JÖNKÖPING UNIVERSITY
School of Engineering

A framework for digitalized information management in food value chains

A study in the Swedish bread and bakery manufacturing industry

Main area: Final Project Work in Production Systems
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Abstract

Purpose: Information management is crucial for a food manufacturing company as it increases productivity, lowers cost, and enables traceability as well as data-driven decision-making. A lack of information management leads to consequences such as lack of customer demand and requirements, which result in high inventory or stockout. The purpose of this study is to enable digitalized information management in food value chains, and this study aims to know which information needs to be considered for data-driven decision-making. The purpose and aim align with adapting to the current trends of industry 4.0 and digitalized information management. To fulfill the purpose, two research questions are formulated: (1) What type of information needs to be considered for data-driven decision-making in food value chains? and (2) How should the parts of the value chain be digitalized to enable data-driven decision-making in food value chains?

Method: The chosen approach for this study was an inductive approach and the chosen strategies were a literature review and a single case study in the Swedish food manufacturing industry. To gain an understanding of the case company's value chain, interviews were used as a data collection technique. The interviews were then analyzed and then combined with the literature review to answer both the research questions. The quality of the study was evaluated by using the trustworthiness criteria. There were also five principles, when it comes to research ethics, that were used during this study.

Findings: After the conducted interviews, the relevant actors were identified and mapped in the case company's value chain. It was found that the company used a lot of manual information management procedures, which led to several challenges for data-driven decision-making within the company. The mapping revealed which information was relevant for the respective actors within the case company. This provided a starting point from which empirical and theoretical data were studied to address these challenges and answer the two research questions and fulfill the purpose of this study.

Analysis: To build a framework for digital information management, it was necessary to customize existing equipment and resources, adapt the process to the specific industry, and move toward the concept of industry 4.0. With these elements in mind, the framework was created using data acquired from both the literature research and the case study. The framework consists of a loop, that allows for continual improvement.

Conclusion: Applying the correct technology is important for digitalized information management, and the food manufacturing industry suffers from limited technologies in this aspect. This thesis informs the reader on how to digitalize information management. The academic contribution is a theoretical framework for the digitalization of information management using industry 4.0 concepts, which can support companies to generate revenue.

Keywords: Decision-making, Digitalization, Food value chain, Information management

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1 Introduction

This chapter presents a background of the chosen topic of this study to the reader. This is followed by the problem description, purpose, research questions, and delimitations. The reader gets a deeper understanding of the context of the problem and why this study is relevant under current circumstances. The chapter is presented mainly from an academic perspective, but also provides insights into how the study affects the concerned industry.

1.1 Background

In the current industrial environment, increased product variability, small lot sizes and rapidly shifting markets have challenged manufacturing companies (Lu et al., 2020). Among the various manufacturing industries, one industry that has been affected is the food industry, owing to the growing population, which increases the demand along the value chain (Hassoun et al., 2022). As a response to the changes, companies must implement new applications and technologies to be able to meet the increasing customer demands (Lu et al., 2020) as well as the supplier demands, which affect the value chain (Demartini et al., 2018).

The need to implement these new applications and technologies has led to the fourth industrial revolution, which is known as industry 4.0. The aim of industry 4.0 is to develop efficient and low-cost production and at the same time maintain flexible workflows for producing personalized high-quality products (Lu et al., 2020). Industry 4.0 includes different technologies such as digital and biological technologies. By implementing the so-called industry 4.0 technologies, food value chains can be digitally and sustainably transformed to reach the aim of reducing costs, improving performance, and saving time (Hassoun et al., 2022).

One of the digital technologies within industry 4.0 is cyber-physical systems (Hassoun et al., 2022). Cyber-physical systems bring advanced intelligence and flexibility to physical production systems that ease the process of meeting customer demands. This has led to a new generation of manufacturing, which can be defined as smart manufacturing. The term can be explained by a set of manufacturing processes that responds to and connects to a form of networked data and information technology to shape future manufacturing operations (Lu et al., 2020).

An important part of smart manufacturing is internet of things, which consists of the interconnection of devices, that are connected to one or more network interfaces and deliver information about their status. A consequence of internet of things is big data, which refers to the production of data, categorized by high volume, velocity, and variety. The collection of big data is crucial since this helps companies to analyze and get useful insight into their machines and other equipment. In tandem with other technologies within the term internet of things, big data is an important factor in industry 4.0 (Femminella et al., 2018).

The whole concept of industry 4.0 can be summed up as a transformation from manually based manufacturing toward automated and digital-based processes. One definition of the digital innovations that come along with the concept can be to use of information and communications technologies to implement new and improved products, processes, networks, business frameworks, and marketing methods. By adapting towards new digital platforms and using new digital technologies, will help companies to meet current customer demands and respond to the turbulent and fast-changing markets that exist in current circumstances (Karabulut, 2020).

Digitalization also needs to be adapted in the information sharing between actors in value chains and not only in physical production technologies and manufacturing processes. By doing so, managers will be able to make the right and timely decisions when the information management can be conducted digitally instead of manually as pen and paper-based alternatives. Information management can in term be described as the administration of the processes and systems that create, acquire, organize, store, distribute and utilize information. The purpose of information management is to support individuals and companies in efficiently and effectively accessing, processing, and utilizing information (Detlor, 2010).

1.2 Problem description

There are several challenges with information management in food value chains. Firstly, having manual information management where the information is partly pen- and paper-based is not only bad for the environment but also time-consuming. Digital information management enables the use of information and communication technologies that can facilitate the usage of resources in a more environmental-friendly way by reducing paperwork and enhancing efficiency (Demartini et al., 2018). Having digital information management rather than a manual can result in better traceability through the whole value chain. Such access to information, that is relevant and reliable, is significant so that managers can analyze and make better decisions with the information. Within a food value chain, traceability enables a company to control the safety and quality of the food throughout the whole value chain (Nene et al., 2019).

Secondly, the lack of information management can lead to other consequences for the company. For example, a lack of information on customer demand and customer requirements can result in high inventory or stockouts. Consequently, there will be high stock levels with high storage costs and low flexibility when it comes to customization (Peeters & van Ooijen, 2020). The bullwhip effect is a well-studied phenomenon, which can be defined as the amplification of demand variation on production and order quantities in value chains (Dolgui et al., 2020). This phenomenon does not only affect the production but also the other participants in the value chain (Fiala, 2005), for example, suppliers of raw ingredients. Therefore, there is a need for data-driven decision-making, which enables the company to make the right decisions according to relevant and up-to-date information. This allows the production to produce according to customer demand, which decreases stock levels, and costs and increases flexibility (Peeters & van Ooijen, 2020; Provost & Fawcett, 2013).

The consequences of these challenges could also be reflected in the case company in this study. Having a production where products are produced-to-stock has led to high levels of both finished products and raw materials as well as unnecessary manually carried out tasks when it comes to information management. This results in losses of relevant resources such as time and capital. These resources could instead have been intended for other important measures, such as increasing productivity.

1.3 Purpose and research questions

Summarizing the problem statements, information management can be significant for a company since it can increase productivity, lower cost, and enable traceability through the value chain. It also enables better data-driven decision-making that can facilitate all the stages in the food value chain. Therefore, the purpose of this study is:

to enable digitalized information management in food value chains

One of the steps to fulfilling the purpose is to understand which kinds of information different decision-makers need in digitalized fashion. Therefore, this study aims to increase understanding of which information needs to be considered for data-driven decision-making and which parts to digitalize in the value chain. The aim and purpose are addressed using the following two research questions:

RQ1: What type of information needs to be considered for data-driven decision-making in food value chains?

The first research question delves into the 'kind' of information that decision-makers, typically middle- and upper management require to be data-driven. Upon identifying this information, the natural next step in this study is to explore how this information can be digitalized in the value chain, enabling traceability and reliability. Hence, the second research question is:

RQ2: How should the parts of the value chain be digitalized to enable data-driven decision-making in food value chains?

1.4 Delimitations

This study will focus on the information management between the three relevant actors, *production*, *warehouse,* and *distribution* in the case company located in Sweden. Therefore, the empirical data collected is limited to that found within these three actors. Only the in-house information management within the three chosen actors will be studied. The choice of the actors is based on the needs of the case company to pursue its industry 4.0 strategy. As the case company belongs to the Swedish bread and bakery industry, the term value chain is addressed in the context of the food value chain. The relevant actors are illustrated with a red rectangular in *Figure 1*.

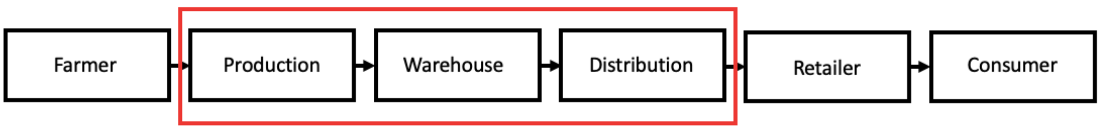

Figure 1. The relevant actors in the case company's value chain.

Also, this study will not provide any information regarding digitalization or automation when it comes to processes within the field of production technology, for example, robotics. The focus will be on the information management between relevant actors in the case company's value chain, which is illustrated in *Figure 1*. Other actors in the food value chain will only be mentioned in conjunction with the relevant actors, to get an overall view of the whole food value chain. The results in this study, such as frameworks and tables, will only be theoretical and conceptual solutions and are not practically tested in this study.

1.5 Outline

To generate a clear outline for this report, the subsequent chapters will be explained further in detail. This is to make it easier for the reader to get an overview of the content in each chapter and to understand the structure of this report.

The first chapter, *Introduction,* gives the reader a background of the chosen topic of this study. This is followed by the problem description, purpose, research questions, and delimitations. This is to get a deeper understanding of the context of the problem statement and why this study is relevant under current circumstances. This, mainly from an academic perspective but also how the study can affect the concerned industry.

The second chapter, *Theoretical framework*, presents relevant theories, which will generate a basis for the thesis and help to answer the two research questions. The presented theories are retrieved from scientific articles and book chapters that are relevant to the chosen topic of this study.

The third chapter, *Method and implementation*, explains the approach of this study, followed by the chosen strategy and a company description. Furthermore, the data collection techniques are presented, together with the description of how the data is analyzed and discuss the quality of this study. The chapter will end by mentioning research ethics.

The fourth chapter, *Findings*, will present the result from the data collection and will generate a mapping of the case company's current state. This will in turn create a basis that, together with the theoretical data, will help to answer the two research questions of this study.

The fifth chapter, *Analysis*, will generate the results of this study by combining the empirical data from the *Findings* and the theoretical data from the *Theoretical framework*. The combined data in this chapter will be used to answer the two research questions.

The sixth chapter, *Discussion*, will discuss the previously mentioned chapters and compare other potential methods and solutions besides the ones that were used in this study. The implications and limitations will also be discussed in this chapter.

The seventh chapter, *Conclusion*, will summarize this study. Compared to the other chapters of this report, personal thoughts will be presented here, to give the reader more perspective on the chosen topics. This chapter will also present recommendations for further studies within the same research area.

2 Theoretical framework

This chapter presents relevant theories, which generate a basis for the thesis and keep the two research questions in mind. The presented theories are retrieved from scientific articles and book chapters that are relevant to the chosen topic of this study.

2.1 Information management

Szuster and Szymczak (2016) describe data as unprocessed, and when the data have been given meaning, it is referred to as information, which later is referred to as knowledge when the gathering of information is appropriate for a situation. Szymczak et al. (2018) mention that the fundamental abilities within information management create knowledge that is required for instance to carry out tasks, maintain relationships and achieve market success. The information that is shared between partners in a supply chain is associated with several aspects within a company, such as the operational, market conditions, and the customers which could be of relevance for the production, distribution, and forecasting. Therefore, the shared information between partners is relevant for the product, planning process, and resources in a company, and to be able to manage the flow of resources and finished products in the supply chain, correct information management is the foundation for enabling the integration of information in the supply chain (Szymczak et al., 2018).

2.2 Information and communication technology

With the development of industry 4.0, the use of information and communication technologies in industries has become essential (Barreto et al., 2017). Internet of things, big data, and cloud computing are examples of information and communication technologies that are being used in different industries (Peraković et al., 2018) to facilitate improved communication and knowledge exchange (Szuster & Szymczak, 2016). Information and communication technologies have the potential to increase the efficiency of the company's processes and enable innovation in the processes, products, and in services that the company produces. Furthermore, information and communication technologies can contribute to establishing a new value chain that can provide value to the customer (Szuster & Szymczak, 2016). In the following sections, seven information and communication technologies that are relevant for this study are presented.

2.2.1 Digitization

The term digitization can be defined as the transformation from manually or analog handled data to digital data handling, which can be beneficial for manufacturing companies in many aspects. Since every company has its structure and belongs to different industries, it is important to adapt the digital transformation to the involved company and the industry. This is also crucial since companies can use different methods or technologies and take different paths, depending on which future goals they are trying to reach (Ritter & Pedersen, 2020).

2.2.2 Digitalization

When it comes to digitalization, companies need to implement digital innovations, which can be done by using several different digital technologies. By doing so, they can go from manual activities and achieve digital transformation. Digital technologies can be seen as composed of information, processing, and communication and some examples are automation, internet of things, big data analytics, and cloud computing.

Digital technologies are used to collect, store, and analyze information in a digital format, and they are causing significant management changes. (Karabulut, 2020).

2.2.3 Cyber-physical system

A cyber-physical system can be defined as the interaction between the physical world and interconnected computing systems. The physical world, which consists of machines and other equipment, is prepared with sensors to transform the physical carried out processes into a digital format that generates relevant data. Cyber-physical systems will in turn also ease the task of connecting objects to digital platforms, where information can be shared (Wang et al., 2015).

Mörth et al. (2020) illustrate a basic view of a cyber-physical system in *Figure 2*, which shows the interactions between physical objects and how the gathered data will generate information. This could eventually be shared throughout other information and communication technologies. The purpose of *Figure 2* is to illustrate a cyber-physical system to get a clearer view of how physical and digital equipment contributes to the concept of industry 4.0.

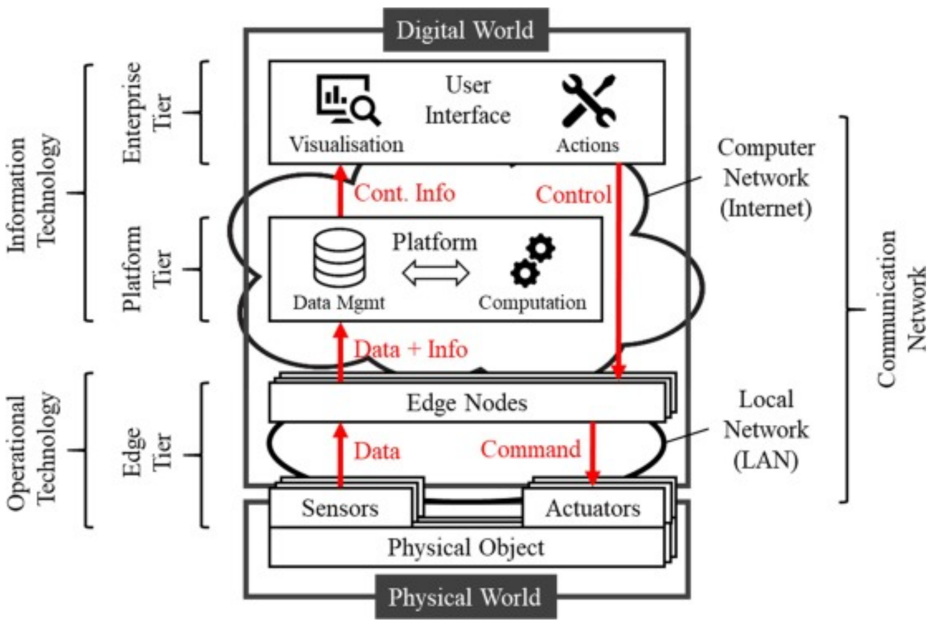

Figure 2. A basic cyber-physical system (Mörth et al. 2020).

2.2.4 Internet of things

Compared to cyber-physical systems, internet of things focuses on creating a digital network over the internet, that contributes to interactions between physical objects in a digital format. The objects could be machines or other equipment in a manufacturing facility, that together produce relevant data with help from sensors and actuators to sense and manipulate the physical environment. Together with other technologies within the concept of industry 4.0, such as big data and cloud computing, internet of things generates methods and tools that will ease the task of gaining relevant data and how to use the data most beneficially. It is important to analyze the data gathered, to be able to gain useful information from it, which then can be applied. Mörth et al. (2020) illustrate the different steps of gain and apply relevant data as a simplified data value chain in *Figure 3*.

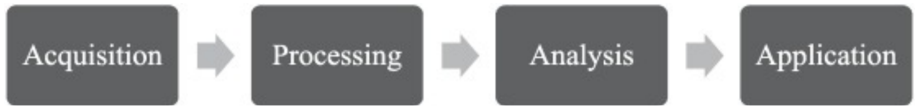

Figure 3. A simplified data value chain (Mörth et al. 2020).

The purpose of the simplified data value chain is to describe how data (of the lowest value) can be transformed into knowledge (of the highest value). The lowest value can be explained by acquiring data from a system, which can be a machine or a network of machines, which includes generating, collecting, and storing data. The next step processes the data to extract relevant data, which in the third step is analyzed through methods and tools to convert data into information and knowledge. The final step includes the application of the gained knowledge produced from previous steps, which in the long run can lead to better decision making for example (Mörth et al., 2020). While the simplified data value chain focuses on a process-centric view, a data-centric view can be explained with help from the DIKW-pyramid (Mörth et al., 2020). The DIKW-pyramid consists of four different hierarchies, which are Data, Information, Knowledge, and Wisdom. Bosancic (2016) illustrates the DIKW-pyramid in *Figure 4*.

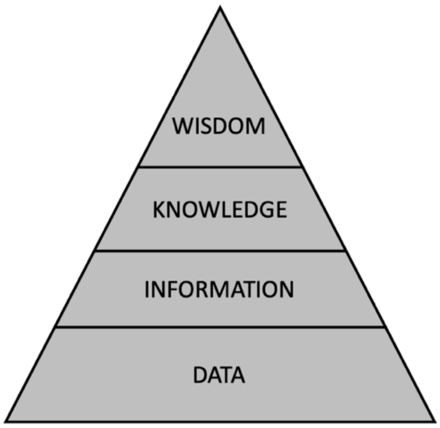

Figure 4. The DIKW-pyramid (Modified from Bosancic 2016).

It is crucial to understand the relationships between the different hierarchies within the DIKW-pyramid and how the surfaces are linked together. The lowest and largest surface consists of data, which after being processed and analyzed will generate information. Information will in turn generate knowledge, which eventually will generate wisdom (Bosancic, 2016). The internet of things technologies will provide identification of relevant data towards a specific situation, which in turn will generate more understanding of the physical system and eventually ease the task of transforming data into wisdom (Mörth et al., 2020).

2.2.5 Big data

The internet of things sensing technologies leads to big data, which can be seen as a term that includes high amounts of data when it comes to volume and velocity. Big data also generate a high amount of data in real-time, which in turn can lead to the challenge of dealing with high levels of variety and veracity. Variety appears from different data types in manufacturing, from power profiles to acoustic emissions to cutting force signals, which all require different purchase parameters. At the shop floor level, there are also noises and uncertainties. Veracity is therefore an important aspect to consider, to be able to have control over the uncertainties that come along with the manufacturing processes. Therefore, companies must invest in beneficial big data analytics technologies and methods, that can handle large-scale data and structure it into desirable categories or patterns that will generate information (Yang et al., 2019).

2.2.6 Big data analytics

Big data analytics can be defined as a set of technologies and methods that provides insights and information from a large amount of data. Since big data analytics in manufacturing companies can generate higher levels of process improvement activities, quality control, and maintenance, for example, big data analytics is a crucial part of today's manufacturing climate and the concept of industry 4.0. Big data analytics can also lead to a higher level of quality when it comes to the decision-making aspect of manufacturing companies. Big data analytics can be implemented in a variety of methods depending on the company's structure, but it will have a beneficial impact on corporate performance in the long run. This is possible provided the technology is properly defined to the company's structure (Wiech et al., 2022).

2.2.7 Cloud Computing

Cloud computing consists of different third-party services, for companies and their value chain, depending on which type of solution is most beneficial. Some examples of solutions that cloud computing involve are Infrastructure as a Service, Software as a Service, Data as a Service, and Platform as a Service. The main purpose of these services is to structure, share and customize network infrastructures, IT platforms, operating systems, and applications of high amounts of data. To sum up the term cloud computing, it can be used as a method to ease and rapid structured information sharing between different actors throughout a value chain (Ardito et al., 2019). The information-sharing can be in terms of the flow of goods and services, which involves movement and storage of raw material, work-in-process inventory, and finished goods from manufacturer to end-consumer. This can be eased by using a common IT platform that includes all the actors in a specific value chain and where relevant information can be shared between them (Liu et al., 2019).

Scheduling and information management through platforms can be beneficial compared to traditional scheduling, but some differences need to be considered. For example, the communication does not go directly between the actors in the value chain throughout the cloud, compared to the traditional way where interactions and collaboration are more common. In comparison to traditional information management, which may be considered stable and long-lasting, the connection in cloud computing information management in the value chain can be seen as dynamic and temporal. On the other hand, platforms provide accessible infrastructures that allow the integration of information between all the actors throughout a value chain, which in turn will ease the decision-making process (Liu et al., 2019).

2.3 Data-driven decision-making

Data-driven decision-making can be defined as a process or application to base decisions on the analysis of data rather than instinct. The benefits that come along with data-driven decision-making are, for example, higher productivity and profitability, which are correlated with a higher return on assets, asset utilization, and market value (Provost & Fawcett, 2013). Data-driven decision-making is also closely related to the technology of big data and big data analytics which can be applied in the information sharing within companies' value chains. It has been shown that companies that use data-driven decision-making in their value chain can reach higher productivity and profitability levels by about 5-6%, compared to companies that do not use the application. Top-performing companies are adopting data-driven decision-making to gain a competitive advantage, and when combined with big data, this application will be much more potent than previous analytics approaches. (Hazen et al., 2018).

Mandinach (2006) presents a conceptual framework for data-driven decision-making within the educational area in *Figure 5*. However, the framework can be beneficial for other industries to adapt to as well. The framework presents three levels of how data is transformed into information and later into knowledge, where the knowledge can be utilized to make decisions. Furthermore, it can be noticed that six activities have been identified for each level in the framework for the decision-making. At the data level, the two relevant activities are called *collect* and *organize*. The activities at the information level are *analyze* and *summarize*. At the knowledge level, the relevant activities identified are *synthesize* and *prioritize*. When the raw data have been collected, it is essential to organize the data in some systematic way so that sense can be made of the data. The result of analyzing and summarizing the data in the second level will transform the data into information. Furthermore, the existing information needs to be synthesized to turn into knowledge, and lastly, the knowledge needs to be prioritized. Prioritizing the knowledge refers to determining the relevant important information and creating possible solutions that can be taken into action. The outcome of the three levels that transforms the data into knowledge is *decision.* The *decision* is later *implemented,* and the consequence becomes an *impact.* Depending on what the *impact* is, the decision-maker can choose to return to one of the activities in the levels to collect more data or reanalyze information. Therefore, the *feedback* loop in the framework is suggested. The data-driven decision-making can be described as an iterative process that begins with data that is transformed into knowledge where the outcome is a decision that is implemented, followed by the impact of the implementation being determined (Mandinach, 2006).

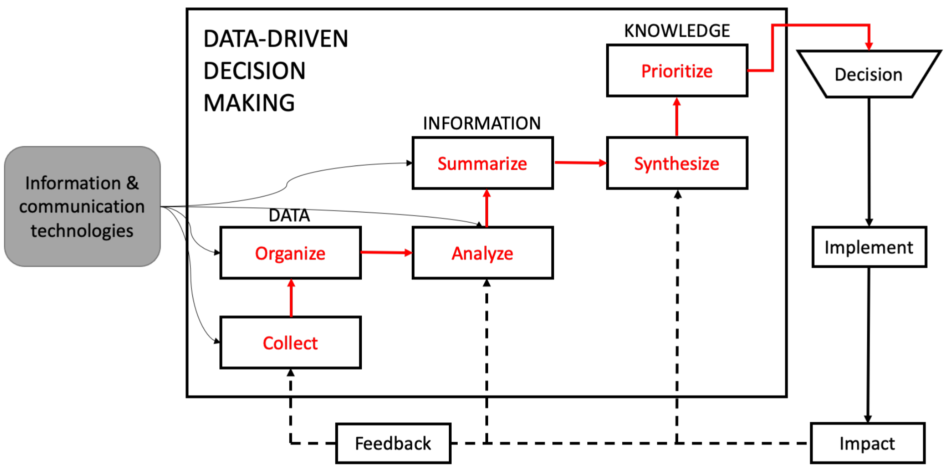

Figure 5. Data-driven decision-making (Modified from Mandinach 2006).

The data-to-knowledge transformation in a food value chain can also be generated with help from applications and technologies, by themselves or in combinations. Each step can also use different solutions, depending on which digital infrastructure, data security, and data ownership exist in that specific step (Hassoun et al., 2022). The technologies, for example, information and communication technologies, can be utilized to support and facilitate the data-driven decision-making (Mandinach, 2006). *Figure 6* illustrates how data-driven applications and technologies can be adapted to a food value chain.

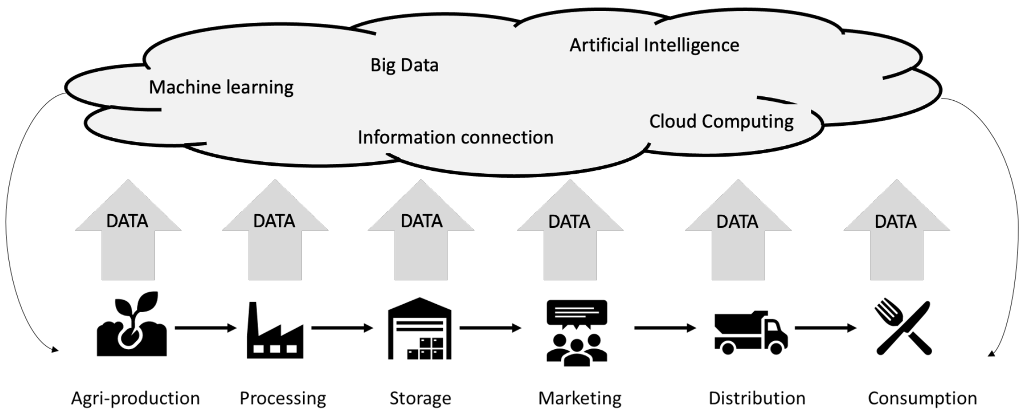

Figure 6. Data-driven decision-making in the food value chain (Modified from Hassoun et al., 2022 and Ferranti, 2019).

2.4 Value chain

2.4.1 Traditional value chain

Value chains can differ depending on what industry it applies to and what type of strategy the company has. A value chain presents the total value and includes *value activities* that refer to the different physically and technologically activities that a company performs to create a product that is valuable to its customers. Furthermore, it also includes *margin*, which is the difference between the overall value and the whole cost of carrying out the value activities. The value activities can be divided into two sub-activities: primary activities and support activities (Porter, 1998). Porter (1998) mentions that in any industry's value chain, there are five main categories of primary activities involved which can be shown in *Figure 7*.

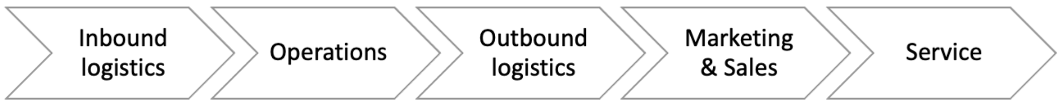

Figure 7. Activities in the traditional value chain (Porter, 1998).

2.4.2 Food value chain

A food value chain can be defined as a network where stakeholders concerning the production of goods and services are included. These stakeholders are involved in the breeding, processing, storing, selling, and consuming of food. The food value chain includes all activities that are necessary to bring agri-food products to the customers tables in
Figure 8. The activities involved are the production of agri-food, processing, and manufacturing of the agri-food, storage of the processed products, marketing, distribution, and lastly, consumption of the products. The main difference between food value chains and traditional value chains is therefore the Agri-production activity (Ferranti, 2019). Ferranti (2019) illustrates the food value chain activities in
Figure 8.

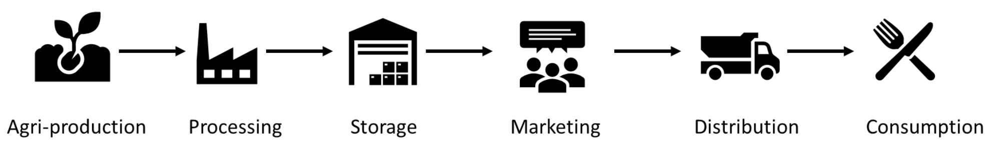

Figure 8. Activities in the food value chain (Ferranti, 2019).

3 Method and implementation

This chapter explains the approach of this study, followed by the chosen strategy and a description of the chosen case company. Furthermore, the data collection techniques are presented, together with the description of how the data is analyzed, and next the quality of this study is evaluated. The chapter closes with a reflection on research ethics.

3.1 Research approach

The chosen approach for this study was inductive. An inductive approach generates new knowledge by exploring a certain topic and is associated with qualitative research (Saunders et al., 2016). The chosen strategies for the study have been categorized into two: a literature review and a case study. The literature review was conducted as a foundation for chapter 2, the *Theoretical framework*, to provide knowledge about the topic to enable the case study. To gain an understanding of the current situation and the problem in the case company's value chain, data was collected from interviews. The interviews aimed to answer research question 1 and to contribute to answering research question 2 by an analysis of the collected data and the literature review. *Figure 9* shows the work process of how the study was conducted.

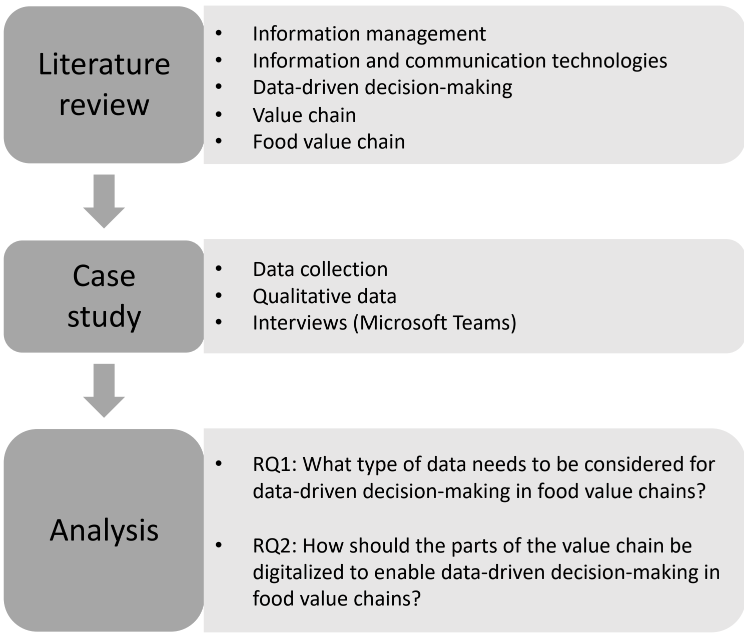

Figure 9. The work process of the study.

3.2 Literature review

To establish a foundation for the *Theoretical framework* and to gain more in-depth knowledge about information management, the technologies, and the food value chain, a literature review was performed. The literature review was conducted in five steps. The first step was to identify the main terms that were going to be utilized in the search. Afterward, search terms could be established containing different synonyms and abbreviations of the main terms for the study. The second step was to select databases. The chosen database, Scopus, was provided through the library at Jönköping University. Scopus was chosen since it was including relevant literature within the technical and engineering field. The third step of the literature review was to delimitate the searches using different filters. The searches were within *article, title, abstract, and keywords* and the filters that were taken into consideration were the field, source type, language, document type, and the published year. The fourth step was to combine the search terms from the first step using Boolean operators to get relevant material and filter out areas that are irrelevant to this study. Several search strings were formulated and used in the literature search. The hits when searching was large at first but was handled by applying filters. The filters that were used were mainly based on years since the authors of this study wanted the latest research, which was up to date. Other filters that were used were to choose the relevant field of the results, which was set towards engineering and results within the technological area, and to combine scientific articles with book chapters, which generated data from different kinds of sources. When the filters were used, the results were narrowed down and sorted on the highest cited database Scopus. This made it easier for the authors to select the most relevant literature, according to what others used in their research. As the final step, the literature that was interesting to the topic was chosen. Three examples can be illustrated in *Table 1*.

Table 1. Search terms with final search strings, hits, and selected literature.

Main terms	**Search terms (synonymous terms)**	**Search strings**	**Hits**	**Hits after filters**	**Search date**	**Selected literature**
“Information management ”	“Information management” OR “big data”	("information management" OR "big data") AND "value chain"	822	40	02-02-2022	Mörth, O., Emmanouilidis, C., Hafner, N., & Schadler, M. (2020). Cyber-physical systems for performance monitoring in production intralogistics. Computers & industrial engineering, 142, 106333
“Food value chain”	“Food value chain” OR “Food industry”	(“Food value chain” OR “Food industry”) AND definition	574	16	01-02-2022	Ferranti, P. (2018). Defining the Concept of Food Value Chain. In P. Ferranti, E. M. Berry, & J. R. Anderson (Eds.), Encyclopedia of Food Security and Sustainability (pp. 1-5). Elsevier.
“Big data analytics”	“Big data analytics” AND “Industry 4.0”	"Big data analytics" AND manufacturing AND "industry 4.0"	176	9	04-02-2022	Wiech, M., Boffelli, A., Elbe, C., Carminati, P., Friedli, T., & Kalchschmidt, M. (2022). Implementation of big data analytics and Manufacturing Execution Systems: an empirical analysis in German-speaking countries. Production Planning & Control, 33(2-3), 261-276.

From the literature review, there were in total of 19 works of literature selected that worked as a foundation for the *Theoretical framework*. The chosen literature that was selected depended on how the main terms were used and in which context. The chosen literature was selected initially by the main terms that were relevant for this study but also depending on relevant keywords and content. Firstly, the abstract of the selected results was read to get an overview of the chosen literature. If the context in the literature were like the context of this study, the main terms were found in the text, and then analyzed in-depth. The in-depth analysis was done to generate relevant figures or text, that could be used to strengthen the upcoming result and framework of this study. The idea of the authors for this study, was from the beginning, to construct a framework based on other figures and frameworks and to compile these into a further developed framework. The authors were guided by the purpose and the research questions and thus could realize in a shorter period if the resulting articles or book chapters were relevant to this study or not. This saved time for the literature review and made the process efficient.

3.3 Case study

A case study can be defined as an investigation of a delimited part, for example, an individual, group, company, or a specific industry. This method is used to get a deep picture of the part that has been chosen to be studied and it is also a recommended option when it comes to investigating processes or changes within a company (Saunders et al., 2016). Since the research questions in this study are limited to the food industry and its value chain, the case study was chosen to provide deeper knowledge about digitalized information management.

The company used in this study works within the Swedish bread and bakery manufacturing industry. It started as a family business and has developed to be a large enterprise, with two production sites in Sweden. At its current state, the company has about 200 employees throughout the whole group and has a turnover of approximately 1000 million SEK. There is also a high variety of products and the company accounts for 50% of the market share in the country. Some examples of products that the company manufactures are flatbread, crispbread, and rye bread.

The company supported the case study by assigning a supervisor, which was the Production Director, to assist with solving issues and providing contact information of relevant employees to reach out for interviews. Meetings were periodically scheduled with the supervisor to ensure the progress and time plan.

The unit of analysis in this study is the information management in the value chain of the company. The three relevant actors *Production*, *Warehouse,* and *Distribution*, highlighted in *Figure 1*, are primarily studied. The actor *Production* consists of two plants together with the actor *Warehouse* and the actor *Distribution* consists of approximately 30 terminals in the whole country. The remaining actors in the case company's value chain were only mentioned to make it easier to understand the context of the relevant actors and to get an overall view of the information management throughout the food value chain.

3.4 Data collection

The data collected in the study was of the qualitative category since it provides a deeper understanding when collecting the data (Saunders et al., 2016). Interviews were chosen since it was the most suitable method to study the chosen topic for the study since they can widen the understanding of a certain case. The interviews were semi-structured to ensure that the participant felt comfortable and could have open conversations that could lead to in-depth insight into the topic. Semi-structured interviews allow for more flexibility during the interview for the participant and the interviewer (Alshenqeeti, 2014). Predetermined questions were shaped to work as a guideline throughout the interviews, according to *Appendix 1*, with the possibility to have follow-up questions and discussions. The questions were divided into four parts to first get to know the participant, their role, and their tasks. Subsequent questions were more specific to the food value chain. The questions were identical for all the interviews to ensure equivalence and for confirmability. When choosing participants for the interviews, employees from the case company with managing positions in different departments were chosen. The employees had roles where they in their daily tasks worked with decision making. All the interviews were performed online via Microsoft Teams. *Table 2* presents the role of the employees and the details of the interviews.

Table 2. Interview details.

Role	**Task in company**	**Length (min)**	**Date**
IT Manager	Manages the technologies and development of IT-solutions	45	02-03-2022
Production Planner	Plans what type of product to produce, when to produce and manages purchase of raw material	45	02-03-2022
Supply Chain Manager/Sales Director	Responsible for production planning and purchase departments. Manages flow in to warehouse and flow out from warehouse to distribution.	30	06-04-2022
Production Director	Responsible for the manufacturing.	30	06-05-2022
Sustainability/Innovations Manager	Responsible for future goals, mainly from a sustainability perspective, by contributions towards strategies and follow-ups.	30	25-04-2022

3.5 Data analysis

The data analysis technique chosen for the study was qualitative data analysis with an inductive approach. The inductive approach refers to collecting data and then studying the data to identify themes that can be relevant for further analysis (Saunders et al., 2016). The interviews conducted for the data collection were recorded and notes were taken during the occasion. The interviews were analyzed firstly by being transcribed to provide information that otherwise could be missed. This facilitated for the authors to revisit and examine the data. Secondly, the interviews were analyzed through a thematic analysis where the data was divided into themes and codes.
The first step of the thematic analysis was to become familiar with the data. This was done by reviewing the data that was collected through listening to the recorded audio and reading the notes of the interviews. The second step was to code the collected data to understand the importance of the data that was relevant to the study. Some of the codes that were identified from the interviews were "data required", "challenges", "software", "kind of information" and "actors' relationship".

The interview questions in *Appendix 1* show that the questions were divided into four parts to facilitate the researcher when interviewing. The parts can be seen as different themes that were identified throughout the study. The following themes were used for the interviews: background of the participant, value chain, important information for decision making, and digitalized parts in the value chain. The codes that were identified can strengthen these themes from the interview questions since they could be connected and enabled for the analysis of the study.

3.6 Research quality

Lincoln and Guba (1985) mention that there are four main criteria for trustworthiness: credibility, dependability, transferability, and confirmability. Credibility can be divided into six sub-categories: prolonged engagement, persistent observation, triangulation, peer debriefing, referential adequacy, and member checks. Prolonged engagement refers to spending an adequate of time for the research to understand a specific happening and accomplish certain goals. Persistent observation provides depth and identifies factors in a situation that are most relevant to the problem being studied. Triangulation is using numerous and different sources, methods, and theories to achieve contextual validation. Peer debriefing refers to having an analytic session where the research is exposed to a neutral audience. Referential adequacy refers to saving raw data so that it can later be examined and compared to other collected data. Member checks imply that data should be available for members to revise (Lincoln and Guba, 1985). Dependability means that the research is conducted with a consistent and repeatable approach. This means that the produced data from the research can be understood, repeatable, and evaluated by others, besides the authors of the specific study. (Saunders et al., 2016). Transferability means that a full description of the research questions, context, design, and findings will provide the reader with opportunities to judge and use the research in other fields of study (Saunders et al., 2016). Confirmability refers to the examination of the research including data, findings, analysis, and recommendations so that it is coherent (Lincoln and Guba, 1985). The trustworthiness criteria were used in this study according to *Table 3*.

Table 3. The trustworthiness criterion.

Trustworthiness criterion	Information	Author's remarks
1. Credibility		
Prolonged engagement	The research started 2022-01-17 and finished on 2022-06-15	The research has been conducted for 6 months.
Persistent observation	Data collection at the case company was performed virtually, and the participants could be contacted for further questions.	The authors could not study the company on site. No observations could be performed, however interviews with different employees at the case company were performed to get a full picture of the issue.
Triangulation	Case study, documents, and semi-structured interviews were used. The data was linked to existing theory.	The interviews resulted in multiple copies of one type of source to reach triangulation, since the same questions were used for the participants.
Peer debriefing	There were three seminars taken regarding planning report, stage-gate report, and final report where supervisor and examiner's feedback and opposition was taken.	Feedback was taken in consideration from opponents as well.
Referential adequacy	Due to confidentiality of data, the raw empirical data could not be in the appendix. The data have been summarized in fluent text.	All the raw empirical data have been saved so it can be revised if needed.
Member checks	Both the authors checked the data.	The data was saved on a shared platform for the authors to revise.
2. Dependability	All data that is available for the authors can be find in the findings.	The participants from the interviews, unit of analysis and coding used in thematic analysis are described.
3. Transferability	The research provides fully descripted interview questions and thorough methodology.	The findings are possible to adapt in other companies in the same industry as the case company, also in companies with general value chains.
4. Confirmability	The analysis was based on case study and the presented *Theoretical framework* to ensure consistency of the analysis.	Relevant parts from already developed frameworks and figures were used to construct the framework of this study.

3.7 Research ethics

The term *research ethics* can be defined as standards of behaviors towards those that are affected by specific research, which can be further developed and divided into ten principles (Saunders et al., 2016). From these ten principles, five principles were used in this research. The first principle is *avoidance of harm*. To ensure this, the semi-structured interviews used in this research allowed interviewees to answer with their own words, and they were not forced to answer in any specific manner. Moreover, the interviewees were anonymous, which also contributed to the well-being of all participants. The second principle is *informed consent of those taking part*. To ensure this, voluntary participation was encouraged with the interviewees and their role in the research was informed. The interviewees were also informed that notes were taken during the interviews and that interviews were recorded. The third principle is *integrity and objectivity of the authors*. To ensure this, the authors of this research acted openly and truthfully toward the participials and focused on the present data without any bias. The fourth principle is *respect for others*. To ensure this, everyone that was involved in this research had their dignity respected and the authors of this research also took responsibility and focused to maintain trust between all participials. The fifth and last principle is *responsibility in the analysis of data and reporting of findings*. To ensure this, individuals and company names were anonymized in this research. The interviewees also had the chance to read through the analysis and findings and suggest if something was wrongly interpreted.

4 Findings

This chapter presents the result from the data collection and generates a mapping of the case company's current state. This creates a basis together with the theoretical data, that will help to answer the two research questions of this study in subsequent chapters.

4.1 The current state of the case company's value chain

After conducting the interviews, according to *Table 2*, a mapping of all the involved actors in the case company's value chain is constructed. This was essential to be able to understand the challenges that the company faced. Since the information management needed to be further developed and adapted to the concept of industry 4.0, it was crucial to get a clear picture of the current state of information management at the case company. The case company's value chain, with all the actors, is illustrated in *Figure 10*. The value chain of the company consists of six main actors: *Farmer, Production, Warehouse, Distribution, Retailer,* and *Customer*.

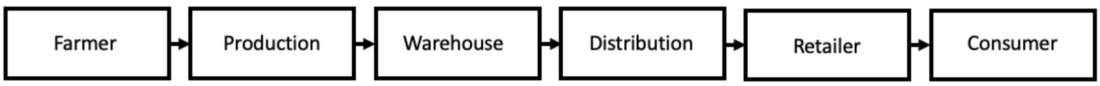

Figure 10. The case company's value chain.

The idea of identifying relevant actors, according to *Figure 1*, in the case company's value chain was mainly a requirement from the case company based on their challenges. Therefore, in this thesis, three relevant actors were chosen and covered: *Production, Warehouse,* and *Distribution* focusing on their information management, information and communication technology, and decision-making as clarified below.

4.1.1 Actor 1: Production

From the interviews, it was clarified that the actor *Production* is seen as the main actor in the company's value chain. The company has two production facilities in two different cities, approximately five hours apart from each other. In the different production facilities, different products are being produced. One of the production facilities is currently rebuilt and is the biggest facility where products that are the biggest sellers are being baked. The production is adapted for baking products with big volumes. The other production facility is smaller with a flexible production line. The controlling of the machines in the production facilities is manually performed by operators, however, the execution at the production lines is automated.

Beyond the function of *Baking* in the production, there are the functions of *Planning* and *Purchase*. In the *Planning* function, the volume, type of product, and time of when the product needs to be baked are being scheduled. The *Purchase* function is responsible for buying raw materials from the supplier.

4.1.1.1 Information management

The actor *Production* receives and gives information from two actors before and after in the value chain: *Farmer,* and *Distribution.* The information from the actor *Farmer* is not directly sent to the actor *Production*. Instead, the information sharing is between the actor *Farmer* and the *Purchasing* function where the *Purchasing* function receives forecast two weeks in advance from the *Planning* function, illustrated in *Figure 11.* The

Planning function receives the information about orders that are placed from the actor *Distribution.*

The orders are placed according to sales forecasts. From one of the interviews, it was mentioned that:

"Forecasts are mostly based on what it has looked like historically"

Once receiving the orders, the *Planning* function can plan for the production and specify a volume, type of product, and time to produce it. All information that is shared between the *Farmer*, *Purchasing*, *Planning*, *Baking*, and *Distribution* is manually managed via phone calls, Excel sheets, and PDF files, and these are sent through email and Microsoft Teams.

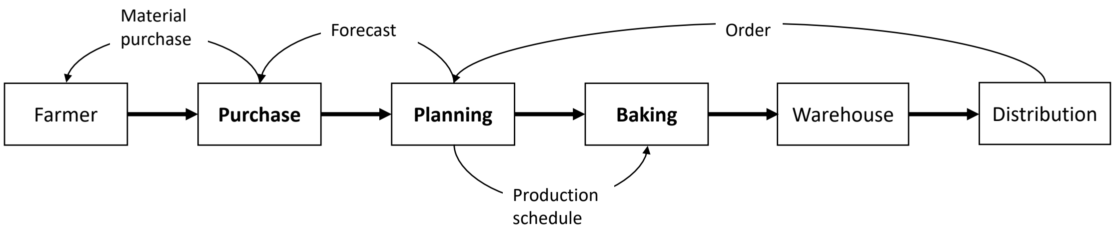

Figure 11. Information shared between the functions in the actor Production.

4.1.1.2 Information and communication technology

When it comes to information and communication technology in the actor *Production* at the case company, it was clarified from the interviews that there is a lack of technologies within the *Production*. It was mentioned that there is an Enterprise Resources Planning (ERP) system, however, the case company does not work with all the features of the system. It was clarified that only the inventory levels were picked out from the system. The administrative processes were thus conducted manually and there was no automated system for production planning or inventory management now. However, the case company is beginning to implement some information and communication technologies. From one of the interviews, it was mentioned that:

"We are in the pre-study phase when it comes to big data, which means that we know how to collect the data but not really how to analyze it"

It was further mentioned that the company has recently developed a project team for this specific matter, to come up with solutions for the analysis of the gathered data, by using information and communication technology.

4.1.1.3 Decision-making

During the interviews, it was explained that the actor *Production* does not take any data-driven decisions, but rather decision based on either behavior or experience. In addition, it was mentioned that:

"We bake our products against experience from those who work here and those who have worked here for a long time"

It was expressed that the strategy within the *Production* actor was to always have raw materials stocked and that the finished products were manufactured with the strategy of make-to-stock.

For decision-making, different information was important for the different managers. For the Supply Chain Manager/Sales Director in the *Planning* and *Purchasing* functions, it was important to know the sales- and production outcomes, theoretical capacity, and activities happening at actor *Retailer*. For instance, marketing campaigns plan for the production in advance and purchase correct raw materials from the *Farmer* so that they are available when producing the products. For the *Production,* the Production Director it was important to know information on old sales and forecasts from the actor *Distribution* when making decisions.

4.1.2 Actor 2: Warehouse

The actor *Warehouse* stocks the finished products and consists of two freezer storages, which store the finished products. The warehouses were in the same physical facilities as the two manufacturing plants in the actor *Production*. The actor *Warehouse* works like the actor *Production* with the strategy of make-to-stock and has a specific volume of each product that needs to be stocked in the warehouse.

As mentioned under the actor *Production,* there was a high level of manually carried out tasks and this manual handling of tasks was a challenge that the actor *Warehouse* faced as well. From one of the interviews, it was mentioned that:

"*There is still a lot of manually carried out tasks between the actors"*

Since the case company wanted to decrease the levels of stocked finished products, because of the digital transformation, the *Warehouse* actor is going to play a lesser role in the future.

4.1.2.1 Information management

The actor *Warehouse* receives and gives information comes from the actor *Production* and the actor *Distribution.* The important data is relying on secondary data since the *Warehouse* actor does not have any direct contact with the actor *Retailer*. The information that is shared from the actor *Distribution* to the actor *Warehouse* is orders based on forecasts from old sales, illustrated in *Figure 12.* These forecasts are provided to the actor *Distribution* from the actor *Retailer.* The information that is shared from the actor *Production* to the actor *Warehouse* is information regarding transport such as in- and out-delivery.

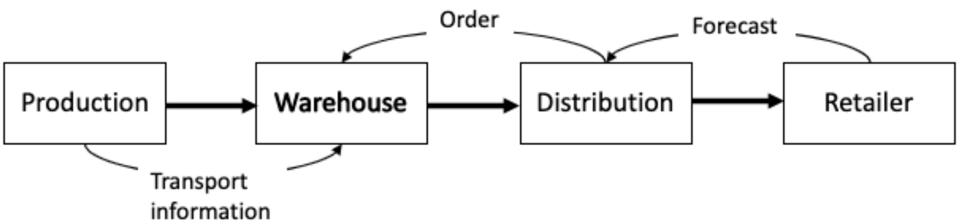

Figure 12. Information shared with the actor Warehouse.

4.1.2.2 Information and communication technology

From the interviews, it was clarified that there was a lack of information and communication technologies within the actor *Warehouse* as well, as could be seen at the actor *Production.* The important information was mediated manually via Excel sheets. This was carried out similarly to how the actor *Production* does, that is, through email and Microsoft Teams.

4.1.2.3 Decision-making

In comparison to the actor *Production,* the actor *Warehouse* does not take any data-driven decisions either. The strategy within the *Warehouse* actor was to always have finished products in stock, which results in high levels of stocked finished products. The purpose of this was to be able to meet shifting demands from the actor *Retailer*. The shifting demands are mainly due to marketing campaigns at the actor *Retailer*, which impact the actor *Production* and in turn the *Warehouse* actor as well. The main impact is that, during a marketing campaign, the order from the actor *Distribution* can be placed only two weeks before the launch. From one of the interviews, it was explained that:

"We do not have a good process for capturing information and what happens in the stores. /.../ luckily, we got the information two weeks before, we panicked and could act"

One of the main challenges for the actor *Warehouse* was the high levels of stock. The case company wanted to improve the information sharing between the actors *Distribution* and *Retailer* and to know the activity happening at stores, to be more prepared when the demand shifts. Furthermore, the case company wanted a digital transformation to reduce the high levels of finished products, which could deploy important resources towards other important functions.

4.1.3 Actor 3: Distribution

The actor *Distribution* was an affiliate of the case company, that took care of the distribution of finished products from the actor *Warehouse* to the actor *Retailer*. The affiliated company took care of 85% of the finished products, while the other 15% was distributed directly to restaurants, travel companies, and municipal units. It comprised 30 different terminals, which were located all over Sweden, and of about 25 different corporations that transported the case company's finished goods towards the actor *Retailer*. The actor *Distribution* also distributed finished products for other companies within the bread and bakery industry, with similar products as the case company.

4.1.3.1 Information management

The *Distribution* actor was depending on forecasts according to old sales from the actor *Retailer*, which consisted of different stores and supermarkets, and mediated forecasts according to old sales from the actor *Consumers*. The actor *Consumer* consisted of end-consumer that bought the finished products in different stores and supermarkets, which contributed to the predicted forecasts.

4.1.3.2 Information and communication technology

There was a lack of information and communication technologies within the *Distribution* actor as well and the important information was mediated manually via Excel files, email, and Microsoft Teams from the actor *Retailer.* As in previously mentioned actors, this was one challenge that the case company faced, which the digital transformation would help to solve to deploy important resources.

4.1.3.3 Decision-making

Corresponding to the actor *Production* and the actor *Warehouse,* the actor *Distribution* does not take any data-driven decisions. The strategy within the *Distribution* actor was to always have finished products in stock, which made this actor ready for shifting demands if the actor *Retailer* had campaigns. Since the *Distribution* actor was the one that had direct contact with the actor *Retailer*, this actor was relying on primary data and was not dependent on any other actor in the food value chain. It was also the *Distribution* actor that the two earlier mentioned actors *Production* and *Warehouse* were relying on, regarding the forecasts from the actor *Retailer.*

4.1.4 Summary of the relevant actors

As listed above, the relevant actors, together with the associated functions, had high levels of manually conducted information management. Most of the information, forecasts, and demands were based on gut feeling from employees with long experience within the case company. This indicated that the company had a lack of knowledge regarding which applications and technologies to use when it comes to digitalized information management. Since all the conducted interviews in *Table 2* confirmed the high levels of manual handling, it was crucial to specify which information is important for each relevant actor. This is the initial step to generating a digitalized solution that would fit the information management throughout the whole food value chain. Therefore, it was crucial to get an overview of all the actors since the relevant actors got important information from the remaining actors as well.

5 Analysis

This chapter presents an analysis of the findings of the study and the theoretical framework to answer the research questions and develop a framework for digitalized information management.

5.1 Analysis of the current state of the case company's value chain

Already after the first interview, it was clear that the information management between the actors was manually conducted. This was mainly done through email, phone, or Microsoft Teams, containing Excel files with relevant information. The following interviews that were performed confirmed the level of manual information management at the company. Moreover, within the actor *Production* with the concerned functions, decisions were made on gut feeling from experienced employees. For example, during a certain season of the year, patterns could be seen, and the production was based on historical sales. Since the production was aimed at stocking finished products at high levels (make-to-stock strategy), there were always products ready to be distributed. These stock levels of finished products had consequences for the case company, such as high costs of tied-up capital in the warehouse. Therefore, making decisions based on forecasts was not the best option and manual handling of information was a contributing factor. The strategy of the company was to always have raw materials and finished products in stock, so the production was able to handle variations in demands. This, however, led to high levels of tied-up capital.

The case company is in the process of using big data and has clear goals regarding industry 4.0 technologies. But, since the manual handling of information was still a challenge, the company postponed its digital transformation. To be able to follow the current trends in the manufacturing environment, such as the concept of industry 4.0, it is important to implement the digital transformation. But, at the current state, the company has limited knowledge of how this could be done. Also, they have limited knowledge of which applications and technologies they could use and combine to reach a digital transformation, which increases their competitiveness (Lu et al., 2020) (Karabulut, 2020).

5.2 Type of information to be considered for data-driven decision-making in food value chains

This section provides answers to the first research question and focuses on the relevant actors in the case company's value chain, according to *Figure 1*. To construct beneficial information management, it is relevant to get a solid basis of which type of information is important for each actor. This will in turn generate beneficial solutions regarding the product, planning process, and resources (Szymczak et al., 2018). Since the case company already uses big data technology, the next step is to generate information from the acquired data. To fulfill the higher hierarchies, according to the DIKW-pyramid in *Figure 4* and reach further steps according to the simplified data value chain in *Figure 3* it was essential to know which type of information the data needed to generate. From the findings, it was clarified that most of the information management was carried out by using Excel sheets, that were shared between actors through email or Microsoft Teams. This was time-consuming and brought consequences, such as high levels of inventory and that unnecessary resources were used, which could have been used for other important tasks in the company.

The important information, that helped to answer the first research question was based on the current state of the case company, which is the initial step towards digitalized information management. The important information for each relevant actor in the case company's value chain is listed in *Table 4*.

Table 4. Important information for the relevant actors.

Actor	**Important information**
Production	Production outcome Theoretical capacity Activities happening at retailers Sales outcome Old sales Forecasts from distribution
Warehouse	Forecasts from distribution
Distribution	Forecasts from consumers Order from production

5.3 Digitalization of parts of the value chain for data-driven decision-making

After identifying the relevant information for each actor, the next natural step is to compile the results to develop the framework for digitalized information management. To construct the framework, it is also important to keep in mind that the framework needs to be adapted to different companies and industries (Szymczak et al., 2018). As the case company has ambitions to undergo a digital transformation, this is facilitated by linking together all the relevant information that the different actors require. One way to do this is by looking at a cyber-physical system, as in *Figure 2*, where different actors can work together with different types of information. In addition, the backdrop of internet of things will make it easier to discern how the aspects are related and where digital advancements will take over manual management.

To digitalize parts of the value chain, the DIKW pyramid and data-driven decision-making model are taken as starting points of inspiration. According to the DIKW-pyramid in *Figure 4*, big data is seen as the lowest hierarchy, which contains unprocessed data that needs to be further analyzed. To gain information from the produced data from the big data technology, big data analytics software is an important component that needs to be implemented. This is seen as the next hierarchy in the pyramid. When the data have been analyzed and processed, the resulted information also needs to be organized, so that knowledge can be drawn from it. This can be done through cloud computing, which needs to be implemented in the case company. Platform as a Service and a common platform for each actor in the value chain is proposed. Through the common platform, the actors can access knowledge that forms the basis for data-driven decision-making. This means that cloud computing is seen as the two highest hierarchies in the DIKW-pyramid since this technology is proposed as an organized solution for the case company. The resulted solution, that converts data into knowledge, which is seen as the highest hierarchy and desired state in this study, means that the company has a basis to build data-driven decisions. According to *Figure 5*, data-driven decisions lead to implementations that will have an impact on different actors or the whole value chain. The impacts will finally result in consequences for the case company, which also provides a basis for feedback. All the different parts in a digitalized food value chain are seen as steps, to achieve a strategic way of work when it comes to continuous improvements. The digitalized information management is also seen as a loop, which can be used repeatedly to help reach future goals. The digitalized information management consists of six steps.

1. Collect the data
2. Analyze the data
3. Share the information
4. Make decisions
5. Implement
6. Feedback

To collect data in step one, big data is one of the technologies to get large amounts of data. To analyze this data, big data analytics software needs to be used. After the data had been analyzed, cloud computing needs to be used to share the outcoming information from the previous step. After the data had been transformed into information, managers could take decisions from the shared information and subsequent knowledge throughout the food value chain. The final step is to implement the knowledge in the processes, which is a basis for feedback for continuous improvements.

5.4 The framework for digitalized information management

The six steps could be illustrated in *Figure 13*, as a developed version of the frameworks in *Figure 5* and *Figure 6*. This, with the focus on the case company's relevant actors in *Figure 1*, is structured according to the activities in *Figure 7* and *Figure 8*.

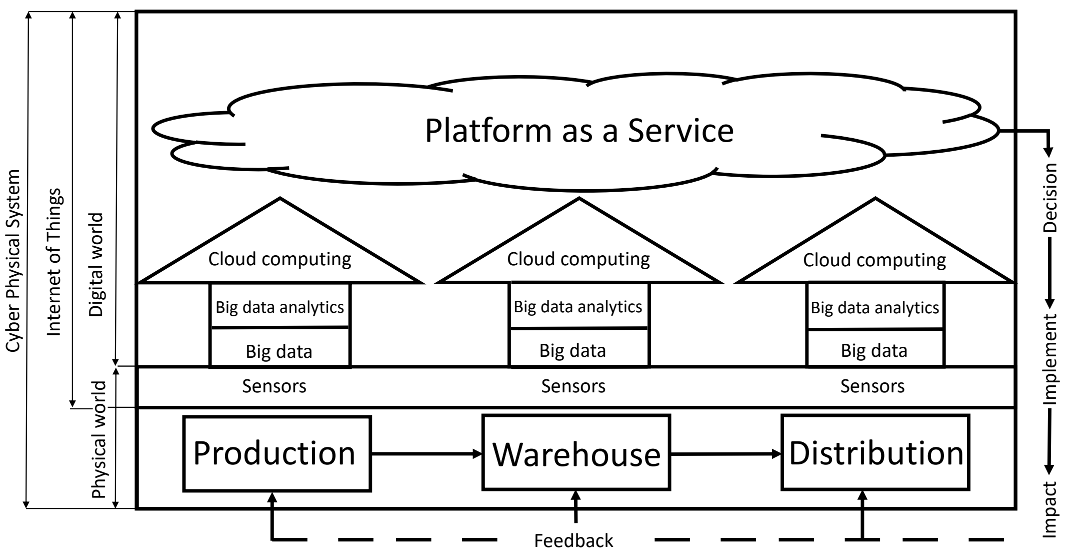

Figure 13. The framework for digitalized information management.

5.4.1 Components of the framework for digitalized information management

The data-to-knowledge components of the framework for digitalized information management are based on the DIKW-pyramid in *Figure 4* and can be seen as the three arrows, together with the cloud, in the framework in *Figure 13*. The sensors can be seen below the three arrows and are physical solutions that will generate digitalized data in form of the big data technology. These components could be seen as one flow, where data is transformed into useful knowledge. This flow, together with the data-to-knowledge components, is illustrated in *Figure 14*.

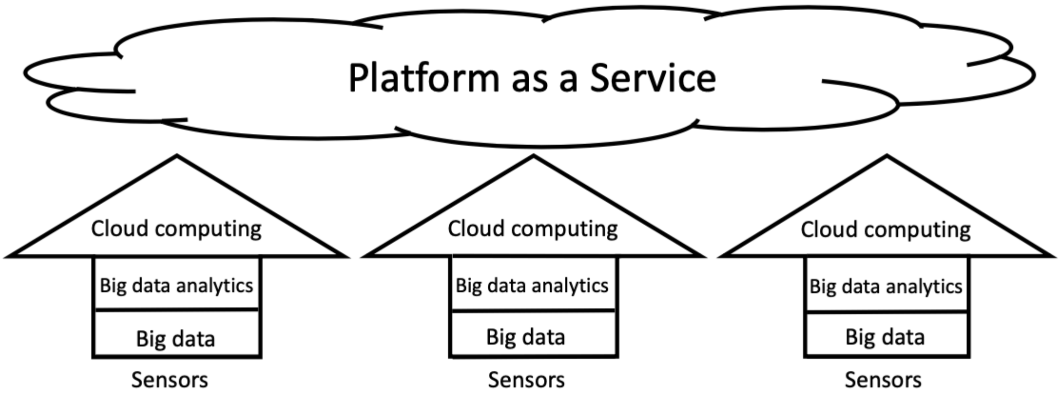

Figure 14. Data-to-knowledge components of the framework for digitalized information management.

From the Platform as a Service solution, according to *Figure 14,* managers can make data-driven decisions from the produced knowledge. The data-driven decision-making components could be seen as the second flow in the framework in *Figure 13* that also generates impacts on the food value chain, which in turn will provide the basis for feedback towards the actors. This second flow is illustrated in *Figure 15*.

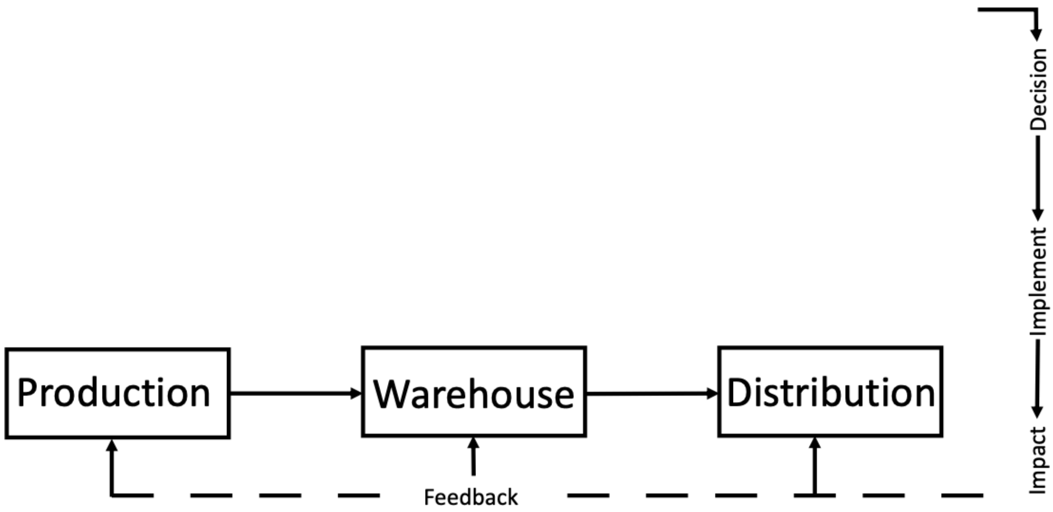

Figure 15. Data-driven decision-making components of the framework for digitalized information management.

5.4.2 The framework for digitalized information management adapted to the case company

Besides the high levels of manual handling, the investigation of the case company also indicated that the company needed to rearrange which information was intended for which actor in the food value chain. Since this study focuses on the relevant actors, the produced framework only illustrates the type of information that is relevant in the framework for digitalized information management for these actors. *Figure 16* illustrates the framework of this study used in the case company in a desired future state.

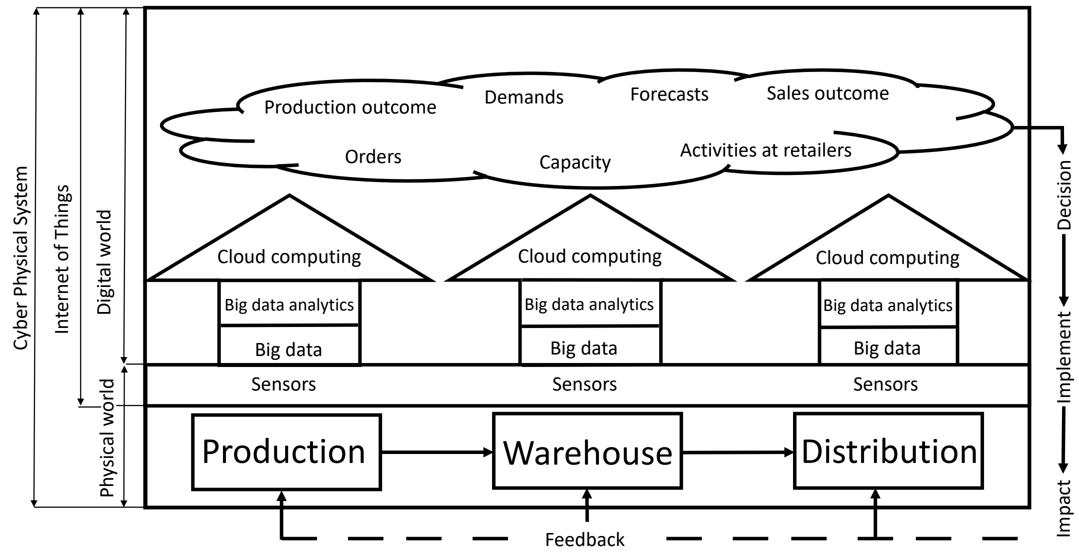

Figure 16. The framework for digitalized information management was adapted to the case company.

In a desired future state, instead of using the actor *Distribution* as a form of intermediary, the actor *Production* should get the demands and activities from the actor *Retailer* directly by using the value chains' common platform. This would generate primary data, which would be timesaving and at the same time reduce the possibility of misinformation that could occur with manual information management. With help from the common platform, important resources such as time and capital could be used for innovations of the production or the products, which is an area that the company could use the saved resources towards. Since the case company's internal goal is to reduce the inventory of finished products, the actor *Warehouse* could get clearer forecasts with information directly from the platform, instead of getting this information from another actor manually. This would ease the task of reducing the inventory and at the same time become timesaving. This means that important resources could be used for other important activities also regarding this actor.

Instead of letting the actor *Distribution* set the demands towards the actor *Production*, it should be a more beneficial choice to have it the opposite way around. This would make it easier for the *Production* to use the make-to-order strategy, which would decrease the high levels of inventory in the actor *Warehouse*. This would result in the actor *Production getting* better control over the entire value chain and that the other actors are dependent on this actor. This would in turn ease the way of reaching the strategy of make-to-order instead of the strategy of make-to-stock, which is a desirable future state for the case company. Also, since bakery products are daily products, the make-to-order strategy would be more beneficial from that aspect as well, which in turn also could reduce the inventories in the actor *Distribution*. All these aspects could be the result of using the framework in this study since all the important information is compiled in the common platform and could be used whenever desirable.

To summarize the framework in *Figure 16*, the important information for each relevant actor in the case company's value chain, according to *Table 4*, is compiled in the common platform in *Figure 17*.

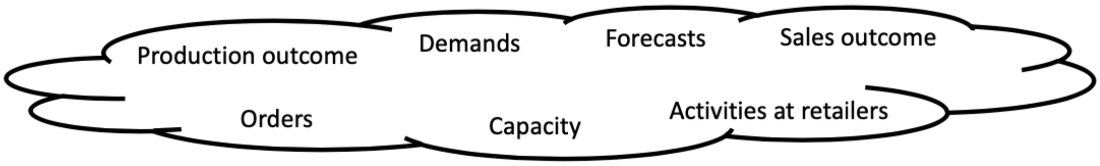

Figure 17. The important information in the case company's common platform.

The main difference in the desired future state is that the important information is digitalized, compared to the manually carried out information management that is used in the current state. After the digital transformation that has been conducted in the desired future state, the case company will be adjusted towards the concept of industry 4.0 and use adapted digitalized applications and technologies. It is also relevant for managers to understand how the different applications and technologies are used and how they contribute to transforming data into important information and thereafter knowledge. This would in turn provide a strategic way of work for the case company, where the six steps and the two types of information flows that were mentioned earlier, could be used to get an increased structure regarding the information management.

6 Discussion

This chapter discusses the previously mentioned chapters and compares other potential methods and solutions besides the ones that were used in this study. The implications and limitations are also discussed in this chapter.

6.1 Discussion of method

The resulting framework, according to *Figure 13*, generates further knowledge within the research area, which is in line with the inductive approach chosen in this study. The conducted interviews in *Table 2* were carried out with the different departments within the case company to search for patterns. The choice of inductive approach was beneficial in this aspect as well. This study used the case study method, including interviews to acquire qualitative data. Limiting the study to three specific actors in the case company's value chain allowed the study to get a deeper understanding of the chosen area. Besides the conducted interviews, other methods like observations or surveys could have increased the trustworthiness of the qualitative data. However, in line with restrictions due to the Covid-19 pandemic, there was a limitation on the method alternatives, for example, company visits, and observations were not possible at the time. It would have been beneficial for the authors to visit the facilities, to get an overall view of the two actors *Production* and *Warehouse,* and to get a tangible view of the processes of these actors. A strength of the conducted interview was that they were from different departments within the case company, which strengthened the trustworthiness of this study.

The trustworthiness criteria in *Table 3* gave concrete explanations concerning how the authors applied these criteria during the study and together with which occasion. These different aspects that were mentioned in the table made it easier for the reader to repeat the way of work and to come up with the same kinds of results. Also, since both a case study and a literature review were conducted, together with the search for patterns in the conducted interviews, triangulation increased the quality of the study. If other methods or data collection techniques, like experiments, for example, would have been conducted instead, the study would have had more of a deductive approach instead.

All the aspects mentioned above increased the quality of this study and indicated that the study could not have been carried out any other way under the current circumstances. Since the case company’s two manufacturing plants were geographically located far away, the visits needed to be carefully planned. This made the methods of observation and surveys, in place at the manufacturing plants, even harder to conduct and was a contributed factor towards that the company visits never accord during this study. This was also the main reason that the conducted interviews were through Microsoft Teams and not conducted in place at any of the case company’s facilities.

6.2 Discussion of findings and analysis

As answers to the research question, the first relevant actors were mapped in the case company’s value chain, followed by knowing which information is important for each actor, followed by constructing a framework for digitalized information management. The first parts of the *Findings* chapter are a result of processing the interviews according to *Table 2*. After mapping all the actors, the authors were tasked with finding out which actors were relevant, keeping in mind the topic of the thesis. The choice of the three relevant actors was done based on the empirical data in the first part of the findings, that was gathered from the conducted interviews. It seemed like the actor *Production* had the most space for improvements since there were more ingoing processes in that actor compared to the other actors. The actor *Distribution* was, as mentioned earlier, an affiliated company to the case company and had a high level of influence on the other actors. Since the actor *Production* were depending on the forecast from the actor *Distribution*, this actor was included in this study. The actor *Warehouse* on the other hand was included since the actor *Production was* in the same facilities. But, since the case company wanted to work more against the make-to-order strategy, this actor could eventually be eliminated from the food value chain. If the inventory of finished products is decreased over a longer period, the outcome would result in reduced dependence on the actor *Warehouse*.

The empirical data contributed directly to answering the first research question by clarifying which information was important for each relevant actor, according to the current state of the case company. The thought of the authors was from the beginning, to compile the empirical and theoretical parts to develop the framework and then test the framework at the case company. This results in a digital transformation from the current state into a future desired state, that would help to solve the challenges that the case company faced.

The empirical data was reliable since the gathered data from the conducted interviews in *Table 2* were up to date and generated the latest available information. Also, since the interviews were carried out with help from different departments at the case company, the data could be confirmed by more than just one source. The conducted interviews did confirm each other and gave primary data, which contributed sufficient data to this study.

Since the case company is in the early stages of using big data technology, the authors had to find a strategic way of working with digital technologies that could benefit the case company to use the produced data to base their decisions. The DIKW-pyramid in *Figure 4* was used to get a general view of how data can be transformed into knowledge, on which managers could base their decisions. When a general view of transforming data into knowledge was presented, the different hierarchies in the pyramid needed to be transformed into digital solutions for the case company. The digital technologies that were mentioned in the chapter *Theoretical framework* were used to represent the different hierarchies in the pyramid and to contribute to the context in which the different parts of the framework belong.

The frameworks in *Figure 5* and *Figure 6* raised an idea of how the framework in this study could be constructed and how the flow of information in the food value chain could be illustrated. The activities in *Figure 7* and *Figure 8* were used to create the base of the framework, which illustrated the flow of processing raw material into the finished products that the case company produced. In the framework, according to *Figure 13*, the three relevant actors according to *Figure 1*, represent this processing flow. All three relevant actors needed to be included in the framework, to be able to share important information and transform secondary data into primary data, which solved the challenge of targeting important information that the case company had at the current state. By using these three relevant actors, the first research question in this study could be answered by using the target important information in a tested framework, according to

Figure 16. *Figure 5* created the data-to-knowledge part of the framework, where *Figure 4* could complement the already existing arrows in *Figure 6* with digital solutions, taken from the information and communication technologies in the chapter *Theoretical framework*. This part of the framework was used to answer the second research question and helped to create a solution to fulfill the purpose of this study. The framework in *Figure 6* was used to illustrate how managers could base their decisions and which digital solutions could be used to create these decisions. Also, since the developed framework in this study could be seen as a loop, the feedback is important to create a base for continuous improvements when it comes to information management. The sum of all the components in the framework, according to *Figure 16* helped to fulfill the purpose of this study, answered the two research questions, and solved the challenges the case company faced at the current state.

Since the case company used big data technology, this indicated that the company already started its digital transformation. This meant that the focus could be taken away from the parts *Digitization* and *Digitalization* under the chapter *Theoretical framework* since the company finds itself in a later stage when it comes to digitalization. This resulted in the focus of regarding technologies and applications that in turn could create solutions to address the case company's current challenges.

All the figures and frameworks mentioned earlier contributed with different components, and compiling these components resulted in the final framework in *Figure 13*. Other literature could have resulted in a different framework, which also could have solved the case company’s current challenges. But under current circumstances, the framework presented in this study was enough to fulfill the purpose of this study and helped to answer the research questions.

The second research question was answered with help from both empirical and theoretical data gathered through scientific articles and book chapters. The developed framework is a theoretical and general point of view, and it can be adapted to the context of the case company. The developed framework is intended to be beneficial to other companies in the same industry as the case company. Furthermore, other technological tools or applications could have been used, instead of those that were used in this study. The study intended to contribute new knowledge to academia. Compiling already constructed frameworks and figures into one framework, contributed to new knowledge in the chosen field of the study. The most important knowledge from the framework was also to understand which digitalized applications and technologies to use and to see the information management as a loop, that could be used for continuous improvements.

In *Figure 16*, both the empirical and theoretical data were compiled to test if the framework in *Figure 13* could be beneficial in an actual case and to the case company. The important information from the case company’s current state was also adjusted and narrowed down to the most relevant information, that would be more beneficial than the current state. By using the Platform as a Service solution, the important information could thereafter be constructed as a basis for data-driven decision-making. Since the case company finds itself in the initial stages when it comes to the use of big data, this indicated that there is limited knowledge within the company on how to proceed from the current state. Regarding this, implementing the right applications and technologies can become time-consuming and it is hard to anticipate how long the implementations and the digital transformation could take. This means that there could be a need for more pre-studies within this field, to get a deeper understanding of how to proceed and which level of knowledge there is within the company. Doing so would create a basis for knowledge about which parts that need to be done by third-party solutions and which parts can be conducted with ingoing resources at the case company.

The result helped to answer the two research questions of this study. Other forms of the result could be in form of recommendations or guidelines in running text. But since the gap of this study was filled with a concrete figure of a framework, this was the most beneficial form of result for this study.

6.3 Implications and limitations

The main implication of this study is from an academic point of view, to generate theoretical solutions to the case company’s challenges. Further implications could also be to inform the reader about the importance of using the right digitalization applications and technologies for the chosen industry from a practical aspect, where the resulting framework in *Figure 13* could be used in different companies. Since both authors have different professional experiences of the consequences when there is a lack of standardization, this implication is important to highlight as well, which could be investigated in further research. Also, the resulting framework in this study could be the beginning of further improvements in other areas, for example, sustainability questions.

The limitation of this study is the need for a maturity model, which could have been used at the case company before the implementation of the developed framework in this study. This would result in even further adapting of information and communication technologies to the case company and could have made the framework custom-made, to solve the current challenges even further efficiently. A maturity model could also generate savings of resources since the level of unnecessary work and planning would be kept to a minimum when it comes to the implementation of the framework in this study. Another limitation of this study is that no company visits were conducted, which would have increased the opportunities for other methods when it comes to the empirical data gathering. If visits were made, observations could have been conducted at the case company to complete and confirm the gathered information from the interviews. The interviews could also be conducted face-to-face with the interviewee, which would have enhanced interactions between the participants. These mentioned aspects could eventually increase the quality of this study even further.

7 Conclusion

This chapter will summarize this study. Compared to the other chapters of this report, personal thoughts will be presented here, to give the reader more perspective on the chosen topics. This chapter will also present recommendations for further studies within the same research area.

7.1 Conclusions of this study

The conclusions of this study are to highlight the importance of implementing the right digitalization applications and technologies in a food value chain. This is beneficial towards the current customer demands, which contribute to shifting markets, etc. Also, to be competitive in the market, adjustments in the value chain towards the concept of industry 4.0 can be crucial to meet the current circumstances in the labor market. Not only drawing the conclusion of digitalization, or automation, to production technology process but having a broader perspective is another conclusion that the reader will gain after reading this report.

It is also important to understand how to transform data into knowledge, that can be used to base data-driven decisions. In a digitalized environment, it is relevant to transform the ingoing steps into digitalized solutions that help to generate knowledge together with different applications and technologies. Having the right applications and technologies, that will help companies to transform data into knowledge, will reduce the consequences that come with manual handling and when there is a lack of information management. Depending on the structure, equipment, and which industry a certain company finds itself in, companies could also use other applications and technologies besides the ones that were used in this study. The ones that were used in this study are just conceptual examples of the case company, which means that they will not solve problems for companies in general. From these aspects, this means that the outcoming findings and analysis helped to answer the two research questions and that the purpose of this study was fulfilled.

Since there should be beneficial to investigate how much knowledge there is within a certain company, when it comes to the digitalization aspect, it is hard to anticipate how much resources that need to be spent on the digital transformation. If a pre-study, with a developed maturity model, is carried out before implementing the framework in this study, companies could have a chance to save important resources in the long run. This, if the right digital applications and technologies are implemented in the right way from the start.

7.2 Further research

The backside of a digitalized information management and decision-making process could decrease the relationship between the actors in the food value chain since every actor gets more independent and does not require the same type of contact as in the current state. This could be an option for further research, to investigate if this could be a problem and to what extent if so. Future research within the same area could also be to study the remaining actors in the case company's value chain. Since the framework, according to *Figure 13*, only generate solutions for the three relevant actors in the case company's value chain, the remaining actors might have other technological solutions. This could, in turn, result in even further developed frameworks, that could be even more beneficial in general value chains, from every actor's perspective. Further developed frameworks could eventually generate a stronger basis for standardization.

After the conducted interviews, according to *Table 2*, and personal experience from earlier working life, the need for standardization is a common problem in many companies. This means that future research could generate even further investigated frameworks, that could form a basis for standards, not only when it comes to information management, but in other areas as well. The need for standardization could be adapted on the shop floor level, as well as other areas at an overall value chain level. This could generate even further savings for companies, in form of less use of important resources such as time and capital.

The interviews also indicate that the case company wants to become more sustainable than it is in its current state. One example from one of the interviews was that the actor *Farmer* could become more sustainable when it comes to the tasks within this actor. For example, the use of more environmentally friendly fuel for vehicles could be further investigated. Also, the case company wanted to look for more environmentally friendly solutions when it comes to the heating of the facilities, mainly in the actor *Production*, as well as when it comes to the energy source for the equipment.

The case company also wanted to get better control over their production technological processes under the actor *Production.* For example, future studies could be more focused on these parts instead of information management. This could be carried out with a focus on the waste in the production and generate standards, to get even further control over this part. Also, to make the equipment within the production communicate with each other in a more beneficial way than they do in its current state could be another research area. This could be done through research regarding the term *machine learning*, which would result in machines that use relevant data to solve problems on their own. This could in terms make the food value more digitalized and automated and reduce the manual handling even further. This would have been a logical next step within the concept of industry 4.0 for the case company.

The content of this study could be summarized in the term digitalization and that there is a strong need for digitalization, regarding the concept of industry 4.0, in the labor market. This could, if the relevant applications and technologies are implemented the right way, generate savings, and become efficient for companies through different aspects and not just regarding the information management.

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Appendices

Appendix 1. The interview questions.

Interview Group	Question
Background questions [These are warm-up questions regarding the experience of respondent in the company and decision making]	What is your role in the company?
	Work experience (in managerial position or SC-decision making)
	What are your previous experience in decision making?
	What types of (managerial) tasks are you involved with?
Value chain questions [These questions give better understanding of value chains]	Which actors do your company's value chain consist of?
	Which part of the value chain that is more time consuming than other parts?
	How is the relationship between the actors?
	How is the communication between actors, is important information shared between all actors in the value chain?
RQ1 questions [Probe on questions related to RQ1] What type of information needs to be considered for data-driven decision-making in food value chains?	Do you work against any forecasts when it comes to customer demands?
	What kind of (digital) systems do you work with ? (ERP, Excel, tex. affärssystem)
	Which software do you work with ?
	What challenges you face when working with digital systems?
	What are the benefits when working with digital systems?
	What type of information do you work with daily?
	Which data you need that helps you understand the information? From who do you get the data? How do you get the data?
	What type of information (and data) you send to the next part of the value chain?
	Which factors are important for you to make decisions?