily for cost and quality	Select primarily for speed, flexibility and quality
Product-design strategy	Maximize performance and minimize cost	Use modular design in order to postpone product differentiation for as long as possible

Table 3.2 The characteristics of the physically efficient supply chain strategy compared to the ones of the market-responsive strategy (Fisher, 1997)

Market mediation for functional products is simple, since the demand of these products easily is predicted. To clarify, the purpose of market mediation is to secure that the produced products match the customer's needs. This makes it easy to match the demand and supply for functional goods. In contrast, speed and flexibility are considered to be far more important aspects than finding the lowest possible cost for innovative products. Here, it is fundamental to react fast and to understand early sales numbers as well as other signals from the market (Fisher, 1997).

The stable demand and low margins imposed by functional products makes a physically efficient supply chain strategy suitable. In contrast, the volatile demand and high margin of innovative products results in a market-responsive supply chain strategy being feasible. In other words, the innovative products require a supply chain that significantly differs from the one required by the functional products. This means that it can be considered as important to match a company's supply chain strategy with the characteristics of its products (Fisher, 1997). Figure 3.2 displays the areas where the supply chain strategies and product characteristics match as well as where there are mismatches.

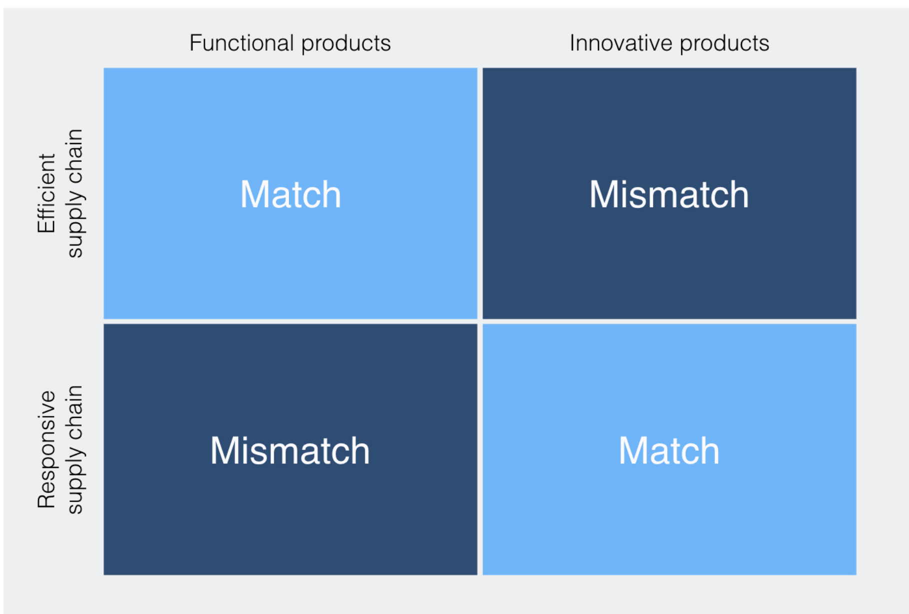


Figure 3.2 The areas where the supply chain strategies and the nature of the products match (Fisher, 1997)

It should be pointed out that various authors have questioned these classifications of products and the corresponding supply chain strategies. Examples include literature written by Birhanu, Lanka and Rao (2014) as well as by Selldin and Olhager (2007). The main criticism relates to the fact that the classifications do not fit all products and companies. For example, there are a number of functional products, such as milk, which do demand that the supply chain has a quick response time (Birhanu, Lanka, & Rao, 2014). In addition, it is not guaranteed that a match between product classification and the supply chain strategy results in improved overall performance. A manufacturing firm can also be unable to construct a supply chain perfectly matched to their products due to limited resources (Sellдin & Olhager, 2007). However, despite the limitations there is an agreement regarding that the classifications can be efficiently applied and work well on a more general level (Birhanu, Lanka, & Rao, 2014; Selldin & Olhager, 2007).

3.2.4 Other Supply Chain Strategies

Alternative approaches to classifying supply chain strategies are the lean, agile and hybrid ones. These can be applied to increase the performance of a supply chain. It is commonly considered that a lean approach is feasible for commodity products, while the agile approach suits innovative products better. A lean supply chain strategy aims at adding value for the customers, but at the same time finding and eliminating waste. Everything that does not add to the customer value is considered as waste (Myerson, 2014). The lean strategy can be considered as equivalent to the physically efficient supply chain strategy on a high level (Birhanu, Lanka, & Rao, 2014).

In contrast, an agile supply chain strategy concerns being able to handle unpredictable aspects and incidents. This is done through continuously adding new as well as innovative products in a both flexible and timely manner. This strategy applies an approach to customer demand that is based on waiting to see what actually is required. Thus, no commitment is made to a specific final product before there is knowledge about the actual demand. In other words, the final commitment is postponed. It is important to be responsive to what actually is demanded as well as being able to use information and data as a substitute for inventory. For example, this can be achieved by increasing the degree of integration and collaboration with important customers and suppliers (Myerson, 2014). On a high level, the agile supply chain strategy matches the market-responsive strategy (Birhanu, Lanka, & Rao, 2014).

If an agile and a lean supply chain strategy are combined, the outcome is considered as a hybrid supply chain strategy (Myerson, 2014). Sometimes this is also referred to as a leagile strategy (Birhanu, Lanka, & Rao, 2014). Today's economy is of a dynamic, volatile and global character, which can make it feasible for firms to work according to a hybrid supply chain strategy. The competitive nature of today's market can add further to this. In addition, a hybrid supply chain strategy can be applied if neither an agile nor a lean strategy fits well. To realize the opportunities of this strategy, it needs to be carefully planned and applied (Myerson, 2014).

3.2.5 Strategic Fit

When considering new technological advances, such as big data and IoT in a manufacturing company, it is important to understand the company's supply chain strategy. This enables a deeper understanding of the underlying reasons for implementing new technology in the firm. Understanding the company's strategy and the motives of implementing the new technology enables making an adequate decision regarding whether or not to implement it in the actual firm. Achieving strategic fit between the enterprise's supply chain strategies and its competitive one is a vital factor to consider in order for a firm to be successful (Chopra & Meindl, 2007).

If the uncertainty originating from the customers and from sources of supply increase, the company should increase their responsiveness to stay in the zone of strategic fit, see Figure 3.3. In other words, to succeed as a high performing company, the firm should make sure to shift the strategy of their supply chain, including the corresponding responsiveness, and their competitive strategy, including the corresponding uncertainty, to a spot that is within the zone of strategic fit. Moreover, the company's functions and the steps in the supply chain should aim for the same goals. These goals should also be aligned with the customers' demand in order to achieve strategic fit (Chopra & Meindl, 2007).

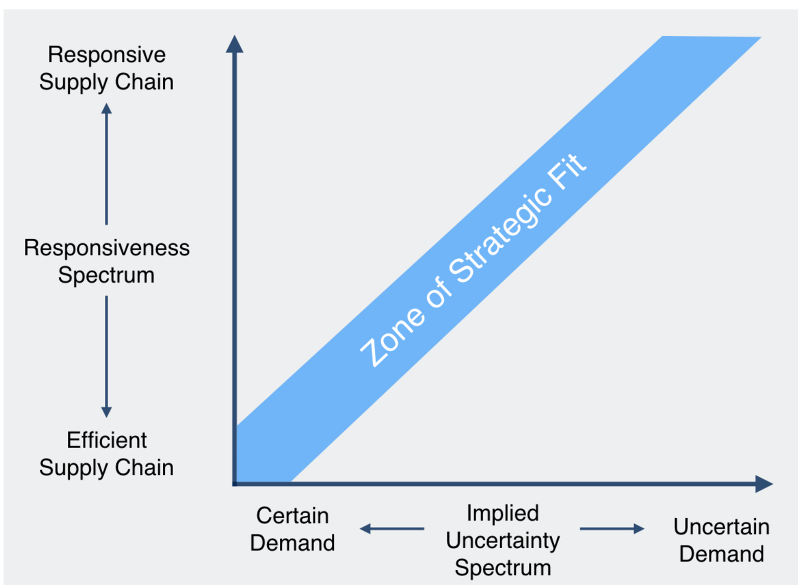


Figure 3.3 The zone of strategic fit (Chopra & Meindl, 2007)

A united overall strategy can be formed when the functional and competitive strategies fit together. There are three fundamental steps for a company to follow in order to realize strategic fit. The first step includes developing an understanding of the uncertainty related to their customers and supply chain. Here, important aspects to cover include the required product volumes per lot, the product price and the variety of products. The second step is where the company should develop an understanding of the capabilities of its supply chain, in other words, what it is constructed to do well. This is important since there is various supply chains, which all are designed to perform different tasks well. The supply chain strategy should be contrasted using a responsiveness spectrum, ranging from highly efficient to highly responsive. In other words, this shows whether or not the firm has a responsive approach and for example makes alterations to their product mix on a daily basis or are more efficient with a low degree of flexibility and options. The third step includes finally attaining strategic fit. This is done by matching the uncertainty stemming from the supply and demand with the responsiveness of the supply chain. Here, it is important that the degree of responsiveness is backed by the strategies of the supply chain (Chopra & Meindl, 2007)

There are two solutions in the case of the company being unable to achieve strategic fit due to a mismatch between its supply chain and competitive strategies. The first option is that the firm can adapt its supply chain strategy to make sure that it is better aligned with its competitive strategy. The second option is that the firm can make changes to its competitive strategy (Chopra & Meindl, 2007). Clearly, strategic fit is an important aspect to keep in mind when considering utilizing new technological advances such as big data and IoT.

To alter the strategies is not always simple and there are two fundamental aspects to keep in mind. First, there is not a supply chain strategy that fits all cases. In other words, the companies must understand what is suitable in their specific case. Second, there is a supply chain strategy that is suitable if considering a certain competitive strategy. In addition, the supply chain strategy needs to be altered as the product proceeds through the PLC and when its competitive situation shifts. For example, a more efficient focus is suitable since the uncertainty decreases as the product matures (Chopra & Meindl, 2007).

3.2.6 Mapping a Production Process

It is important to understand the characteristics of a situation before a change is performed as well as it is important to understand what impact the change actually has. For this purpose, mapping through flowcharts can be utilized. Moreover, this enables understanding of a company's supply chain. Material- and information flows can be mapped as well as the activities or process steps the product passes (Oskarsson, Aronsson, & Ekdahl, 2013). Thus, mapping the current state does also enable a deeper understanding of the company's supply chain strategy and production process.

Clearly, a map of a company's production process can be developed to understand its current state and setup. There are various symbols that can be used when mapping a production process. For example, triangles are commonly used to symbolize warehouses (Oskarsson, Aronsson, & Ekdahl, 2013). Symbols used in this master's study are displayed in Figure 3.4.

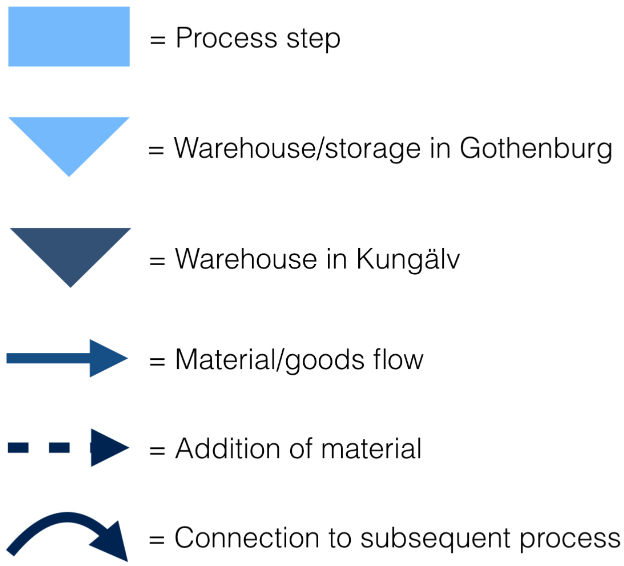


Figure 3.4 Symbols used for mapping purposes (adapted from Oskarsson, Aronsson, & Ekdahl, 2013)

3.3 Big Data and Internet of Things

The phenomena Industry 4.0, big data and IoT are in an early research phase. This results in that there are various definitions and descriptions of the concepts. The term Industry 4.0 originally emerged from a political initiative in Germany. It was established to keep production sites within the country's borders (Ramin, 2016). To understand the general concepts of the new technologies, this study is based on a consolidation of the many definitions of Industry 4.0.

Big data and IoT are considered to be core components of Industry 4.0 and help enabling the revolution, much like the steam power during the first industry revolution or electricity during the second (Accenture, 2014). More specifically, the first industrial revolution took place during the latter parts of the 18th century. Here, power originated from both steam and water made mechanical production possible. The second industrial revolution involved assembly line production and started around 1870 and proceeded for the next coming ten years. During this revolution, it became possible to mass-produce goods through labor division and usage of electricity. The third industrial revolution took place between 1970 and 1980. It involved programmable systems for controlling purposes. Both electronic engineering and IT was exploited during the ten years of this revolution. Today's fourth industrial revolution considers the smart factory, big data and IoT (Ramin, 2016). As presented in Figure 3.5, big data and IoT are two of the nine enabling technologies of Industry 4.0.

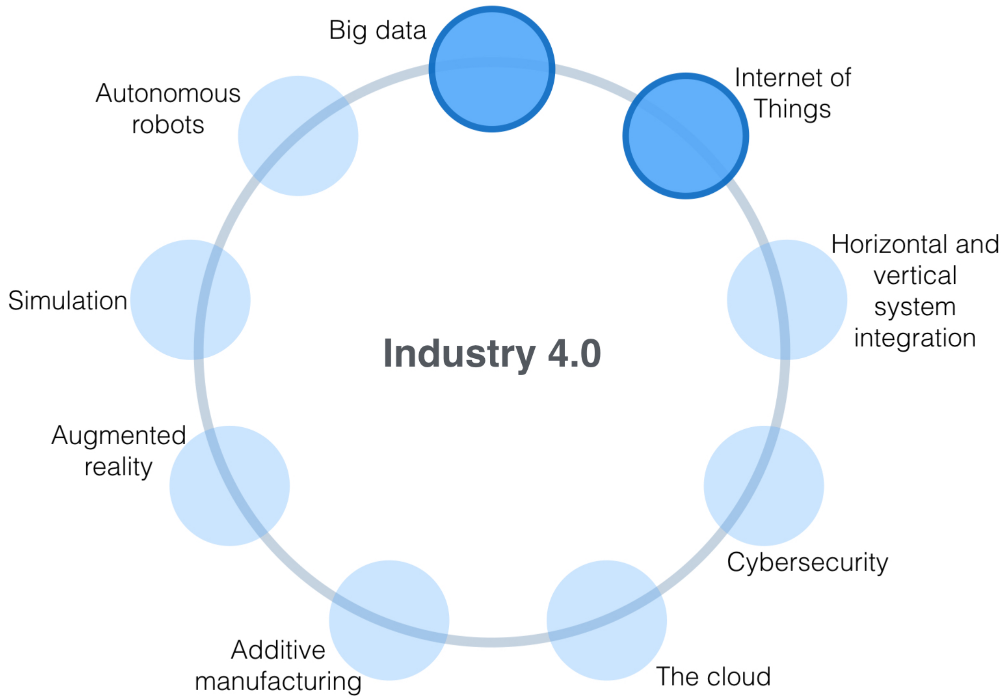


Figure 3.5 Nine technologies that are changing the industrial production (Rüssmann et al., 2015)

By exploiting the technological advances included in Industry 4.0, the physical world in a factory can be connected with the digital one. Moreover, the technologies can be utilized to fully digitize the physical production processes within a factory. It enables collection of more accurate data to improve productivity and quality in the factory as well as monitoring and controlling all elements of the production (McKinsey Global Institute, 2015).

3.3.1 Definition of Big Data

As one of the nine technologies of Industry 4.0, big data is enabled by the opportunity to access and store massive data sets in a cheaper, more efficient manner than ever before. In fact, there has been more data documented during the last two years than in the history of mankind. Basically, big data enables collection and analysis of substantial amounts of data to find new and sometimes unexpected correlations (Waller & Fawcett, 2013). Davenport (2014, p. 45) describes those correlations as needles in a haystack. Furthermore, he defines big data in the following way. Note that the choice of definition was based on the applicability to this master's thesis.

"...the collection and interpretation of massive data sets, made possible by vast computing power that monitors a variety of digital streams – such as sensors, marketplace interactions and social information exchanges – and analyses them using 'smart' algorithms."

Big data is considered as unique due to its three characteristics, namely volume, velocity and variety. Volume is related to the scale of the data, in other words, the large amount of information that can be stored (IBM, 2014; McAfee & Brynjolfsson, 2012). Costs of elements in data handling, such as storage, memory and connectivity is constantly decreasing. This makes it possible to handle the large volumes of data (McAfee & Brynjolfsson, 2012). For example, more than 40 trillion gigabytes of data will predictively be generated by 2020, which corresponds to an increase of 300 times compared to 2005 (IBM, 2014).

Velocity is associated with the speed of uploading data, such as the opportunity of doing real time updates. In many cases, real time updates or velocity can be more powerful than volume when considering becoming more flexible than competitors (McAfee & Brynjolfsson, 2012). An illustrative example of velocity including analysis of streaming data is today's modern cars, which are equipped with about a hundred sensors. Those sensors serve the purpose of supervising numerous aspects including the tire pressure and fuel level (IBM, 2014).

Variety relates to the different types and forms of data that are collected. Data can be collected from both internal and external sources. Messages or updates on social networks, sensor registrations, GPS signals and weather forecasts are some sources of big data (McAfee & Brynjolfsson, 2012). To further understand the terminology of volume, velocity and variety, an example associated with time and location is described. Volume of sensor data can detect the locations of, for example, misplaced inventory. The velocity can determine the present location and movement of inventory. The variety can estimate not only the exact location of inventory, but also what it is close to, who handles it and its predicted path (Waller & Fawcett, 2013).

However, as big data is a new technological advance there are numerous variations regarding the characteristics of the phenomenon. In addition, new ones emerge on a continuous basis. For example, complexity and veracity are two examples of terms included in various articles. Complexity relates to the objective that the data should be of a comparative character. To handle the complexity related to prediction, the data should be presented and analyzed in comparison with models. Therefore, ensuring that the incoming data has a structure that allows it to be analyzed is important for an automated prediction.

The complexity of the incoming data can be handled by extensive planning of data collection and types (Fox & Do, 2013).

Veracity relates to the uncertainty of the data. A poor data quality commonly results in significant costs. For example, in the US, poor data is costing over three trillion USD each year. It is common that companies are uncertain about how much of their data that actually is accurate and it is common that business leaders do not actually trust the information that they use to perform business related decisions (IBM, 2014). However, despite the fact that various characteristics of big data are discussed in the literature, the majority of the literature discusses particularly volume, variety and velocity. Thus, this study focuses on these three characterizing elements.

3.3.2 Definition of Internet of Things

As for big data, there are various definitions of IoT, which also is one of the nine technological advances of Industry 4.0. IoT is facilitated by the vast number of objects that are connected to a larger system of other objects. The advancements in IoT occur quickly and in 2020, 50 billion devices are predicted to be connected, compared to today's 5 billion. The network of connected things or nodes will, within a foreseeable future, include one trillion nodes (Chase, 2013).

A general definition of IoT that incorporates many other definitions is the following one by Chase (2013, p. 1).

> *"The IoT creates an intelligent, invisible network fabric that can be sensed, controlled and programmed. IoT-enabled products employ embedded technology that allows them to communicate, directly or indirectly, with each other or the Internet".*

The abbreviation IoT or the term the Industrial Internet of Things is a combination of two very different terms, namely "internet" and "things", which leads to an indistinctness of the technology. The first term leans towards a more networked based vision or in other words includes the actual network. The second term focuses more on the actual objects to be part of an integrated structure. The objects, or things as referred to in this context, can include RFID, tags, sensors, actuators or mobile phones. The objects are connected to the network using IP addresses (Atzori, Iera, & Morabito, 2010).

3.3.3 The Relationship between Big Data and Internet of Things

The definitions of big data and IoT can indirectly explain their relationship. Big data analyzes massive amounts of data and IoT partly generates the data needed for the big data analysis. To connect sensors to a machine or to connect a machine to another machine does not by itself provide insights to better decision-making (Lee et al., 2013). As a result, there is a strong relationship between the two technologies.

As displayed by Figure 3.5, big data and IoT are also related to seven other technological advances. For example, there is a strong connection between big data, IoT and the other technologies, such as cybersecurity as well as horizontal and vertical system integration (Rüssmann et al., 2015). Thus, those technological advances should be kept in mind when studying big data and IoT.

3.4 Opportunities of Big Data and Internet of Things

As mentioned, the recent technological development has resulted in that opportunities of big data and IoT have emerged. This means that a large variety of industries can be digitized. Examples of included industries are agriculture, healthcare and manufacturing (McKinsey Global Institute, 2015). In this section, general opportunities of big data and IoT are discussed.

Clearly, big data enables a massive data collection. This is considered to contribute to both improved quality of decision-making and profitability (Waller & Fawcett, 2013). Data can be leveraged by firms to make their services or products adapted to be more in line with the customers' needs, develop new revenue sources as well as optimizing both operations and infrastructure (IBM, 2014). With big data and IoT, manufacturing companies are able to collect and integrate data from all production equipment as well as enterprise and customer management systems (Rüssmann et al., 2015).

This all means that big data and IoT can help companies to understand the behavior of the customer, improve the efficiency on a factory site in terms of inventory, quality and maintenance, and adapt the product when the sales decline (Jingran et al., 2015).

3.4.1 Proactive Way of Working

Applying a proactive production approach means that capabilities are obtained in advance of when needed. This means that the company takes the control required to act prior to a future situation occurs, but it also includes acting to facilitate the occurrence of a certain happening. In contrast, working reactively refers to an approach where the company are either waiting for a specific happening to occur or only adjusting their settings to comply with a certain situation. This means that working proactively may be feasible in turbulent, uncertain and changing environments where an entrepreneurial approach is of high value. The reactive approach can be considered as more beneficial in stable situations where no or few significant deviations from the normal case occur. Historically, the manufacturing industry has been dominated by a reactive approach (Lindberg, 1990).

Big data and IoT provide a possibility to find problems in a proactive manner (Saint, 2014). As mentioned, these technological advances do also enable companies to find new, previously unidentified and unexpected correlations (Waller & Fawcett, 2013). This could enable working more proactively, rather than reactively.

Predictive and prescriptive data analyses are two new types of data analysis that emerge through Industry 4.0 and can be considered to be of a more proactive character. Previously, the data analysis has been of a more descriptive or, in some cases, diagnostic character, which both are more reactive in their approach. Descriptive analysis aims at answering what happened, for example through service notifications and error messages. Basically all companies do currently apply this kind of data analysis. In contrast, diagnostic analysis aims at answering why a certain thing happened. This can for example be managed through error analysis, alarm handling or analysis of root causes. Today, about one of three companies applies this form of analysis of data. Predictive analytics focuses on what will happen and could for example include prediction of error, output levels or energy consumption. Currently, about one of ten firms applies this kind of data analysis. Finally, the prescriptive analysis concerns what needs to be done. This approach is used by a very limited share of companies and includes the optimization of operations as well as downtime avoidance (Ramin, 2016).

Manufacturing issues can be divided into two categories, namely visible and invisible issues. Visible issues can include machine failure, product defects or time delays. While invisible issues are unforeseen and can include machine degradation or component wear. Traditionally, visible and well-defined problems, such as quality, productivity and costs, are solved reactively through continuous improvement. Through both identifying invisible problems and working proactively, the problems can be solved before they actually occur (Lee et al., 2013). For example, preventive and predictive maintenance provides an opportunity to work more proactively (Jingran et al., 2015; Ramin, 2016).

3.4.2 Vertical Integration

Vertical integration refers to integration of operations within the company (Rüssmann et al., 2015), in other words, to the company's internal integration. This means that the vertical value chain includes the own businesses of the firm. With a high degree of vertical integration, different functions such as sales, marketing, product development, manufacturing, and distribution are closely connected. In addition, the various functions can be integrated into a digital information flow (PwC, 2015). However, this is usually not the case today since there often is a lack of a complete integration within the separate functions of a company (Rüssmann et al., 2015).

As mentioned, big data and IoT are closely related to vertical system integration (Rüssmann et al., 2015). It enables a firm to digitize as well as increase the level of integration of their vertical value chain. By linkages in the internal organization, a company can better connect with their business partners as well as their customers. Ultimately, this vertical integration can result in an increased customer value (PwC, 2015). Moreover, functions and departments of a company are enabled to be much more cohesive with Industry 4.0 (Rüssmann et al., 2015).

More things, in some cases even unfinished products, can be equipped with enclosed computing and linked together by usage of standardized technologies when utilizing IoT. This enables devices to communicate, interaction between other devices as well as controllers of a more centralized character, all depending on what is required by the specific situation. In addition, it enables a more decentralized approach to analytics and to making decisions. This makes responses in real time possible (Rüssmann et al., 2015).

By increasing the vertical integration, a higher level of transparency as well as improved data management can be realized (PwC, 2015). More widespread information sharing in an organization can also result in mitigation of problems associated with information islands. Thus, more efficient data sharing as well as improved credibility in decision-making can also be realized (Bi, Xu, & Wang, 2014).

3.4.3 Horizontal Integration

Horizontal integration considers the integration between a company and its suppliers as well as its customers. As for vertical integration, big data and IoT are closely related to horizontal system integration. In today's business environment, it is common that firms are neither closely connected to their suppliers nor to their customers (Rüssmann et al., 2015).

There are numerous aspects that enable an increased horizontal integration as well as successfully utilizing big data and IoT. Included ones are the interconnection of the value chain's operators, suppliers and customers, the linkages between both machines and sensors, and being capable to analyze large sets of data to find systematic patterns and formulate conclusions. In addition, it is of high importance that the corporation keeps its own data in a suitable order. This makes it necessary to have good data structures and a clear division of responsibilities. It is important to know what responsibilities apply for what data structures (PwC, 2015).

As for the vertical integration, transparency is also required in order to enable openness towards sharing information with both suppliers and customers. In other words, it is of significant importance to know what data to share with which business partner or customer. Similar to the situation for vertical integration, an increased horizontal integration can ultimately result in creation of improved customer value (PwC, 2015).

3.5 Challenges of Big Data and Internet of Things

The general challenges faced by companies when it comes to digitalization can be divided into four different categories, namely financing, technology, competencies, and administration. First, financing is considered as the most significant challenge and relates to the fact that adapting to modern technologies requires significant investments with no clear economic benefits. In other words, it can be hard to quantify the actual business benefits of big data and IoT. Second, the technology challenge concerns that the required technology is not adequately developed or that the top management does not consider digitalization as a matter of high priority. Third, the competence challenge relates to employees with inadequate knowledge in the area. Fourth, the administration challenge considers the lack of standardization and norms. In addition, the new technologies require an organizational change, which is a challenge in itself (PwC, 2015). This and a number of other challenges are described in more detail in the following sections.

3.5.1 Capital-intensive Equipment

Factories can be considered to be capital-intensive as well as having a low replacement rate of machinery. In order to enable an adoption of IoT, upgrades or replacements of machines and devices may be required (McKinsey Global Institute, 2015). Typically, the product life of machines is rather long, which means that it may take time before all installed machines are completely digitized (PwC, 2015). Clearly, capital is required to make it possible to adopt the factory and its machinery to IoT. As a result, the opportunity to upgrade a company's machinery is an important enabling factor of IoT (McKinsey Global Institute, 2015).

Usually, it is possible to upgrade the machinery currently in possession of a company to make it ready for adoption to IoT. A contributing factor to this is the past four decades of factory automation resulting in the fact that many machines either have sensors or can be adjusted to incorporate the required electronics. This means that today's situation provides a great difference compared to the situations of previous industrial waves, during which a tremendous share of the machinery had to be replaced (McKinsey Global Institute, 2015).

Since the introduction of IoT in a company's factory today does not require a complete replacement of the machinery, the conditions regarding adapting to today's changing business environment are more beneficial than before. However, it can be feasible with a gradual adoption, especially when considering small and medium sized corporations. Taking it step by step enables the company to account for the capital requirements and undertake the corresponding changes without negatively affecting the company's production process (McKinsey Global Institute, 2015).

3.5.2 Managing Data

Large amounts of data are generated by data sources such as sensors and other equipment. As a result, massive, unstructured amounts of data are created. For a company to benefit from big data and IoT, a clear strategy is required to understand what data to collect, how to manage it, what it is aimed for, and how to analyze it (Rotter, 2016). To handle the challenge of what data to collect and how to analyze it, the data can be managed through understanding the characteristics of big data, more specifically volume, velocity and variety (Fox & Do, 2013).

First, the volume must be managed in an efficient way. When handling large volumes of data, all data must be comprehensive when it is retrieved from a source. Examples of sources are single components, an assembly line or an entire engine system. This volume aspect can be managed by defining the minimum data sources needed to establish a comprehensive picture of the current condition (Fox & Do, 2013).

Second, the velocity or speed is, as mentioned, a critical aspect. Real time data, which is a result of velocity, is considered to be vital when improving processes. To attain real time data, both complex and adapted algorithms are needed (Fox & Do, 2013).

Third, the variety plays a critical role when managing the data. Depending on whether the data is collected from a single component, an assembly line or a whole system, the type of data is different. In order to manage the variety of data, it is of great significance to plan exactly what data to collect and from which source. The selection of data is based on the importance of the data source, such as a specific component, assembly or position in the engine system (Fox & Do, 2013).

Today, the main part of the collected IoT-related data is completely unused. In addition, the data that actually is used is not utilized to its full potential (McKinsey Global Institute, 2015). There is also a challenge regarding storage of data, which can be solved by investing in a software program with strong cloud capabilities (Rotter, 2016). The opportunity of a cloud function enables data resources to be retrieved from the Internet through web-based storage instead of through a server (Bi, Xu, & Wang, 2014). The cloud is further discussed in section 3.7.2.

3.5.3 Security

Cybersecurity is one of the nine technological advances of Industry 4.0 (Rüssmann et al., 2015). Security becomes a vital part of the new technologies, especially as more things are connected with each other and more data is generated (Atzori, Iera, & Morabito, 2010; Rotter, 2016). To reduce the risk of external data leakage, security systems with encryption algorithms that are used in financial trading can be applied to manufacturing. Even theft of a small piece of data can be troubling as it can result in stolen ideas or designs (Jingran et al., 2015).

In addition to external security risks, internal data sharing is a challenge. The lack of trust between different functions of a company reduces the sharing capabilities and transparency within the company. This issue can result in inadequate analysis (Jingran et al., 2015).

3.5.4 Organizational Support

As mentioned, big data and IoT facilitate the digital transformation in manufacturing industries. In order for a company to adapt to this transformation, the company must also adapt their business plan and way of working (Rotter, 2016). Big data and IoT do not only impact technological aspects, but also organizational and competence related aspects. The right competence and involvement are needed on both an operational and a top management level. The operational level needs to understand the technology and possess the sufficient competence, while top management needs to support employees and form a clear strategy for the transformation (PwC, 2015).

3.5.5 Obtaining the Necessary Competencies

It is common that companies face challenges of finding and obtaining the necessary competencies. Since big data and IoT imply changes to the work being conducted due to aspects such as digitization and automation, the required skills and competencies change. Thus, if not handled properly, there is a risk of both competency and personnel shortages (PwC, 2015).

3.5.6 Potential Hype

Since both big data and IoT are relatively novel technological advances, there could be a risk of them being overhyped. Thus, Gartner's hype cycle for emerging technologies is reviewed. It compiles key emerging technologies in order to display the ones that will result in significant consequences across industries as well as having the potential to have a major impact and contribute to transformation. This means that the technologies placed on the hype cycle could have a large business impact on various firms and should therefore be observed and considered. Moreover, the hype cycle can contribute to addressing the risk and maturity levels of a technological advance (Gartner Inc., 2016a).

In addition, Gartner's hype cycle for emerging technologies shows in which way these technologies can be relevant when it comes to solving actual business related issues and utilizing new potential areas. It also displays how the included technological advances are projected to develop as time passes. Thus, the hype cycle can be used to understand how a firm can act in accordance with its business goals while accounting for emerging technologies (Gartner Inc., 2016b).

More specifically, enterprises can benefit from using the hype cycle when considering incorporating an emerging technology in their business. Whether or not to move early and make early investments depends on how risk averse the company is. Making an early move towards adoption of an emerging technology implies a significant risk. Thus, the company needs to be aware of taking this risk does not always pay off. Even though, the payoff can be larger when moving early, it can be feasible for firms to act more moderately. In this way, the company can avoid proceedings and investments in technologies that are not completely proven to work sufficiently. In cases where there are several questions that has not been provided with an answer in this stage, the company could benefit from waiting to see whether other firms succeed in achieving actual value from usage of the technologies. Here, uncertainties include ones regarding commercial viability. It should be noted that this hype cycle comprises of five fundamental phases included in the life cycle of a technology (Gartner Inc., 2016a), see Figure 3.6 for further details.

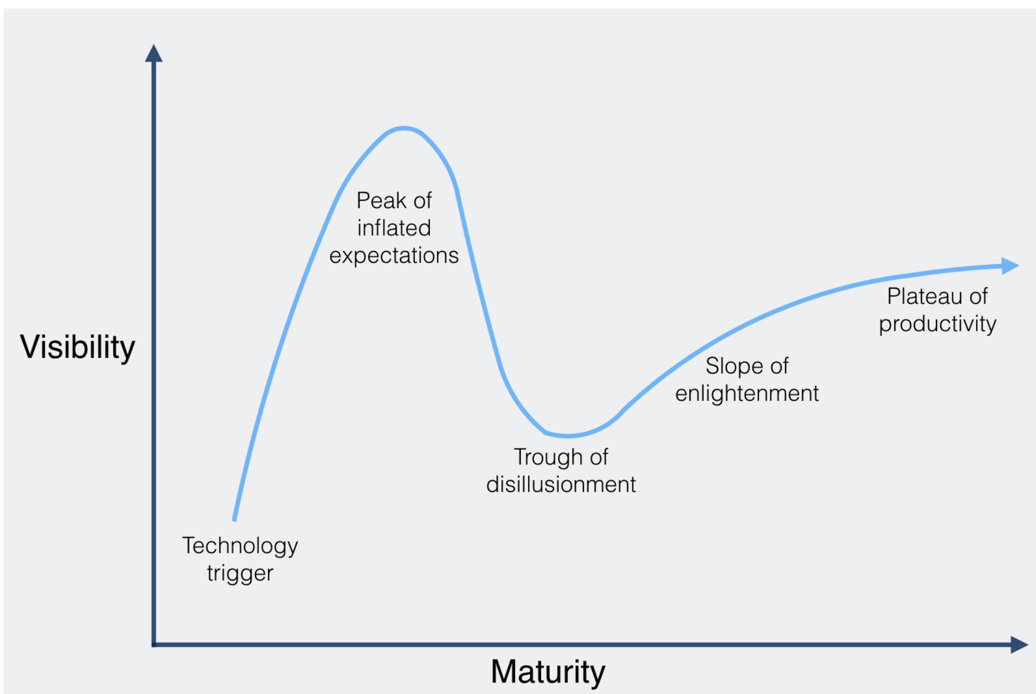


Figure 3.6 The five stages of Gartner's hype cycle for emerging technologies (Gartner Inc., 2016a).

The first step is the technology trigger, which is initiated by a potential and important technological discovery. Usually, the product cannot be used in this stage, its commercial viability is not yet proven and it usually results in massive media attention. The second step is the peak of inflated expectations during which early publicity results in numerous potentials to succeed. During this step, there are some firms that decide to act, while some choose to wait. The third step is the trough of disillusionment during which the interest in the technology decrease following from an inability to accomplish a successful introduction. The only way in which investments will proceed in this step is if the remaining producers are able to improve their product in accordance to the requirements of the early adopters. The fourth step is the slope of enlightenment during which more examples of how a company can benefit from the technology emerge. In parallel, a deeper and wider understanding of the technology is developed. At this point, the producers of the technology deliver products of a second or third generation. More companies begin to investigate the potential of the technology by launching pilots, even though conservative companies stay hesitant. The fifth and final step, is the plateau of productivity. Here, the technology is widely introduced and its broad usefulness as well as relevance in the market is paying off significantly (Gartner Inc., 2016a).

In 2014, both big data and IoT were included in the hype cycle, see Appendix C for further details regarding the positioning. Big data was moving from the peak of inflated expectation towards the trough of disillusionment, while IoT was right at that peak (Gartner Inc., 2014). In 2015, big data was excluded from the hype cycle, but IoT was still positioned at the peak of inflated expectations, see Appendix D for further details. This could imply that IoT is presently overhyped in the market for technologies (Gartner Inc., 2015).

There are several potential reasons that could explain the removal of big data from the hype cycle of 2015. For example, a reason may be that big data is widely used and therefore has lost its prominence (Peddibhotla, 2016). This means that big data is considered to have become prevalent the current business environment and thus not a hype any longer. However, it can be argued that big data was taken off the curve a bit too soon (Woodie, 2015).

In addition, big data is often referred to as a vague term having indefinite limits. It is common to use vague terms to describe technological matters. How big data was defined around year 2000 differs from what is considered to be big data today. Hypes are often described in a manner that is both very positive and vague. It is important for managers to be able to see through the hypes in order to realize what both big data and IoT actually can do and add to their businesses. It is also essential to ensure understanding of the limitations of the technologies to avoid unrealistic expectations (Fox & Do, 2013).

3.6 Possible Applications of Big Data and Internet of Things

As mentioned, previous research suggest that big data and IoT can be applied in a manufacturing process to enhance its flexibility and efficiency (McKinsey Global Institute, 2015; Rüssmann et al., 2015). To understand which applications are the most suitable for a company's specific needs, it is crucial to understand what they want to achieve by implementing big data and IoT. In other words, it is vital to understand the company's supply chain strategy as well as the product, its requirements and the corresponding production process (Jingran et al., 2015).

Generally, big data and IoT are more or less applicable depending on where in the PLC the product is. The potential usage areas of the two technological advances vary in accordance to the product's placement in the PLC. By understanding the characteristics of the product, big data and IoT can be implemented where they are likely to have the most impact (Jingran et al., 2015). Note that the connection between the PLC and the different applications of big data and IoT is developed by the authors based on studying various sources.

3.6.1 Design

When products are in the first two stages of the PLC, introduction and growth, it is crucial to understand the product design and who it is that buys the finished product (Andersson & Zeithami, 1984). To develop the optimal design, a market analysis is conducted. The purpose of the analysis is to understand who buys the product and how it will be used. Here, big data enables massive data collection that is useful to answer these questions. As previously mentioned, big data can be utilized to analyze data from various sources to attain a holistic picture of the market. From the market analysis, the design and product specifications can be formulated (Jingran et al., 2015). However, this matter is not further discussed due to the focus and delimitations of this master's thesis.

3.6.2 Manufacturing Optimization

When products are in the maturity phase of the PLC, an efficient production process is crucial. As mentioned, through usage of big data and IoT, companies can increase the efficiency by optimizing the production process (McKinsey Global Institute, 2015). Optimizing the production is a broad statement based on a number of aspects. To clarify this statement, it is divided into four fundamental parts that are further described below. Table 3.3 provides an overview of these aspects.

Aspect number	Description
1	A comprehensive perspective of the manufacturing process
2	Real time control including quality control and resource management
3	Tracking and monitoring
4	Increased flexibility through self-optimization as adjustments can be made to fit a certain batch

Table 3.3 Four fundamental aspects of production optimization enabled by big data and IoT

First, a comprehensive picture of the manufacturing process and its performance can be achieved by exploiting big data and IoT. The latter enables manufacturing firms to collect data from machines, sensors or other devices that are connected to a network. The data can then be used and combined with tools of an analytic character to monitor certain information. This enables an opportunity to identify certain patterns, which helps manufacturers to develop an understanding of which particular factors may result in errors and breakdowns. As decisions are based on data rather than human judgment, they can be more accurate. Thus, less pressure can be put on the operators (Saint, 2014).

In addition to a comprehensive picture, digital integration leads to higher optimization. It is considered that corporations in Sweden will be digitally integrated within the next five years. This integration will be both internal and external. The internal integration considers integration within the company, such as between various departments and functions. In contrast, the external integration considers aspects such as customers and partners. Important aspects to keep in mind regarding information sharing internally in organizations as well as with partners are that it is of high importance to make sure to have or develop a clear structure for transparency as well as for how data is managed and handled (PwC, 2015).

Second, a crucial element of big data and IoT for optimizing the production process is real time control. What to control depends on the product, supply chain strategy and key performance indicators (KPI) of the company. Examples of real time control are quality controls, environmental conditions or resource usage. By continuously controlling the quality of the product through real time controls, real time adjustments can be made. These adjustments enable a minimization of both defects and waste (McKinsey Global Institute, 2015). More specifically, a manufacturing firm can make their quality management better by gaining this deeper knowledge regarding where the actual problems are in their current production process. In today's setup, it commonly takes unjustified amounts of time to localize problems and their underlying reasons. What IoT contributes with here, is an opportunity to find and pinpoint issues in a much timelier manner (Saint, 2014).

The sensing technology of IoT can also measure environmental conditions, such as humidity and temperature. By using the environmental data, the relationship between the production efficiency and the environment can be drawn (Chen et al., 2016). Furthermore, energy and water usage play an important role in the production process. By observing and understand the real time usage of energy and water, the consumption of the two components can decrease. There are generally two ways to minimize the usage of these resources; improving the equipment configurations and introducing resource management methods for the equipment. Without the input from big data and IoT, it is difficult to understand which equipment should operate at what speed and at what time to minimize the energy and water usage (Jingran et al., 2015).

Third, big data and IoT contribute with opportunities for measuring, identification of products' positions, monitoring and tracking. This all contributes to potentially increasing the automation level in manufacturing (Bi, Xu, & Wang, 2014). For example, sensors can be used instead of using human judgment for the purpose of making adjustments to the machinery's performance (McKinsey Global Institute, 2015). When the automation level become higher, the amount of errors and the production costs could potentially become lower (PwC, 2015).

Lastly, exploiting big data and IoT a manufacturing company can increase the flexibility in the production process and enable manufacturing of smaller batch sizes in an economically feasible way. Self-optimization of devices enables automated adjustments of settings based on the characteristics of the unfinished good. In other words, a machine is not only able to by itself realize when to change its parameters, but also able to perform these changes, all to fit the properties of a specific product. It is this machine-to-human and machine-to-machine based communication that makes small batches as well as a higher customization level possible (Rüssmann et al., 2015).

3.6.3 Predictive and Preventive Maintenance

As mentioned, a predictive approach is focusing on prediction of the occurrence of future events, such as of errors (Ramin, 2016). In contrast, a preventive approach means that future events are prevented by actions taken before the occurrence of a certain event. In other words, both predictive and preventive maintenance enable avoidance of future issues by taking measures before they actually happen. Thus, these two approaches differ from the more traditional maintenance approach that has a rather corrective nature (Jingran et al., 2015).

Utilizing real time data for predictive maintenance can facilitate both prediction and prevention of breakdowns in a production facility. Predictive maintenance includes usage of sensors with the purpose of monitoring the machinery in a continuous manner. This is done to avoid breakdowns that are not planned, but also to decide when maintenance is required instead of applying planned maintenance on a fixed schedule. Moreover, IoT provides an opportunity to alter the maintenance setup from being focused on repairs and replacements, to being focused on predicting and preventing upcoming events. Improving the maintenance in a firm's factory is considered to be a way to create increased value (McKinsey Global Institute, 2015). By exploiting the opportunities associated with Industry 4.0, big data and IoT, companies can potentially reduce maintenance costs significantly (Ramin, 2016).

It is partly development of IoT sensors that enables the wider data collection from equipment and machines. Then, the collected data can be combined with a big data approach to develop predictive and preventive maintenance (Jingran et al., 2015). IoT basically provides a systematic opportunity to supervise how well the machinery is performing (McKinsey Global Institute, 2015).

In addition, the new maintenance opportunities can be described as self-aware and self-maintained machines. Here, the machines can assess their current health and wear status by themselves. Data-driven algorithms can complete the health assessment with data from both the specific machine and the external environment (Lee, Kao, & Yang, 2014). Another way to integrate big data and IoT into maintenance is to trigger alerts when the machine operates outside specific parameters (Rotter, 2016).

In a manufacturing company, the equipment can be considered to be a vital part of the production and closely connected to the performance of the overall production process. Regarding equipment management, two factors are of great concern, namely the wear estimation and energy consumption (Jingran et al., 2015). Utilizing sensors and connectivity provides an opportunity to supervise equipment in real time. This makes more cost-efficient maintenance setups possible. For example, it enables detection and repairs of machines prior to breaking the upstream machines or even shipping faulty products (McKinsey Global Institute, 2015).

The actual reduction of costs for maintenance of equipment associated with Industry 4.0 is estimated to be somewhere between 10 and 40 percent (Ramin, 2016). In addition, the downtime of devices can be decreased by as much as 50 percent and the useful life length of machinery can be increased resulting in up to five percent lower costs for investments in equipment (McKinsey Global Institute, 2015).

3.6.4 Product Recovery

New products are constantly introduced into the market. As a result, the product life cycle is usually shortened. To adapt the product to the constant change and to minimize negative impact on the company and the external environment, waste should be handled in a correct manner. This means that material and equipment should be recycled or reused if possible when reaching the decline phase. Even though, it is not possible to produce a certain product anymore, all its components are not worthless. This makes it an important matter to predict the length of the lifetime of the components. Big data can be used to accomplish qualified predictions with support from historical data. In the same way, big data can be used to assess which part of the equipment that can be reused somewhere else (Jingran et al., 2015). However, the product recovery application is not further discussed in this master's thesis due to its focus and delimitations.

3.6.5 Logistics

In addition to manufacturing optimization and maintenance, logistics play a vital part of the efficiency in a production process. It includes both inventory management and product transportation (Jingran et al., 2015). However, the logistic application is not further discussed in this master's thesis due to its focus and delimitations.

3.7 Required IT Landscape

There is a required IT landscape for big data and IoT to work in a proper manner. Many of these key components existed before the concepts of the two technologies were developed. Due to lower prices of the hardware, larger processing power, network capacity and new ways to store, both big data and IoT are more accessible (McKinsey Global Institute, 2015). This section provides a presentation of hardware, software and competence requirements that are essential to fulfill a successful utilization of the two technologies.

3.7.1 Hardware Requirements

There are several enabling technologies of IoT to generate appropriate data in a manufacturing company. The aim here is not to give a comprehensive description, but a brief understanding of what role each technology plays for big data and IoT. Key components of IoT include among others, the tags and systems for Radio Frequency Identification (RFID). RFID is not a new technology and it has existed since the Second World War. However, due to today's lower prices its popularity has increased. The RFID technology can replace barcode and scanner technologies (Jun et al., 2009).

The two components of the RFID technology are a transponder or a tag as well as a RFID reader. When the tag is within a certain distance of a reader, it reacts with an impulse and whatever information the tag holds, is transmitted to the reader through wireless communication on radio frequencies (Jun et al., 2009). As a result, objects can be monitored in real time without being spotted by the human eye (Atzori, Iera, & Morabito, 2010). This means that RFID tags basically eliminate delays associated with information sharing (Delen, Hardgrave, & Sharda, 2007). Monitoring objects and integrating their location in the virtual world are two functionalities that are aligned with the IoT approach (Atzori, Iera, & Morabito, 2010).

Another key hardware component of IoT is the sensor. Similar to the RFID, the technology is used to track the status of objects, such as locations, temperatures or air humidity. The gap between the physical and the digital world can decrease by gathering information about a specific environment (Atzori, Iera, & Morabito, 2010).

3.7.2 Software Requirements

For the hardware components to collect data in an efficient manner, a trustworthy data network is necessary. First, when operating data in a production site, the data network must be adapted to the existence of large amounts of electromagnetic interference. Second, as large flows of data exist between the IoT hardware components, machines and IT systems, the network requires high-bandwidth. This means that a network can be comprised of software, hardware, data flows and devices (McKinsey Global Institute, 2015).

Another requirement for big data and IoT at a production site is how the data is managed. To account for the challenges previously described, the data must both be stored and analyzed in an efficient way. The data can either be stored on in a cloud or on a server. Due to recent technology development, the cost of data storage through a cloud service continues to drop (Bi, Xu, & Wang, 2014).

A cloud is based on Internet Protocol (IP) connections that enable large-scale data storage. This software component has a self-service nature, where users can access the data or information themselves without using IT assistance. As a result, information sharing and system flexibility increases. Furthermore, the cloud has a high elasticity. Depending on the quantity of the data storage at a specific moment, the users can either increase or decrease the capacity to continuously optimizing the storage capacity (Bi, Xu, & Wang, 2014).

When implementing a cloud for data storage in a company, the security aspect should be considered (McKinsey Global Institute, 2015). The traditional way to store data is through an internal server. Bi et al. (2014) argue that servers cause ineffective data exchange and inflexibility and that a cloud service can solve these issues. However, a cloud is not suitable in all business environments. Small companies or startups benefit from storing data in a cloud, while a transition from servers to a cloud setup is too expensive for many larger companies who already use servers to store data (Forbes, 2013).

To reach the potential benefits of big data and IoT, the correct tools for analytics also play an important part. In other words, algorithms are needed to understand and identify patterns in the real time data collected from RFID tags, sensors or machines. Furthermore, the results from the analytics must be presented in a useful way, meaning that the information has to be visualized for the specified user (McKinsey Global Institute, 2015).

3.7.3 Competence Requirements

As big data and IoT are implemented in a manufacturing company, not only the technology requirements play an important role. In fact, the competence of the employees has a big impact on the success (McAfee & Brynjolfsson, 2012).

Utilizing big data and IoT are not about reducing the number of employees. Instead, it is about empowering the employees in their daily work. As a matter of fact, studies even show that big data and IoT may lead to an increase in the employment level during the next coming ten years. For example, competencies in mechanical engineering, IT technologies and software development will be required to a wider extent than before. However, it should be pointed out that some work tasks, such as repetitive ones, may change in character. Thus, different skills than in today's factories will be required (Rüssmann et al., 2015). For new technologies, such as big data and IoT, to be successful the right competencies are needed both on an operational and a strategic level (Mörstam, 2016).

Traditionally, the work tasks on an operational level can include simple and repetitive tasks, quality controls or reactive maintenance. The tasks can also include physically challenging duties or requiring handling of dangerous substances. Today, many of these tasks can be replaced by standardized robots, which improve the working conditions of the operators significantly. The assignments, including quality controls and reactive maintenance, can also shift focus as big data and IoT are utilized. Due to the technological changes, the traditional tasks are modified and the operators focus more on supervision than performing the tasks themselves. In order for this change to be successful, the combined competence in the areas of production and IT is crucial (Mörstam, 2016). Furthermore, Mörstam (2016) describes this competence as a hybrid, where the knowledge of the operators should be combined with knowledge of IT. In addition, the operators need to possess soft requirements of openness to change and cross-functional learning as well as flexibility to change tasks. To reach the new competence requirements, manufacturing companies can need to reeducate their employees (Mörstam, 2016).

To manage the technology changes on a more strategic level, specific leadership or management qualities are needed. Here, the aspect of awareness of the technological opportunities and challenges is included. The management must also adapt the functions to enable new digital ideas. Another included quality is an open attitude towards the digitization, experimenting and possible failures. A final quality should be an enabler in the organization, where all employees are able to fulfill reasonable requirements (Mörstam, 2016).

3.8 Implementation

Clearly, there are a number of important factors to consider for enabling a successful adoption of big data and IoT (McAfee & Brynjolfsson, 2012; Rüssmann et al., 2015). Additionally, there are common issues that may result in significant failure rates when considering implementation of IT projects (Standing et al., 2006). Thus, these aspects should be kept in mind in order to successfully utilize big data and IoT in a manufacturing company. This section provides an elaboration regarding key challenges concerning the implementation of IT projects as well as what critical success factors there are for implementing big data and IoT in a manufacturing company.

3.8.1 General Challenges of Implementing IT Projects

The failure or success of IT projects is hard to define. However, when implementing an IT project, there are numerous sources of the problems that may be encountered. Generally, it is common that IT projects fail to live up to the implied original expectations and objectives. There are various failures that usually occur as a result of either one or several potential underlying reasons. The knowledge level of organizational problems may be too low, there may be a too low degree of user involvement, a too poor training of the users, or an insufficient alignment of the IT adoption and the company's business strategy. In addition, poor leadership, changed user requirements, non-existing support from the IT department, and the size and complexity of the project are also commonly occurring reasons of failures. These factors should all be kept in mind and avoided in order to enable succeeding with an IT project (Standing et al., 2006).

In contrast, successful projects can be defined as to what degree the project takes part in reaching the goals of the firm. The people managing the projects as well as their support play an important role regarding whether the project fails or succeeds. Important factors to succeed with an IT project include meeting the requirements of the user, meeting the budget and staying within the time frame of the project. In addition, it is important to be able to assess risks of the project (Standing et al., 2006).

3.8.2 Critical Success Factors of Implementing Big Data and Internet of Things

In order to benefit from the potential of big data and IoT, it is important that manufacturing firms make prioritizations regarding the processes in their production. For example, important aspects to improve should be recognized. Quality, speed, productivity, and flexibility are all included ones. After this, it should be investigated how big data and IoT can be used regarding the identified aspects. Here, it is important to see how these technological advances can be utilized to make a significant alteration possible, rather than only relying on approaches of an incremental character. It can also be considered how big data and IoT can be combined with the remaining seven technological advances for the purpose of reaching fundamental changes (Rüssmann et al., 2015).

Additionally, it is of high importance that producers increase and alter the competencies of their employees. A strategic plan regarding the competencies should be performed based on an analysis of the long-term impact of the changes. For example, this could be conducted through adapting the recruitment, altering current roles, and providing professional education in order to provide the employees with the IT knowledge that will be a necessity in the future state (Rüssmann et al., 2015).

Moreover, it is considered that firms have to be able to handle alterations efficiently in order to realize the complete potential of big data and IoT. There are numerous management challenges that are necessary to handle to succeed with big data. Included are ones related to the decision-making, technology, leadership, talent management, and to the corporate culture (McAfee & Brynjolfsson, 2012).

3.9 Summary of the Frame of Reference

When considering utilizing the potential of technological advances, such as big data and IoT, it is of high importance that companies actually understand the requirements of their own products. As mentioned, the implied product requirements vary depending on the maturity of the product. Thus, the product requirements can be understood based on a model such as the PLC. In addition, the product can be understood in terms of being functional or innovative. By understanding the product properly, the most suitable supply chain strategy can be applied. It is also vital to understand what information that actually is necessary to collect and what it should be used for.

There are many potential advantages and applications of big data and IoT, but there are also several challenges that should be considered. Thus, before starting with an adoption of big data and IoT in a firm's manufacturing process, the company should have a clear picture of what they actually want to achieve by doing so. In addition, it is important to have a clear picture of who in the organization should facilitate the work with big data and

IoT. For example, employees with analytical skills are required to analyze all the generated and collected data. Clearly, it is important to consider whom the data is relevant for.

Additionally, there could be risks of big data and IoT being hyped technological advances. How risk averse the company is, determines when it is most feasible to invest in the emerging technologies. Even though, big data was removed from Gartner's hype cycle in 2015, some professionals consider this movement as premature. Then, there is also the fact that big data is a vague term, which further adds to these risks.

Big data and IoT both have several potential applications. Included ones are in the areas of design, manufacturing optimization, preventive and predictive maintenance, logistics, and product recovery. When considering the various applications, it is of high importance to consider the requirements implied by the products' characteristics. It is also crucial to understand the own firm's supply chain strategy in order to ultimately enable achieving strategic fit.

A company considering exploiting big data and IoT should make sure to be equipped with the sufficient software, hardware and competencies. Moreover, top management support is a vital factor to succeed when implementing an IT project, such as when considering utilizing big data and IoT. Finally, a company's success in the adoption of technological advances can be facilitated through making adjustments in incremental steps.

4 Empirical Data

Several elements from the single case study are presented in this chapter. First, a general background of the company, the changing business environment and the chosen product are discussed. Then, the production process is presented, in terms of the actual steps, data collection, and improvement opportunities. In addition to the production process, the general IT landscape is elaborated on. Finally, key findings from the case study are discussed.

4.1 Company Background

Today, SM produces products that are sold in more than hundred countries (Swedish Match, 2015d). The products of SM are divided into three categories, namely Snus and moist snuff, Additional tobacco products, such as cigars and chewing tobacco, and Lights, including matches and lighters. The largest category is snus and moist snuff, representing 38 percent of the revenue and 62 percent of the operating profit (Swedish Match, 2015a). The main markets for this category are located in Sweden, Norway and the United States (Swedish Match, 2015c). Well-known brands included in the category are General, Göteborgs Rapé and Longhorn (Swedish Match, 2015a).

The company is the leading player manufacturing snus in the Scandinavian market. More specifically, SM has a market share of 70 percent in Sweden and 60 percent in Norway (Swedish Match, 2015a). In the United States, SM has a position as the largest manufacturer of chewing tobacco, the second largest actor in the snus market, and as the third largest producer of moist snuff (Swedish Match, 2015d).

In 2014, SM had 4,395 employees and the revenue was 13,305 million SEK (Swedish Match, 2015a). Moreover, SM operates in nine countries and have twelve factories located in six of those countries. The largest production facilities are located in Sweden, the United States and the Dominican Republic (Swedish Match, 2015d). Snus and moist snuff are produced in Sweden respectively in the United States. In Sweden, SM has production factories for snus in Gothenburg and Kungälv (Swedish Match, 2015c).

Swedish Match owns and operates a large part of the value chain of their snus, from sourcing the components to selling the products to Swedish Match Distribution (SMD). In this master's thesis, SM and SMD are treated as two separate companies, even though they are both part of the same corporate group. Therefore, SMD is represented as the only customer of SM. SM provides the products to the customer's distribution center (DC) regularly. However, if inventory is low or stock outs occur, SM can respond within a few days (Managers at SM, 2016). Then, SMD takes responsibility to deliver the goods to retailers and consumers. In addition, SM has a number of suppliers who deliver raw tobacco, plastic cans, lids and labels. The raw tobacco harvested in each region once a year, therefore the raw tobacco is delivered to SM in connection to this. The inventory level of the raw tobacco corresponds to one year's production. While, the cans, lids and labels are delivered on a daily basis for the production on the following day (Project managers at SM, 2016).

4.1.1 Factory Conditions

The factory in Gothenburg opened in 1981 (Näringsliv, 2014). The equipment in the factory has gradually been updated. As a result, there is a large variety of old and new machinery. A significant part of the machinery has a low replacement rate and some machines have even been in the factory since the start (Managers at SM, 2016). The Kungälv factory, on the other hand, opened in 2003 and is equipped with new production technology (Swedish Match, 2003). Since the factory in Kungälv is more modern and built more recently, there are some differences in the conditions, technical maturity and the amounts of data collected in the two factories. However, the production processes of the two factories are similar when studied from a higher perspective (Managers at SM, 2016).

Historically, SM has produced large volumes of few products according to a supply chain strategy driven by minimizing costs. However, SM has strived to adapt towards a strategy that considers the market more in recent years. In other words, this newer intention is on attaining an increased level of responsiveness towards their customers and consumers (Managers at SM, 2016).

4.1.2 Changing Business Environment

As previously mentioned, the competitive environment of snus has changed in Scandinavia. Significant changes have been initiated as the market has gone from being a monopoly to a competitive landscape with price-pressuring competitors. To remain competitive when the conditions have changed, SM has both diversified their product portfolio and put more emphasis on quality and awareness (Project managers at SM, 2016).

As the product portfolio is increasingly diversified, the number of SKUs increase and more data needs to be handled. To manage all data, SM has implemented many stand-alone systems. These information systems gather data themselves and are not integrated with the other systems. Therefore, it is a perception that large amounts of data are collected, but as the data is basically stored in information islands, it cannot be analyzed in an efficient manner and a holistic view cannot be reached. In addition, when purchasing stand-alone solutions, the company usually only utilize parts of its potential, while paying the full price (Managers at SM, 2016).

SM cares for their employees, more specifically their work tasks should be manageable and too much pressure should not be put on single employees. Therefore, to facilitate the daily tasks of the operators as much as possible is an important aspect to consider and strive towards achieving. This has become especially important during recent years, as the complexity in the production process has increased due to the rise in number of SKUs. In addition, the employees need to keep much knowledge in their heads, as standardized solutions are not always possible in today's production process. Previously, there has been a tendency to perceiving new IT systems as a simple solution to the problem, even if it means purchasing stand-alone systems. It is important to make sure to avoid putting too much pressure on the employees, both for health and efficiency aspects, thus some sort of new and integrated IT approach could be an answer to the issue (Managers at SM, 2016).

The vision of SM is *a world without cigarettes* (Swedish Match, 2015a). It supports the reduction of cigarettes as well as continuously improved quality and awareness of the product. SM has developed a quality standard known as GOTHIATEK®. It addresses limits of undesirable substances and is based on the three cornerstones quality, openness and consumer care. The standard is stricter than the regulations implied by the Swedish National Food Agency, Livsmedelsverket and World Health Organization (WHO). This is considered as a fact that is making the company unique (Swedish Match, 2015b).

To attain these low levels of undesirable substances, a large amount of both planning and research is required (Project managers at SM, 2016). The company also emphasizes on quality throughout the entire production process. If the individual snus portion or the can does not meet the requirements, it is rejected. Many rejections result in large waste volumes (Managers at SM, 2016).

4.2 The Portioned Packed Snus Original General

The PSO General is one of SM's largest products when considering sales volumes and can be categorized as a standard product in SM's product portfolio. The PSO General was introduced in the snus market in 1985, but the brand General actually celebrates its 150th birthday this year (Swedish Match, 2016a). The brand General consists of different product category, see Table 4.1. Each type of General has a varying production process. As mentioned, this master's thesis focuses on the PSO General. The PSO General is the brown random packed snus and is its own product category (Project managers at SM, 2016).

			
Loose Snus	Portioned Packed Snus Original	Star Formed Portioned Packed Snus White	Random Filling Portioned Packed Snus White

Table 4.1 Different types of product categories included in the General Brand

Today, General accounts for the largest market share when considering the premium segment for snus in Sweden. In addition, General is SM's largest product in Norway and there is a positive trend for the brand in the US (Swedish Match, 2015a). The product's features vary depending on the market. For example, the labels on the can and the weight of the pouch change depending on which market the product is sold on (Operators at SM, 2016). The demand of the product is stable and increases in a pace that is slightly lower than the pace in which the entire market's demand increases. In addition, the consumer demand of the product is not seasonally based, but it is stable all year around (Managers at SM, 2016). Due to the importance of General, it is prioritized if there would be any shortages in the production process, which limits the possibility to produce all other goods as intended. In other words, empty shelves are not an option as the PSO General should be available whenever it is demanded (Project managers at SM, 2016).

General is a premium product, therefore the consumer value high quality and a strong brand. The product also has a high profit margin. Generally, this is true for all the SM snus products. As previously mentioned, there are also many competitors for this specific product. Basic ingredients include tobacco flour, water and salt (Managers at SM, 2016). Figure 4.1 displays a can containing the PSO General.

Figure 4.1 A can containing the PSO General

4.3 The Current Production Process

The production process studied in this master's thesis is, as mentioned, the one for the PSO General. This process comprises of three sub processes, namely the mill, the pasteurization and the packaging. Figure 4.2 displays a map showing how they are connected. It should be pointed out that Appendix B shows the key themes that this empirical data is based upon. As in most factories, it is of high importance that the production process runs smoothly at all times. Throughout the entire production process, high quality of the finished snus is emphasized (Managers at SM, 2016).

Figure 4.2 A schematic overview of the current production process of the PSO General (Swedish Match, 2016b)

The packaging process is studied at a specific line, where the PSO General mainly is produced. In addition, it is the newest, most technologically advanced packaging line in the Gothenburg factory and thus most prepared for change (Managers at SM, 2016).

Since it is of high importance to SM that the production process always runs and that the produced snus is of high quality, the company does not want to risk a production process failing due to new technology. This can result in skepticism towards new technologies and updates as long as the current systems and working methodologies work (Project managers at SM, 2016). As a result, there are indications of skepticism towards the application of big data and IoT in the production process at SM. The two phenomena are frequently referred to as vague terms. However, there is also a great interest in learning how they could empower the operators and the company as a whole in the new industrial shift (Managers at SM, 2016; Operators at SM, 2016).

Both external and internal factors could potentially affect the production process and the quality of the PSO General. External factors include the outside temperature, atmospheric pressure and variations in the power line. Internal ones are factors such as the quality of direct material, personnel, machines and maintenance. Direct material includes cans, lids and pouch paper. Currently, there are not any clear implications that the external factors affect the production. On the other hand, the internal ones are considered to have a significant impact in the production process of the PSO General. There are a number of issues resulting from these factors in the current production process. Included problems are ones such as large waste volumes and excessive energy usage (Managers at SM, 2016).

The production's sub processes are further described in the rest of of this section. In addition, data collection and improvement opportunities in the process as well as the current IT landscape are further elaborated on in the remaining part of this chapter.

4.3.1 The Mill

The main purpose of the mill is to ensure the succeeding pasteurization process with access to approved milled tobacco. It is this tobacco flour that is used for making snus. Basically, the mill process includes all manufacturing of milled tobacco from ordering the raw tobacco to the point when the tobacco flour is stored in a silo. Figure 4.3 displays some of these silos. Moreover, the mill located in the Gothenburg factory provides both the Gothenburg and Kungälv factory with tobacco flour (Managers at SM, 2016).

The raw tobacco consists of both stems and leafs. It is stored on the next to the factory in Kungälv and is ordered to the Gothenburg factory in the beginning of each day. Current inventory levels, in other words, the amounts of milled tobacco stored in the silos, determine what and how much that is ordered. The ordered raw tobacco is delivered to the mill two days after the point of ordering. In addition, it should be pointed out that the finished tobacco flour usually includes a mix of grain sizes. A large part of this production process is managed automatically by the mill, and the operators working in the mill use a control panel to supervise the mill process (Managers at SM, 2016).

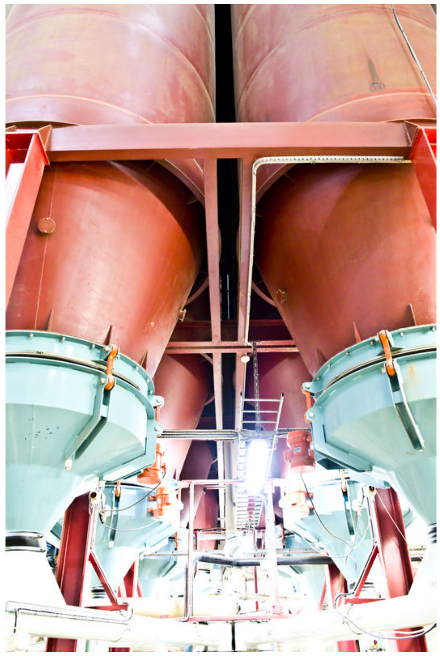


Figure 4.3 Silos where the milled tobacco flour is stored until it is needed in the pasteurization process (Swedish Match, 2016b)

The Steps of the Mill Process

As outlined in Figure 4.4, six steps follow after cardboard boxes containing the raw tobacco arrive to the mill. First, the boxes are stored on pallets until there is enough space in the subsequent steps. Second, the cardboard boxes are put on a conveyor belt, which is bringing them forward to the next step and the operators perform a visual inspection. This inspection includes making sure to remove any material not intended for the production process as well as discarding raw tobacco of poor quality. Third, the actual milling of the raw tobacco and sieving of the milled tobacco takes place. This includes cutting the raw tobacco into pieces that more easily can be handled by the mill. Then, the tobacco is processed through a mill after which the milled tobacco is sieved. This means that grains that are too large to comply with the recipe's specified granularity are sent back and processed through the mill one more time. Fourth, the milled tobacco is processed through a mixing machine, which blends various grain sizes to attain a homogenous composition. The mixing machine is started manually after the mill has stopped. It stops automatically after a predetermined time has elapsed. Fifth, the moisture and fraction division of the milled tobacco is controlled. Sixth, the approved tobacco flour for the PSO General is stored in a silo used for this specific flour. This step is started manually (Managers at SM, 2016). The flour can be stored in the silos for a long period of time as it does not go bad. The average time is 18 days (Operators at SM, 2016).

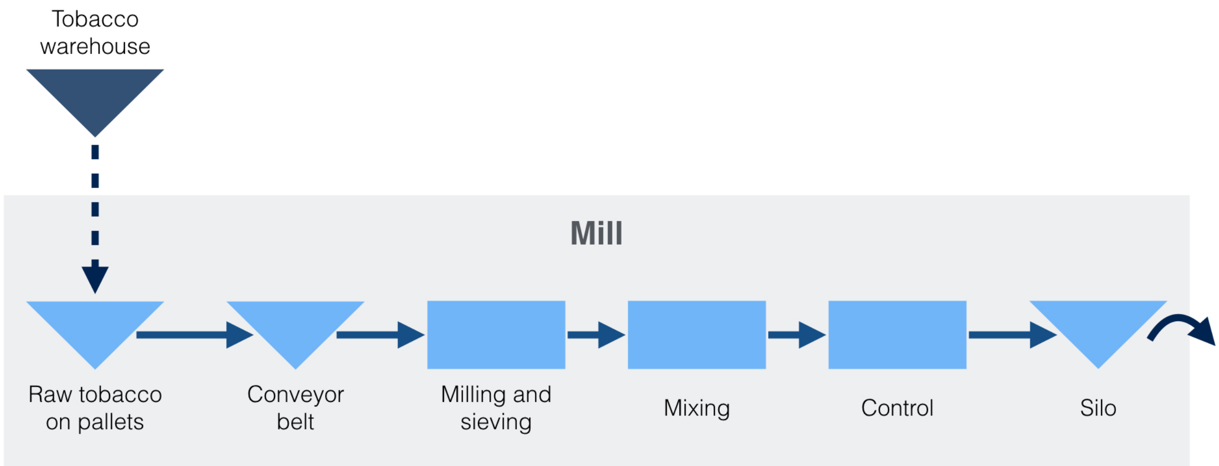


Figure 4.4 An overview of the mill process

In the mill, the overall process of manufacturing the different flour types used in the recipe of the PSO General does not vary significantly from the flour of any other product type (Operators at SM, 2016).

Data Collection in the Mill Process

Data is only collected at a few points throughout this part of the production process. The level of the flour in the silos is the first part of data that is collected. The operators use this data to decide when to order raw tobacco from Kungälv. The second main point of data collection in the mill process takes place in the control after the milling, sieving and mixing steps. Here, data containing information from the controls of the milled tobacco is collected. This data is used to determine whether the flour is of a quality corresponding to it being approved for the next sub process in the production process (Managers at SM, 2016).

Improvement Opportunities in the Mill Process

Historically, the mill has been operationally reliable and it has had few problems. This has resulted in little need for investments in the mill equipment. However, the equipment is currently starting to get old. Combining these aspects with today's demand for a faster milling process and a more complicated product assortment, results in the current equipment being considered as outdated. In addition, the mill provides both the Gothenburg and Kungälv factory with tobacco flour. If the mill would break down during a longer period, it stops the following steps in the production process in both production sites. Clearly, these factors result in a greater sensitivity in the mill process (Operators at SM, 2016).

The operators working in the mill have deep knowledge and skills, which clearly is required by the current setup to attain tobacco flour of a feasible quality. Human judgment is required to control the milled tobacco during the process. This makes it is troubling that the staff turnover increases. Much of the daily work in the mill considers process supervision, addition of tobacco and taking samples, which are all necessary factors to ensure a good quality of the tobacco flour. An increased degree of automation could ease the work of the operators as well as reduce the risks of errors, stops and employees changing jobs (Operators at SM, 2016).

Additionally, there is lack of real time control in the mill. As mentioned, the process starts and the flour is controlled and analyzed first when the whole process is completed. The only measurement taken during the process is when the operators measure the flows of milled tobacco through the system, which is done by feeling it with their hands. Furthermore, there are no sensors measuring environmental conditions, such as temperature or air humidity. As the samples are taken when the entire process is completed, adjustments are difficult to make. The only way to change the composition of the finished flour is to redo the entire process, which is not economically feasible. Therefore, the tolerance spectrums for the moisture and the fraction division applied for approving the quality of the flour are rather wide. In addition, there is a limited understanding of why the finished flour varies (Managers at SM, 2016).

Furthermore, there is no direct connection between the mill and the subsequent steps in the production process in terms of quality and information sharing. This is demonstrated in two main ways. First, there is little knowledge regarding how the characteristics of certain tobacco flour affect the later packaging. The characteristics can include the humidity, fraction division as well as the composition of different raw tobacco types. Depending on whether the tobacco is grown in the United States or in Indonesia, the type of tobacco differs. Little is known regarding whether and how this affects the manufacturability and the production process. Second, the little information that actually is collected is registered in an Excel sheet within the mill function, which is not shared with the other sub processes in the production process (Managers at SM, 2016).

4.3.2 The Pasteurization

The main purpose of the pasteurization process is to ensure the subsequent packaging process with access to packable snus. Thus, the snus needs to be of a good quality. The pasteurization process includes the actual pasteurization of the tobacco, the addition of flavor according to the recipe and to deliver the snus to the packaging process. The responsible operator plans the start of new recipes on a daily basis. This work is supported by the collection of updated and detailed planning lists every morning. The planning lists are based on what products that are packed at the packaging process (Managers at SM, 2016). An example of a mixer in which the snus is pasteurized is visualized in Figure 4.5.

Figure 4.5 A mixer used to pasteurize the snus (Swedish Match, 2016b)

The Steps of the Pasteurization Process

The pasteurization process follows right after the mill process and comprises of six subsequent steps, see Figure 4.6. The majority of the steps in this sub process are managed automatically. First, a specified recipe is started when the planning is finished and all required additives are available. Salt, water and tobacco flour are added to the mixer and processed between 16 and 24 hours depending on the type of snus. The tobacco flour is retrieved from the silos in the mill. Second, substances, such as flavor and soda are added to the snus in the mixer and it is tumbled. Note that the tobacco is processed through pasteurization and cooling in the mixer. Third, the chemical analysis laboratory takes a sample of the snus in the mixer to control that predetermined specifications are met. Fourth, the tobacco is emptied into containers once the sample is approved. Fifth, the containers are stored until they are emptied into the packaging line. If the container with snus is to be stored for a longer time period, it is put in a refrigerator warehouse. Sixth, the containers are put on top of an emptying machine. It pours the snus out of the containers by continuously sending doses of the tobacco right into the packaging process. The size of these doses is adapted to the capacity of the packaging process (Managers at SM, 2016).

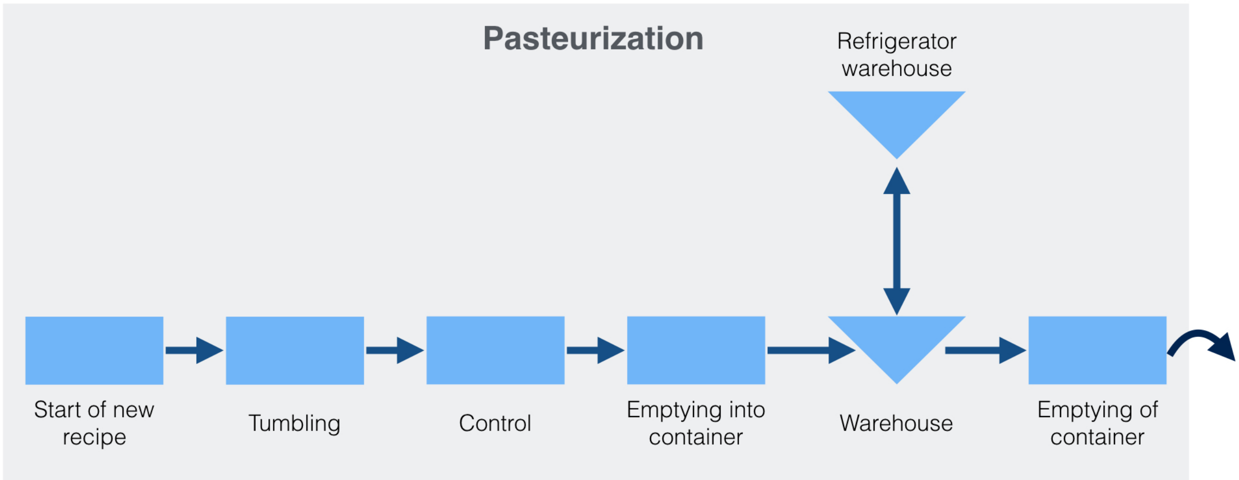


Figure 4.6 An overview of the pasteurization process

In the pasteurization process, the overall procedure varies slightly depending on whether it is the PSO General or another product. First, the process time is 18 hours for the PSO General. Second, General uses a specific mixer size. There are different mixer sizes, and it is the demand of snus and the volume produced that determines the size of the mixer. As the demand for General is high, usually the larger mixers are used to pasteurize this specific product. After the snus sample is approved, the snus is usually stored in a cooler storage. The snus can be refrigerated up to ten days, and when a product is stored during a longer time, it results in a high level of inventory. However, General is rarely stored in the refrigerator storage as the volume turnover of this product is high. Usually, it is the products corresponding to a smaller consumer demand that are stored longer (Operators at SM, 2016).

Data Collection in the Pasteurization Process

Similar to the approach in the mill process, data is only collected at a few points in this part of the production process. First, the machine itself registers the current temperature and humidity as the snus is tumbling. This information is used for the machine to add more water vapor to maintain appropriate levels of the temperature and humidity. After the tumbling step is completed, data is collected through a control. This control can be referred to as sampling. It is this data that ultimately determines whether the snus is approved or not. The information from the control is put on a RFID tag that is connected to a specific container (Managers at SM, 2016). The RFID tags and the application at SM are further described in the end of this chapter.

Improvement Opportunities in the Pasteurization Process

A significant issue in the pasteurization process is large amounts of waste. Every year, a significant quantity of high qualitative and approved snus is thrown away from the Gothenburg factory. This implies a major monetary waste as well. The levels of waste have increased during recent years, much due to the introduction of new products and smaller batch sizes. A contributing cause of this issue is the fact that the pasteurization process is adapted to mass manufacturing of few SKUs. This means that the mixers are too large to handle today's increasing number of SKUs in an efficient manner. Currently, SM is not able to meet the demanded quantities exactly per kilogram, which would be a feasible scenario in order to reduce the waste (Managers at SM, 2016; Operators at SM, 2016).

However, it should be noticed that the even demand and large production volume of General contribute to the fact that this product accounts for a relatively small portion of the overall waste (Managers at SM, 2016; Operators at SM, 2016). Moreover, the large sales volume of General implies significant production volumes of the product. Thus, the large mixers can be used for pasteurization of General without resulting in massive waste. The waste stemming from General is therefore smaller than the corresponding ones from SKUs accounting for a smaller portion of the total sales volume (Operators at SM, 2016).

The characteristics of the manufactured snus deviate from time to time, even though what seems to be the exact same procedure and recipe are repeated. Each recipe has a few ingredients that are fixed, such as salt, sodium and flavor. The amount of water vapor to adjust temperature and humidity is unknown. Also, the characteristics of the specific tobacco flour is unknown the operators in the pasteurization process (Managers at SM, 2016).

In addition, the properties of the snus emptied in a number of containers but manufactured in one mixer at the same time vary, despite the fact that those characteristics should be identical. Currently, SM lacks knowledge to the underlying reasons of this issue. Additionally, the tolerance spectrum regarding the characteristics of the snus leaving the pasteurization process are perceived as quite wide, which may result in problems in the following packaging process (Managers at SM, 2016). The perception in the pasteurization process is that it is not that hard to provide snus within the required tolerance spectrum and that it should be possible to apply a narrower spectrum (Operators at SM, 2016).

An issue arisen during the last year is undesired lumps of sodium carbonate in the produced snus. The lumps are formed due to a natural process, but there is no knowledge of why this suddenly started occurring at SM. This causes problems in the subsequent packaging process (Operators at SM, 2016). As for the mill, there is also the issue of limited direct connection between the pasteurization and the subsequent packaging process, as well as the previous mill process. This may result in inability to find the causes of the occurred problems, such as the sodium lumps (Managers at SM, 2016).

Another issue in the pasteurization process is the reactive way of working, especially in terms of quality controls and maintenance. As previously described, quality controls are performed after the entire process is completed. Currently, about one of ten samples is not approved due to poor quality. Then, either an adjustment is made or the entire batch is rejected altogether. None of these two situations are economically supportable (Operators at SM, 2016).

As mentioned, maintenance of the equipment in the pasteurization process is mainly performed manually and rather reactive. This means that it is common that it takes place after a device breaks down. As the pasteurization takes 18 hours, it continues during the night. Naturally, problems or stops in the machines can occur during nighttime. Currently, certain operators are on standby and whenever a stop occurs, they can either solve it through their computer that they bring home or by going to the factory directly. However, some problems cannot be solved until the employees with the right skills arrive the next morning. Both unintended stops and breakdowns slow down the pasteurization process and complicate the work of the operators. However, planned maintenance based on certain time intervals has recently been implemented to decrease the unintended downtime (Operators at SM, 2016).

Another issue is that the operators experience high pressure due to the increasing number of SKUs. Moreover, the operators in the pasteurization perform planning, supervision of the process and correcting minor unintended stops. Much work is performed based on previous experience, since there is deep knowledge about the process and how to manage it. Training of new employees to provide them with fundamental experience requires about a year. As all tasks become more complicated, it is more demanding for the employees to base decisions on experience. As a result, the planning of what should be produced at what time is becoming harder as more SKUs are introduced. In addition, the work of the employees in the pasteurization can be obstructed by difficulties to find necessary information and there is a continuous aim for avoiding excessive waste (Operators at SM, 2016).

4.3.3 The Packaging

The main purpose of the packaging process is to ensure attaining desired inventory levels of finished PSO of the right product quality (Managers at SM, 2016). As mentioned, there are several lines in the packaging department. This study focuses on a specific packaging line, which is producing the PSO General. The packaging line has of six pairs of packers, resulting in 12 single packers. In addition, there are machines for labeling, wrapping and packaging finished goods in cardboard boxes (Operators at SM, 2016). Compared to other packaging lines, this one has a higher degree of modern equipment, which can be beneficial if new technologies are implemented (Managers at SM, 2016).

The main part of the packaging process is managed automatically, even though some manual handling occurs. The packers are provided with cans, lids, tobacco and pouch paper that are sent from their respectively storage. The processed tobacco is supplied to the packer directly in pipelines from the pasteurization process. Cans and lids are sent to the packaging line using a conveyer belt, while an operator needs to manually add rolls with pouch paper (Operators at SM, 2016). Figure 4.7 visualizes the part of the packaging process where lids are added to the cans. The cans on the picture have been filled with portioned packed snus in a previous step.

Figure 4.7 A part of the packaging process, where lids are attached to the cans, which have been filled with portioned packed snus (Swedish Match, 2016b)

The Steps of the Packaging Process

Similar to the mill and pasteurization process, the packaging process comprise of multiple steps, more specifically of eight on each other following steps, see Figure 4.8. First, the processed tobacco is put in pouch paper. After this, the machine cuts and welds it into separate portions of snus. Then, the cans are filled with a predetermined number of portions and a lid is put on. Second, the cans are transported on a conveyor belt and an operator controls the characteristics by taking a sample. The controls are conducted based on a fixed time interval and considered aspects include the final weight and appearance of each individual pouch. Third, a conveyer belt transports the snus cans to a labeling machine, where labels are attached. Fourth, a wrapping machine batches groups of ten cans into rolls covered with plastic. Fifth, the rolls are brought through an oven. This fixes the rolls as the plastic shrinks around it. Sixth, a robot puts a predetermined number of rolls in a cardboard box. Seventh, a machine puts the filled cardboard box into an elevator. Thereafter, it is transported into refrigerator storage. Eight, the cardboard boxes containing rolls of snus cans are stacked on pallets in the refrigerator storage until being further transported to the customer's premises (Managers at SM, 2016).

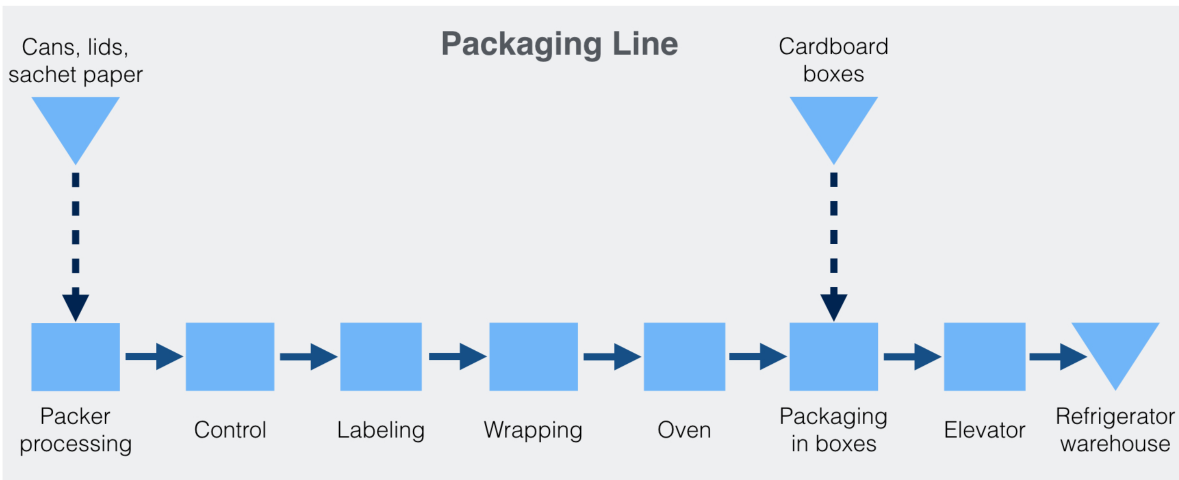


Figure 4.8 An overview of the packaging process

In the packaging process, the steps in the process of producing the PSO General do not vary significantly from any other product type. Compared to General Classic White, which is produced in Kungälv, moisture is added after the tobacco is put in the pouch paper. This results in the pouch becoming light brown in their color, instead of white. However, the specific packaging line, where the PSO General is produced varies from other packaging lines in the factory. First, the equipment is more modern than in others in the Gothenburg factory. Second, less downtime and planning are needed, since it mostly is the PSO General that is produced at this line. This means that there are lower changeovers times required, compared to a line where many different products in smaller batches are manufactured. When many small batches are produced, a larger flexibility is needed in the production line (Managers at SM, 2016; Operators at SM, 2016).

Data Collection in the Packaging Process

Compared to the mill and the pasteurization, the packaging process has the highest number of data collection points (Managers at SM, 2016; Operators at SM, 2016). Note that the points of data collection are not described on a detailed level, since this master's thesis is limited to a general description of the production process. The examples of data collection are only presented to provide a general idea of the matter.

First of all, the machines register data, such as the one about the number of produced cans, the amount of machine stops as well as of what types of stops that occur. This data is used to further optimize the packaging process, for example by changing the pace of the machines (Managers at SM, 2016). In addition, data is collected through both automatic and manual controls. Automatic quality controls are performed continuously by usage of sensors to determine the weight of the can or whether the lid is attached correctly. If the snus is to light-weighted or if the lid is crooked, the can is automatically thrown away. Manual controls are performed three times each hour. The purpose of the manual controls is to check the final weight and appearance of each individual pouch. The data from this control is registered on papers and stored in folders. If the data from the control shows that the snus is not within the right tolerance spectrum, it is rejected (Managers at SM, 2016; Operators at SM, 2016).

Improvement Opportunities in the Packaging Process

Similar to the mill and the pasteurization process, there is neither a clear nor standardized connection between the packaging process and the two previous sub processes (Managers at SM, 2016). The majority of the problems in the packaging line are solved manually (Operators at SM, 2016). The quality of the outgoing snus of the packaging process is more or less affected by all incoming material. Moreover, the quality and characteristics of the incoming cans, lids and pouch paper have an impact on the packaging process and whether it runs smoothly or not (Managers at SM, 2016).

For example, lids could get stuck on the line (Operators at SM, 2016) and glue on the pouch paper can make it harder or even impossible to use it in the packaging process (Project managers at SM, 2016). Problems regarding the characteristics of the incoming snus include it being either too sticky or too crumbly. Another issue is lumps of sodium carbonate that get stuck in the packer, which ultimately results in stopping the packer. There is also a risk of not identifying all lumps prior to sending the finished goods to the customer. This can result in the consumer being the one who finds the lumps, which is problematic for the company. In fact, there are examples of consumers claiming to have found glass in the snus. However, the real answer here is that what they have found usually are sodium lumps. Of course, this is not feasible but it does not imply the same kind of risk for the consumer as glass does (Operators at SM, 2016).

Another issue in the packaging process is the reactive way of working, especially in terms of quality controls and maintenance. As previously mentioned, both automatic and manual quality controls are completed in this sub process. The manual controls are performed in a reactive manner as they are conducted three times per hour after the snus has been packed. When finding snus that does not fulfill the predetermined criteria during the controls, it is likely that the snus in this specific can is not the first to be inadequate. As a result, the operators either have to go through the cans that have been produced during the past 20 minutes or if time is limited they have to reject everything produced in that specific time span. Furthermore, the maintenance of the machines in the packaging process takes place according to a specific time schedule. More specifically, the machines are continuously controlled every sixth week (Managers at SM, 2016).

In this sub process, much has been adjusted recently to facilitate the work of the operators. For example, information that previously had to be handled manually is now automatically handled. Many of the operators are satisfied and cannot think of any specific or major issues in this step of the production process (Operators at SM, 2016). However, there is still significant pressure put on the employees doing the production planning even though much has been improved (Project managers at SM, 2016).

4.4 Current IT Landscape

Currently, SM has numerous hardware and software components as well as employee competencies to support the steps of the production process. The number of components and the degree of technology implemented vary throughout the production process (Managers at SM, 2016). To fully understand the current hardware, software and competencies at SM, each element is presented in the sections below.

4.4.1 Hardware

There are different types of hardware components in the production process. The purpose of the hardware presented in this section is related to generating appropriate data. SM uses machines, sensors and RFID tags in their production process to gather and register data. In the mill, pasteurization and packaging, there are different types of hardware components. The amount of hardware components in the mill is limited. Here, data is gathered manually, more or less with no help from hardware components (Managers at SM, 2016).

There are more hardware components in the pasteurization process. In the mixing process of the snus, the machine or mixer registers the current temperature and humidity levels. Between the process of mixing the snus and emptying container into the packaging line, RFID tags are used. These RFID tags register information of the snus automatically, instead of having the operators perform this task manually. Each container has a passive RFID tag that informs the emptying machine regarding the information about the snus (Operators at SM, 2016; Project managers at SM, 2016).

Lastly, there are hardware components in the packaging process. First, the packaging machines themselves can gather the data that is used to calculate KPIs, such as performance measurements. Second, there are multiple sensors throughout the packaging line. These sensors are partly used to control a number of quality aspects, such as the weight of the snus and that the lids are put on correctly. In addition, the sensors are used to identify stops in the process. Moreover, there are multiple sensors on the conveyer belt between the machines that register if the conveyer belt is overfilled with snus cans or not. The packaging, labeling or wrapping machine can stop if the conveyor belt is overfilled. Which machine that stops is depending on where the problem occurs (Operators at SM, 2016).

4.4.2 Software

In this master's thesis, the software components at SM are divided into three categories based on how the hardware components are connected, how the collected data is stored and how the collected data is analyzed.

First, a wireless local area network (WLAN) is used in the Gothenburg factory. Moreover, SM has built a network comprising of three levels, namely an administrative level, a demilitarized zone (DMZ), and a process level. For example, corporate mailboxes are located on the administrative level while human-machine interfaces (HMI) are located on the process level. SM has introduced the DMZ to secure the systems that are controlling the machines closely related to the production process. The DMZ is a sub network that is used to protect the internal network from an unreliable network, such as the Internet. Therefore, the machines are not directly connected to the WLAN in the factory (Operators at SM, 2016; Project managers at SM, 2016).

Second, the collected data is stored on servers and not through utilizing a cloud. Due to the DMZ, machines are connected to internal servers. In addition, the data that is gathered is stored in different information systems depending on where in the process the information is collected (Project managers at SM, 2016).

Third and last, the collected data is analyzed in different ways. How information is analyzed today is represented by three examples. The first example refers to that the production plan is determined using manual analysis of market demand and factory capacity. The second example considers the continuous analysis of the efficiency measurements in the packaging process, which is performed in order to optimize the speed of the machines and to minimize breakdowns. The third example includes that customer complaints are received from the customer department around two months after the point in time when snus is produced. This can make it hard to understand what actually caused the problem with the specific finished product (Project managers at SM, 2016).

4.4.3 Competencies

Currently, the operators working in the production process represent many different generations. There are several examples of employees in production process who have over 20 years of experience. Naturally, there are also other ones who only have worked there for a few years or for an even shorter time period. Generally, younger generations are inclined to change employer more often, while older generations tend to be more loyal towards their employer. The number of young employees increases in the company, which is a contributing factor to the fact that the employee turnover has increased during recent years. However, it is still considered as quite low (Operators at SM, 2016).

Historically, the work tasks of the operators have been adapted to the standardized way of working. This was a feasible approach to apply when the product portfolio included a limited number of SKUs. However, more responsibility is put on both operators and resource planners as the complexity currently increases. Many decisions included in the operators' work are based on previous experience and human judgment. As a result of these experience-based decisions, it takes a long period of time for operators to fully learn and understand the production process. For instance, it takes more than a year to acquire what is considered as enough knowledge to run the pasteurization process in an optimal manner (Operators at SM, 2016). When considering the resource planning, it should be pointed out that an increased number of SKUs makes the production planning more complex. Therefore, the employees working with planning experience increased pressure (Managers at SM, 2016).

During recent years, the employees have partly adapted to a new IT structure as an enterprise resource planning (ERP) system for management of business processes was implemented. SM has an IT department to support the production and its operators in an environment where IT and its importance are becoming increasingly present. The IT department is centralized and it can be reached by phone during the daytime. The department is mainly responsible for the systems and network outside the DMZ. More specifically, this includes the information systems on an administrative level rather than the control systems in the production process (Project managers at SM, 2016).

4.5 Summary of the Empirical Data

A consistent theme throughout the production process is that the quality of the end product is of significant importance. When investigating the production process of the PSO General, a number of overall improvement opportunities emerge. The four main improvement opportunities are displayed in Table 4.2.

	Improvement opportunities
1.	Lack of internal process integration
2.	Reactive approach, instead of proactive
3.	High pressure is put on employees
4.	Perception that much data is stored, without being made available, combined or visualized at the right place

Table 4.2 Summary of key improvement opportunities in the production process of the PSO General

First, there is limited internal process connection between the sub processes, meaning that there is lacking knowledge in the mill, pasteurization and packaging regarding the other sub processes, its conditions and problems. In other words, the internal process integration in the production process is low. This makes it hard to find and understand root causes of various problems. Thus, there is a limited ability to mitigate these emerged issues.

Second, there is a reactive approach to the work being conducted throughout SM's production process. For instance, SM strives towards working more proactively by steering and directing the production process, instead of controlling already produced goods. Moreover, there is currently an overall reactive approach towards controlling the goods in each production sub process. The produced goods are controlled after parts of the manufacturing process is completed, rather than applying a more proactive approach where incoming goods are controlled to a wider extent in the steps of each sub process. In other words, the process should be controlled instead of the finished goods to enable making it correct from the beginning. In addition, SM applies an approach to maintenance meaning that a machine is served based on a fixed time schedule or in some cases, first after a breakdown. Ultimately, this results in consequences such as unintended downtime and breakdowns.

Third, high pressure is put on the operators in the production process even though this is something that SM strives towards avoiding. Reasons include that much work is conducted based on previous experience as well as the increased challenge of planning what to produce at what time. More specifically, the employees working with planning do sense increased pressure as the production planning is becoming more difficult due to the increased amounts of SKUs. In addition, human judgment is required in many steps throughout the manufacturing process.

Fourth, there is an overall perception that significant amounts of data are gathered, for example from hardware components including sensors and RFID tags. This data is then stored in internal servers in the production process of General. However, it is not clear which data that is actually collected and it is not available at the right location when needed nor combined or visualized in a clear manner. In some cases, the required data for performing a certain task is not available to the employees or even missing, since the right data is not always collected. There are examples of data that is collected in the production process that is not used, simply because there is a perception that it always has been collected. In addition, the collected data is not always perceived as reliable, meaning that additional quality assurance is necessary.

5 Analysis

This chapter begins with an analysis of the characteristics of the studied product and a matching supply chain strategy is suggested. Then, a gap analysis is conducted to find possible applications of big data and IoT in the production process of SM. In addition, a risk analysis is conducted to point out critical risks that need to be accounted for when utilizing the two technological advances. Lastly, the analysis is summarized and suitable applications are suggested.

5.1 Supply Chain Strategies

As mentioned in the frame of reference, it is of high importance to understand SM's product offering, its characteristics and the implied requirements. In addition, it is essential to understand which supply chain strategy that is matching the characteristics of the product. This knowledge enables making a suitable decision regarding whether or not to perform a certain change to the business and its setup. Therefore, these aspects are also fundamental when a firm considers utilizing new technological advances, such as big data and IoT. Moreover, this enables the firm to maximize the potential of the technologies and to understand what applications are most feasible in a specific case. Therefore, this chapter elaborates on these matters. First, the PSO General is analyzed in terms of the PLC and whether it can be considered as a functional or innovative product. Then, a supply chain strategy matching the product's characteristics is suggested and strategic fit is also considered.

5.1.1 The Product Life Cycle

As discussed in the frame of reference, the PLC can be used to evaluate a product. More specifically, the product is assessed depending on its sales volume over time. When considering the characteristics of the PSO General, there are indications of a stable sales volume over time. There are also an increasing number of competitors penetrating the snus market in Scandinavia. These two factors indicate that the PSO General is in the maturity phase. There are three factors of great importance for a product in the maturity phase. The included ones are high quality, an efficient production process and a strong brand. Based on the vision and strategy of the company, SM empathize quality significantly. This further motivates the positioning of the studied product in the maturity phase of the PLC. Figure 5.1 visualizes the positioning of the PSO General.

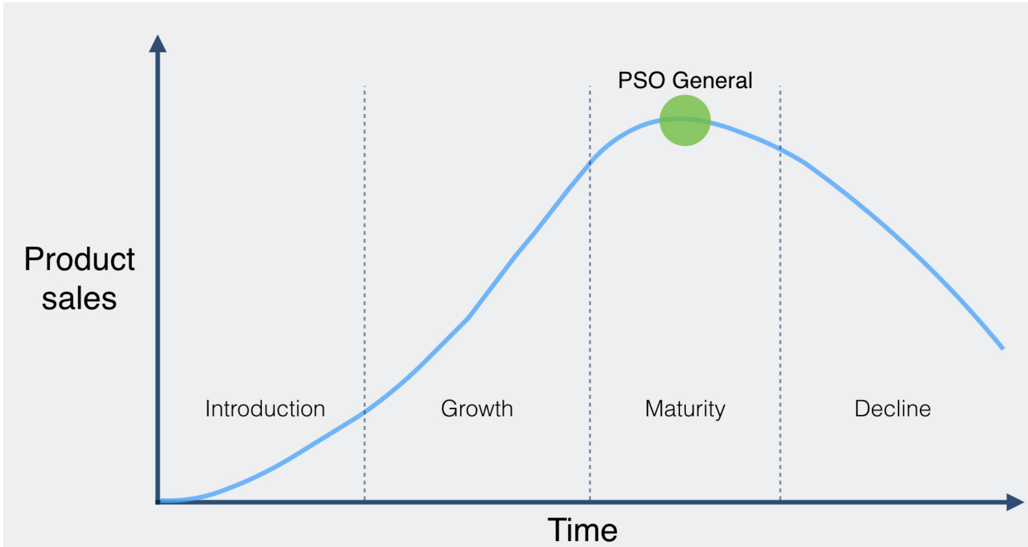


Figure 5.1 The PSO General is positioned in the maturity phase of the PLC

5.1.2 Functional or Innovative Product

In addition to the PLC, the attributes of a product can determine whether it is functional or innovative. Depending the product categorization, a suitable supply chain strategy can be recommended. As mentioned in the frame of reference, there are eight attributes to consider suggested by Fisher. The first attribute relates to the characteristics of the demand. The PSO General has a stable demand that does not vary by the seasons. As a result, the demand is predictable and this attribute implies that the PSO General is a functional product.

The second attribute relates to the length of the product's PLC. More specifically, to how long the product is competitive in the market. The PLC of SM's products vary depending on whether considering standard or nonstandard products. The PSO General is classified as a standard product and therefore this analysis focuses on standard products. As mentioned, the brand General has existed in SM's product portfolio for 150 years. This motivates that the PLC of the PSO General is longer than the two years, which is suggested by Fisher for classifying it as a functional product.

The product's contribution to margin is the third attribute. In the case of the snus and SM, the margins are generally high. In fact, this is the case for the PSO General, which suggests the product being innovative. The fourth attribute is associated with the variety of the product. When observing the General PSO, the product varies rather little. For example, labels are modified to correspond to either the Swedish or Norwegian market. Moreover, the modifications for this PSO do not reach beyond the 20 variants that Fisher has specified as an upper level for functional products. Consequently, this attribute further motivates that the PSO General is a functional product.

Other attributes relate to accuracy of forecasts, stockout rates and seasonal discounts. As the demand of the product is stable and does not change depending on the season, the forecasts are reliable, the average stockout rate of the PSO General is low, and discounts are rare.

The eighth and last attribute considers the lead time required for made-to-order products. Depending what is included in the lead time of SM, the lead time required by a product varies. If the lead time includes the purchasing of raw tobacco, the mill, the pasteurization and the packaging process, the lead time is over six months at SM. However, the lead time can instead be measured from pasteurized snus to having a cardboard box of finished snus. This reasoning is motivated by the fact that there are large amounts of stored tobacco flour in the silos and pasteurized snus in the cooling containers. If applying this second approach to the lead time, it is only a few days long and much more flexible. As a result, SM can respond quickly in order to fill up the missing inventory if there are stockouts in the customer's DC. The shorter lead time motivates that the product is innovative rather than functional.

Based on the attributes used to categorize the product, the PSO General leans towards being a functional product. Even though there are some rather innovative attributes, such as the high contribution to margin and the short lead time, the majority of the attributes motivates the PSO General to be a functional product. More specifically, the indications show that the PSO General checks six attributes corresponding to it being a functional product and two for being an innovative product. See Table 5.1 for an overview of these characteristics.

Aspect	Functional product	Innovative product
Characteristics of demand	X	
PLC	X	
Contribution to margin		X
Product variety	X	
Average margin of error in the forecast at the time production is committed	X	
Average stockout rate	X	
Average forced end-of-season markdown as percentage of full price	X	
Lead time required for made-to-order products		X

Table 5.1 The PSO General leans towards being a functional product since it checks six of these characteristics and only two of the innovative ones

5.1.3 The Matching Supply Chain Strategy

As mentioned, it is important to understand both the product and the supply chain strategy to enable an adequate decision regarding changes. This includes alterations associated with the ones concerning the utilization of new technologies, such as in this case when considering big data and IoT. Consequently, this understanding can be considered as fundamental to enable maximizing the potential benefits associated with a change or staying competitive in a changing business environment.

Since the PSO General is considered to be a functional product, a physically efficient supply chain strategy is the most appropriate one. Moreover, this supply chain strategy is similar to the lean approach defined in the frame of reference. This all means that SM should apply a supply chain strategy that is focused on supplying the predictable demand of the PSO General in an efficient manner while minimizing costs. This can for example be realized by making sure to keep a high average utilization rate and minimizing lead times as much as possible, all as long as it does not result in increased costs. Figure 5.2 displays the matching area between the functional product and the physically efficient supply chain strategy.

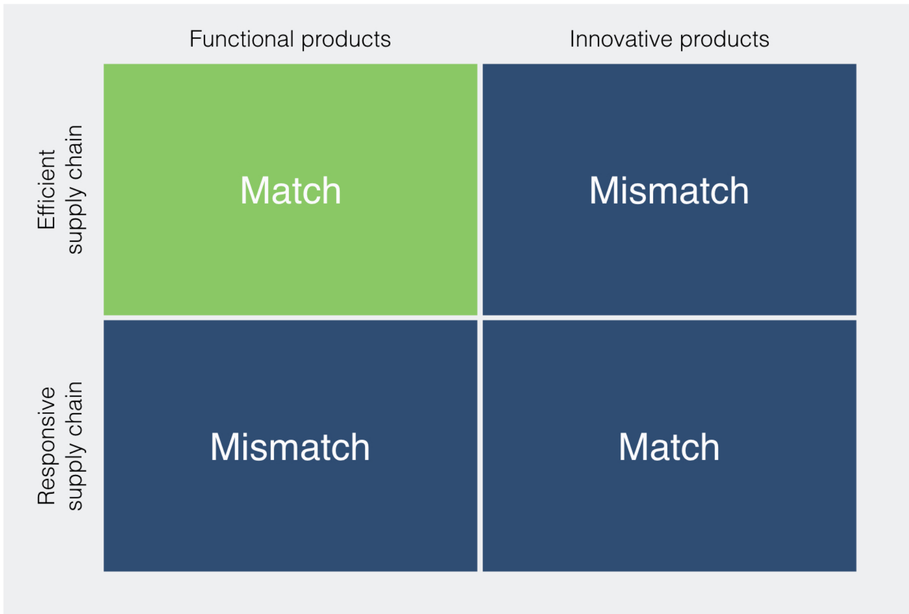


Figure 5.2 The matching area between the functional PSO General and a physically efficient supply chain strategy

5.1.4 Strategic Fit

As mentioned, it is of high importance for the success of a company to achieve strategic fit between its supply chain strategies and its competitive strategy. Therefore, it is important to understand SM's supply chain strategy in great depth. This becomes especially important due to the fact that SM considers utilizing big data and IoT in their production process. By both understanding the motives and SM's supply chain strategy, the most suitable decision regarding whether or not to implement big data and IoT can be made.

Clearly, it is essential to understand what incentives and reasons there are for SM to implement the two technological advances. Key motives for SM to implement big data and IoT include the fact that their business environment has shifted. The increased complexity in the production process that has followed motivates the search for new technology. Here, it is important to make sure not to implement new technologies only based on a reason such as the feeling that all competitors do so. SM need to make sure that implementing big data and IoT in their manufacturing process actually enables alignment between the functions of the company, facilitates problem solving, and fosters attainment of mutual goals.

The most suitable supply chain strategy is, as mentioned, considered to be the physically efficient one since this master's thesis focuses on the PSO General. It is important to make sure that this supply chain strategy is well aligned with SM's competitive strategy. Furthermore, Figure 5.3 highlights the zone of strategic fit for the PSO General. Clearly, the demand uncertainty for this product is considered to be low and to stay in the zone of strategic fit, an efficient supply chain strategy is the feasible one to apply. This further motivates the reasoning regarding the suitable supply chain strategy in this study.

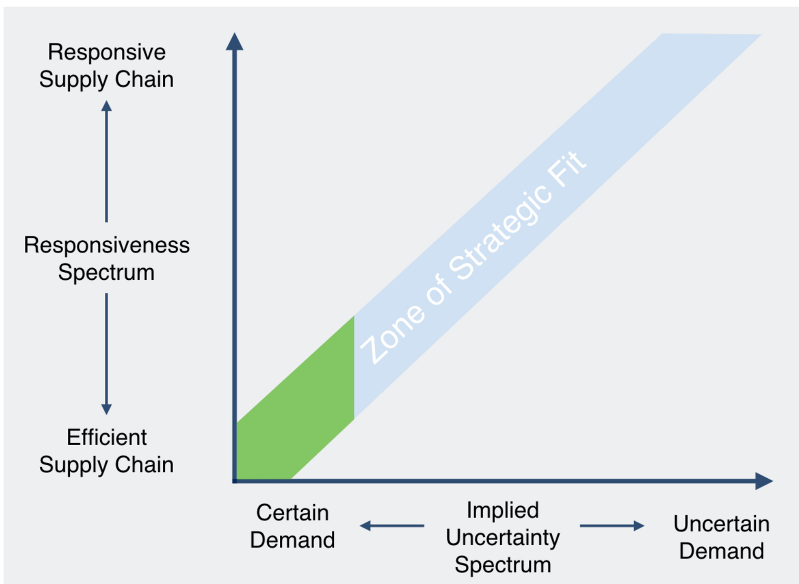


Figure 5.3 The highlighted area indicates the zone of strategic fit of the PSO General

5.1.5 Summary of Supply Chain Strategies

To summarize the reasoning in the sections above, SM should focus on increasing the efficiency in their production process while minimizing costs. Since this master's thesis focus on the PSO General, which shows indications of having a certain demand and being a functional product, the suitable supply chain strategy is the physically efficient one. In addition, this enables realizing strategic fit, which is an important factor for being a well-performing company in a market with increasing presence of competitors.

After first understanding the product's characteristics and the suitable supply chain strategy, it becomes clear that the most appropriate applications of big data and IoT in SM's production process are within the fields of manufacturing optimization as well as preventive and predictive maintenance. This is also motivated by the fact that the PSO General has a certain demand and is in the maturity phase of the PLC, where the focus should be on establishing and maintaining an efficient and lean production process. In addition, the high quality of the finished goods is an essential aspect to consider. Thus, it should be emphasized at all times throughout the entire production process. This is an aspect that can be improved and that is clearly connected to both manufacturing optimization as well as preventive and predictive maintenance. In other words, this further motivates the focus on these two areas of applications.

Furthermore, the focus should not be on understanding the product from the perspective of customers or consumers. This is motivated by the fact that little attention is required to predict the future demand of the PSO General. In contrast, prediction of the future demand is of a higher importance if considering an innovative product. The same principle applies for products in the introduction or growth phases of the PLC. In addition, the focus should not be on efficiently terminating the production of the PSO General by minimizing obsolete inventory and machines for a time when the product is no longer produced. This would, however, be the case if the product had been in the declining phase of the PLC. This reasoning and the one presented in the frame of reference make it clear that SM should focus on different aspects depending on where the product is in its PLC.

This reasoning makes it clear that there are suitable applications of big data and IoT to utilize in a production process. As mentioned, the most feasible ones for SM and the PSO General is in the areas of manufacturing optimization as well as preventive and predictive maintenance. Both applications can increase the efficiency SM's production process while at the same time minimizing its costs. This means that the two applications are both well aligned with the suggested supply chain strategy. The applications will be further discussed in the next part of this chapter.

5.2 Gap Analysis

Once it has been established that big data and IoT can be utilized successfully by SM and after the recognition of relevant applications, an analysis regarding how more specific issues in the production process can be resolved through big data and IoT is conducted. The purpose is to understand why SM would like to implement big data and IoT, and how the production process can be optimized using the two technologies. In this master's thesis, optimization refers to an uninterrupted flow of finished goods and avoidance of defects.

In the empirical data, four main issues were identified in production process of SM. Table 5.2 provides a comparison of the current situation, the desired situation as well as the resulting gap between these two situations. There are four gaps, one for each issue identified in the empirical data. The four gaps are within the fields of a lack of internal process integration, a reactive approach, a high pressure put on employees, and data management.

	Current situation	Desired situation	Gap
1	Limited information sharing between sub processes in the production process	Well-integrated internal processes	Lack of internal process integration
2	The process steps and the goods are controlled after they are completed, which comprises quality, efficiency of resource usage and maintenance	Steer the process steps and prevent errors from happening, all to improve quality, resource usage and maintenance	Reactive approach, instead of proactive
3	Work based on previous experience and decisions based on human judgment	Standardized approach to work-tasks and decision-making based on data	High pressure is put on employees
4	Data is collected in a non-standardized manner	Collection of data that is combined, visualized and made available to employees	Much data is stored, without being available, combined or visualized at the right place

Table 5.2 Gaps revealed by comparing current situations with the desired ones

In the following sections, each gap is further analyzed. Here, important aspects to cover are reasons causing the gap to occur and its consequences on the production process. The desired situation explains how the production process would function if the gap is reduced. Furthermore, the possible solution discusses how each specific gap can be reduced with the help of big data and IoT. It should be pointed out that many gaps can be addressed using similar approaches or solutions.

5.2.1 First Gap: Lack of Internal Process Integration

The first identified gap is lack of internal process integration. In other words, there is limited connection between the mill, the pasteurization and the packaging process in terms of information sharing. As the sub processes are integrated in a limited manner, the SM does not know how the different sub processes affect each other. There are difficulties related to understanding the underlying reasons to why quality variations occur. In addition, there is little knowledge regarding how these variations or defects affect the subsequent steps in the production processes. There are several undesirable consequences of insufficient quality in the production process at SM. Included ones are increased amounts of waste and unintended production stops.

The gap is further explored by elaborating on its influence on the quality of each of the three sub processes in the production process. First, there is limited knowledge of how the characteristics of certain tobacco flour in the mill affect the pasteurization and the packaging process. In addition, the amount of data that is collected in the mill is limited and not displayed further down in the production process. Second, quality issues in the pasteurization process include variations in the finished snus, despite using a consistent recipe. These variations include fluctuations in moisture level and lumps of sodium carbonate. As the recipe is not altered, the variations are likely a result from non-regulated ingredients. Examples of these ingredients are water vapor and the exact tobacco flour. No conclusions can be drawn and no new optimizations can be made if the amount of water vapor used or the specific fraction division of the tobacco flour is not documented. Third, the variations do also affect the packaging process. Results of the snus being either too dry or too moist in the packer include that the snus either cannot be put in the pouch properly or that the snus gets stuck in the packer. With many unintended stops and breakdowns, the production process cannot reach its full potential.

Furthermore, the lack of internal process integration can affect the finished snus product. For example, if lumps of sodium carbonate are not discovered by the production, the consumer can identify them instead. As a result, the image of SM and the quality can be reduced in the eyes of the consumer. Ultimately, this could potentially result in a decreased sales volume.

Desired Situation

The desired situation includes understanding the underlying reasons to why quality deviations and defects occur. This contributes to an improved foundation serving as a basis for making sufficient conclusions. In addition, it enables the quality work to be optimized in an efficient manner. One part of the quality work is to attain minimal levels of variations in the finished snus. By minimizing the variations in the snus, its quality increase, the waste level is minimal and the time required for reprocessing snus in the pasteurization process is reduced. The desired situation does also include improvements in the packaging process. Unintended stops are minimized as the snus is neither too dry nor to moist. Also, the increased quality contributes to realizing a higher degree of customer satisfaction.

Possible Solution

To reduce this gap, big data and IoT can be utilized. An appropriate application of the two technologies is therefore to establish a comprehensive perspective of the manufacturing process. More specifically, IoT enables a producing company to collect data from equipment such as machines, sensors and RFID tags. Then, big data enables this data to be used and combined with analytical tools to understand certain patterns that can optimize the production process. At SM, the opportunity of big data and IoT can help the company to integrate data from the mill, the pasteurization and the packaging process.

If previously collected data from the mill is integrated with the data held by the pasteurization process, the operators in the pasteurization are likely to strengthen their knowledge regarding why variations in the finished snus occur. The data collected from the mill includes the fraction division and humidity of the tobacco flour as well as the origin of the raw tobacco. This data currently exists in a separate information system. If SM would find that the characteristics of the finished snus is not affected by the characteristics of the tobacco flour, the pasteurization process needs to understand the impact of the remaining non-regulated ingredient, which is water vapor. To realize how much water vapor is added in the process, hardware components need to be installed in the mixer. Here, a sensor is an example of a suitable hardware component. This component can then provide necessary data to the analytic tool. In summary, by integrating existing data with newly generated data, the underlying reasons of the quality variations can hopefully be identified. The proposed solution to this gap is summarized in Table 5.3.

Gap	**Possible solution**
Lack of internal process integration	• Integrate currently collected data from the sub processes through a big data approach • Gather additional data in the pasteurization through sensors

Table 5.3 The first gap with a possible solution

5.2.2 Second Gap: Reactive Approach

The second gap is related to the second improvement opportunity that is introduced in the empirical data. More specifically, it concerns the reactive approach to the way of working that is currently applied at SM. A reactive approach is appropriate to use in a stable situation with no or few deviations. However, a reactive way of working is not suitable in this case since deviations more or less exist in each step of the production sub processes in SM's Gothenburg factory. This reactive approach is identified throughout the production process, in terms of quality controls, resource usage, and maintenance controls.

First, quality controls are generally performed after each step in the production processes is completed. In the mill, measurements of the tobacco flour are taken once the mixing is completed. As the measurements are taken after the mixing is completed, the characteristics of the flour vary significantly. In the pasteurization process, the batch is approved after the tumbling is completed. Similar to the mill, the result of the pasteurization process varies. Lastly, many of the quality controls in the packaging process are performed in a reactive manner as they are performed after the packaging of the pouch in the can is finished. A consequence of these quality controls in each sub production process is that inadmissible snus is either reprocessed or rejected late in the process, none of which are economically supportable.

Another area that currently applies a reactive approach is resource usage, more specifically the energy and water usage. Currently, SM is unaware of how these resources are consumed in correlation to the speed of the machines or at what time they run. By not understanding how the resource usage can be managed in a proactive manner, the company can neither optimize the energy nor water usage in an efficient manner. Therefore, the firm does indirectly lose economic means and increase its environmental impact.

Lastly, maintenance controls are performed in a reactive manner at SM. Operators working with maintenance mainly focus on the pasteurization and the packaging process. In the pasteurization process, maintenance is mainly performed after a device has broken down. The pasteurization process runs during both day and nighttime. Breakdowns or unintended stops occurring during the nighttime require longer time for repairing and therefore also complicates the process. Recently, the company also started implementing time-scheduled maintenance controls in order to minimize unintended stops and breakdowns in the pasteurization process. In the packaging process, time-scheduled maintenance controls are applied. By controlling each machine every sixth week, the maintenance is not adapted to the machine's utilization rate, number of previous breakdowns or its novelty. As a result, time is spent on controlling machines that are not in need of maintenance, while the machines in need of maintenance are not controlled in time. This means that the maintenance in both the pasteurization and the packaging process are conducted in a reactive manner. In addition to maintenance controls, there is a lack of predictive maintenance, in other words, prediction of when errors or breakdowns will happen.

Desired Situation

The desired situation is to work proactively throughout the production process in terms of quality controls, resource usage and maintenance. This includes identifying errors before they occur and break down the production process or cause rejections of snus. With a smaller number of breakdowns, the utilization rate of the machines can increase as well as the overall efficiency of the production process. Furthermore, working proactively can also result in a continuously increased quality of the snus and therefore also a higher customer satisfaction.

Possible Solution

The second gap is somewhat related to the first gap. By establishing and attaining improved internal process integration, a proactive way out working is partly established. However, what differentiates the solutions of the first and second gap from each other is that the solution to the first gap includes a holistic perspective. In contrast, the solution to the second gap focuses on including improvements in each specific sub process. The solution to this gap is summarized in Table 5.4.

Big data and IoT can be used to mitigate the gap of reactive quality controls, resource usage and maintenance. Therefore, it enables working more predictively and proactively. Regarding the different quality controls within the mill, pasteurization and packaging process, hardware components, such as sensors, can be implemented to measure the ongoing process through real time control. Real time control can be used as an alternative to controlling the product when it is finished. By continuously controlling the quality of the product through real time controls, real time adjustments can be made. These adjustments enable a minimization of quality defects before it is too late.

As big data and IoT enable real time control, the two technological advances can also minimize the gap related to a reactive resource usage. By recognizing the patterns of resource usage through real time monitoring, adjustments can be made. An example of an adjustment is to change the speed of the machines to enable an efficient production of snus that is adapted to the specific direct material.

Furthermore, the maintenance can be improved using big data and IoT. Currently, the maintenance of the equipment in the factory is also conducted in a reactive manner. Here, big data and IoT can be implemented in order to enable working in a more predictive and preventive manner regarding maintenance. Regarding predictive maintenance, IoT components provide a systematic opportunity to continuously monitor how well the machinery is performing. These real time controls require new IoT hardware components in SM's Gothenburg factory. These hardware components can either alert the operators or call the maintenance department or team directly. Another possible solution is for the machines to adjust the errors by themselves. Regarding preventive maintenance, big data can facilitate the planning of the maintenance controls. As the machines can gather data about their run time, utilization rate and previous maintenance pattern, big data and its analytical function enables calculation of what time is optimal for each machine to be controlled. This means that instead of completing maintenance controls every sixth week, each machine can be controlled when it is actually needed. Currently, the machines in the packaging process of SM collect a large part of the necessary data. Thus, no new data is needed to plan the controls. However, the currently collected data types needs to be combined and integrated with each other. This can save time for both the employees and the company as a whole.

Gap	Possible solution
Reactive approach, instead of proactive	• Real time controls to make real time adjustments for improved quality and resource usage • Real time controls to implement predictive maintenance • Integrate currently collected data types from machines to implement preventive maintenance

Table 5.4 The second gap with a possible solution

5.2.3 Third Gap: High Pressure Put on Employees

The third gap implicates that high pressure is put on the employees of SM. Due to market changes as well as technological changes, the way of working is changing at SM. More specifically, it has evolved from being a traditional way of working to involving tasks implying more supervision, planning and responsibilities. A traditional way of working can include simple and repetitive tasks. Furthermore, the pressure that is put on employees differ between the mill, the pasteurization and the packaging process, especially in terms of who is affected, what preventions that have been implemented and the consequences of the increased pressure.

In the mill, it is the operators' work that is affected by the increased number of SKUs. As a result of this increase in SKUs, a larger number of tobacco flour types are implemented. This does result in the fact that more pressure is put on the operators. However, the most critical issue for the operators in the mill is to attain the proper knowledge required to produce high quality tobacco flour. As the work tasks in the mill generally are based on the knowledge of the operators, experience is crucial and the human-judgment has to be accurate. A few operators have worked in the production process of SM for a long time. As employees of younger generations are hired, the chance of them staying as long is limited since they tend to stay shorter in one company. Clearly, this makes it even more troubling that much work is based on previous experience.

In the pasteurization process, operators do also experience high pressure due to the increased number of SKUs. As mentioned, the operators in this production sub process perform planning, supervision of the process and correct smaller unintended stops. As most tasks become more complicated, it is more demanding for the employees to base the majority of their decisions on experience. Up to now, little has been done to facilitate the work in this sub process, as many of the tasks are still performed manually.

The work tasks in the packaging process differ from the ones in the mill and the pasteurization. Here, operators mainly supervise the process and correct minor unintended stops. In this sub process, other employees are responsible for the development of the production plan. The operators do not experience any major problems with the current setup. In addition, they believe that the studied packaging line used for the PSO General runs smoothly. A probable reason for the perception of few problems in this production sub process can be the fact that a lot has already been done to improve the operators' way of working. Furthermore, decisions are not based as much on experience as in the other sub processes and the required training is not as extensive. However, the employees planning the packaging process experience pressure due to the changed market situation. The planning is based on previous experience and a large amount of information is only kept in the heads of the employees.

A general theme throughout the sub processes is the decision making based on previous experience rather than on data. Basing decisions on experience does not only result in higher pressure on the employees, but does also cause costly problems for the company. First, a consequence of human judgment is the increased number of errors. Usually, irreparable errors result in rejections and waste. Second, having a few employees who are very experienced males the company dependent on them. If these individuals are absent or retire, the production would not be able to run as smoothly as today. Third, as experience is crucial for decisions, training requires more time. The longer the training is, the more it costs for the company.

Desired Situation

The desired situation is to use a standardized approach to work-tasks and to apply decision-making based on data. This can result in less pressure put on the employees. By minimizing the share of decision-making based on human judgment, the number of errors can decrease. In addition, the company becomes less dependent on a few experienced individuals. Furthermore, the time required for employees to acquire enough knowledge through training can be minimized. Sufficient training takes time for both experienced and new employees. By minimizing this time, the company can eventually save money. Additionally, manual decisions take time and the desired situation leads to time saved for both employees and the business.

Possible Solution

To reduce the gap and to arrive at the desired situation, big data and IoT can be utilized. A suitable application of the two technologies is to collect and analyze sufficient amounts of data. This can form the basis of reliable decisions, see Table 5.5. For example, it can include which type of snus to pasteurize at what time and in what order. It can also include step-by-step instructions to solve unintended stops. By utilizing big data and IoT to collect and analyze appropriate data, less experience about the production process is needed among the employees.

It should also be pointed out that introducing big data and IoT in the production process of SM does not only facilitate the decision making within the company, but do also result in the need of new competencies. This competency requirement is further discussed in the risk analysis.

Gap	Possible solution
High pressure is put on employees	• Utilize big data and IoT to collect and analyze significant amounts of data as a basis for decision making

Table 5.5 The third gap with a possible solution

5.2.4 Fourth Gap: The Perception that Much Data is Stored

The fourth and final gap addresses how data is collected and managed at SM. Currently, there is a general comprehension that large amounts of data are collected by the company. In fact, each sub process has a number of collection points. For example, the mill collects data regarding the approved tobacco flour, the pasteurization collects data of the finished snus and the packaging has a number of collection points where data is gathered. However, each sub process collects data in different information system or subsystem. This means that the data gathered from the different processes are not integrated in an optimal manner. As the information is not integrated or combined, it is isolated in so-called information islands. If it is believed that an information system is missing, new stand-alone modules or information systems are implemented to solve any occurring issues. Usually, these modules solve a short-term issue and do not motivate a long and sustainable way of collecting data. Also, to add new information systems in this manner are neither economically justifiable for the company nor facilitating the increasingly complex work tasks of the employees.

Furthermore, the employees cannot reassure that the specific data that they need is accurate even though data is collected in various ways throughout the production process. Therefore, it cannot be used for analysis and improvements in the production process of SM.

Desired Situation

The desired situation includes combining, analyzing, visualizing and making the data available for the right employees. This enables an improved understanding of the entire production process. Similar to the first gap, proper management of data can enable a more holistic view of the production process. Instead of only improving product quality and reducing waste, a holistic view can also identify possible bottlenecks in the process, reduce inventory between the steps of the production process, and secure deliveries to the customer.

Possible Solution

To reduce this last gap and to reach the desired situation, big data and IoT can be utilized. As mentioned, the previously described gaps can generally be minimized by collecting and analyzing data with the help of big data and IoT. However, there is no use to perform real time controls if the employees do not know where to find the real time data or if the real time controls are not accurate. Therefore, this fourth gap and its solution is closely related with the three other gaps. Table 5.6 provides an overview of this gap and its suggested solution.

First of all, the data must be accurate. There is a great difference between if the data is collected manually or automatically when considering its accuracy. By manually recording the data in the information system, which is performed in the mill, there is a chance of human error. By automatically recording the data with the help of an RFID tag, which is performed in the pasteurization process, there is a less likely chance of human error and more accurate data can be attained. The company can install additional hardware components, such as RFID tags and sensors, to ensure accurate data.

Then, the collected data must be combined, analyzed and visualized. All to enable the employees to utilize the data in a proper manner. Big data uses the collected data from all steps in the production process and analyzes it in an efficient way. This means that the data can be combined. Here, it is important to keep in mind that the big data algorithm must be integrated with the information systems where the data is located. Another alternative is that the hardware component generates the data directly to the big data algorithm.

Furthermore, the data has to be visualized in a way that is easily accessible for the intended user. When an operator uses the information, it is probably filled with more specific details than if a manager uses the information.

Gap	Possible solution
Much data is stored, without being available, combined or visualized at the right place	• Use IoT components to improve data collection and its accuracy • Use a big data approach to analysis to combine and analyze existing data • Identify missing data types and collect this data through usage of IoT components • Identify the users and adapt the visualization for them

Table 5.6 The fourth gap with a possible solution

5.3 Risk Analysis

Clearly, SM can minimize the identified gaps through utilization of big data and IoT. The approach to reach the desired situations in the gap analysis can be considered as an IT project. Furthermore, identifying and assessing risks is considered to be a critical success factor for IT projects. Thus, an analysis of the associated risks is conducted to enable a successful adoption of the two technological advances at SM. Performing a risk analysis in this case is motivated by several factors, such as the fact that both big data and IoT can be considered as relatively new technological developments. This means that there are several risks associated with utilizing them in a production process. In addition, it is essential that the production process runs smoothly at all times at SM and that the produced snus is of high quality. Combining these aspects with the fact that SM does not want to jeopardize a production process that is functioning today to utilize new technologies provides an indication regarding SM's risk averseness towards new technologies. In other words, SM can be considered to be quite risk averse on the matter.

In this master's thesis, six key risks associated with utilizing big data and IoT in the production process of SM are identified. More specifically, this identification is based on the challenges described in the frame of reference and the ones in the empirical data. Assessing these six risks enables SM to understand what risks to focus on. Table 5.7 displays the identified risks as well as the corresponding probabilities and potential impacts faced by SM if utilizing big data and IoT in the production process. In this master's thesis, both the probability and potential impact of the risks are graded as low, medium or high depending on their features and significance to SM. It should be pointed out that the grades are based on the information gained during the interviews with employees of SM.

Risk	**Probability of the risk occurring**	**Impact on the potential outcome of utilizing big data and IoT**
Too large investment	Medium	High
Inefficient data management	Medium	Medium
Cyber attacks	Low	High
Lack of organizational support	Low	Medium
Hard to find required competencies	Medium	High
Overhyped technologies	Medium	Medium

Table 5.7 An assessment of the risks associated with utilizing big data and IoT in the production process at SM

Furthermore, it should be pointed out that this risk analysis does not specifically focus on monetary impact due to the focus and delimitations as well as the qualitative approach of this master's thesis. Instead, the focus is on a more strategic level with emphasis on the probability of the specific risk occurring as well as its impact. Moreover, the risks are assessed by analysis of what it is that can occur, the probability of this specific event to occur and the impact of the consequences, all on a level with a strategic character.

Finally, this all enables the authors to construct a map of the risks in a chart and to categorize them into three groups, namely low-level risks, medium-level risks, and critical risks. Figure 5.4 shows an overview of the map that is developed by the authors of this master's thesis. Furthermore, the three categories provide an opportunity to prioritize what risks to manage first. For example, the critical risks are essential to handle at an early stage. More specifically, these risks should be managed and mitigated first. The medium-level risks are next in line, while the low-level risks should be managed last or in some cases they can even be ignored. The prioritization order of the risks at SM is described further in the end of the risk analysis. First, the probability and potential impact of each risk is described in SM's setting and an approach to mitigate the risk is also provided.

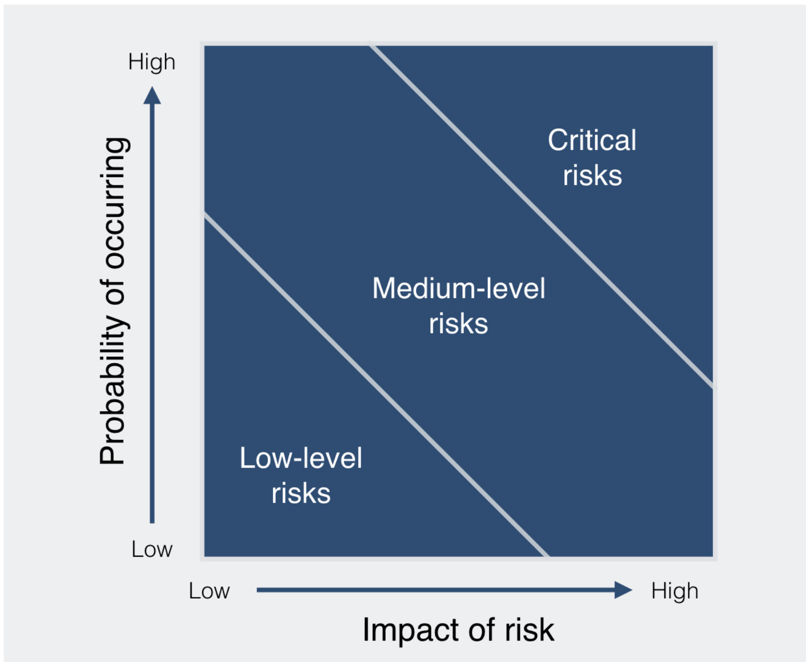


Figure 5.4 The map constructed by the authors to categorize the risks into three groups

5.3.1 Too Large Investment

The probability of the investment being too large for SM is considered to be of a medium size, while the impact if it would occur is considered to be high. A main reason for the probability being assessed as medium and not high is that SM already has some of the required equipment in their production process. Examples include RFID tags in the pasteurization process and sensors in the packaging process. However, much updates, establishments of new linkages as well as new equipment is required throughout the production process to enable full utilization of big data and IoT. The necessary equipment tends to be capital intensive, which further motivates the medium probability of this risk. In other words, this does also mean that the probability cannot be considered as low.

There are various reasons for considering the impact on the potential outcome of utilizing big data and IoT of this risk as high. A main reason is that significant investments are required to enable success of this utilization. In other words, the investments cannot be avoided since it is extremely hard to reach the full potential of big data and IoT if no investments are made. Therefore, it is of high importance to predict what investments that will be necessary to utilize the two technological advances. In addition, how big data and IoT can be combined with some of the other seven technologies included in Industry 4.0 should be considered to maximize the benefits. However, this is likely to result in additional investments. Here, SM should focus on the ones that they could benefit most from, which makes it similar to cherry picking.

As mentioned, the process of utilizing big data and IoT in the production process at SM can be considered as an IT project. Thus, it is important to make sure to meet the budget as well as staying within a predetermined timeframe for the success of the project. A possible response to mitigate the risk of the investment being too large is to take it step by step through iterative investments. This can be feasible for SM to avoid affecting their production process negatively during the change, even though SM can be considered as a large company.

As mentioned in the theoretical framework, it is of great importance that SM makes prioritizations in their production process in order to realize where to start and to find the low hanging fruits. Moreover, this can be considered as a critical success factor for utilizing big data and IoT successfully in the company's production process. It is important to make sure to only invest in equipment that actually is needed and will add value in SM's production process. By performing updates where it is possible rather than replacing machines, investments can be kept at a minimal level. In addition, it is essential that the new equipment can be integrated in a complete factory setup. For example, stand-alone approaches should be avoided since they usually result in SM paying for a complete solution while only utilizing parts of its potential. In other words, it is essential to consider what the entire company can benefit from instead of focusing on short-term solutions in separate functions or departments.

Clearly, SM should not only rely on a short-term approach in separate functions. Instead, it is a critical success factor that SM realizes how big data and IoT can be exploited to enable a significant change throughout the production process. For example, even though SM already has some of the required devices, several machines will either have to be upgraded or replaced to enable adoption of big data and IoT. Here, it is important to realize that it is likely that a large part of the equipment currently in possession of SM can be upgraded to enable adoption of big data and IoT. This further adds to the reasoning that all equipment and machines do not need to be replaced completely. The largest change is likely to be required in the mill, which currently is not that heavily equipped with modern technological devices and therefore has a limited technological maturity. In addition, much manual handling currently takes place in the mill due to this aspect. The pasteurization process is more up to date even though some investments will be required here as well. As mentioned, the packaging process is the most updated one of the three sub processes when considering technological maturity. However, some upgrades will still be required here to enable integration of various systems and hardware devices, such as sensors.

5.3.2 Inefficient Data Management

The second risk considers inefficient approaches to managing the large amounts of data that is generated by various data sources, such as sensors, RFID tags and machines. The probability of inefficient data management being the case at SM when utilizing big data and IoT is rated as medium. The potential impact is also considered to be of a medium size. Rating the probability as medium is motivated by the fact that SM currently shows some limitations considering this aspect. For example, data is collected but then not visualized or in some cases not even used. Furthermore, the impact is rated as medium, because SM will neither be able to utilize big data nor IoT, if there is a too poor ability to manage data. There is also the perception that much data is stored, but not made available, communicated or visualized in a clear manner. Moreover, it can be hard to quickly find the data that is required for the employees to perform their work tasks in an efficient manner. The reason for not rating the impact as high is that SM is currently developing an approach to managing data. There is a potential structure for managing data through usage of a network including three levels, namely the administrative level, the DMZ and the process level.

An increased understanding of what data to collect, how it should be handled, what it is aimed for as well as how to analyze it are potential ways to mitigate the issues associated with this risk. Moreover, the probability of this risk occurring as well as its potential impact can be minimized through developing an understanding of the characteristics of big data. As discussed in the frame of reference, volume, velocity and variety are important characteristics to fully grasp. In other words, it is essential to first understand the data to its full extent to understand how to manage it most efficiently.

To utilize big data and IoT beneficially, a clear strategy towards data management should be applied. Moreover, it is a success factor that this strategy is aligned with SM's overall strategy and it should clarify what data to collect, how to handle it, what the data is intended for, and how it should be analyzed. For example, SM should focus on data that facilitates increased quality of finished goods as well as the efficiency throughout the production process.

It is also important to make sure to use the data that actually is collected, which currently is neither always the case at SM nor in the industry as a whole. Instead, there is data collected that is completely unused, which can be seen as a waste of resources. Clearly, the probability and impact of this risk can be mitigated through a clear structure for data management. Furthermore, this risk can also be mitigated by investing in a software in which strong cloud capabilities are included. Currently, SM store collected data on internal servers and this kind of transition could imply costs that are too large for the change towards a cloud-based setup to be feasible for SM. In addition, if investing in a cloud based data storage the security aspect needs to be considered.

5.3.3 Cyberattacks

The third risk concerns cyberattacks, which for example includes external data leakage, internal sharing of data as well as undesirable hacker attacks. The probability of cyberattacks occurring is considered to be low, while its potential impact is seen as high. A fundamental reason for considering this probability as low is that SM currently can be considered as a cutting edge company when considering the security aspect. This is motivated by their network setup, where connections between different levels are limited by the DMZ. More specifically, the DMZ contributes to a lower probability of cyberattacks since it protects the internal network from less reliable networks, such as the Internet.

Even though the probability of a cyberattack is considered to be low, its impact on the potential outcome of utilizing big data and IoT in the production process at SM is likely to be significant if occurring. This is motivated by the fact that it is fundamental for the company to have a reliable production process that is running and only stops when it is intended to do so. For example, if the production process is infiltrated by malicious software, it can potentially damage SM's software and making it impossible to run the production process. In addition, there is also a risk of unauthorized people taking control of the process as well as its settings. Ultimately, this can result in losing control of the production process, damaged products, and poor quality. Clearly, the potential impact of this risk is of a significant size.

SM can decrease the probability as well as the potential impact associated with this risk by applying security systems, similar to ones used in financial trading. More specifically, encryption algorithms can be utilized in the production process. In fact, studying other industries and focusing on the companies performing best on certain aspects can help much. In addition, it is of high importance to establish and maintain a high level of internal trust between the sub processes of the production process. This is likely to result in avoidance of faulty analysis as well as increased transparency within the production process of SM.

As mentioned, servers can be considered as both inflexible and ineffective. Cloud based storage can be seen as a better approach on the matter. However, a cloud based storage is commonly perceived as riskier compared to using an internal server amongst companies.

This aspect is especially important when considering the risk of cyberattacks. Therefore, SM can wait with implementing a cloud-based approach. By waiting, SM can study other manufacturing companies and learn from their success and mistakes related to a cloud based storage and cybersecurity. Basically, whether or not to wait due to this reason comes down to how risk averse SM actually is on the matter.

5.3.4 Lack of Organizational Support

The risk concerning lack of organizational support is considered to have a low probability to occur. In contrast, its potential impact on the possible outcome of utilizing big data and IoT is considered to be of a medium size. The low probability is motivated by several aspects. Among the included ones is the fact that many employees have worked in the production process for a long time. Another aspect that further adds to this reasoning is the fact that SM cares about their employees and their well-being. This seems to result in a trust among the operators towards SM. In other words, the corporate culture is rather supportive at SM. The probability of this risk at SM can for example be further reduced with increased information sharing.

However, poor organizational support is likely to affect a large part of the company if occurring. Moreover, the potential benefits of associated with an adoption of big data and IoT are likely to be small or even non-existing if the organizational support is absent. This motivates the medium level of impact on the potential outcome of utilizing these two technological advances in SM's production process. That it is not rated as a high impact risk is motivated by the fact its potential consequences are rather limited, even though they can be present in several parts of the company. Basically, if there is no organizational support, there is no project and even less a successful one.

To mitigate the probability and potential impact of this risk, SM should make sure to adapt to the transformation through making necessary alterations to their way of working as well as to their overall business plan. In this way, the goals and the approach to arrive at the future state become clear to the entire organization. Moreover, it is essential for the company to involve people with desired competencies on both the top management level and the operational level. The top management should ensure a clear strategy for the transformation as well as support the employees. For example, there should be a prioritization of the processes in the production and it is important that the operators understand the technology. A supportive corporate culture is a key component of a successful utilization of big data and IoT. In SM's case, this seems to be in place, but it is still vital to ensure communicating the change to maintain this culture minimize the risk.

5.3.5 Hard to Find Required Competencies

The probability associated with the risk of it being hard to find the required competencies is graded as medium and its potential impact as high. The reasoning behind rating the probability as medium is based on the fact that big data and IoT imply changes to the way of working due to increased digitization and automation. This results in altered requirements put on skills and competencies of both operators and managers. Clearly, this is important to consider at an early stage to enable avoidance of later shortages of employees with the required competencies. At SM this means that the work tasks of the operators will shift in its character, especially when concerning repetitive or standardized tasks, thus another set of skills will also be required. In other words, SM need to change the competencies of their employees. However, it is important to keep in mind that big data and IoT are not about reducing the number of employees, but rather on empowering them in their daily work.

The reasoning underlying rating the impact on the potential outcome of utilizing big data and IoT in SM's production process as high, is based on the fact that SM will not be able to utilize big data and IoT efficiently is the required set of competencies is not in place.

Since a hybrid competence in the fields of production and IT will be required, a feasible response towards this risk is to educate the employees on the matter. In other words, it can be beneficial for SM to combine the knowledge of the operators with IT knowledge. This can be attained by reeducation of some of the operators. Furthermore, the management needs to provide the possibilities required to enable new digital ideas as well as to conduct strategic planning for the future. This planning can be based on a long-term analysis of the impact of the changes. Here, there are a number of alternatives that can be suitable for SM. Included ones are altering current roles, changing requirements during recruitment, and, as mentioned, offering reeducation. In this change, SM's project managers and their support play an essential part for the success of the project.

5.3.6 Overhyped Technologies

The risk of big data and IoT being overhyped technologies is considered to have a medium probability. The potential impact on the possible outcome of utilizing big data and IoT is considered to be of a medium size. Basically, this risk concerns whether the two technological advances will be able to deliver according to the expectations of the industry and more specifically the ones of SM. If not able to live up to these expectations, the technological advances are considered to be overhyped. To avoid investing in overhyped technologies, it is fundamental to have reasonable expectations that match the actual potential of the technologies.

Rating the probability of the risk as medium is motivated by the fact that the two technologies have been listed at Gartner's hype cycle for emerging technologies. More specifically, their positioning close to the peak of inflated expectations adds further to this reasoning. As elaborated on in the frame of reference, big data was removed from the cycle in 2015. Furthermore, there are several potential reasons for this, such as the fact that big data is now prevalent in the business environment. This can be considered as likely for some lines of business including the financial sector, but not for all. If considering the manufacturing industry separately, it is likely that big data still would be positioned at the hype cycle. In addition, this reasoning is in line with the argument that big data was removed from the hype cycle a bit too soon. This matter is further motivated by the fact that big data still frequently is described as a vague term.

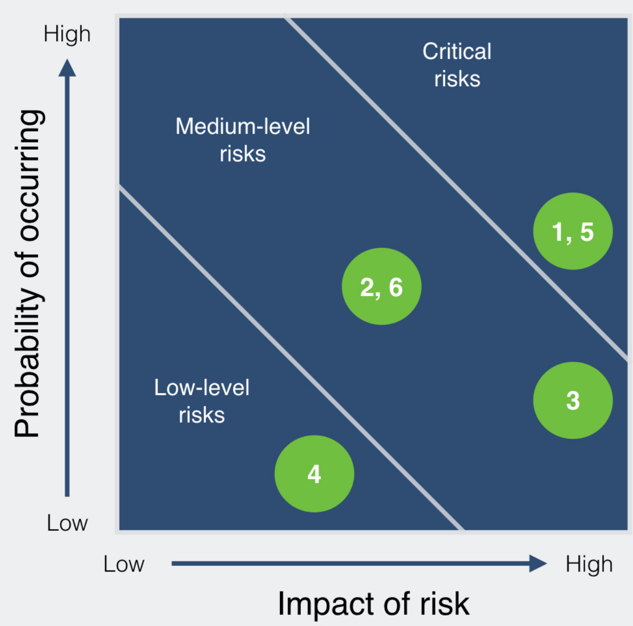
Considering the potential impact of this risk to have a medium size is motivated by the fact that technologies placed on the hype cycle are likely to have a significant business impact on numerous companies, including SM. More specifically, SM will probably not be able to realize their original expectations if the two technological advances are overhyped. For example, this can show in investments failing to pay off.

Possible responses to mitigate both the probability and the potential impact of this risk include, as mentioned, to make sure to have reasonable expectations regarding what can be accomplished by an adoption of the technologies. Here, it is important to fully understand big data, its opportunities, limitations as well as applications in the production process of SM. In other words, the management at SM should make sure to see through the hype and vague terms.

The earlier SM moves towards an adoption of big data and IoT, the larger the risk is. It is essential for the company to be aware of the fact that taking on the risk does not always pay off, even though the fact that the potential payoff is likely to be larger if moving early. Thus, for a risk averse company, another response to decrease the probability and potential impact of this risk is to wait with the utilization of big data and IoT. By acting more moderately, SM has the possibility to study other companies and learn from their success as well as mistakes. How long to wait, depends on how risk averse SM is. As previously mentioned, SM can be considered as quite risk averse towards implementing new technology in the production process. For a very risk averse company, this all can indicate that the company should wait until the technologies are fully proven to work sufficiently in a production setting.

5.3.7 Prioritization of Risks

The risks are mapped based on their corresponding probability of occurring and their potential impact in the event of it happening. By mapping the risks, it becomes clear that the six risks can be prioritized based on a division into three groups, namely critical risks, medium-level risks, and low-level risks. Moreover, this enables SM to establish an approach to allocation of resources to manage the risks. Figure 5.5 provides the map developed for this master's thesis. Furthermore, this map provides an overview of the three risk groups.



#	Risk
1	Too large investment
2	Inefficient data management
3	Cyberattacks
4	Lack of organizational support
5	Hard to find required competencies
6	Overhyped technologies

Figure 5.5 Mapping of the risks based on the probability of occurrence and the potential impact reveals what risks to prioritize

As mentioned, the first group to consider and handle is the critical risks. The risk of the investment being too large and the risk of it being hard to find the right competencies are both critical risks that should be prioritized and looked into first. This means that it is essential for SM to allocate resources to handle these two risks. Since these two risks have a medium probability of occurring and a high potential impact, SM should strive to minimize both aspects. However, most attention should be paid to reduce the potential impact first due to its significant size.

The second group to consider and mitigate comprises of the medium-level risks. In other words, this group should to be handled after the first group has been managed. In the production process of SM this group includes three risks, namely the risk of inefficient data management, overhyped technologies, and cyberattacks. The first two are both risks with medium probability of occurring and a medium potential impact. Here, both factors should be minimized. The risk of cyberattacks on the other hand, has a low probability of occurring but a high potential impact. Thus, the focus when managing this risk should be on minimizing its potential impact in the event of it happening.

The third group comprises of low-level risks corresponding to the lowest priority, which motivates managing this group last. In some cases, risks in this category can even be ignored, especially if considering risks with both low probability and low impact. In the setting of SM's production process, this category includes the risk concerning lack of organizational support. This risk has a low probability to occur as well as a medium sized potential impact. Thus, the focus should be on minimizing the potential impact. Once it has been reduced to a low level, little attention is required to be paid to this risk.

Clearly, there are numerous risks when considering utilizing new technological advances, such as big data and IoT, in a production process. Thus, it is important for SM to understand and assess these risks. In addition, SM need to make sure to allocate the resources needed to manage the critical risks first, the medium-level risks secondly and then finally the low-level risks.

5.4 Summary of the Analysis

The analysis shows that there are several applications of big data and IoT that are suitable to use in the production process of SM. Before determining these applications and how they can be used at SM, it is essential to understand what the actual needs are. The functional product and the physically efficient supply chain strategy do both motivate introducing applications of big data and IoT associated with manufacturing optimization as well as preventive and predictive maintenance. Moreover, these application areas are closely aligned with SM's current motives to change and the issues that the company is experiencing. Once it is established that there actually are applications of big data and IoT that are appropriate to utilize in the production process of SM, an analysis regarding how these can be implemented in a more detailed manner can be performed. In addition, it is also important to assess the risks associated with a potential implementation.

How the two technological advances can be implemented at SM is specified through a gap analysis. Four gaps are included in this gap analysis and each gap can be reduced with the help of big data and IoT. Table 5.8 provides an overview of these gaps and the corresponding solutions. Here, it should be noticed that many gaps have similar solutions. For example, if the company reduces the fourth gap with big data and IoT, the other three gaps can partly be reduced as well. In other words, by managing data in an efficient way the company can partly integrate the whole production process, work more proactively and make data-driven decisions.

Gap	Possible Solution
Lack of internal process integration	• Integrate currently collected data from the sub processes through a big data approach • Gather additional data in the pasteurization through sensors
Reactive approach, instead of proactive	• Real time controls to make real time adjustments for improved quality and resource usage • Real time controls to implement predictive maintenance • Integrate currently collected data types from machines to implement preventive maintenance
High pressure is put on employees	• Utilize big data and IoT to collect and analyze significant amounts of data as a basis for decision making
Much data is stored, without being available, combined or visualized at the right place	• Use IoT components to improve data collection and its accuracy • Use a big data approach to analysis to combine and analyze existing data • Identify missing data types and collect this data through usage of IoT components • Identify the users and adapt the visualization for them

Table 5.8 The identified gaps and the corresponding possible solutions

Furthermore, each gap affects the mill, the pasteurization and the packaging process more or less. Therefore, it is difficult to recommend the company to begin to implement the two technologies in a specific part or a single sub process in the production process. Many components, such as sensors and RFID tags, already exist in the production process of SM. A reasonable explanation to this is the fact that many of the components of big data and IoT include older technologies. This means that SM does not have to start from the absolute beginning. The packaging process has a higher degree of technology and automation compared to the mill process, which makes the step to implement big data and IoT smaller in the packaging process. In other words, the technological maturity in the packaging process can be considered as higher than the one in both the mill and pasteurization process.

Furthermore, the root cause to most gaps can often be found at an early stage of the process. More specifically, this means that problems in the packaging process often originates from issues in the mill and the pasteurization process. Examples include problems such as the limited understanding of why quality deviations occur and that much pressure is put on the employees, which are associated with the first and third gap. Thus, the best outcome would probably be realized by implementing big data and IoT in the two earlier sub processes of the production process, rather than focusing too much on the packaging process.

In addition, there is a difference between integrating data that is currently collected through a big data approach and implementing IoT components to collect additional types of data. As discussed in the gap analysis, some of the gaps can partly be reduced through integration and combination of the data types currently collected. This can be realized through applying a big data approach, thus this is an appropriate task for the company to focus on. A suitable next step is therefore to implement the IoT components needed to collect any missing data. This enables performing a holistic analysis of the production process. When integrating currently collected data types, the company must account for the software requirements and apply a suitable network solution.

As mentioned, SM must keep a number of risks in mind when considering a utilization of big data and IoT. The risk analysis shows that there are two critical risks that SM need to consider first when implementing big data and IoT, namely the risk of a too large investment and it being hard to find the required competencies. It is these two risks that the company should focus on as they both have a large probability of occurring and have a large potential impact on the success of the implementation of big data and IoT. To mitigate the problems associated with these risks, the company should have a clear strategy regarding which investments to prioritize and hire or educate employees with the appropriate competencies.

6 Discussion

This chapter elaborates on aspects that have the potential to affect the analysis and results of this master's thesis. Included factors are the choices of the studied product as well as the considered factory. Finally, the choice of studying the production process of Swedish Match and how this specific choice of company can affect the findings are discussed.

6.1 The Studied Product

SM clearly has a product portfolio with products of varying character, thus it is a reasonable assumption that the results of this master's thesis would deviate if another product had studied. Furthermore, it can be hard to find a supply chain strategy that fits the entire product portfolio. For example, it is likely that the results of this master's thesis would change somewhat if another product with less certain demand had studied. A more market responsive supply chain strategy could be feasible in some cases, especially when considering innovative products. The following sections elaborate on the impact on the preferred approach to big data and IoT if another product would have been studied, alternative supply chain strategies that could fit more innovative products, but also on which strategy that can be considered as suitable for the complete product portfolio.

6.1.1 The PSO General

The large sales volumes of the PSO General result in the fact that even minor issues or changes have a large resulting impact on the production process. This motivates to start with studying the PSO General, which is the case in this master's thesis. Furthermore, this shows that the focus and delimitations applied in this master's thesis are reasonable. However, if another product with smaller sales volumes would have been studied, it is likely that the planning in the production process would become harder and that this product therefore would correspond to larger waste volumes. In that case, it is also likely that the feasible approach to utilizing big data and IoT would differ from the one suggested for the PSO General in this study. For example, possible utilization areas of the two technological advances include ones associated with increased flexibility, minimized changeover times as well as support for planning of what to produce at what time.

The same principle applies if a product in another stage of the PLC is considered, since the requirements implied by a product in the introduction, growth or decline phase differ from the ones corresponding to a mature product. For example, research and development play a more important part in the earlier phases. Therefore, the main focus in these phases is not on realizing the most efficient production process. In other words, the approach to a utilization of big data and IoT will vary depending on the characteristics of the product. For example, the applications can vary between being focused on areas such as design, logistics or product recovery.

6.1.2 Strategic Approach for Innovative Products

As mentioned, what is considered to be the most suitable strategic approach depends on the characteristics of the product. Understanding this strategy enables realizing the most suitable applications of big data and IoT for a certain company and setup. Here, it is important to point out that the physically efficient supply chain strategy that is proposed to match the characteristics of the PSO General is not likely to be considered to fit all SM's products. A main reason for this is the fact that SM also produces products of a more innovative character. In these cases, a market-responsive supply chain strategy would be more feasible as it focuses on answering to a more unpredictable demand in a timely manner. All this to minimize obsolete inventory, forced markdowns, and stockouts. Here, the focus in the production process should be on deploying excess buffer capacity instead of on keeping high utilization rates on average.

The reasoning underlying the suggestion to apply a physically efficient, or lean, supply chain strategy for the PSO General is well aligned with how SM has worked historically. However, as stated in the empirical data SM is currently striving towards working according to a more market responsive strategy. This combined with the introduction of several new SKUs that are more innovative than functional in their character, motivate the assumption that SM's overall supply chain strategy should be directed more towards the responsive side, rather than the efficient one. This means that the applications of big data and IoT should focus a bit more on flexibility, planning, and understanding the customer as well as consumers.

Clearly, different products imply different requirements to the supply chain strategy. What supply chain strategy that matches the characteristics of specific products may differ. All this means that it can be hard to apply a single supply chain strategy for the entire product portfolio of SM. However, when combining all aspects, the indications suggest that currently, the matching supply chain strategy when only considering the PSO General is the physically efficient one. Therefore, the suitable applications of big data and IoT are within manufacturing optimization as well as preventive and predictive maintenance. These are applications that focus on maximizing the efficiency of the production process while minimizing the costs.

6.1.3 Strategic Approach for the Entire Product Portfolio

As pointed out, a supply chain strategy completely focused on being either physically efficient or market responsive is unlikely to match all products in a company's product portfolio. This matter is likely to apply in SM's case, since the diversity of the company's product portfolio continuously increases. As mentioned, a lean supply chain strategy corresponds to the physically efficient one when studied on a higher level, while the agile strategy corresponds to the market responsive.

In addition, the high margin of the PSO General is a characteristic that could indicate that it is a innovative product, even though it checks a majority of aspects that makes it considered to be a functional product. Here, it is important to keep in mind that the products of SM generally correspond to a high margin. However, this indicates that a more agile approach might be required, rather than a completely lean supply chain strategy.

This all combined with the fact that SM strives towards working according to a more market responsive strategy than historically, add up to the fact that a hybrid, or leagile, supply chain strategy might be feasible for SM. Moreover, this strategy is basically a mix between the lean and agile approaches. Thus, it could fit a wider spectrum of SM's products than the lean or agile strategies can do separately. This means that suitable applications of big data and IoT differ when considering the entire product portfolio compared to when only studying the PSO General. For example, increased variations in demand require more focus on understanding the market.

6.2 The Studied Factory

In this master's thesis, the scope is limited to the snus factory in Gothenburg. As the factory is older than the snus factory in Kungälv that was built in 2003 the production equipment in Gothenburg has a lower degree of technological maturity. One of the most significant differences is the newer equipment in the packaging process in Kungälv. This results in the fact that the machines in the Kungälv factory can gather more specific data. This data can be very useful in the utilization as well as in the integration of a big data approach. The more types of data a machine can gather, the less amount of new IoT components need to be installed. As a result, the discussions regarding the implementation of big data and IoT in the packaging process would probably differ slightly if this study would include the Kungälv factory. However, the pasteurization process in the Kungälv factory is very similar to the pasteurization process in Gothenburg, therefore this result is not likely to vary much. Since there is only one mill that is located in Gothenburg, the result on this point would not vary at all if the Kungälv factory would also have been considered.

In addition to the novelty of the equipment, the process of making the snus varies somewhat between the two factories. The Kungälv factory produces the portioned packed snus White, which differs from the PSO General as it has a higher moisture level and is packed in a star formation in the cans. These variations only affect the process description on a very detailed level and therefore it is not likely to affect the results of this master's thesis.

Finally, the scope of this study is also limited to a specific packaging line in the packaging process of the Gothenburg factory. As mentioned, this choice was motivated by the fact that it is considered as the most technologically developed packaging line and therefore ready for a change. In addition, the PSO General is mainly manufactured on this packaging line. The results of this master's thesis are likely to change somewhat if another packaging line would be studied. However, these changes are likely to be small and not affect the overall conclusion in any major way.

6.3 The Studied Company

The choice of company to study in this master's thesis is motivated by a number of changes in the business environment that SM experience. This has led to SM showing willingness to increase the digitization level within the company and develop a production process that is easy to establish a comprehensive picture of. Furthermore, the finished snus product is a consumer product with few components and three major processing steps. As there are few components, there are also a limited number of suppliers. More specifically, there are three types of suppliers. For example, the plastic suppliers deliver goods on a daily basis, which makes the inventory level of these goods low. Additionally, the company has only one customer, SMD, to which products are delivered on a daily basis. Therefore, SM does not have a complex supplier network, a diverse warehouse or a large distribution network.

If the studied company would offer products with more components, the result of this master's thesis would likely be different. A large amount of components or various customer requirements can imply a larger number of suppliers, more inventory within the production process, and a more complex distribution network. Such a company would probably find the applications of big data and IoT concerning logistics or inventory control more useful. Consequently, the result of this master's thesis would differ if another company would have been studied.

Finally, the results would likely be different if not only internal data is considered for usage. For example, market information and data from social medias can be used to enhance the accuracy of the analyses. Ultimately, this could affect the production process and enhance its efficiency as well as the quality of the finished products.

7 Conclusion and Final Remarks

This chapter provides answers to the research questions presented in the first chapter. In addition, a recommendation to the studied case organization is provided. The recommendation is based on the findings in this master's thesis. Lastly, suggestions for future research in the studied field are presented.

7.1 Answering the Research Questions

To fulfill the purpose of this master's thesis, the four research questions are answered in this section. First, RQ1 is answered and this question is as mentioned supported by the three following sub-questions.

RQ1. How Can Big Data and IoT Be Utilized to Optimize the Production Process at Swedish Match?

To identify how big data and IoT can be utilized to optimize the production process at Swedish Match, a supply chain analysis, a gap analysis and a risk analysis are conducted. After these analyses are finished, this master's thesis discovers that big data and IoT can be utilized at SM to optimize the production process in terms of understanding the process better, predicting errors, making more accurate decisions and understanding what data is collected. However, when implementing the new technologies, the company must keep a number of risks in mind, some of which are more critical than others. To minimize these risks, a clear strategy is needed, which should include a gradual implementation.

RQ2. Why Should Swedish Match Utilize Big Data and IoT?

SM should implement big data and IoT in their production process, because it will help the company to address a number of gaps in this process. The four main gaps these two technological advances will help to mitigate are the lack of internal process integration, a reactive approach, instead of a proactive one, high pressure is put on employees, and much data is stored, but not available, combined or visualized at the right place. Mitigating the issues associated with these gaps will help SM increase the efficiency in their production process while minimizing the costs. Furthermore, SM will be able to establish a comprehensive picture of the production process and ultimately among others increase quality throughout the process as well as of finished goods. In addition, it will help SM to develop a foundation for standardized and more accurate decision-making.

RQ3. What Are Suitable Applications of Big Data and IoT at Swedish Match?

There are two main application areas of big data and IoT that are suitable in the production process of SM. These two areas are motivated by the characteristics of the studied PSO General and the matching physically efficient, or lean, supply chain strategy. More specifically, these two areas are within manufacturing optimization as well as in preventive and predictive maintenance. Here, the most extensive area of utilization with the greatest potential influence on SM's production process is in manufacturing optimization. Therefore, this is also the most important application area for SM to consider. Furthermore, there are several applications included in manufacturing optimization. For example, this area includes applications that increase efficiency and minimize costs, utilize real time data, enable establishing a comprehensive picture of the entire production process, and that enable collection of information that provides a foundation for standardized and more accurate decision-making.

The four gaps in SM's production process tell a lot regarding what are suitable and possible applications of big data and IoT at SM. A main reason for this is that SM's production process can be improved significantly in terms of quality and efficiency if mitigating the issues associated with these gaps. Thus, this section elaborates on how each of these gaps can be addressed by big data and IoT applications.

As mentioned, the first gap considers lack of internal process integration. In other words, SM needs to develop a holistic picture and understanding of the situation throughout the entire production process. This will enable understanding what factors result in what outcome. More specifically, this gap can be addressed by SM through utilization of big data and by integrating currently collected data types from the sub processes. In addition, new or additional data can be gathered in the pasteurization process by usage of hardware devices, such as sensors. This will ultimately enable SM to arrive at the desired state with well-integrated internal processes. Moreover, the collection and integration of data can enable SM to realize an increased quality throughout the production process and of the finished goods.

The second gap does, as mentioned, consider that SM is applying a rather reactive approach, instead of a proactive throughout the production process. Working more proactively can be accomplished by three application approaches. First, quality and resource usage can be improved by utilizing real time controls to make real time adjustments. Second, real time controls can be utilized to implement predictive maintenance. Third, currently collected data from the machines can be integrated to implement preventive maintenance. Finally, this all enables realizing a proactive approach to quality, resource usage and maintenance.

The third gap considers the fact that high pressure is put on employees and can be addressed by utilizing big data and IoT to apply a standardized basis for decision making. This can be based on collection and analysis of large amounts of data. In other words, this can result in an ability to realize a standardized approach to work tasks and decision making based on collected data. Ultimately, this will ease the pressure put on employees.

Finally, the fourth gap is considering the fact that much data is stored, but not made available, combined or visualized at the right place. This gap can be addressed by four main application approaches of big data and IoT. First, data collection and the accuracy of the collected data can be improved through usage of IoT components. Second, a big data approach can be applied to analysis in order to combine and analyze currently collected data. Third, there is an application considering identifying what data that is missing and to collect this data by using IoT components. Fourth, by identifying the user, SM can adapt the visualization to fit their needs. Ultimately, this all results in the fact that data can be collected, combined, visualized and made available to employees.

Table 7.1 displays a summary of the applications suitable to apply in the production process of SM, note that a division has been made between applications in manufacturing optimization and the ones within preventive and predictive maintenance.

Application area	Description of applications (#)*
Manufacturing optimization	• Integrate currently collected data from the sub processes through a big data approach *(1)* • Gather additional data in the pasteurization through sensors *(1)* • Real time controls to make real time adjustments for improved quality and resource usage *(2)* • Utilize big data and IoT to collect and analyze significant amounts of data as a basis for decision making *(3)* • Use IoT components to improve data collection and its accuracy *(4)* • Use a big data approach to analysis to combine and analyze existing data *(4)* • Identify missing data types and collect this data through usage of IoT components *(4)* • Identify the users and adapt the visualization for them *(4)*
Preventive and predictive maintenance	• Real time controls to implement predictive maintenance *(2)* • Integrate currently collected data types from machines to implement preventive maintenance *(2)*
**(#) = the number of the gap that the application solves*	

Table 7.1 Applications suitable to apply in the production process of SM divided by area

RQ4. In Which Parts of the Production Process Is It Most Appropriate to Start?

The gaps connected to why SM should implement big data and IoT, affect the whole production process including the mill, the pasteurization, and the packaging process. Therefore, it is hard for the company to begin in a specific sub process with the purpose of reducing a gap entirely.

Currently, SM has the highest degree of technological maturity in the packaging process. As many improvements already have been completed in this sub process, the implementation of big data and IoT in this part is likely to have the least effect on the existing gaps compared to the other sub processes. Instead, the root causes to the majority of the gaps can be found in the beginning of the production process. Therefore, it is appropriate to start in the pasteurization or mill process. Furthermore, the company does not have to implement all components of big data and IoT instantly. Alternately, the company can focus on integrating already existing data through a big data approach and in a latter step implement new IoT components to collect additional types of data.

SM should consider the critical risks when starting the adoption of big data and IoT in the production process of SM. In this study, two critical risks that require attention are identified. More specifically, this concerns the risk of a too large investment being required and it being hard to find the required competencies. It is important that the company make sure to allocate resources to mitigate the problems associated with these risks. This will ultimately enable a successful implementation of big data and IoT.

7.2 Recommendations to Swedish Match

To enable a successful utilization of big data and IoT in the production process of SM, it is extremely important that the company starts by fully understanding what their actual goals for the utilization are. The company should assess how much they can save by mitigating the gaps, both in terms of monetary value and unutilized resources. Also, they should assess how critical each gap actually is. For example, how much the quality needs to increase or how many production stops need to be reduced. Once this is established, the company needs to fully understand the potential, but also the limitations, of the two technological advances in the setting of SM and the specific production process. If this is not done first, it is hard to realize the full potential of such a project. This all becomes a clear conclusion when taking all mentioned aspects into consideration regarding utilizing big data and IoT in the production process at SM.

Furthermore, SM needs to understand what software, hardware and competencies that are required for a successful implementation of big data and IoT. In addition, it needs to be possible to integrate the data already in possession of SM with additional data. Thus, SM need to apply a software tool for analysis of data. Sufficient competencies that understand the company and its requisites are required to perform the actual analysis. Attaining the required competencies can partly be accomplished by educating the current employees. In this way, the employees are prepared for the change and empowered in their work. Here, communication regarding upcoming changes is essential to avoid dissatisfaction amongst employees. Then the data needs to be visualized in a way that is adapted to the employee that will use it. For this purpose, adapted screens displaying chosen information could be a feasible alternative.

In addition, it is also important that SM understands the risks associated with utilizing the two novel technological approaches. Here, the critical risks should be prioritized highest and resources should be allocated to manage them and to mitigate the associated problems. A next step for SM that is suggested by the authors of this master's thesis is to understand what gaps that are most urgent and that will have the biggest impact in the company's production process. In this way, SM is able to realize which one that is the most economically feasible one to start with. Due to the fact that utilizing big data and IoT implies significant alterations to SM's production process, the company should act with a clear goal from the start. The way to realizing this goal however, can be divided into multiple sub steps that ultimately enable a full adoption. This reasoning is further motivated by the fact that a significant investment is likely to be required for adoption of the two technological advances. This means that it can be difficult to do everything at once, even though several aspects are closely connected.

7.3 Future Research

This master's thesis contributes with an extensive description of big data and IoT. In addition, it provides a description of the two technological advances in a specific manufacturing company, namely Swedish Match. The different applications of big data and IoT are more or less useful for a company depending on the characteristics of the product and the overall supply chain strategy. Based on theoretical descriptions of big data and IoT, the authors exemplify how the technologies can be applied in a specific case. As this is a case study of exploratory character, it increases the currently limited research level on the subject of big data and IoT in a manufacturing company.

To gain a wider understanding of current usage areas of big data in the industry as a whole, a multiple case study can be conducted. A multiple case study allows a less limited perspective of the two technologies and a measurement of best practice is enabled. In this way, a manufacturing company, such as SM, can compare its degree of technological maturity to other manufacturing enterprises and step towards operating according to Industry 4.0. Furthermore, the company can also learn from the successes and failures of other companies. An additional suggestion for future research is to apply the result of this report to other companies as this enables understanding the transferability of the results.

References

The references used to support this master's thesis are displayed in this section. Both verbal and written references are used. To avoid misconceptions, the statements of the interviewees are compared with each other. In addition, all written references are carefully reviewed and selected to avoid usage of unreliable theory. In some cases, articles are compared to eliminate any insecurities regarding the reliability of the chosen literature.

Verbal References

In order to keep the interviewees identities anonymous in accordance with the wishes of the studied company, no names of the respondents are included. Instead, a list displaying the total time spent per interviewee group and the roles of the employees included in each group are provided.

Interviewee group	**Total time spent per group**	**Included employees**
Operators	3 hours 40 min	• Operator Mill • Operator Pasteurization • Operator Packaging • Production Technician
Project Managers	2 hours 31 min + continuous	• Project Manager • Engineer • Business Engagement Liaison
Managers	4 hours 29 min	• Supply Chain Manager • Factory Manager Gothenburg • Factory Manager Kungälv • Area Manager Mill and pasteurization • Area Manager Packaging

Written References

Aberle, L. (2015). E-guide, Manufacturer's Guide: IoT, Sensors, & Predictive Analytics. *TechTarget*.

Accenture. (2014). *Digital Industry 4.0*. Retrieved February 9, 2016, from http://prd.accenture.com/microsites/digital-industry/digital.html

Andersson, C., & Zeithami, C. (1984). Stage of the Product Life Cycle, Business Strategy, and Business Performance. *Academy of Management Journal, 27*(1), pp. 5-24.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A Survey. *Computer Networks*, pp. 2787-2805.

BBC. (2014). *Design & Technology, Graphics product development, evaluation and ICT*. Retrieved April 7, 2016, from http://www.bbc.co.uk/schools/gcsebitesize/design/graphics/evaluationictrev3.shtml

Bi, Z., Xu, L. D., & Wang, C. (2014). Internet of Things for Enterprise Systems of Modern Manufacturing. *IEEE Transactions of Industrial Informatics, 10*(2), pp. 1537-1545.

Birhanu, D., Lanka, K., & Rao, A. N. (2014). A Survey of Classifications in Supply Chain Strategies. *Procedia Engineering, 97*, pp. 2289-2297.

Bloor, M., & Wood, F. (2006). *Keywords in Qualitative Methods* (1st ed.). SAGE.

Bryman, A., & Bell, E. (2011). *Business Research Methods* (3rd ed.). Oxford: Oxford University Press.

Bryman, A., & Bell, E. (2015). *Business Research Methods* (4th ed.). Oxford: Oxford University Press.

Chase, J. (2013). *The Evolution of the Internet of Things.* Texas Instruments.

Chen et al. (2016). Industrial Internet of Things-Based Collaborative Sensing Intelligence: Framework and Research Challenges. *Sensors, 16*(2), pp. 1-19.

Chopra, S., & Meindl, P. (2007). *Supply Chain Management, Strategy, Planning and Operations* (3rd ed.). New Jersey: Pearson Prentice Hall.

Davenport, D. (2014). How strategists use “big data” to support internal business decisions, discovery and production. *Strategy & Leadership, 42*(4), pp. 45-50.

Delen, D., Hardgrave, B., & Sharda, R. (2007). RFID for Better Supply Chain Management through Enhanced Information Visibility. *Production and Operations Management, 16*(5), pp. 613-624.

Eriksson, P., & Kovalainen, A. (2008). *Qualitative Methods in Business Research* (1st ed.). SAGE Publications Inc.

Fisher, M. L. (1997). What Is the Right Supply Chain for Your Product? *Harvard Business Review, March-April*, pp. 105-116.

Forbes. (2013). *Do You Replace Your Server Or Go To The Cloud? The Answer May Surprise You*. Retrieved March 22, 2016, from http://www.forbes.com/sites/quickerbettertech/2013/04/29/do-you-replace-your-server-or-go-to-the-cloud-the-answer-may-surprise-you/#7b6389562c23

Fox, S., & Do, T. (2013). Getting real about Big Data: applying critical realism to analyse Big Data hype. *International Journal of Managing Projects in Business, 6*(4), pp. 739-760.

Gartner Inc. (2014). *Gartner's 2014 Hype Cycle for Emerging Technologies Maps the Journey to Digital Business*. Retrieved February 23, 2016, from http://www.gartner.com/newsroom/id/2819918

Gartner Inc. (2015). *Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor*. Retrieved February 23, 2016, from http://www.gartner.com/newsroom/id/3114217

Gartner Inc. (2016a). *Gartner Hype Cycle*. Retrieved March 22, 2016, from http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Gartner Inc. (2016b). *Special Reports, Hype Cycles 2015*. Retrieved February 23, 2016, from http://www.gartner.com/technology/research/hype-cycles/

Gibbert, M., Ruigrok, W., & Wicki, B. (2008). Research Notes and Commentaries - What Passes as a Rigorous Case Study? *Strategic Management Journal*, pp. 1465-1474.

Goetschalckx, M. (2011). *Supply Chain Engineering.* Boston, MA: Springer US.

Hennink, M., Hutter, I., & Bailey, A. (2011). Qualitative Research Methods. *SAGE Publications Ltd*.

IBM. (2014). *Infographics & Animations: The Four V's of Big Data*. Retrieved March 16, 2016, from http://www.ibmbigdatahub.com/infographic/four-vs-big-data

Jingran et al. (2015). Big Data in Product Lifecycle Management. *Springer*, pp. 667-685.

Jun et al. (2009). A framework for RFID applications in product lifecycle management. *International Journal of Computer Integrated Manufacturing, 22*(7), pp. 595-615.

Lee et al. (2013). Recent Advances and Trends in Predictive Manufacturing Systems in Big Data Environment. *Manufacturing Letters, 1*(1), pp. 38-41.

Lee, J., Kao, H., & Yang, S. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. *Procedia CIRO, 16*, pp. 3-8.

Lindberg, P. (1990). Strategic Manufacturing Management: A Proactive Approach. *International Journal of Operations & Production Management, 10*(2), pp. 94-106.

Mörstam, M. (2016). Vilken kompetens behöver svensk industri för att ta del an industri 4.0? Gothenburg: SP dagarna 2016.

McAfee, A., & Brynjolfsson, E. (2012). Big Data: the Management Revolution. *Harvard Business Review*(October).

McKinsey Global Institute. (2015). *The Internet of Things: Mapping the Value Beyond the Hype.* McKinsey & Company.

Mentzer et al. (2001). Defining Supply Chain Management. *Journal of Business Logistics, 22*(2), pp. 1-25.

Myerson, A. P. (2014). *A Lean and Agile Supply Chain: Not an Option, But a Necessity*. Retrieved March 16, 2016, from http://www.inboundlogistics.com/cms/article/a-lean-and-agile-supply-chain-not-an-option-but-a-necessity/

Näringsliv. (2014). *Svenskt snus är världsunikt*. Retrieved March 4, 2016, from http://www.naringsliv.se/tidningar/2014-4/medicon-valley-2020/alvstaden/svenskt-snus-ar-varldsunikt/

Oskarsson, B., Aronsson, H., & Ekdahl, B. (2013). *Modern logistik - för ökad lönsamhet* (4th ed.). Stockholm: Liber AB.

Patel, R., & Davidson, B. (2011). *Forskningsmetodikens grunder* (4:7 ed.). Lund: Studentlitteratur AB.

Peddibhotla, G. B. (2016). *Gartner 2015 Hype Cycle: Big Data is Out, Machine Learning is in*. Retrieved March 22, 2016, from http://www.kdnuggets.com/2015/08/gartner-2015-hype-cycle-big-data-is-out-machine-learning-is-in.html

Petersen, C., & Plenborg, T. (2010). How Do Firms Implement Impairment Tests of Goodwill? *Abacus, 46*(4), pp. 419-446.

PwC. (2015). *The Smart Manufacturing Industry.* Retrieved February 19, 2016, from http://www.pwc.se/sv/verkstad/the-smart-manufacturing-industry.html

Rüssmann et al. (2015). *Industry 4.0. The future of Productivity and Growth in Manufacturing Industries.* The Boston Consulting Group, Inc.

Ramin, P. (2016). Industry 4.0: Approaching the next industrial paradigm. *SP dagarna 2016.* Gothenburg: German Innovation Centre for Industry 4.0.

Rotter, J. (2016). Automating service programs via IoT. *Contractor Magazine*, p. 35.

Rowley, J., & Slack, F. (2004). Conducting a literature review. *Management Research News, 27*(6), pp. 31-36.

Saint, A. (2014). Internet of Things, Brave New World. *Engineering & Technology*, pp. 80-83.

Selldin, E., & Olhager, J. (2007). Linking products with supply chains: testing Fisher's model. *Supply Chain Management: An International Journal, 12*(1), pp. 42-51.

Standing et al. (2006). The attribution of success and failure in IT projects. *Industrial Management & Data Systems, 106*(8), pp. 1148-1165.

Sundin, E., Östlin, J., & Björkman, M. (2008). Product life-cycle implications for manufacturing strategies. *Journal of Cleaner Production*, pp. 999-1009.

Swedish Match. (2003). *Världsunik snusfabrik invigs i Kungälv*. Retrieved March 4, 2016, from http://www.swedishmatch.com/sv/Media/Pressmeddelanden/Press-releases/1996-2004/Varldsunik-snusfabrik-invigs-i-Kungalv/

Swedish Match. (2013). *Company History*. Retrieved February 9, 2016, from http://www.swedishmatcpany-history/h.com/en/Our-company/Com

Swedish Match. (2015a). *Annual Report*. Retrieved February 9, 2016, from http://www.swedishmatch.com/Reports/Annual%20reports/2014_SwedishMatch Arsredovisning_SV.pdf

Swedish Match. (2015b). *GOTHIATEK® Swedish Match Quality Standard*. Retrieved February 9, 2016, from http://www.swedishmatch.com/en/Snus-and-health/GOTHIATEK/

Swedish Match. (2015c). *Snus and moist snuff*. Retrieved February 12, 2016, from http://www.swedishmatch.com/en/Our-business/Snus-and-moist-snuff/

Swedish Match. (2015d). *Swedish Match, Company Presentation.* Retrieved February 12, 2016, from http://www.swedishmatch.com/Documents/Presentations/2015_CompanyPresentation_SwedishMatch_EN.pdf

Swedish Match. (2016a). *General - En 150-årig snushistoria*. Retrieved April 8, 2016, from http://snus.swedishmatch.com/sv/Produkter/General/

Swedish Match. (2016b). Retrieved April 7, 2016, from Swedish Match's Picture Bank.

Wallén, G. (1993). *Vetenskapsteori och forskningsmetodik.* Lund: Studentliteratur.

Waller, M., & Fawcett, S. (2013). Data Science, Predictive Analytics, and Big Data: A Revolution That Will Transform Supply Chain Design and Management. *Journal of Business Logistics, 36*(2), pp. 77-84.

Woodie, A. (2015). *Why Gartner Dropped Big Data Off the Hype Curve*. Retrieved March 22, 2016, from http://www.datanami.com/2015/08/26/why-gartner-dropped-big-data-off-the-hype-curve/

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations. *International Journal of Operations & Production Management*, pp. 195-219.

Yin, R. K. (2013). *Kvalitativ forskning från start till mål* (1:1 ed.). Lund: Studentlitteratur AB.

Yin, R. K. (2014). *Case Study Research - Design and Methods* (5th ed.). SAGE Publications, Inc.

Appendix

Appendix A

This appendix displays a general version of the interview guide used during the interviews. It should be pointed out that alterations were made to the interview guide to adapt the interviews to the expertise areas of the interviewees. Since all interviews were conducted in Swedish, the interview guide provided here is in Swedish. In addition, it should be noted that some questions are not directly related to the empirical data. Instead, these questions are used to provide the authors with an understanding of the current IT knowledge at SM.

Bakgrund

Vad har du för roll i företaget?
Vilka ansvarsområden har du?
Hur länge har du arbetat på Swedish Match?
Hur länge har du arbetat på den avdelning där du arbetar nu?
Har du arbetat på någon annan avdelning på företaget?

Avdelningens ansvarsområden

Vilka aktiviteter/processer ansvarar din avdelning för?
Hur arbetar din avdelning med planering och prognoser?
Hur sker samarbete med andra avdelningar (strukturerat/kontinuerligt/etc.)?
Med vilka avdelningar delar din avdelning information?
Vilken information delas med andra avdelningar?

Datainsamling i produktionen

Vad är syftet med att samla in data/information inom er avdelning?
Hur samlas data in i produktionen idag?
Vilken typ av data samlas in i produktionen?
Hur utvärderas information som samlas in i produktionen?
Finns det information som samlas in och inte används inom produktionen?
Hur visualiseras information som samlas in i produktionen (varningssignaler/telefonsamtal/etc.)? Framtida möjligheter?
Finns det problem med datahantering i produktionen idag? Om ja, vad är det för problem?

Förbättringsområden

Vad betyder automatisering för dig?
Vilken automatisering finns för datahantering i produktionen?
Sker manuell informationshantering inom produktionen?
Vad finns det för framtida möjligheter för automatisering av informationshantering?

Big data och IoT

Vad är din definition av big data?
Vad är din definition av IoT?
Upplever du att det finns en förståelse för vad big data och IoT är inom produktionen?
Upplever du att produktionsprocessen kan förbättras genom IoT och big data? Om ja, hur?
I din mening, vilken information bör samlas in för att möjliggöra arbete med IoT och big data?
Känner du till några företag som arbetar med big data och/eller IoT i dagsläget? Om ja, vilka företag? Vilka resultat har nåtts?

Kontaktförslag

Har du tips på andra personer vi kan tala med för ytterligare information på ämnet?

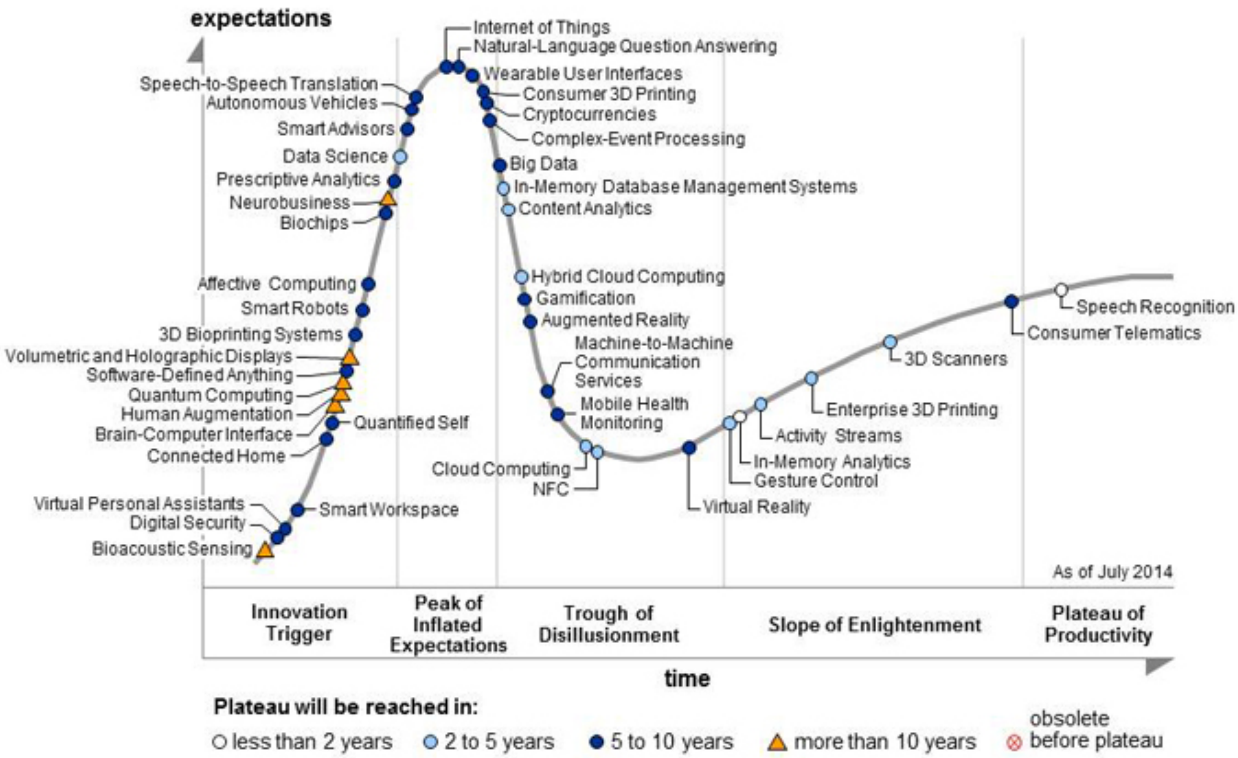
Appendix B

The table displays the ranking of key themes discussed by interviewees and is the result of the coding process. The ranking is based on how many of the interviewees that discussed the theme. This means that the most commonly discussed one is that a reactive approach is applied, instead of a proactive. This issue was brought up by all except from one of the interviewees.

Occurrence	**Key themes**
11	Reactive approach, instead of proactive
10	Quality is of high importance throughout the entire production process
9	Much data is stored, without being made available, combined or visualized at the right place
8	Lack of internal process integration
8	High pressure is put on employees
7	Large amounts of waste
6	Big data and IoT is seen as vague terms that can be hard to understand
5	There is limited knowledge regarding why the characteristics of the finished batches deviates significantly
3	The collected data is not always reliable
2	Skepticism towards change, even if improvements can be made. This is caused by fear of a production process unable to run and especially applies if things currently work

Appendix C

The figure displays Gartner's hype cycle for emerging technologies for 2014 (Gartner Inc., 2014).



Appendix D

The figure displays Gartner's hype cycle for emerging technologies for 2015 (Gartner Inc., 2015).