Value Stream Mapping as a Basis for Waste Removal in the Agri-Food Industry

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MIOM05 Degree Project in Production Management

Abstract

Title:	Value Stream Mapping as a Basis for Waste Removal in the Agri-Food Industry
Authors:	Ebba Almqvist and Mathilda Mellberg
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Background:	The case company is a Swedish family-owned business, operating in the agri-food industry. Their philosophy is to develop, produce, and sell frozen products from the vegetable kingdom with a focus to be organic and convenient. The company has realized that the production layout and the material flow cause a lot of waste and have great potential for improvements regarding efficiency in production and related processes. Value stream mapping (VSM) will be used to identify and reduce waste at the company. In addition, there is a gap in knowledge when it comes to the use of VSM in agri-food production. Therefore, a comparison of the use of VSM in the agri-food industry to a previously (well) studied industry will be made.
Purpose:	The purpose of this study was to analyse the current production set-up and the related processes at the case company using VSM, to test its applicability in the agri-food industry and how it differs from a previously well studied industry.
Research questions:	**RQI** What waste can be identified by VSM and how does that affect the business? **RQ2** How can the identified waste be reduced? **RQ3** How does the use of VSM in the agri-food industry differ from a previously (well) studied industry?
Method:	A combination of an inductive and deductive approach was chosen in this study, and a descriptive and explanatory strategy was used. Further, it was chosen to do a single case study. A combination of primary, secondary data, qualitative and quantitative data was used.
Conclusions:	The study showed several types of waste affecting the business: waiting, transportation, unnecessary inventory, and defects. The authors were able to find root causes of the identified waste and based on this, several suggestions that could potentially reduce the identified waste were presented. The use of VSM in the agri-food industry was found a good tool to identify and potentially eliminate waste. However, some differences between the use of VSM in the agri-food industry and a previously (well) studied industry were found.
Keywords:	Value Stream Mapping, Lean manufacturing, Agri-food industry

Preface

This master thesis was written during spring 2021 and represents the final part of the Mechanical Engineering programme with a focus on Logistics and Production Management.

We would like to thank the case company for giving us the opportunity to write our master thesis. Further, we would like to thank our supervisor Lina Johansson who has supported and guided us through the entire project. Finally, we would like to thank each other for completing this together.

Lund, *3rd June 2021*

Ebba Almqvist

Mathilda Mellberg

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List of abbreviations

EOQ	Economic Order Quantity
EPQ	Economic Production Quantity
FEFO	First Expired First Out
FIFO	First In First Out
KPI	Key Performance Indicator
KRAV	Food produced without artificial chemical pesticides, good animal welfare, reduced climate impact, more biodiversity and better working conditions.
SMART	Criteria a KPI should be based on. Stands for Specific, Measurable, Attainable and Realistic.
TPS	Toyota Production System
VSM	Value Steam Mapping
WIP	Work In Progress

1. Introduction

This chapter aims to provide the reader with a background to why this study was conducted. The chapter contains a theoretical background, which explains the existing gap in theory that this study aims to partially fill. In addition, this chapter will introduce the case company and the research questions as well as the scope and delimitations for this study.

1.1 Background

For any profit-driven industry company, the primary goal is to create profitability through an efficient production (Olhager 2013). In order to reach profitability targets, a traditional company usually needs to consist of three main sections: a sales- or marketing function, a manufacturing- or production function and an economic- or administration function. For these functions to work, it is necessary to have procurement, logistics and material- and production control (Segerstedt 2018). Porter (1985) has created The generic value chain, which illustrates the important functions of a company and can be seen in Figure 1.1. Having efficient and appropriate logistics leads to short lead-times, high safety in given lead-times, low levels of tied up capital as well as high utilization of the capital invested in machines, equipment and personnel (Segerstedt 2018).

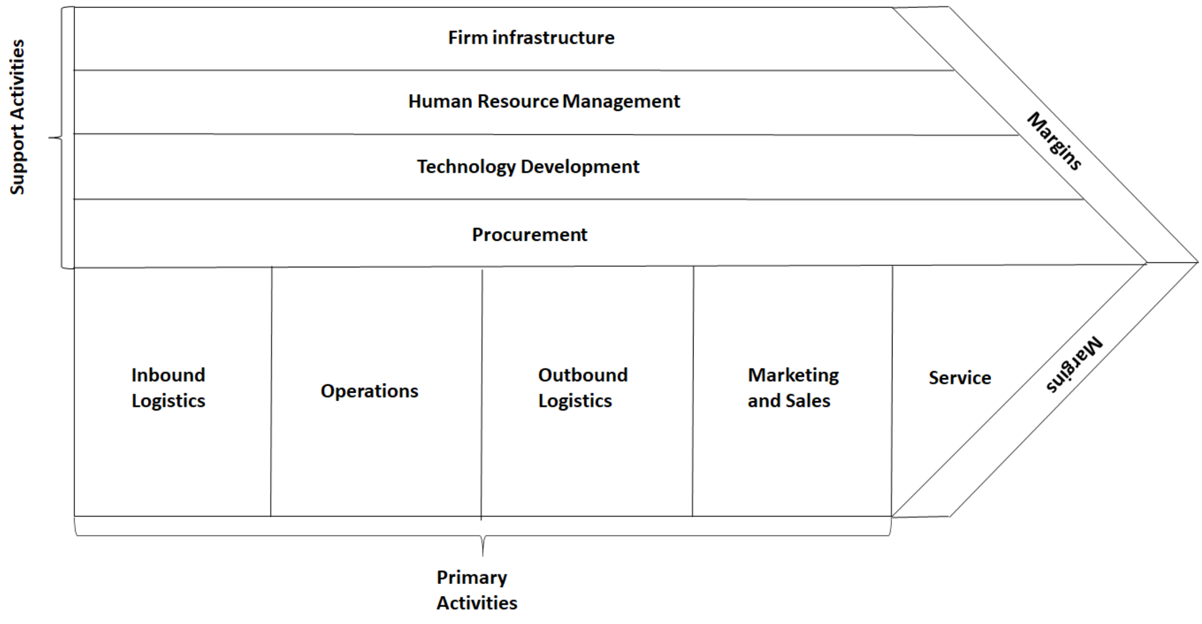

Figure 1.1 The generic value chain (Porter 1985).

Lean manufacturing was first derived from the Toyota Production System (TPS) with the main objective to use the company's resources in the most effective and efficient way. Lean considers the use of any resources for any goal other than the creation of value for the customer to be wasteful. The lean practice can be defined as a philosophy, a set of principles and as a bundle of practices (Čiarnienė and Vienažindienė 2012).

For more or less all organizations in any sector of the economy, the control of the material flow from suppliers of raw materials to final customer is a crucial problem (Axsäter 2006). To understand the flow and identify waste, it is necessary to map inter- and intracompany value adding processes (Hines and Rich 1997). Value Stream Mapping (VSM) was first developed as a tool for transforming the production according to the lean philosophy (Schmidtke et al.

2014; Fukuzawa 2020). VSM is used to document, analyse and improve the information and material flow needed to produce a product or service (Patrocino 2015). Argued by Andreadis et al. (2017), VSM need to be coupled by other lean tools, as the waste identified by VSM needs to be removed. This is best done using other lean tools as e.g. 5S and Kaizen. Seven commonly defined wastes in a production system are overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion and defects (Hines and Rich 1997; IfM 2020).

Lean and VSM are mainly practiced within the automotive industry and their equipment suppliers (Shou et al. 2017; Pattanaik and Sharma 2009). Despite the fact that the automotive industry is the most well studied industry to use VSM, the tool has been used in other sectors as well. Tanco et al. (2013) study the use of VSM and other lean techniques in a nougat producing company, Satolo et al. (2020) contribute with a multiple case study of the use of lean tools in Brazilian agribusiness units and Muñoz-Villamizar et al. (2019) examine the gaps for integrating lean and green management in the agri-food industry. Another example is De Steur et al. (2016) that systematically reviews 24 studies that apply VSM in the food industry to show the potential of VSM in this sector. Even though VSM has potential and has been used in the food-industry previously, Satolo et al. (2020) states that the agribusiness segment features a large gap in literature regarding the lean philosophy and its historical aspects, implementation challenges and benefits of its adoption. This is further strengthened by Tanco (2013), who highlights that literature studying lean mainly focus on highly automated, repetitive production environments and that there is little research on the application of lean in food industries.

There are many definitions of the food industry, but no formal one. One of the definitions are the complex network of farmers and diverse businesses that together supply much of the food consumed by the world population and covers all aspects of food production and sale (New World Encyclopedia n.d). As for the food industry, there is no joint definition for the agri-food industry. Explained by SCCS-UAH (n.d) the agri-food industry includes both the products obtained from the agrarian and fisheries sector for final consumption (agriculture, livestock, forestry and fishing) and the products manufactured by the food industry (food, beverages and tobacco). In the theory used for this study, both expressions are applied. As the two definitions often overlap and many times are difficult to distinguish, this study will use the term agri-food industry.

Compared to typical industries where lean and VSM are often used, there are several characteristics in the food industry that differs. These can be short shelf life, heterogeneous raw materials, seasonality, varied harvesting conditions and high demand uncertainty (Tanco et al. 2013; Powell et al. 2017; Muñoz-Villamizar et al. 2019).

The manufacturing process of food can also be complicated due to laws and requirements, and high demands are put on quality and safety (Mehrotra et al. 2011). The food legislation law exists to ensure safe foods in Sweden and for the consumer to get the information needed to make conscious choices (Livsmedelsverket 2020). In addition, the European Union has joint regulations concerning all its member countries.

1.2 Case company

The company where this study was conducted wished to remain anonymous and will here on be referred to as “the company”. The company is a Swedish family-owned business, operating in the agri-food industry. Their philosophy is to develop, produce, and sell frozen products from the vegetable kingdom with a focus to be organic and convenient, all in collaboration with their customers. The company grows, produces and imports processed vegetables and berries. They produce both KRAV-certified products and non KRAV-certified products. The company has customers in Sweden and Denmark targeting three different segments: the food industry, foodservice and the consumer segment.

The company has one production line and one packaging line. In 2020 the company handled an average of 150 tons of raw material per week in their production. The average of handled volumes in the packaging line exceeded 106 tons per week in 2020. The same year, the company handled 275 production orders and 489 packaging orders. The company revenue was 230 MSEK.

1.3 Problem formulation

The company has realized that the production layout and the material flow cause a lot of waste. Hence, there are potential for improvements regarding efficiency in production and related processes. This study addressed this with a focus on the material and information flow at the company.

De Steur et al. (2016) presented 24 companies in the food industry where VSM has been successfully used. However, to the best of our knowledge no study considers VSM in the context of similar production processes as for the case company. Furthermore, the number of studies regarding VSM in the food industry does not come close to the number of times it has been used in the automotive industry. Therefore, it is interesting to compare the application of VSM within the two industries to find differences and similarities. This was explored in the study.

1.4 Purpose

The purpose of this study was to analyse the current production set-up and the related processes at the company, using VSM to test its applicability in the agri-food industry and how it differs from a previously well studied industry. VSM was a central part in achieving the purpose of this thesis and is further presented in Section 3.4.2.

This study aims to explore and propose improvements to reduce waste generated by the material- and information flow at the production site. To achieve the purpose of the study, the problem was broken down into three research questions:

RQI What waste can be identified by VSM and how does that affect the business?

RQ2 How can the identified waste be reduced?

RQ3 How does the use of VSM in the agri-food industry differ from a previously (well) studied industry?

1.5 Scope and delimitations

This study was conducted at the company, focusing on operations and related processes. Only the flow of products through the wash and production line was mapped and evaluated. Due to the limited time frame of 20 weeks, this study focused on the flow of products produced during the first quartal of the year. These products were divided into four different product families. These four families represented around 57% of the company’s total production and packaging volume in 2020. To further narrow the scope, the starting point of the mapping was when products arrive at the production site and the end was as products are placed, by an operator working on the production line, in the internal warehouse where the products are stored before entering the packaging line. The different areas of the company that were investigated are displayed in Figure 1.2 and are further presented in Section 4. In addition, the information flow between all areas displayed was also investigated.

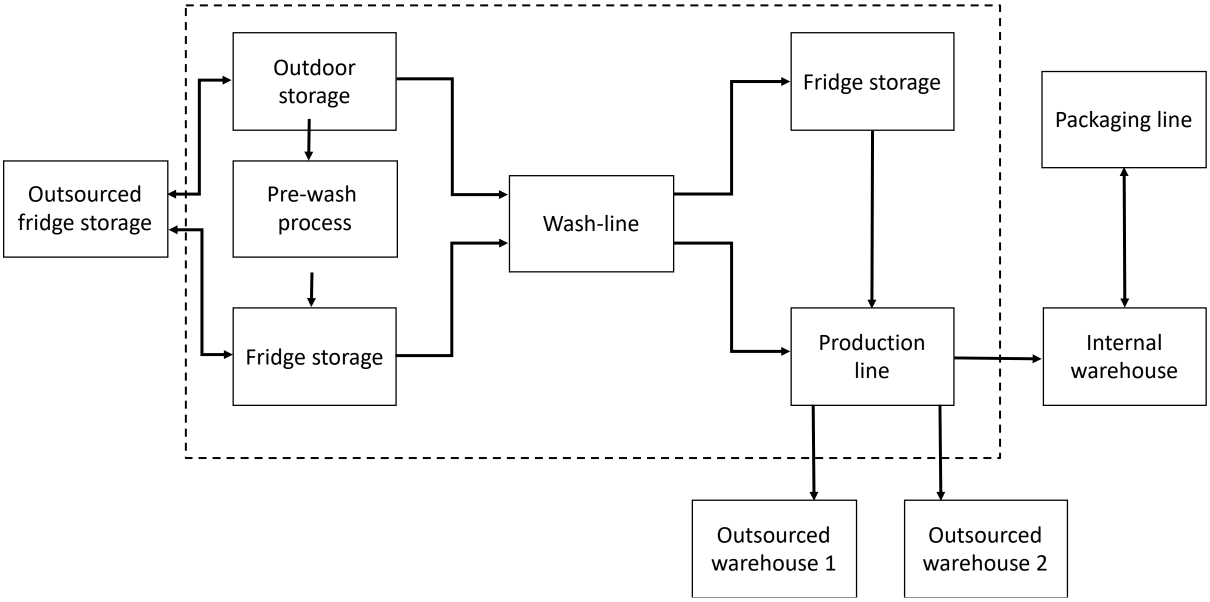

Figure 1.2 Illustration of the areas of the company included in this study.

Since the company is small and that the industry they are operating in generates modest profits, the final suggestions on improvements to reduce waste needed to be feasible with regards to both time and financial capability. The cost and time related to making changes in the production line are too high, which is why that was not evaluated. Instead, focus was placed on the flow of products and information from arrival to departure.

1.6 Thesis outline

Chapter 1. Introduction

In this chapter, a background to the study and the case company are presented. In addition, the problem formulation, research questions and scope of the study are introduced.

Chapter 2. Methodology

The frameworks followed to complete the study are presented in this chapter. The research strategy and design, data collection, data analysis as well as the different phases of the study are also presented. The last part of this chapter contains a discussion of the research credibility and integrity. In each section of this chapter, the approaches and methods will be presented together with a motivation of the choices made.

Chapter 3. Theoretical framework

In this chapter, theory relevant to completing this study are presented. The theoretical framework includes theory from the following areas: Supply Chain Management and Logistics, Warehouse design and configurations, Material- and Information flow, Lean and VSM as well as Key Performance Indicators.

Chapter 4. Current state

This chapter presents the case company and its internal processes further. The company layout as well as the company structure is presented. In addition, this chapter contains the current state of the company and presents the VSMs as well as spaghetti diagrams of the production site.

Chapter 5. Analysis

In this chapter, the empirical findings are presented and analysed. Problems related to the current way of working, identified waste, and the impact it has on the company is presented.

Chapter 6. Recommendations

In this chapter, suggestions to solve or ease the identified problems are presented. The suggestions are divided based on which part of the company they will impact, either the wash line or the production line. This is followed by a risk analysis of the suggestions where the implementation effort and potential impact of the implementation has been assessed on a scale from low to high.

Chapter 7. Conclusion

This chapter summarizes the findings of the study. The recommendations to the company are ranked, and the research questions are answered with the aim to clarify and concretise the findings of the analysis. This is followed by a discussion of how the study can contribute to further studies and research.

2. Methodology

This chapter describes the overarching frameworks used to conduct this study. The chapter contains a presentation of the research approach, strategy and design used. The data collection, data analysis, research process as well as the credibility and integrity of the study will be presented. In each section of this chapter, the approaches and methods will be presented together with a motivation of the choices made.

2.1 Research approach

Described by Saunders et al. (2006), the choice of research approach is important for the design of a study. The approach for the research can be deductive or inductive. Using a deductive approach, the researcher develops a theory and a hypothesis and designs a research strategy to test the hypothesis. In an inductive approach, the researcher collect data and develop a theory as a result of the data analysis. Golicic et al. (2005) describes the deductive approach as typically quantitative and the inductive as typically qualitative.

Starting with the research questions, the beginning of this study was an as-is analysis of the current situation at the company and a theory was developed as a result of the data analysis. This way of working follows an inductive approach. However, the study relies on well-studied subjects as lean and VSM which would imply a deductive approach. Argued by Golicic et al. (2005), a combination of the two approaches might be the best, as balance is achieved by tacking back and forth between qualitative and quantitative approaches. Furthermore, a qualitative research approach is suitable to answer questions such as “who, what, how and why?” whereas a quantitative research aims to answer questions such as “how much, how often, how many?” (Nyberg and Tidström 2012). Based on this reasoning, a combination of a qualitative and a quantitative research approach is most suitable for the previously presented research questions. This decision is also strengthened by Flyvbjer (2006) who claims that a combination of qualitative and quantitative methods will often do the task best.

2.2 Research strategy

Choosing the right research strategy is crucial to get the best outcome possible. According to Saunders et al. (2006), the chosen strategy should be based on how the research questions are formulated, what the objective of the research is and what resources are available. This is strengthened by Nyberg and Tidström (2012) who claims that the chosen research questions are crucial for the decision of research approach and suitable methods.

Research can be approached in an exploratory, descriptive or explanatory way (Saunders et al. 2009; Yin 2018). According to Saunders et al. (2006), a descriptive study is the research for which the purpose is to produce an accurate representation of persons, events or situations. An exploratory study aims to seek new insights into phenomena, to ask questions, and assess the phenomena in a new light. Explanatory research focuses on studying a situation or a problem in order to explain the relationships between variables.

In this study, the purpose is to understand the processes at the company, identify waste and provide recommendations on how to reduce it. A descriptive approach was therefore chosen to answer research question one. To answer research question two and three, an explanatory approach was used. This since the goal was to explain the root causes to waste as well as the relationship between characteristics of the agri-food industry and the use of VSM.

In addition to the descriptive and explanatory approach chosen in this study, Yin (2009) distinguishes between five major research strategies: experiment, survey, archival analysis, history and case study.

Experiment – Studies links between variables, i.e., whether a change of an independent variable produces a change of another dependent variable.

Survey – Allows collection of a large amount of data from a sizeable population in a highly economical way. Often obtained by using questionaries, the data is standardized, allowing easy comparison of data.

Archival analysis – Makes use of administrative records and documents as the principal source of data. Can refer to recent as well as historical documents.

History – Preferred when there is no virtual access or control. Occurs mainly when the researcher must rely on primary- and secondary documents and cultural- and physical artifacts as the main source of evidence.

Case study – Studies a phenomenon in its real context and through observing the actual practice, knowledge is gained and used to generate relevant theory.

According to Yin (2009), the right research method is preferably selected with the help of three conditions: Form of research question, requirement of control of behavioural events and focus on contemporary events as presented in Table 2.1.

Table 2.1 Relevant situations for different research methods (Yin 2009, p. 8).

Method	**Form of research question**	**Requires control of behavioural events**	**Focuses on contemporary events**
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case Study	how, why?	no	yes

As seen in Table 2.1, a case study is preferred when the research questions are “how” or “why”, when no control over behavioural events is required and in situations where focus lies on contemporary events. The main research questions in this study are based on “how”, control of behavioural events is limited, and focus lies on the present to propose improvements to the future. This strengthens the choice of a case study strategy.

2.3 Research design

It is critical to consider the design of a case study, even if changes are required in practice due to the reality of what is encountered in the field (Simons 2020). Voss et al. (2002) presents a framework, consisting of five steps, to write a case study. The steps are as follows: develop the research framework, constructs and questions; choosing cases; developing research instruments and protocols; data documentation and coding; data analysis, hypothesis development and testing. Doing a case study research is a linear but iterative process (Yin, 2009). Therefore, a research framework combining the processes presented by Yin (2009) and Voss et al. (2002) has been created and is displayed in Figure 2.1. Each of the steps will be further presented in the sections below.

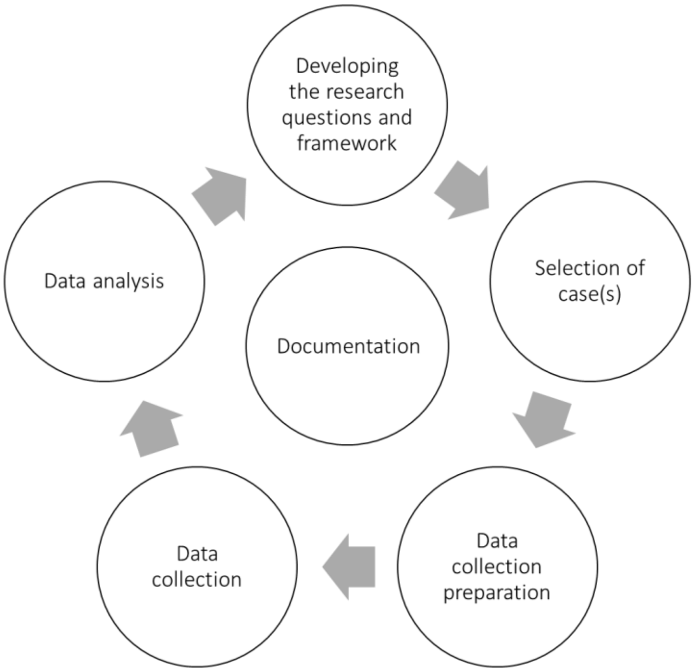

Figure 2.1 A visualization of the research framework.

The reason “documentation” has been illustrated as a centre piece in Figure 2.1 is that it is a central and fundamental part of completing this study. According to Voss et al. (2002), the existence of good documentation of observations and multiple sources of evidence allow a chain of evidence to be established. All steps in the figure were documented as the work progressed and the most essential findings are presented in this report. Documentation can include typing up of notes and/or transcription of interviews. Other documentation can include gathering documents and other material collected in the field or through other sources. It should also include documenting ideas and insights that arose during or after the field visit (Voss et al. 2002).

The first step is to “develop research questions and a research framework”. The research questions have already been developed and are presented in Section 1.4. The research frameworks however still need to be addressed in more detail. The overarching framework for this study will be as presented in Figure 2.1, but in addition to this a conceptual framework is needed. The use of a conceptual framework is suggested by Miles and Huberman (1994). It aims to explain the main things that are to be studied – the key factors, constructs or variables – and the presumed relationship amongst them (Voss et al. 2002). The building of a conceptual framework will provide a careful and selective approach when choosing which constructs and variables to include in the study (Voss et al. 2002).

The conceptual framework for this study is presented in Figure 2.2. The three pieces of the circle are the areas included in this study. The company operates in the agri-food industry and this is therefore overarching the other areas. The industry was therefore considered to a certain extent in every part of the study. The framework provided relevant theoretical knowledge that was required to map the current state, analyse it, and provide recommendations to the company. In addition, the area regarding lean was especially important to understand the differences between using VSM in the agri-food industry and the automotive industry.

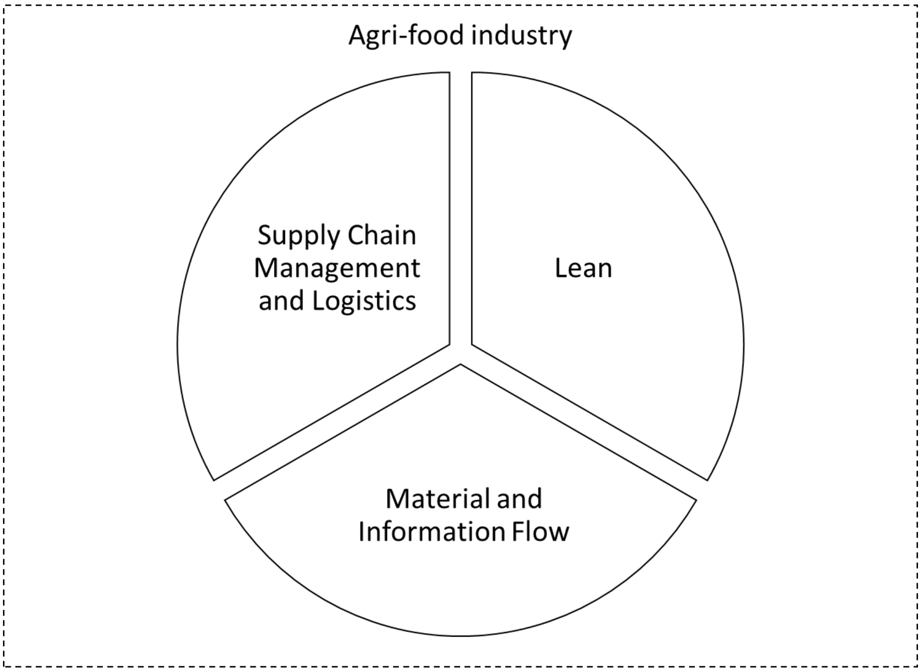

Figure 2.2 Conceptual framework.

The second step is "selection of case(s)". Yin (2009) distinguish between four different case study designs, single case vs multiple case, and holistic vs embedded case, as shown in Figure 2.3. The primary decision is to choose between a single or multiple case design. A single case design will give the opportunity of a more in-depth study compared to studies involving several cases (Voss et al. 2002). It is also suitable when the observed case is representative or typical (Yin 2009). A multiple case study design focus on the comparison between different cases. The second decision is whether the case design should be holistic or embedded. A holistic design examines the holistic nature of the case, whereas an embedded design pays attention to subunits within the case.

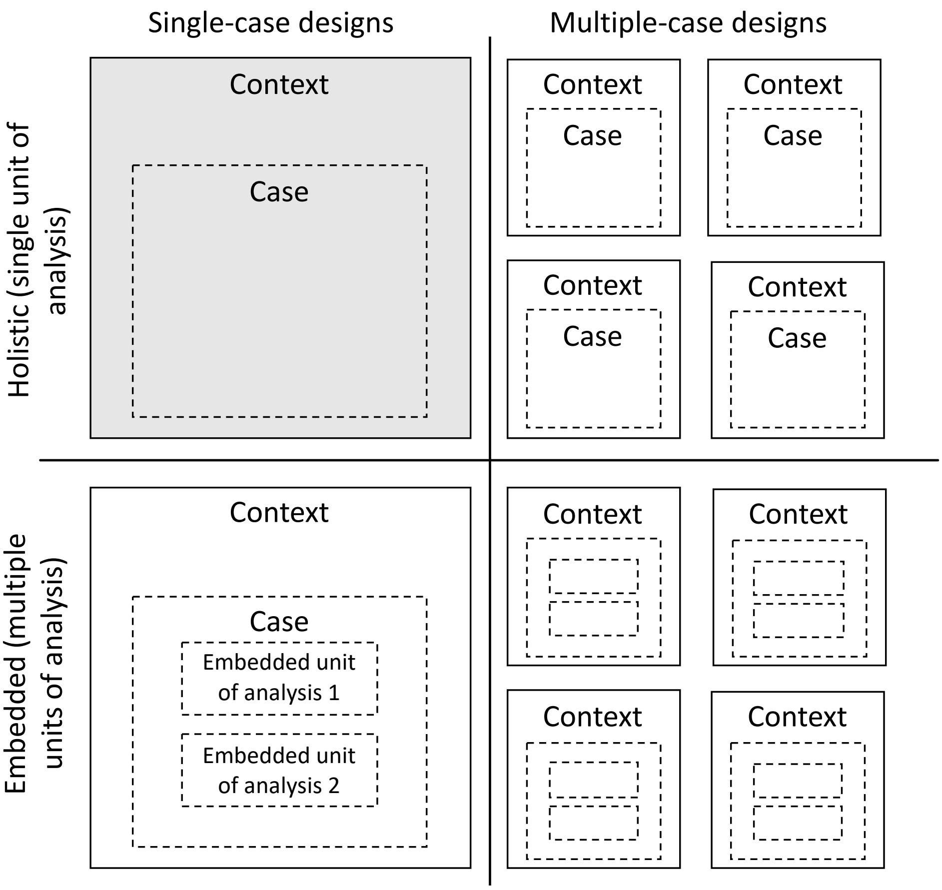

Figure 2.3 Basic types of designs for case studies (Yin 2009, p. 46).

In this study, the purpose was to analyse the current production set-up at the company and the related processes. As VSM is used to document, analyse, and improve the information and material flow needed to produce a product or service, the tool was used to answer the research questions. Furthermore, VSM was used to test its applicability in the agri-food industry and how it differs from a previously well studied industry. This requires an in-depth analysis at a typical agri-food company, why a single case study is best suited. As the material- and information flow studied will require the full picture of the company, a holistic approach was chosen.

The last three steps of the research framework require a thorough description and are therefore presented separately in the following two sections.

2.4 Data collection

Data collection for case studies can come from many sources of evidence. In fact, Yin (2009) highlights this as one of the benefits of a case study. Using multiple sources allows the researcher to take advantage of the different methods' strengths and weaknesses, at the same time as it allows for triangulation on the same set of research questions. However, using multiple sources makes the collection of data more complex.

The empirics collected can be sorted into two main categories, primary data and secondary data (Ghauri and Grønhaug 2002; Saunders et al. 2009). The former can be described as the data collected and gathered directly by the researchers while the latter consists of already collected and existing data. Secondary data can be raw data or compiled data such as data from information systems, layout maps and company documentations. Primary data can be collected through observations and interviews (Ghauri and Grønhaug 2002).

The primary and secondary data can be further divided into quantitative or qualitative. It is necessary to distinguish between the two in order to analyse the data meaningfully. Quantitative data is based on meanings derived from numbers, and the collection results in numerical and standardised data (Saunders et al. 2006). Qualitative data is instead based on meanings expressed through words, and results in non-standardized data. For this study, both qualitative and quantitative data was gathered to answer the research questions. The main factor behind the choice of data collection methods was the predetermined use of VSM in the study. The different data collection methods presented in Section 2.4.1-2.4.4 were all needed to complete the mapping. In addition, the choice of using multiple sources was based on the fact that it allows for triangulation. Qualitative data was gathered mainly through observations and interviews whereas quantitative data was gathered through secondary data.

2.4.1 Literature review

To gain a steady foundation of knowledge and theoretical understanding, a literature study was conducted. According to Bell (2010), the literature review can be approached in two different ways. Either with a source-oriented or a problem-oriented approach. In the first approach, the nature of the sources will determine the project and the research questions i.e., rather than bringing predetermined questions to the sources, the material the sources contain will lead the way. The other approach is used when questions are formulated based on previous research. It investigates what has already been discovered about the subject before establishing the focus of the study and then researches the relevant primary sources. Based on this reasoning, a problem-oriented approach was used in this study.

To achieve the purpose of the study, literature about supply chain management and logistics, warehouse design and configurations, material- and information flow, lean and VSM as well as performance measurements within the agri-food industry was gathered. In order to define a supply chain and logistics both from a general perspective as well as in a food industry perspective, related literature was used. Since VSM is a tool derived from lean, both subjects were studied using literature. This to gain a thorough understanding of the origin of VSM as well as other tools related to waste removal. Literature related to performance measurements was researched to understand its impact on changes in organisations. The main sources for retrieving information in this study has been LUBSearch and Google Scholar. These two in combination provides sufficient and relevant articles and journals within the previously mentioned research areas. In addition, literature obtained at the Lund University Library was used.

2.4.2 Observations

Observations typically involves the systematic observation, recording description, analysis and interpretation of people's behaviour and can be distinguished between participant observation and direct observation (Yin 2018). In participant observations, the observer takes an active role to get a deeper understanding of what is going on and why. During direct observations, the observer is passive and can range from formal to more casual depending on the purpose.

To answer the first research question, a thorough understanding of the material flow and processes at the company was required. Therefore, it was chosen to complete direct observations at the company. Due to the current pandemic, participant observations were not possible even though it would have been relevant for this study. The direct observations were carried out through several stages of the data-collection process. One of the first steps of this study was to get an overall understanding of the material flow and its related processes, why initial Gemba walks were done. The Gemba walks were done by walking through the production following the material flow, and insights about the production were gained. The initial Gemba walks were followed by more structured walks and direct observations. An overview of these observations is provided in Table 2.2.

Table 2.2 Overview of performed observations.

Action	Purpose	Date
Initial Gemba walk	Understanding the material flow on the production site	2021-02-02
Gemba walk wash line	Understanding the material flow to, through and from the wash line	2021-02-15 2021-02-16
Gemba walk production line	Understanding the material flow to, through and from the production	2021-03-03 2021-03-05
Direct observations wash line	Understanding the operations related to the wash line process	2021-02-22 2021-02-23 2021-03-15 2021-04-07
Direct observations production line	Understanding the operations related to the production line processes	2021-03-08 2021-03-12

2.4.3 Interviews

Yin (2018) argue that the interview is an essential source of evidence for case studies. Specific advantages of using interviews to gain in-depth data are the opportunity to document multiple perspectives and experiences as well as establish which issues are most significant in the case (Simons 2020).

Saunders et al. (2006) mentions three different kinds of interviews: the structured interview, the semi-structured interview, and the unstructured interview. Structured interviews can be seen as oral questionnaires since they utilise a standardized set of questions. Semi-structured interviews may vary and cover areas that are not on the predetermined list even though interviewers use a list of themes and questions. Unstructured interviews do not use predetermined lists of questions and are used to explore general areas in depth.

To answer the first research question, a combination of semi-structured and unstructured interviews was used. The semi-structured interviews were used in the beginning of the study to get a thorough understanding of the material and information flow within the company. An overview of the held interviews is shown in

Table 2.3. The material flow from fields to the company's production facility was rather complicated, therefore two interviews with the cultivation manager were required. As a complement to the information received in the semi-structured interviews, unstructured interviews were held during and after the Gemba walks in order to get more information about the observed events. Unstructured interviews were also held when information gaps were identified. As the unstructured interviews occurred spontaneously as needed, the date of occurrence has not been documented.

Table 2.3 Overview of held semi-structured interviews.

Participant	**Purpose**	**Date**
Cultivation Manager	Understanding the material flow from fields to the company	2021-02-05 2021-03-08
Maintenance Manager	Understanding how maintenance and preventive maintenance is carried out	2021-02-05
Warehouse Administrator	Understanding the material flow from end of production line to warehouse and within the warehouse	2021-02-09
Production Leader	Understanding the material and information flow within the production line	2021-02-09
Packing Planner	Understanding the planning process for the packaging line	2021-02-16
Production Planner	Understanding the planning process for the production line	2021-03-16

2.4.4 Secondary data

Quantitative data was obtained in the form of secondary data that could strengthen and triangulate the data obtained from literature, observations and interviews. The collected data was mainly used to answer research question one, but it was also useful to motivate the recommendations in research question two. Secondary data was mainly obtained from a company MS Excel-file. The company works daily with the file and documents production volumes in and out, production time and down time together with date, order number and article number. The file also contains comments explaining down times and production volumes. The company information system was also used to obtain data regarding sales volumes and prices of finished products.

2.5 Data analysis

Central to effective case research is the coding of the observations and data collected in the field (Voss et al. 2002). The analysis conducted will be dependent on the characteristics of the data i.e., if the data is qualitative or quantitative (Runeson and Höst 2009). According to Runeson and Höst (2009) quantitative data analysis typically includes analysis of descriptive statistics, correlation analysis, development of predictive models, and hypothesis testing. To get an understanding of the collected data, it is common to create descriptive statistics using mean values, standard deviations, histograms and scatter plots. To describe the relationship between a subsequent set of processes, a correlation analysis can be used. Hypothesis testing is conducted to determine if there is a significant effect of one or several variables on one or several other variables (Runeson and Höst 2009). In this study, descriptive statistics and correlation analysis were used to get an overarching understanding of the data related to the processes.

In case study research qualitative data analysis methods are commonly used (Runeson and Höst 2009). The objective of the analysis is to derive conclusions from the gathered data, keeping a clear chain of evidence (Runeson and Höst 2009). The analysis of qualitative data is to be carried out parallel to the data collection since the approach is flexible and new insights are often discovered during the collection of data. Therefore, it is necessary to gather new data in order to investigate the new insights (Runeson and Höst 2009). In this study, the qualitative data analysis was carried out as presented above, simultaneously to the data collection.

The analysis needed to achieve the purpose of this study was divided in three parts. The first analysis was of the data collected related to the current factory set-up and the empirical findings. The main analysis here was the analysis of qualitative data gathered from interviews. In addition to the interviews an analysis of the measured times and production volumes was conducted i.e., quantitative analysis.

The second analysis was a qualitative analysis based on the previously gathered information, related to the as-is analysis of the company. In order to reach the purpose of this thesis, the as-is analysis was compared to the data gathered in the literature review in combination with the limitations of the company. This was done to provide improvement suggestions based on previous research while still being feasible for the company to implement.

The third analysis was a qualitative analysis of the feasibility of conducting VSM at a company in the agri-food industry. This was done based on the insights gained from the completion of the VSM, in combination with the findings from literature regarding VSM in the food industry as well as in the automotive industry.

2.6 Research process

To summarize and provide the reader with an overview of the research process, Figure 2.4 was created. The research process was divided into four main phases which are further presented below. Both authors performing this study took an equal part in all phases.

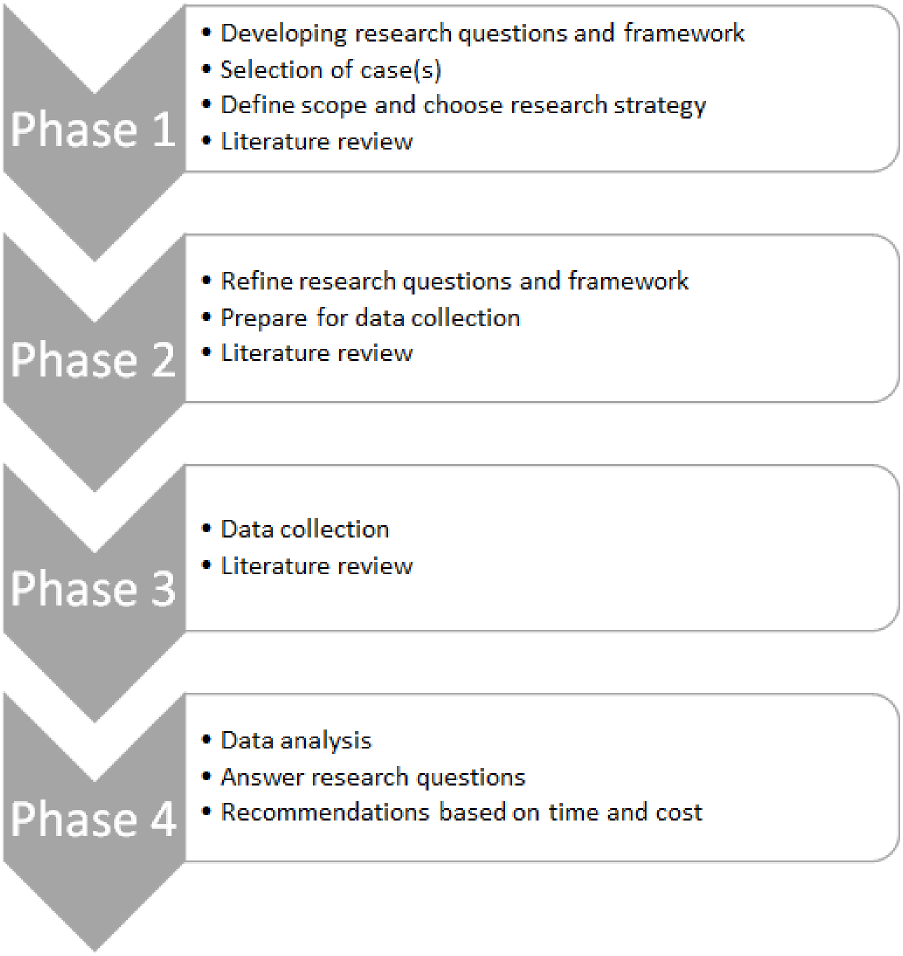

Figure 2.4 The different phases of the research process.

Phase 1 involved the development of the research questions and the framework. The research questions were formulated based on the gap in literature regarding VSM in the agri-food industry in combination with the issues that the company are experiencing. In this phase it was also selected that the study was going to be a single case study. The scope was defined and the research strategy was chosen. The last part of the first phase was the initiation of the literature review which included searches on research methodology, the agri-food industry as well as the food industry in general, lean and VSM.

Phase 2 involved a refinement of the research questions as well as the framework based on gathered information from the previously initiated literature review. In addition, preparation for the data collection was done by defining the data needed as well as where to collect it from. In this phase the initiated literature review continued to get a deeper knowledge within the previously mentioned areas.

Phase 3 was mainly data collection. Interviews were held, Gemba walks were conducted, and documents from the company were gathered. Parallel to the data collection, more information from literature was gathered.

Phase 4 was the final phase and here, the data was analysed, the research questions were answered, and the recommendations to the company were written.

2.7 Credibility

Assuring research quality and credibility is important when conducting a case study. According to Yin (2009), there are four tests that can be used to build quality of any research design: Construct validity, internal validity, external validity and reliability. These tests should be applied all through the case study.

Construct validity is the identification of correct operational measures for the concept being studied (Yin 2009) i.e., how well a study investigates what it is supposed to investigate. To increase construct validity during a case study, Yin (2009) presents three tactics to use, using multiple sources of evidence, establish chain of evidence and to have the draft of the case study reviewed by key informants.

Internal validity is used for explanatory studies and seek to establish relationships between variables. It is mainly used when the researcher is trying to explain how and why event x led to event y (Yin 2009). If the researcher incorrectly concludes that there is a relationship between the variables without knowing a third factor, z, the research design has failed to deal with a threat to internal validity.

External validity deals with the problem of knowing whether the findings of the study are generalizable or not. Critics typically state that this is a major barrier in single case studies, but Yin (2009) points out that this mainly concerns survey research that rely on statistical generalization. Case studies rely on analytic generalisation, why generalization from a narrow result to a broader setting can be done. By using theory in single case studies, the researcher can overcome the issue.

The objective of reliability is to demonstrate the repeatability of the study (Yin 2009). The researcher needs to make sure that if a later researcher where to follow the same procedure conducting the case study, the same findings and conclusions would be reached. To reassure that this is the case, the researcher should use a case study protocol and develop a case study database.

The measures taken to reassure the quality and credibility of this study are shown in Table 2.4.

Table 2.4 Measures taken to ensure quality and credibility of the research.

Test	**Literature review**	**Research methodology**	**Data collection**	**Data analysis**
Construct validity	The studied literature is relevant to agri-food supply chains. Several supporting sources were used. A journal quality list was used to assure reliable sources.	Frequently used methodology from well-known authors were used.	Different sources were used to enable triangulation. E.g., various data collection methods and several interviews.	The study where continuously reviewed by key informants. A chain of evidence was established.
Internal validity	Several supporting sources were used.	Several supporting sources were used when choosing the research methodology.	Conducting several Gemba walks and interviews with different employees to understand the full picture and avoid biases.	Multiple analytical techniques were used.
External validity	Theory used is relevant to agri-food supply chains and confirms that the company is a typical agri-food company.	N/A	The data was collected from a typical agri-food company.	N/A
Reliability	Peer reviewed articles were used. A journal quality list was used to assure reliable sources.	The methodology chosen was followed and documentations were done throughout the study.	The data collection was documented.	The analysis was documented and well described.

2.8 Research integrity

A good research practice is based on fundamental principles for integrity in research (ALLEA 2018). The principles are as follows:

Reliability – ensuring the quality of the research, which is reflected in the design, methodology, analysis and use of resources.

Honesty – develop, conduct, review and report as well as inform about the research in an open, justly, fully, and objective way.

Respect – for colleagues, research participants, the society, ecosystems, cultural heritage, and the environment.

Accountability – for the research from idea to publication, for management and organisation, for education, supervision, and mentorship as well as for its further consequences.

The *reliability* of the study was ensured by creating a methodology with clear structure and design from the beginning. The initial plan and the different steps presented in the methodology were followed throughout the study. The analysis has been conducted based on the data gathered during the study, the data has been analysed and identified misleading or questionable information has been presented in Section 7.5. In addition, several employees at the company were interviewed and the answers received were compared to ensure that the content of the study is correct.

The *honesty* of the study has been followed in this report. All identified relevant information to the research questions have been presented in the different chapters of this report. The authors have had an objective approach to the task at hand and the report can be considered as non-bias.

Respect for colleagues and research participants played a major role in completing this study. During the data collection for this report, the authors have had a respectful approach to everyone involved in the study. All interviewees could choose to not answer questions and the set time was always kept in respect for the participant’s time. In addition, it is never mentioned in the report who provided which information, in respect to the individual.

The authors of this report takes full *accountability* for the material presented in this report.

3. Theoretical framework

This chapter contains the theoretical foundation needed to complete the study. The theoretical framework will cover relevant theories, research and other material needed to gather data and conduct the analysis. The purpose is to provide the reader with an understanding of the subject and the information needed to comprehend the contextual aspects of the study.

To ensure a careful and selective approach to theory, the conceptual framework presented in Chapter 2 will be used. This will provide the reader with an overview of the theory included in this study and can be seen in Figure 2.2.

3.1 Supply chain management and logistics

There are several definitions of supply chain, logistics, supply chain management and logistics management. Defined by the Council of Supply Chain Management Professionals (2021), a supply chain encompasses all activities needed to convert raw material to final products. From sourcing through manufacturing, final assembly to distribution to end-markets. It includes all necessary handling and storage activities, and the return flows of products and material. Almost always, these activities encompass several companies or organizations working jointly in a chain or network. Logistics refers to the transportation and storage of materials, parts and products in a supply chain. It includes inbound and outbound processes to and from warehouses, as well as internal and external material handling.

Supply chain management encompasses the planning and management of all supply chain operations (CSMP 2021). It includes the coordination and collaboration with channel partners as suppliers, intermediates, third party service providers, and customers. Supply chain management integrates supply and demand within and across companies. Logistics management is the part of supply chain management that plans, controls and implement the efficient, effective and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customer demands.

3.1.1 Internal logistics

For many decades, the cost of internal logistics has been intensively investigated and several studies have focused on finding solutions to minimize the total cost of internal logistics (Cai et al. 2020). The layout design is one of the decisions that have a direct impact on the production costs of firms (Adem and Kuvvetli 2021). The purpose of the layout design is generally to create a high use of capacity, short lead times and high flexibility (Olhager 2013). Tompkins et al. (2003) claimed that effective facility layout in manufacturing systems can reduce the total operating costs by approximately 10-30%. Furthermore, the transportation costs associated with the layout design correspond to 20-50% of the operating costs and 2-10% of these costs can be reduced with good plant planning (Hosseini-Nasab et al. 2017).

3.1.2 Production management

The dominant performance measure in logistic and production has for a long time been cost efficiency, i.e., maximum output should be achieved using minimal material and manpower utilization (Zijm et al. 2019). This made the initial focus in industrial production lie on large batch manufacturing and low variety of products. However, depending on the product, the production process needs to vary with it. The Hayes and Wheelwright (1979) product-process matrix is shown in Figure 3.1. It illustrates that production management, layout and processes should be designed so that it fits the characteristics of the products produced.

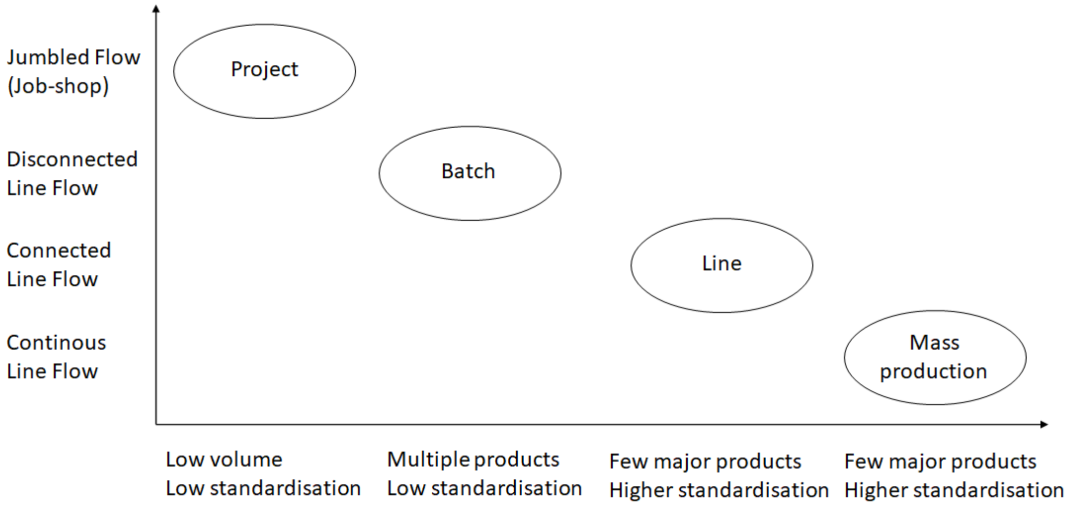

Figure 3.1 The product-process matrix (Hayes and Wheelwright 1979, p. 135).

Material planning can be seen as a tactical planning level which concerns balancing supply and demand (Jonsson and Mattsson 2006). It deals with the initiation, control and monitoring of manufacturing of purchasing orders to maintain a continuous flow and value-adding activity in manufacturing. The material planning function need to take available inventories into account and together with purchasing have an essential input to the job planning process (Zijm et al. 2019).

3.1.3 Warehouse and storage

A warehouse is often necessary, but at the same time a non-engaged resource (Segerstedt 2018). However, warehousing is essential for most supply chains and could represent up to a quarter of the total logistics cost (Kembro et al. 2017).

The fundamental function of every storage is decoupling, from the internal production or from the external demand or from the deliveries from suppliers (Olhager 2013). This, to enable the individual segment to optimise its production based on their capabilities with maintained service level to the next segment. The different storages from a value stream perspective are raw material storage, Work in Progress (WIP) and finished goods warehouse (Olhager 2013).

Typically, a warehouse has operations for receiving, put-away, storage, picking, sorting, packing and shipping (Bartholdi and Hackman 2019; Pedersen and Aase 2004). A few of the relevant operations are further described below.

Receiving may begin with advance notification of the arrival of goods. This allows the warehouse to schedule receipt and unloading to efficiently coordinate with other activities within the warehouse (Bartholdi and Hackman 2019). Common activities are the physical unloading of received goods, quality checking items to ensure the right items have been delivered without damage and the registration of received items in the warehouse system (Rushton et al. 2017).

Put-away starts when the arriving goods have been assigned a storage location. When the goods are placed at its correct location, the location should also registered in the computer system.

This operation accounts for around 15% of the total warehouse operating expenses (Bartholdi and Hackman 2019).

Picking occurs when a customer order has been assigned to the warehouse. The first step is to check if the requested goods are available, and the second step is to produce order-picking lists for the warehouse operators. Lastly, any necessary shipping documentation needs to be prepared and the order-picking as well as the shipping needs to be scheduled (Bartholdi and Hackman 2019).

When it comes to the storage space, there are two different strategies that can be used. Dedicated or shared storage. Dedicated storage is when a shelf is reserved for an assigned product and only that product can be placed there. Because the locations of products do not change, more popular items can be stored in more convenient locations and workers can learn the layout, all making order-picking more efficient. A drawback with dedicated storage is that it does not use space efficiently (Bartholdi and Hackman 2019).

The other strategy is called shared storage meaning that a product can be assigned to more than one storage location. This is beneficial compared to the dedicated storage since it allows greater space utilization. However, as the locations of products change over time, workers cannot learn locations. Another disadvantage is that it becomes more time-consuming to put away newly received products because it must be taken to more locations (Bartholdi and Hackman 2019).

There are different types of warehouses, mainly categorized by the customers they serve (Bartholdi and Hackman 2019). A perishable goods warehouse is typically a link in an extended cold chain and handles chilled products at temperatures around 2° C and frozen products at temperatures around -18° C. A few complicating factors with perishable goods warehouses are short lead times, space efficiency since cooling is expensive, shipping according to First In First Out (FIFO) or First Expired First Out (FEFO) as well as handling restrictions (Bartholdi and Hackman 2019).

3.1.4 Inventory management

Inventory management plays an important part in a manufacturing company (Zijm et al. 2019). Inventories arise in case of temporary foreseen shortage of resource capacity, making it necessary to manufacture products in advance of their perceived demand. Another reason for having inventories is to buffer against demand fluctuations and uncertainty. Production in batches is another source of inventories, often due to the advantage of economies of scale. The Economic Production Quantity (EPQ) essentially balances set-up costs against inventory costs. If set-up costs are high, larger batch sizes are preferable (Zijm et al. 2019).

According to Axsäter (2006), the total investment in inventories is enormous, and the control of capital tied up in raw material, work in progress, and finished goods offers a very important potential for improvement. In addition, scientific methods for inventory control can give a significant competitive advantage. This is further strengthened by Nahmias (2011) who claims that cost-effective control of inventories can cut costs significantly and contribute to the efficient flow of goods and services in the economy.

Inventory theory has its roots dated back to the early 1900s, however, the inventory control of perishable goods has been ignored over a long period of time. The reason being that the problems are difficult to analyze (Nahmias 2011). Nahmias defines perishable goods as one that has constant utility up until an expiration date (which may be known or uncertain), at which point the utility drops to zero. Based on that definition, a way to calculate the Economic Order Quantity (EOQ) and re-order point for perishable goods was developed.

3.1.5 Performance Measurements

A company should always measure its performance, compare to others and plan to improve (Bartholdi & Hackman, 2010). Neely et al. (1995) defined performance measurement as the process of quantifying the efficiency and effectiveness of action. Tonchia and Quagini (2010) state that performance measurement is a fundamental part of business management as it helps companies understand where they were, where they are now, where they want to go and how they know that they are there.

"If you can't measure it, you can't manage it!" (Tonchia and Quagini 2010)

As there are several purposes for measuring performance, there is no appropriate measurement for all occasions (Neely 1999). The type of industry, process and product line e.g., affects the measurement decision (Grimson and Pyke 2007). However, a Key Performance Indicator (KPI) should be based on criteria that make it suitable for further analysis, which is supported by the SMART criteria (Shahin and Mahbod 2007).

- *Specific* Goals should be detailed and as specific as possible to avoid broad or loose measures. This makes it much easier to hold someone accountable for the achievement.
- *Measurable* Goals should be easy to measure, against a standard of performance and a standard of expectation. This, to clearly determine if the goal has been achieved.
- *Attainable* Goals should not be out of reach, rather they should be reasonable and attainable. However, setting goals is a balance between the degree of attainability, challenge and aspiration.
- *Realistic* Attainable measures still need to be realistic in the particular working environment.
- *Time-sensitive* Goals should have a time frame for completion. Having a time frame will provide a structure and allows the analyst to monitor progress.

3.2 Lean manufacturing

Lean manufacturing, lean management, lean enterprise or as hereby referred to as lean, considers the use of any resources for any goal other than the creation of value for the customer to be wasteful (Čiarnienė and Vienažindienė 2012). The lean practice can be defined as a philosophy, a set of principles and as a bundle of practices. The philosophy aims to optimize time, human resources, assets, and productivity while improving the quality of products and services to a company's customers. Lean is today used in many different businesses, and the original concept have been broadened to not only concern productivity (Olhager 2013). Womack and Jones (1996) describe lean thinking as the antidote to waste and presents five lean principles:

1. *Specify Value*. Value can be defined only by the ultimate customer. Value is distorted by pre-existing organizations, especially engineers and experts. They add complexity of no interest to the customer.
2. *Identify the Value Stream.* The Value Stream is defined as the number of activities needed to bring a product through the internal value chain to the customer.
3. *Flow*. Make the value-creating steps flow. Eliminate departments that execute a single-task process on large batches.

4. *Pull.* Let the customer pull the product from you. Sell one. Make one. This to reduce inventory of finished products and cut lead times.
5. *Pursue Perfection.* There is no end to the process of reducing time, space, cost and mistakes.

Lean manufacturing is about reducing or eliminating waste. Derived from the TPS, there are seven commonly defined types of waste. Explained by Hines and Rich (1997), they are:

1. *Overproduction.* Often considered as the most serious type of waste as it discourages a smooth flow and is likely to inhibit quality and productivity. Leads to excessive lead and storage times.
2. *Waiting.* Occurs when time is used ineffectively, as when goods are not moving or being worked on. Affects both goods and workers, each spending time on waiting. In an ideal case, there should be no waiting resulting in a constant faster flow of goods.
3. *Transport.* Involves movement of goods that should be minimised. Moreover, double handling is a type of transport that is likely to cause damage.
4. *Inappropriate processing.* Occurs when the process is made much more complicated than needed e.g., having more complex machines than needed. Over-complexity generally discourage ownership and encourages employees to overproduce to recover the large investment in the complex machines.
5. *Unnecessary inventory.* Creates significant storage costs, tends to increase lead time and to prevent rapid identification of problems.
6. *Unnecessary movements.* Involve the ergonomics of production where operators must stretch, bend and pick up when these actions could be avoided. This is likely to lead to poor productivity and quality problems.
7. *Defects.* The bottom line of waste as these are direct costs. Refers to a product deviating from the standards of its design or from customer expectations. Should be regarded as opportunities to improve rather than something to be traded off against what is ultimately poor management.

3.2.1 5S

5S is a lean tool with origin in the TPS. 5S are principles with the aim to keep the processes as simple as possible and keeping order at the workplace (Olhager 2013). The main idea is that an organised workplace makes it easier to optimize productivity and quality. The five principles are:

1. *Sort*. Distinguishing between necessary and unnecessary things and eliminate what is not needed at the workplace.
2. *Systemisation*. Organise so that parts and tools are neatly arranged. A place for everything and everything in its place.
3. *Sanitise*. Keep it clean so that problems can be more easily identified. Operators should clean their equipment and working area after use.
4. *Standardise*. Set up standards for a neat and clean workplace.
5. *Self discipline*. Implement above behaviours and make them a habit. Have regular check-ups, education and continuous improvements.

3.2.2 Kaizen

Kaizen is the philosophy of continuous improvements (Olhager 2013). It means that employees on all levels of the company always seek ways of improving the operations. A successful implementation of Kaizen has been proven beneficial for companies acting in competitive environments in which efficiency and speed are crucial (Oropesa Vento et al. 2017). Moreover, the philosophy seeks to attain greater quality and productivity as it helps to improve accountability and commitment from employees. All human resources are considered essential in order to make changes, and the success of the philosophy is based on the participation from employees.

3.3 Material and information flow

The control of the material flow from suppliers of raw materials to final customer, is a crucial problem. To understand the flow and identify waste, it is necessary to map inter- and intracompany processes. Spaghetti diagram and VSM are two tools used to visualize, understand and improve the material and information flow.

3.3.1 Spaghetti diagram

To choose the right factory layout, there are various criteria that can be taken into consideration, e.g., workers movements, information flow or product flow (Senderská et al. 2017; Roser 2015). In order to map such flows and movements, a spaghetti diagram, also called spaghetti chart, can be used. Womack and Jones (2003) define a spaghetti chart as a map of the path taken by a specific product as it travels down the value stream in a mass-production organization, so-called because the product's route typically looks like a plate of spaghetti. Allen (2006) suggests using the following process when drawing a spaghetti diagram:

1. Obtain an existing or create a facility layout diagram or drawing.
2. Obtain an existing routing sheet or create one using a typical product going through the facility.
3. Draw a continuous curve starting at the first location on the routing sheet to the remaining locations.
4. Calculate the total travel distance.
5. Estimate the travel time.
6. Study the spaghetti diagram to identify flows with long travel distances and areas that are rarely or never used.
7. Move the processes closer together or rearrange to reduce total travel distance.
8. Repeat steps 4–7 using new layouts.

3.3.2 Value Stream Mapping

A value stream is the actions currently required to bring a product through the main flows essential to that product (Rother and Shook 1999). VSM is a lean tool used to visualise and understand manufacturing principles and how the manufacturing system works (Rüttimann 2018). The tool helps the user to see and understand the information and material flow as a product makes its way through the value stream, from raw material to customer (Rother and Shook 1999). The process of value stream mapping can be seen in Figure 3.2.

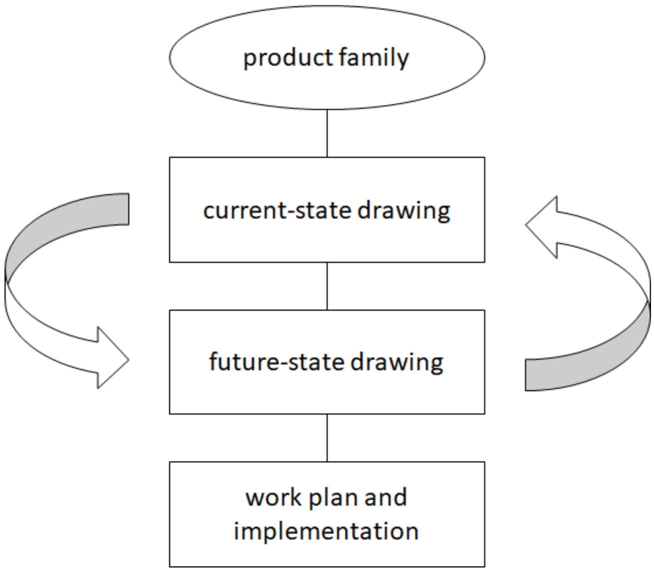

Figure 3.2 The initial VSM process steps.

The first step of the process is to select a product family. This is done due to the fact that the customer focuses on their specific product and so should the developer of the value stream map (Rother and Shook 1999).

The second step is to create the current state map. This is easiest done beginning with a walk along the value stream to get an overview of the processes (Rother and Shook 1999). The purpose is to draw and understand all processes without adding any data. The process symbols used in a VSM can be seen in Figure 3.3. When all processes have been documented, it is time to add process data. The data can be e.g., cycle time, changeover time and number of operators and is explained in Table 3.1. During the second step, the user can identify bottlenecks and identify waste for removal in the third step.

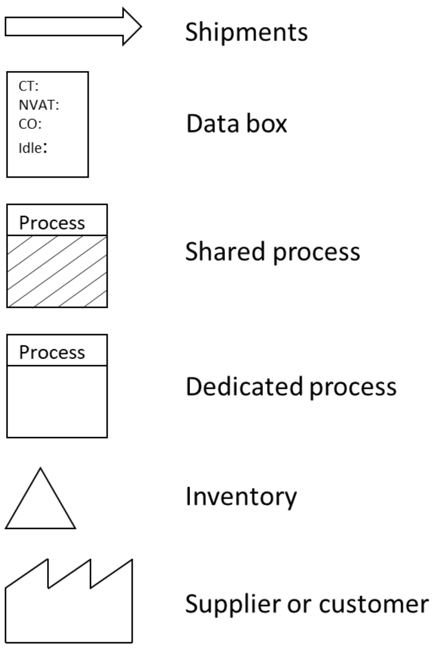

Figure 3.3 VSM Symbols (Jasti and Sharma 2014, p. 94).

Table 3.1 Data used in a VSM.

Cycle time (C/T)	The time a single operation, i.e. the machine or operator, needs to manufacture one piece before handing it to the next station, generally not including setup time (Rüttimann 2018).
Value added time (VAT)	The value added time for which the customer is willing to pay and corresponds generally to the "touch" time (Rüttimann 2018). I.e. the time the product or service is being worked on.
Non-value added time (NVAT)	Pure waste and involves unnecessary actions which should be eliminated (Hines and Rich 1997)
Necessary non-value added time (NNVAT)	Operations that may be wasteful but is necessary under current operating procedures (Hines and Rich 1997).
Lead time (L/T)	The time it takes one piece to move all the way through a process or value stream, from start to finish (Rother and Shook 1999).
Change over time (C/O)	The time to switch from producing one type of product to another (Rother and Shook 1999). The setup time is also included here. The setup time is the time taken to prepare the manufacturing processes and system for production.
Operators (Op)	Number of people required to operate the process (Rother and Shook 1999).

The third step is the creation of a future state map. The creation of the current and future state maps is an iterative process, and the development of the maps requires overlapping efforts (Rother and Shook 1999). Ideas for the future state map will come up as the current state is mapped. As the future state is mapped, important and overlooked information about the current state might come up.

The final step is to prepare and begin the implementation plan that describes how to achieve the future state (Rother and Shook 1999). As the future state map becomes reality, a new future state map should be drawn.

3.3.3 Information flow and sharing

Edwards (1994) presents two levels of information sharing: the sharing of artifacts, e.g. documents, and the sharing of coordinating information, e.g. the information required by a session manager. Using VSM for the information flow can reveal those areas of the company that does not collect relevant information (Pojasek 2004). To know which information to collect, a rule of thumb is to document as little as possible, but as much as necessary (Newslow 2013).

3.4 Agri-food industry versus automotive industry

The manufacturing of processed food, i.e., raw ingredients transformed into consumable human food, is a major industry in most developed and developing economies (Mehrotra 2011). The sales of food within the consumer business in Sweden was 232 000 MSEK in 2019 where 19 000 MSEK was fresh, chilled or frozen vegetables (SCB 2020). Since food is a necessity, the demand for processed food is less affected by economic fluctuations compared to other industries (Mehrotra et al. 2011). However, there are factors that distinguish and complicate the production of food compared to the automotive industry – one of the industries where the use of VSM is most well studied. The main differences between the industries can be seen in Table 3.2.

Table 3.2 Comparison of the agri-food industry and automotive industry.

Characteristic	Agri-food industry	Automotive industry
Product variety	High product variety and foods containing allergens requiring intensive cleaning and sterilization of the production lines when changing product, leading to high set-up times (Mehrotra et al. 2011).	Low product variety, focusing on different market segments but often have a high degree of customization[1] (Guerzoni 2014). The customization does not require any intensive cleaning and sterilization of the production line.
Shelf life	Short shelf life of raw material and/or finished products (Powell et al. 2017)	The most commonly used material is different types of steel, offering characteristics such as thermal, chemical or mechanical resistance, ease of manufacture and durability (Salonitis et al. 2009). Hence, both raw material and finished products have long shelf life.
Profits margins	Intense competition between several major multinational and domestic players in most markets results in price wars which leads to low profit margins. This, in combination with high inventory levels and products with little to no differentiation results in low profit margins. (Mehrotra et al. 2011).	One of the most profitable industries in developed countries (Krasova 2018).
Seasonality	Harvesting seasons that creates specific combinations of weeks in which products can be produced (Mehrotra et al. 2011; Moazzam et al 2018).	Demand seasonality creating challenges for the industry (Turner and Williams 2004).
Perishable goods	Common with perishable goods requiring special handling (Moazzam et al 2018).	The characteristics of steel implies goods with no need of special handling.
Overall economic dependency	Less affected by economic fluctuations since food is a necessity (Mehrotra et al. 2011).	High dependency on external factors and overall economic conditions (Krasova 2018).
Digitalization	Companies are not consciously engaged in digitalisation yet, but they exploit their opportunities (Nagy et al. 2020).	There is an ongoing rise and importance of information, technology and communication – the digitalisation of the industry (Peters et al. 2016).

[1] Characteristics that can be chosen by the customer when purchasing a car, e.g. exterior or interior color.

4. Current state

In this chapter, the current state of the company is presented. The chapter will start off broad with an introduction to the company structure, the facility layout and the different product families. After that, the different sections of the company will be further presented. These sections are the wash line and the production line as well as the planning process, the flow of goods and the used KPIs.

4.1 Introduction to company

The company operates in the agri-food industry and produces, distributes, and sells frozen vegetables. The company has in-house production of vegetables in different cuts. The products are sold direct to customers or repacked at the company's packaging department. The company structure is showcased in Figure 4.1.

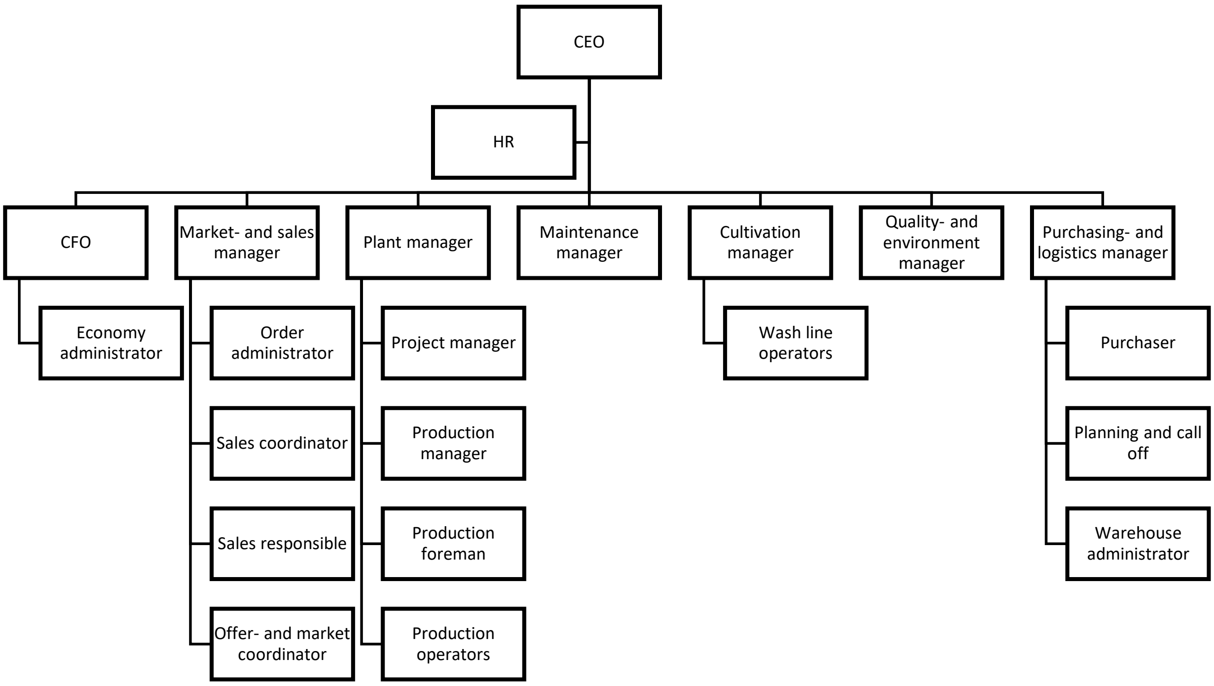

Figure 4.1 Company structure.

4.1.1 Company layout

Raw material aimed for production comes from the company's own farming or from contracted farmers across Sweden. The raw material is delivered to the company by hired transportation providers and the company's own trucks. As the raw material arrives it is either placed in the outdoor storage, immediately washed and sent straight to production or stored until it is time for production. After the production is completed, the finished product is placed in the old warehouse until it is time to deliver to a customer or to the internal packaging line. Figure 4.2 is a map of the company's layout, see Appendix A for greater resolution.

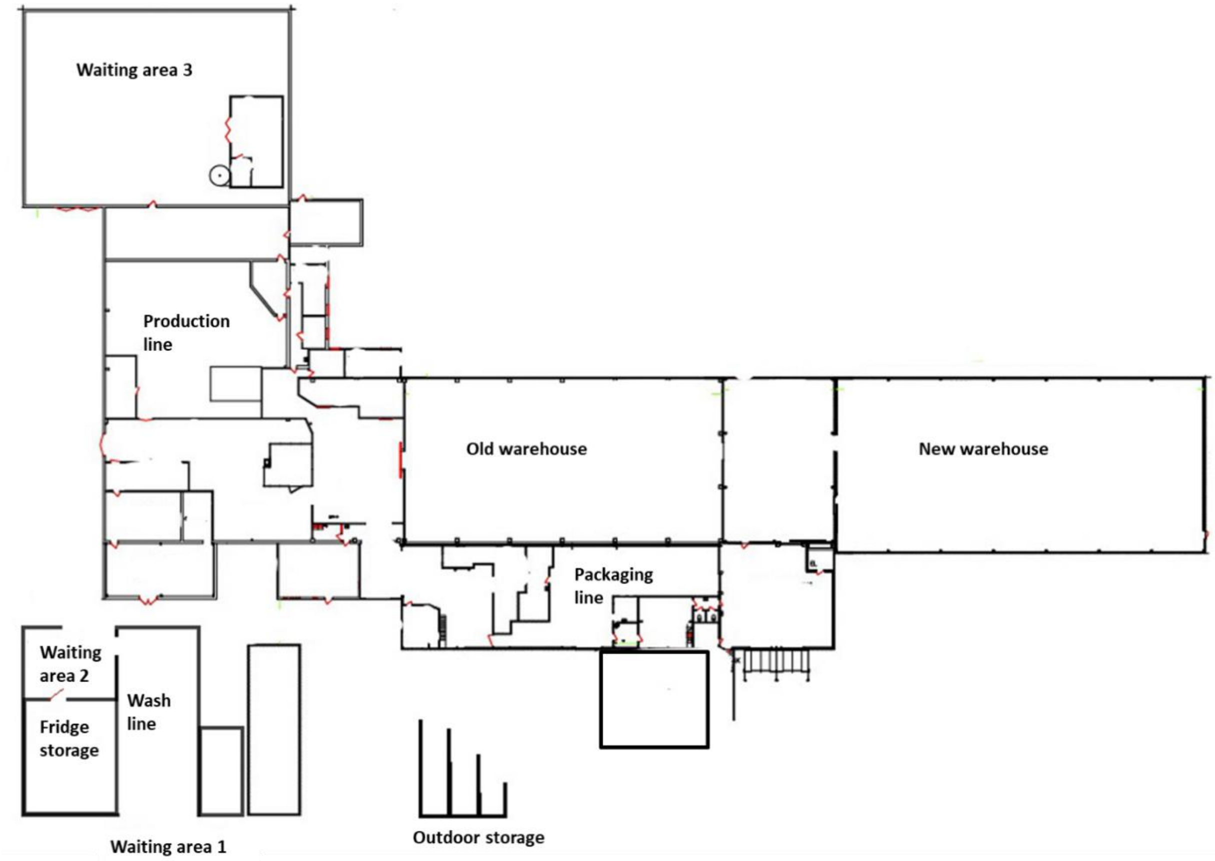

Figure 4.2 Map of the company layout.

4.1.2 Product portfolio

At the production site, the company handles different product families. During the time period of this study, four product families were used in the production. These four product families were hence used as basis for the analysis. To visualise the volumes the company handle, the production volumes of these four families during a two-year period are presented in Figure 4.3 During the study it was found that the presented proportions between the different families are representative for the studied period.

The product families can be further divided into KRAV or commercial products and into specific cuts. The main difference between KRAV and commercial products, for the company, is that KRAV products require more extensive cleaning of the production line before they can be produced. Within each product family there are different cuts. The cuts are different sizes of the product or of the product packaging. To illustrate the complexity of the product portfolio, the cuts divided into commercial and KRAV for Family B can be seen in Figure 4.4. Family B is the largest product family based on weight and thus a major part of the flows and activities at the company.

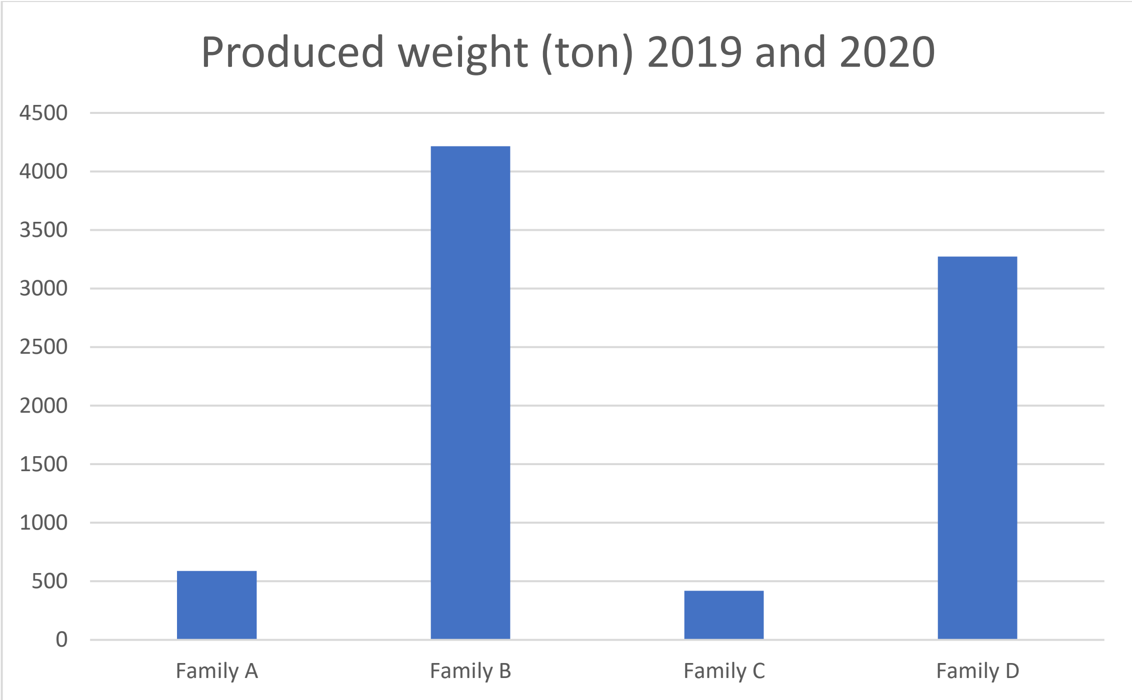

Figure 4.3 Total produced weight during the last two years.

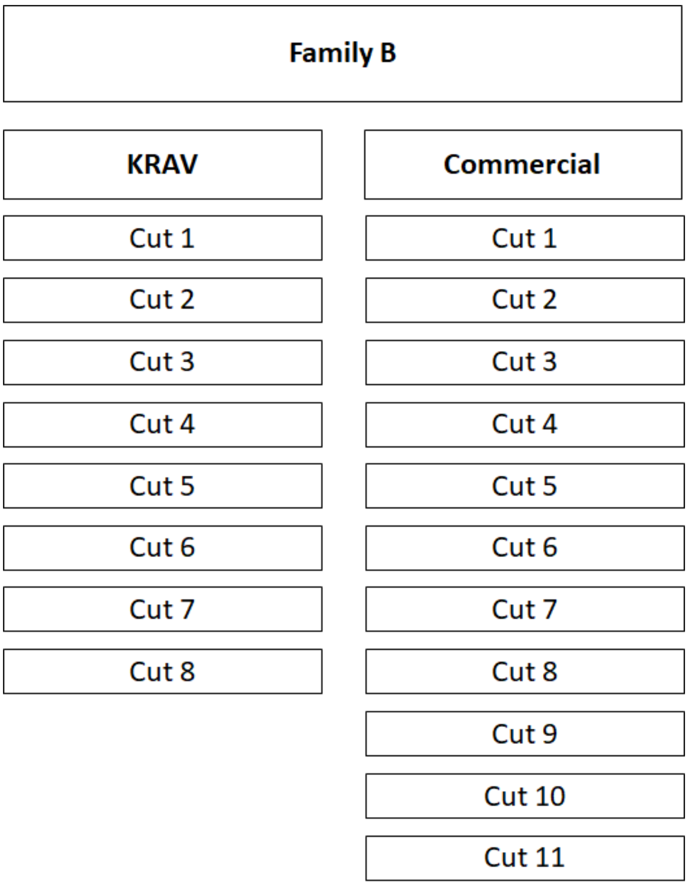

Figure 4.4 Overview of product variety for Family B.

4.2 Wash line

This is the first process to be completed after the raw material has been delivered. The different steps of the process can be seen in Figure 4.5. There are several different paths that the products can take, as illustrated in the figure, and the different steps will be presented further below. After the wash, the washed raw material is placed in pallets or trailers. The trailers are tractor trailers that can hold around 4 tons of raw materials whereas the pallets hold around 1 ton. There is one operator working at the wash line, the shift is 8 hours starting at 7 am until 3 pm and then another operator starts the second shift which runs from 3 pm until 11 pm. The operators are assisted, if needed, during their shift by the cultivation manager.

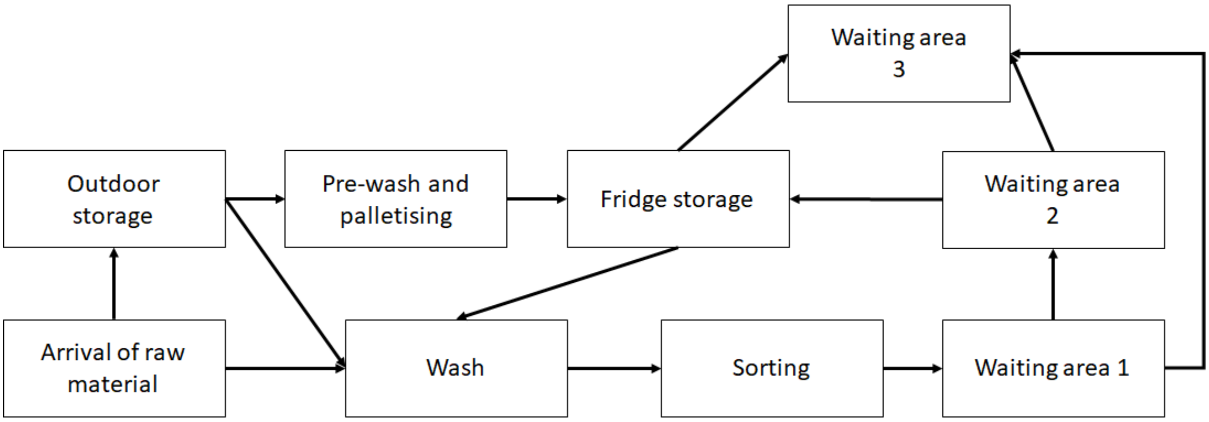

Figure 4.5 Sub-processes in the wash line

Arrival of raw material is the first step for the wash line. A truck arrives with containers fully loaded with raw material. From the arrival there are two possible ways for the material to take, either straight to the start of the wash line or to the outdoor storage.

Outdoor storage is usually the first step that the raw material goes through. The outdoor storage is located on the premises, about 50 meters from the start of the wash line. Raw material is placed here before it is transported, by an operator using a wheel loader, to the pre-wash and palletising area or to the wash line.

Pre-wash and palletising are done when the raw material needs to be placed in the fridge storage. The pre-wash removes dirt from the raw material which results in an increased shelf-life for the products placed in the fridge storage. The pre-wash is an automatic transportation band that, after the dirt has been removed, drops the raw material into pallets. The pallets are then transported by an operator to the fridge storage.

Fridge storage is the step after the previously presented operation of pre-washing and palletising. Products that have passed through the wash line can also be placed here if the production line is working on a different size of raw material, or if there is no available production capacity.

The *wash* is the main operation within the wash line. Here, raw material is placed at the beginning of the line and then carried on a transportation band where the product is cleaned from dirt with brushes and then with water. After that, the product is transported to the sorting.

Sorting is done as a sub-process in the wash line. The raw material is automatically sorted based on its size: below 30 mm, between 30-40 mm, between 40-50 mm and above 50 mm.

Each category of raw material is placed in pallets. However, if a certain size is supposed to be used for production the same day or the day after, that size is loaded onto a trailer. The size used in production is dependent on the desired cut, for example slices requires the smallest size while cubes can be produced from any size. If the desired cut in the production line does not require a specific size on the raw material, the sorting step is skipped, and all raw material is loaded onto a trailer. During this process, the operator must make sure that the raw material placed in trailers and pallets are even, this to minimize the risk of products falling out onto the floor. Once a pallet or trailer is full, the operator uses a forklift to move it to waiting area 1.

Waiting area 1 is located in connection to the sorting. Fully loaded pallets and trailers are placed here. After the item is placed in the waiting area, the operator brings a new, empty, pallet or trailer to the sorting line.

Waiting area 2 is located in connection to the fridge storage. Cleaned and sorted raw material in pallets are placed here by the operator if they are to be used during the next shift or if they are to be placed in the fridge storage. When an operator goes to place pallets here, new empty pallets are brought to waiting area 1 on the way back.

Waiting area 3 is located in connection to the production line. If the production is using trailers, they are placed in this area by the production foreman. If the production is using pallets, the pallets are placed in this area by the wash line operator.

4.3 Production line

The production process at the company is similar independently of the product produced. The different parts of the production process are displayed in Figure 4.6 and will be presented further below. The company produces all their products on the same production line. The only sub-processes that are changed in order to produce a certain product are the peeling/deep cleaning process as well as the cutting process.

There are two operators working at the production line. One is stationed by the manual sorting**,** and one is stationed by the palletising process. The operators are assisted by a foreman who helps them if needed. The foreman's job is to monitor and set up the line, do quality tests, and to make sure everything runs smoothly. There are three shifts operating the production line and each shift runs for 8 hours. The shifts are as follows: 7 am to 3 pm, 3 pm to 11 pm, and 11 pm to 7 am.

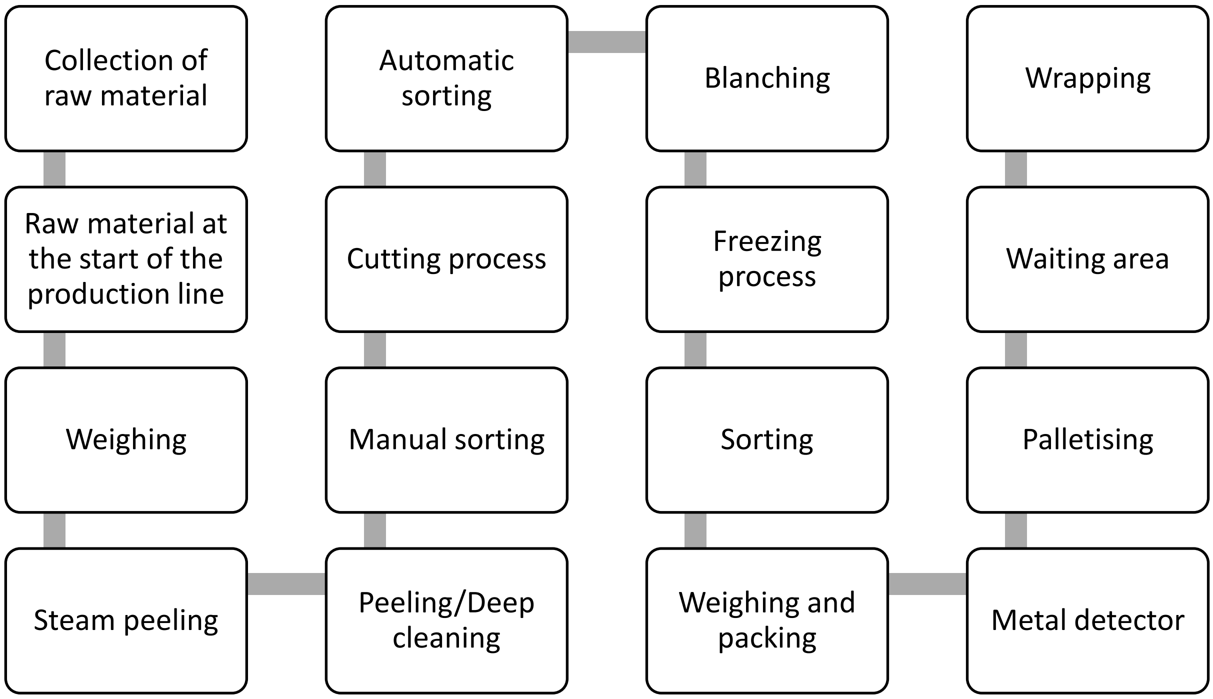

Figure 4.6 Production process broken down into sub-processes.

Collection of raw material is done by the foreman working that shift. The foreman drives to waiting area 1 and collects a trailer with washed raw material that is then brought back to waiting area 3. If the production line is using raw material stored in pallets, then they are collected by the foreman from waiting area 3.

Raw material at the start of the production line is tilted onto a band that transports the material into the production line.

Weighing is the first sub-process on the production line. The product is batched in different weights based on the capacity of the steam peeling machine.

Steam peeling is conducted after the weight batching is completed. The steam peeling uses steam to peel the product.

Peeling/deep cleaning are two different types of further peel removal. The foreman decides which type of process to use based on which product they are producing and the quality of the raw material. This process is, except for the decision of which process to use, fully automated.

Manual sorting is the first process that is conducted by an operator. The operator stands next to the transportation band and removes products that are of bad quality as well as unwelcome items that might have slipped thought the wash line. The unwelcome items could be stones or other things collected from the fields during harvest.

Cutting process is where the product is cut into the desired size. After the manual sorting the product is transported by the transportation band to a tub filled with water. From that tub the product continues its journey with a flow of water through the knives that cuts the product. The different cuts require different set-ups of this part of the production line. The set-up is completed by the personnel working that shift.

Automatic sorting is done using a machine with compressed air that can identify unwanted colours on pieces and then sorts them out using compressed air. The approved products are then transported to the blanching.

Blanching is a process where the products is boiled to a specific temperature and then cooled using cold water in order to reduce quality loss over time. After blanching, the products are transported to a shaking table where excess water is removed before the product enters the freezing process.

Freezing process is where the product is frozen to at least -18°C. The product is transported from the shaking table into a flow freeze which uses compressed air to toss the products around to make sure that each individual piece of product becomes at least -18°C.

Sorting is done after the freezing process to make sure that only product that fulfils the dimension requirements are transported to the weighing and packing area. The sorting is done by letting the product pass through metal grids of various sizes. Products that cannot pass through get sorted in different tanks.

Weighing and packing is done at the end of the production line. The scale is filled with frozen product until the weight reaches 20 kg. An automated process cuts a bag of the correct size and feeds the machine with the bag that is automatically opened and placed under the scale. A lid opens which allows the frozen product to fall into the bag. After the bag has been filled, it is closed and placed on a transportation band which leads to the metal detector. In this position, the operators' main task is to make sure that every operation works smoothly, e.g., refill packaging materials, refill labels and make sure no product is stuck and blocking the line. The packaging material is stored about 150 m away from the packaging station and the foreman must bring the material to the packaging line using a forklift.

A metal detector is used to make sure that no unwanted metals have passed through the production. For example, all ear plugs used for noise protection has a small metallic ball inserted which the metal detector then can detect. If the metal detector notices any metal, a robot will place the bag in a separate part of the line. The bag is den manually checked by the operator that disposes the bag. If no metal is detected, the robot will place the bag on a pallet.

Palletising is done by a robot and the hight of the pallet is pre-determined by the customer order. The foreman changes the settings of the robot depending on how many bags each pallet should contain. Once a pallet is fully loaded it is discharged from its position and transported to a waiting area by the operator. Here the operator must make sure that there are empty pallets that the robot can use.

The waiting area is where a fully loaded pallet ends up. The operator working at the packaging area is responsible for bringing the pallet, using a forklift, to the wrapping station. Before the pallet is brought to the wrapping station, the operator needs to walk about 50 m to a room where there is a printer. The operator then prints two pallet labels which will be used later. The operator then walks back to the packaging area.

Wrapping is the final step of the production line. The operator uses a forklift to move the pallet from the waiting area to the wrapping machine. The operator starts the wrapping machine which wraps plastic around the entire pallet. When the wrapping is completed the operator places both labels on the plastic and transports the pallet into the old warehouse which is located about 5 m from the wrapping machine.

Every morning the maintenance manager goes through the production line to make sure that there are no issues to attend to. The maintenance manager talks to the personnel from the night shift and resolves any issues that they might have experienced. Every night the production line is cleaned by a cleaning company, and during that time the water used in the production line is changed. When the cleaning and water change are completed, samples are gathered from the line to make sure that there are no bacteria present. The samples are usually gathered by the foreman who also gathers samples of the finished product several times a day.

4.4 Cultivation planning

The company uses both inhouse and contracted growers. Growers are contracted by volume per year and per hectare. At times, additional orders are placed in case of bad harvest or similar events that reduces the quality and number of crops. The time of the harvest is decided between the company and the grower. For most of the crops, the harvesting season is during September to December each year. Three weeks prior to the harvest start, the cultivation manager visit the different locations where crops are growing to make an estimate of when to harvest each field. The field where the crops have grown the most will be harvested first, and then in a chronological order.

The deliveries are planned approximately one week before arrival at the company. Most of the crops are delivered the week before or the same week or day as they are to be used in production. If the plan is to use the raw material later, it is stored in the company fridge. The cultivation manager plans the deliveries to fit the production plan and works closely with the production planner.

4.5 Production planning

The production planning is done by the production planner who obtains input from forecasts, stock levels and customer orders to support the plan. In addition, the company works with yearly estimates of how much to produce, and the production planner plans the production so that these volumes are met. The planning is done manually, no system support is at place. The production planner works in collaboration with the cultivation manager who contributes with knowledge about raw material availability and quality. The production planner has no access to stock levels of raw material.

The production planning is an iterative process done approximately ten weeks ahead of production, but depending on new information such as quality of raw material and new customer orders, the plan can be changed. Details can be changed as late as the same week that the products are to be produced. Before every production week, the production planner, the cultivation manager, the production leader, and the logistics manager discuss next week's production. Last minute changes such as which cut to produce each day and during which shift are made, to minimise waiting time in the production. A generalised illustration of the production planning process is shown in Figure 4.7.

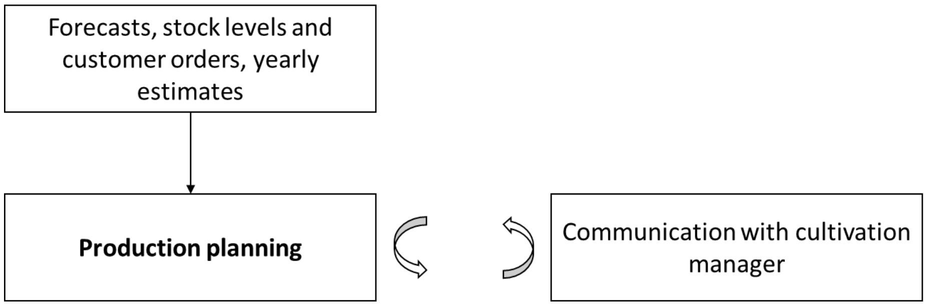

Figure 4.7 Production planning process.

4.6 Flow of goods

To understand the material flows at the company, spaghetti diagrams and VSMs were created. All four product groups have the same flows, which was why the maps were made based on routes rather than a specific product or product family. The flow in the beginning of the wash line can be divided into three different routes depending on if the raw material is used immediately after delivery, a few days after delivery or weeks after the delivery. Further, the washed material can be transported by pallets to the production, by trailer, or by pallets via the fridge storage. Therefore, three different spaghetti diagrams and six VSMs were created. The results from the analysis of the flow of goods are further presented in Section 4.7.1-4.7.2.

4.6.1 Spaghetti diagrams

The routes will be different depending on a few factors, if the product is placed in pallets or on a trailer and if it is to be used in the production immediately or later. The routes for pallets are illustrated in the maps with red color and the route for trailers are illustrated in green color. The black dots represent locations where the material pauses. The black lines represent the route of the delivery, and the grey lines represent the route of the wheel loader. The blue line represents the production line.

Immediate use of raw material

The route taken when the raw material is used immediately after delivery is illustrated in Figure 4.8. This route is the most efficient one where raw material arrives in trailers at the company and is offloaded directly on the wash line.

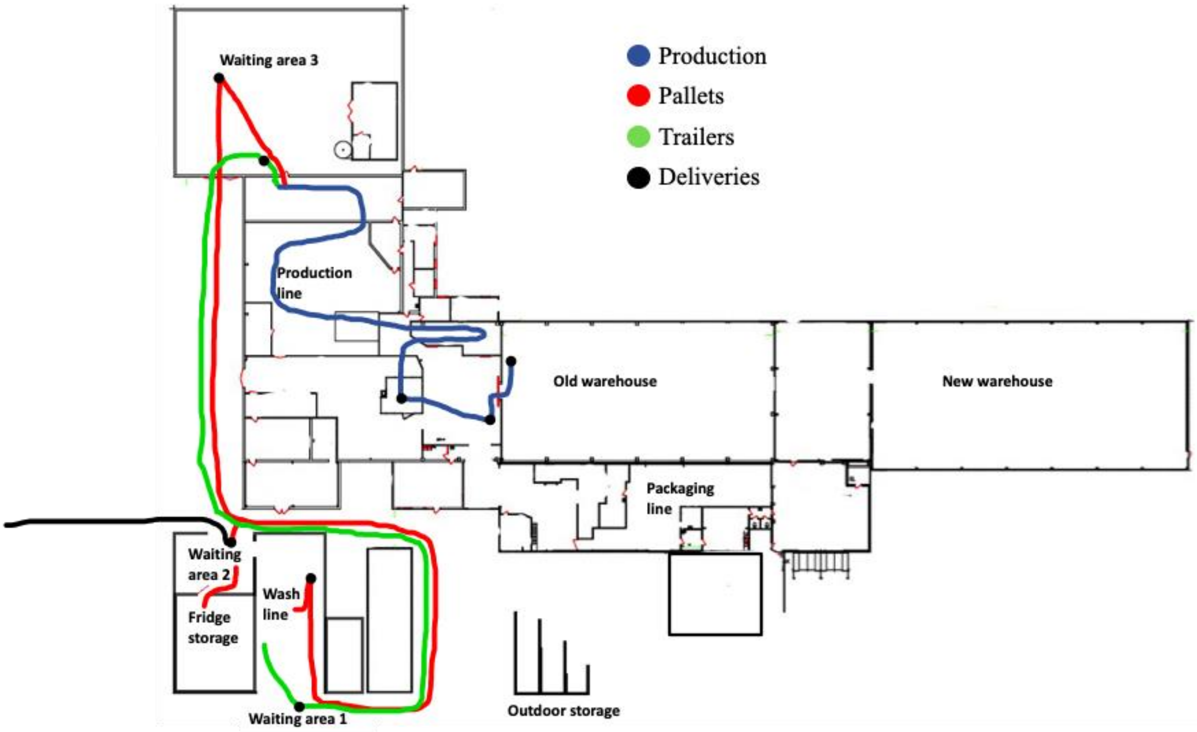

Figure 4.8 Spaghetti diagram of Immediate use of raw materials

Use of raw materials a few days after delivery

In this route, raw material is placed in the outdoor storage upon arrival until it is time to use it. The spaghetti diagram for this route is displayed in Figure 4.9.

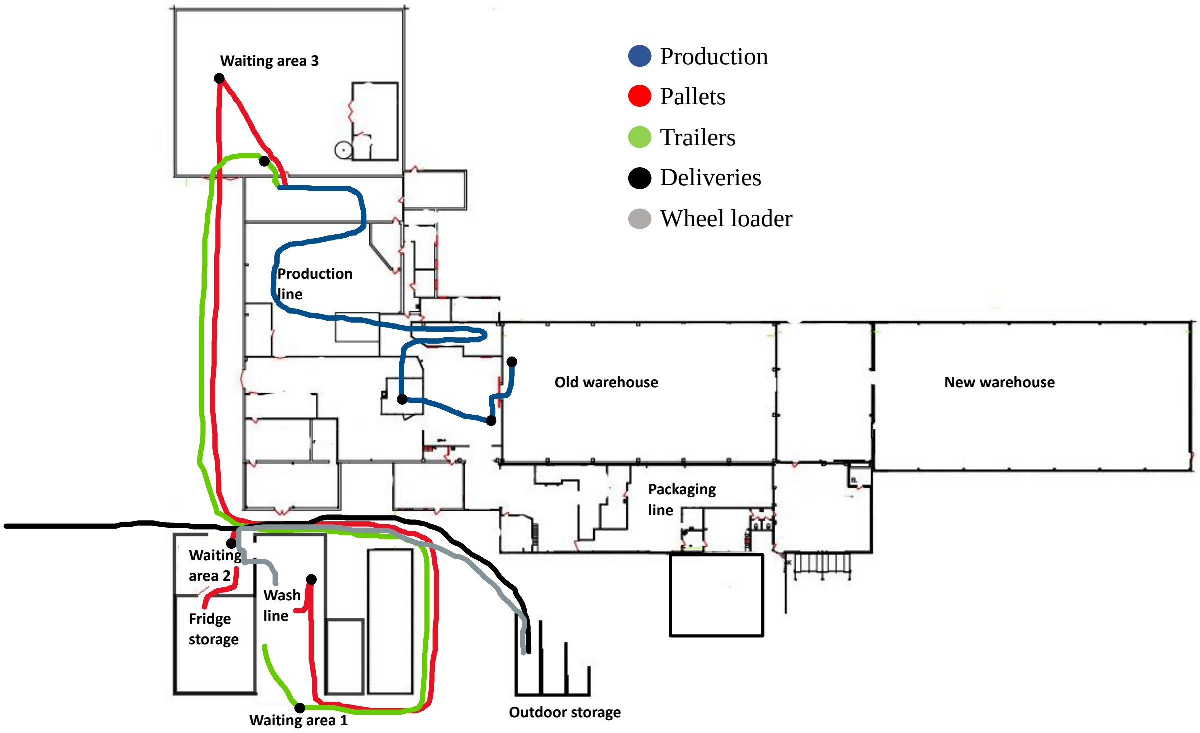

Figure 4.9 Spaghetti diagram of Use of raw materials a few days after delivery.

Use of raw materials weeks after delivery

In this route the raw material is placed in the outdoor storage area and after that taken to the pre-wash area. The pre-wash area is represented by a black square in Figure 4.10. After the pre-wash, the raw material is placed in the fridge storage in pallets.

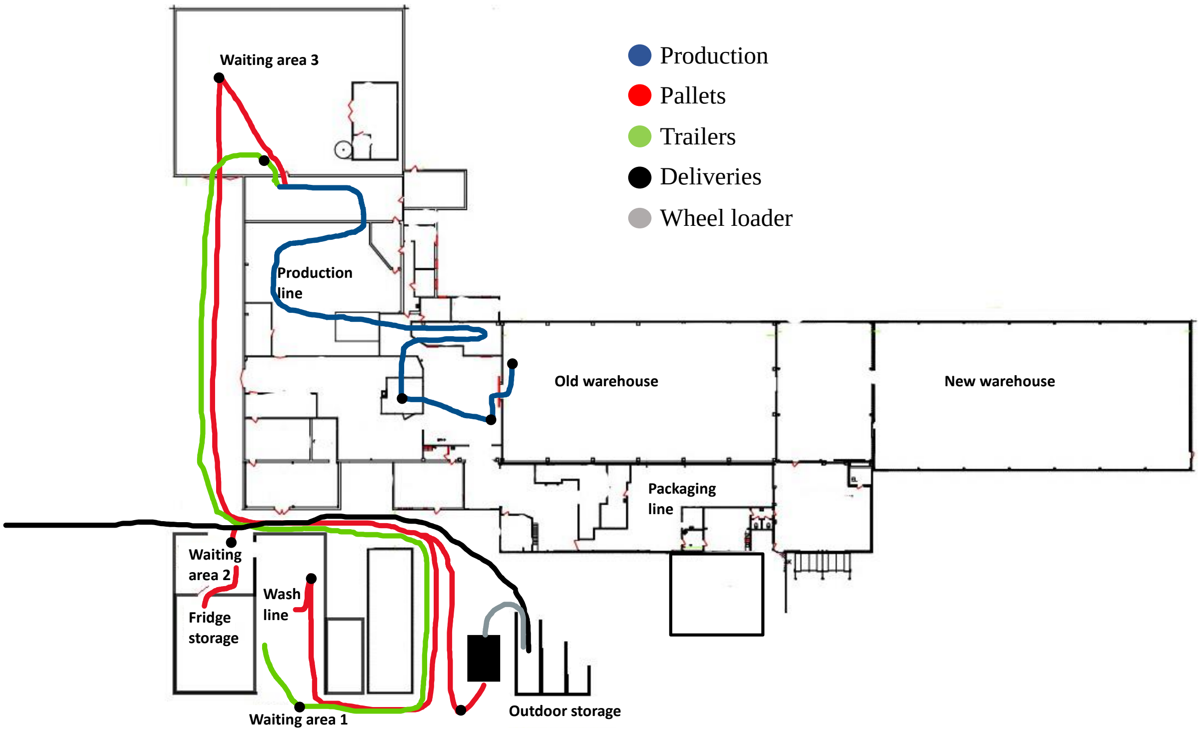

Figure 4.10 Spaghetti diagram of Use of raw material weeks after delivery.

4.6.2 Value Stream Mapping

The VSMs were developed to get a holistic view of the activities at the production site and to identify the value and non-value adding activities. The VSMs were also made to gain more detailed information that the spaghetti diagrams did not provide. The main goal with the VSMs were to identify waste. The majority of the data related to the wash line was collected manually. To get more reliable values, different processes were timed at different occasions. To get a more accurate representation of reality, even more times could have been registered but due to the limited timeframe, that was not possible. When comparing the collected times in the production line to the ones retrieved from the Excel file, it was clear that the collected times could be considered accurate.

As previously described, the material can take three different routes before the wash line and three different routes after the wash line. Because all product families can take all routes and the times for the routes are the same independently of family and cut, the creation of VSMs were based on routes rather than a specific product or product family. The VSMs were divided in two parts, before and after the wash line. Three VSMs describing the process before the wash line, and three VMSs describing the process after the wash line were created. An overview of the VSMs can be seen in Figure 4.11.

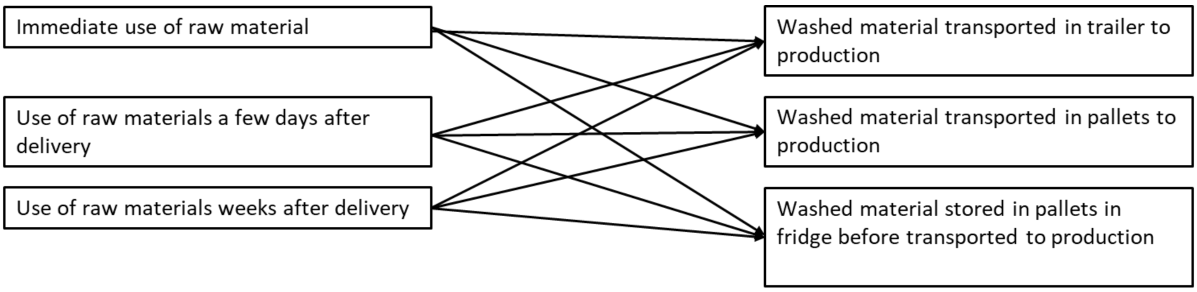

Figure 4.11 The six VSMs created.

The six VSMs can be seen in Figure 4.12-Figure 4.17. Table 4.1-4.7Table 4.7 under each VSM illustrates all steps and the corresponding average times of the routes. Figure 4.15-Figure 4.17 can also be seen in Appendix B for greater resolution.

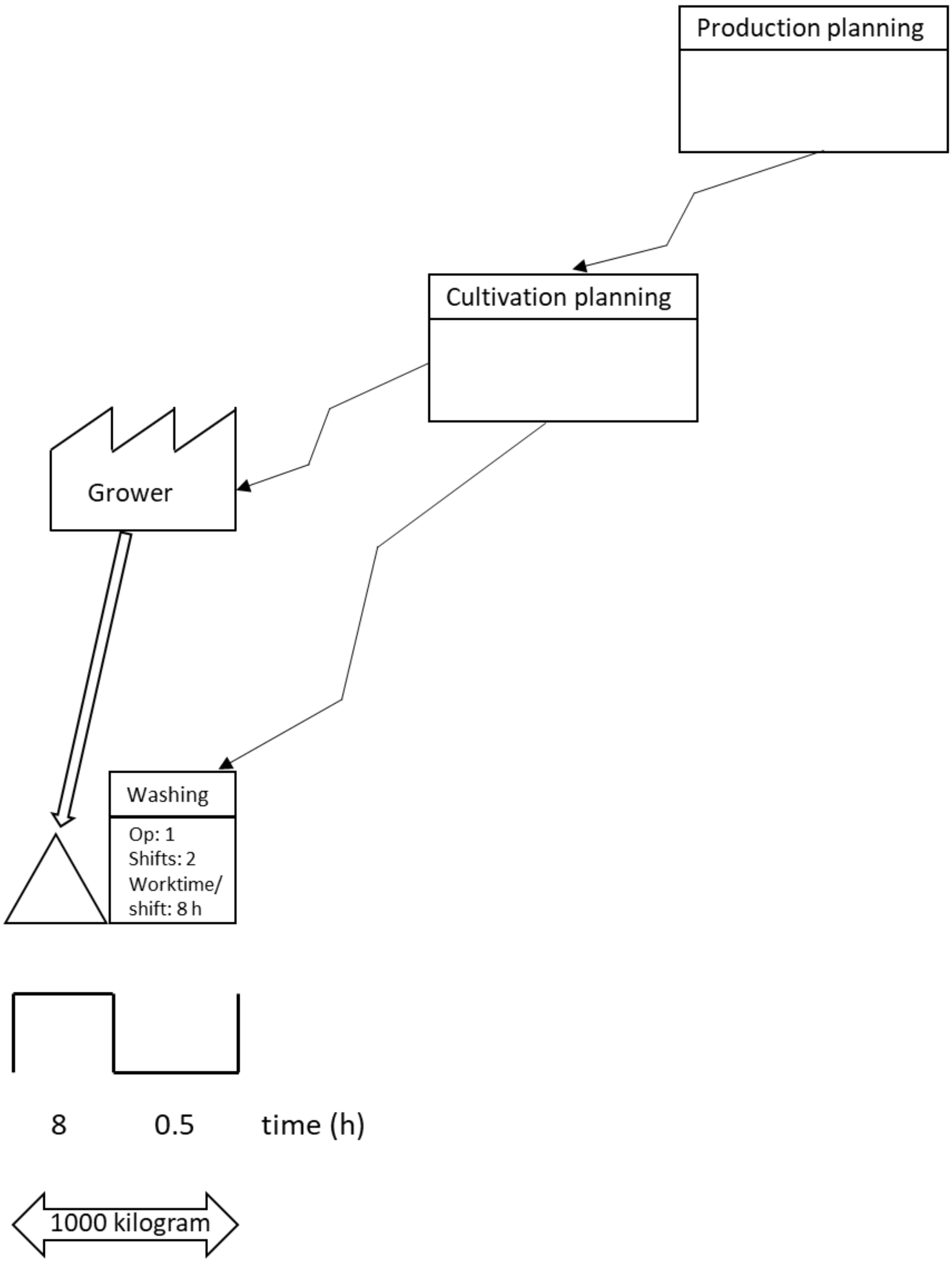

Figure 4.12 VSM of Immediate use of raw material.

Table 4.1 Processes for Immediate use of raw material.

Action	**Time (h)**	**VAT/NVAT**
Waiting for washing	8	NVAT
Washing	0.5	VAT

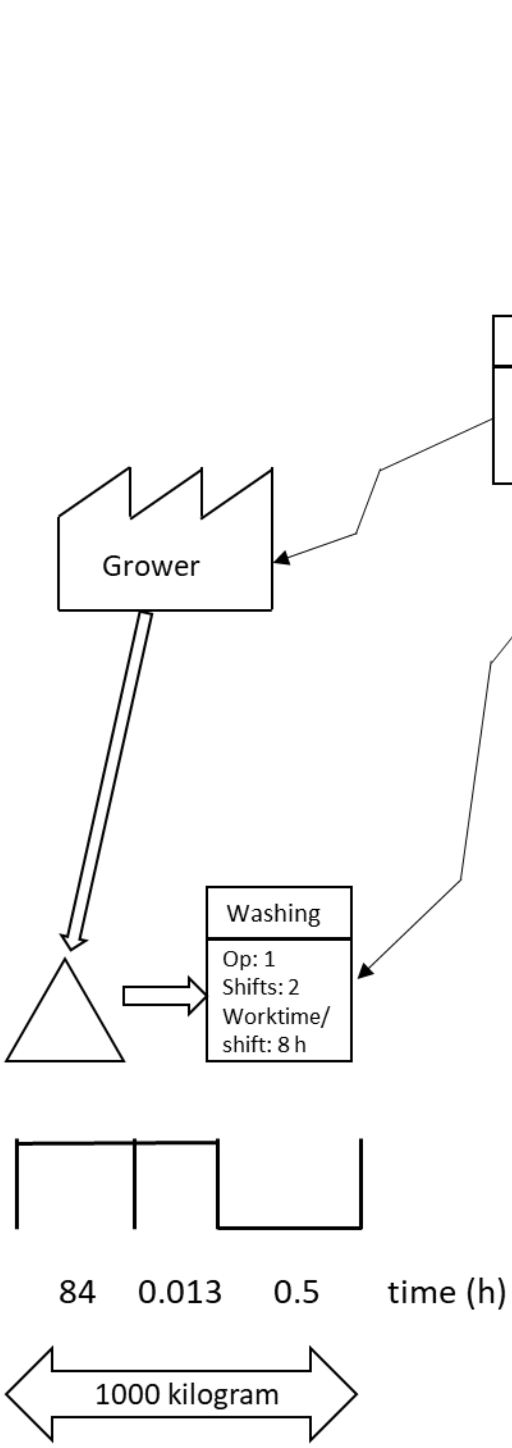

Figure 4.13 VSM of Use of raw materials a few days after delivery.

Table 4.2 Processes for Use of raw materials a few days after delivery.

Action	Time (h)	VAT/NVAT
Waiting to get transported to wash line	84	NVAT
Collection and transporting of raw materials	0.013	NVAT
Washing	0.5	VAT

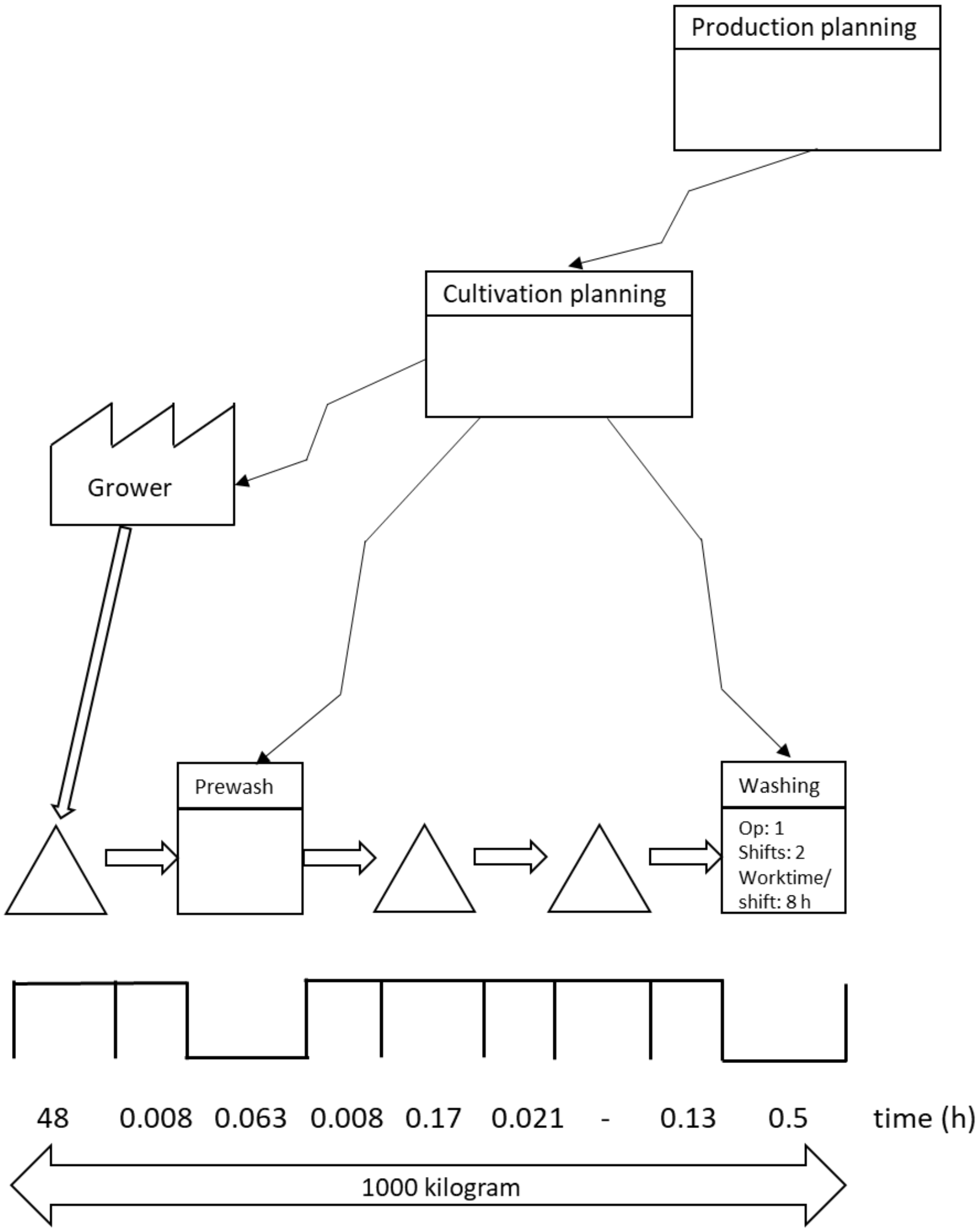

Figure 4.14 VSM of Use of raw material weeks after delivery.

Table 4.3 Processes for Use of raw material weeks after delivery.

Action	Time (h)	VAT/NVAT
Waiting to get transported to pre-wash line	48	NVAT
Collection and transportation of raw material	0.008	NVAT
Prewashing	0.063	VAT
Offloading next to prewash	0.008	NVAT
Waiting to get transported to fridge	0.17	NVAT
Transported to fridge storage	0.021	NVAT
Fridge storage	-	NVAT
Transported to wash line	0.013	NVAT
Washing	0.5	VAT

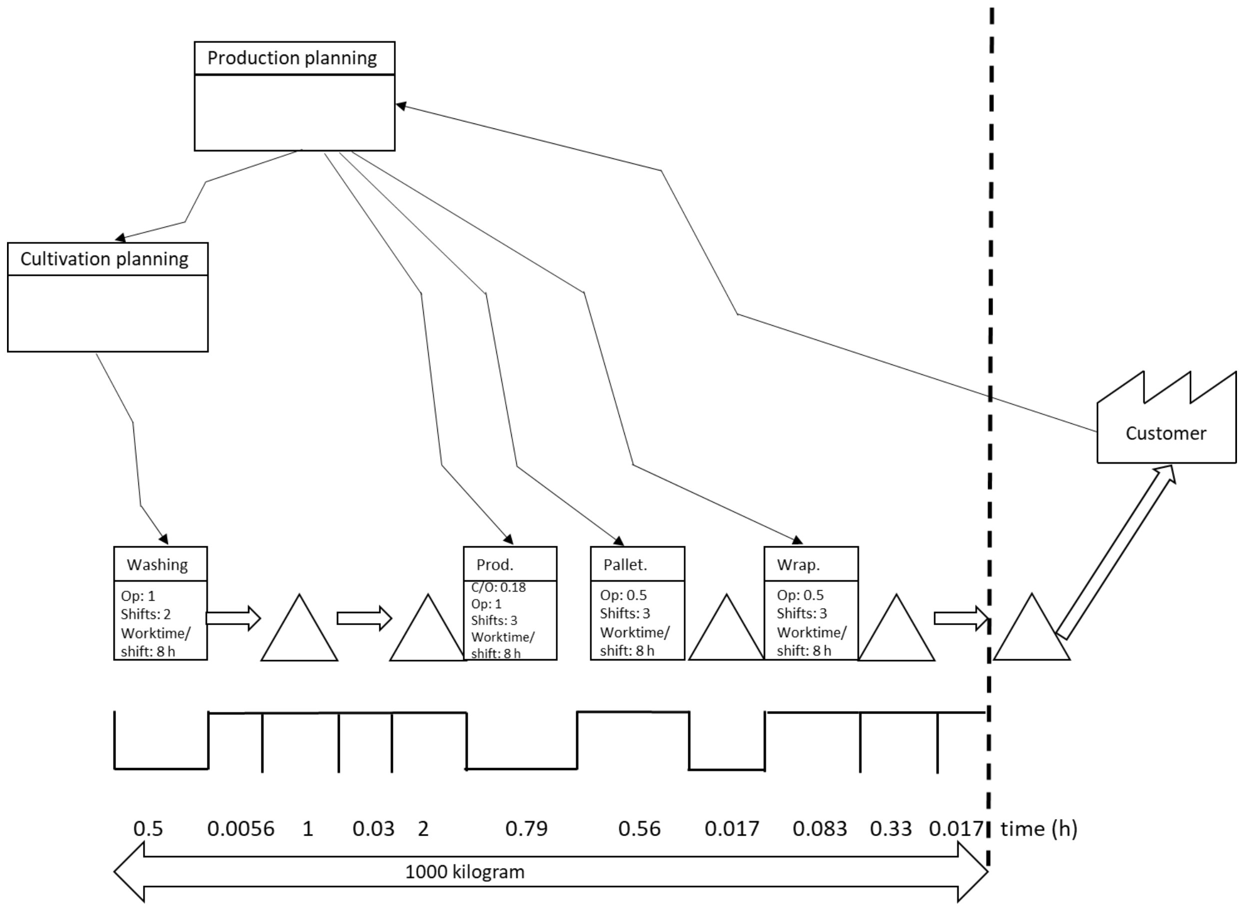

Figure 4.15 VSM of Washed material transported in trailer to production.

Table 4.4 Processes for Washed material transported in trailer to production.

Action	Time (h)	VAT/NVAT
Washing	0.5	VAT
Transportation to waiting area 1	0.0056	NVAT
Waiting to get transported to waiting area 3 from waiting area 1	1	NVAT
Transportation to waiting area 3 from waiting area 1	0.03	NVAT

Table 4.5 Processes related to the production line, common for all VSMs in Figure 4.15-4.17.

Action	Time (h)	VAT/NVAT
Waiting for production in waiting area 3	2	NVAT
Production	0.79	VAT
Palletising	0.56	NNVAT
Waiting for wrapping	0.017	NVAT
Wrapping	0.083	VAT
Waiting to get transported to warehouse	0.033	NVAT
Transportation to warehouse	0.017	NVAT

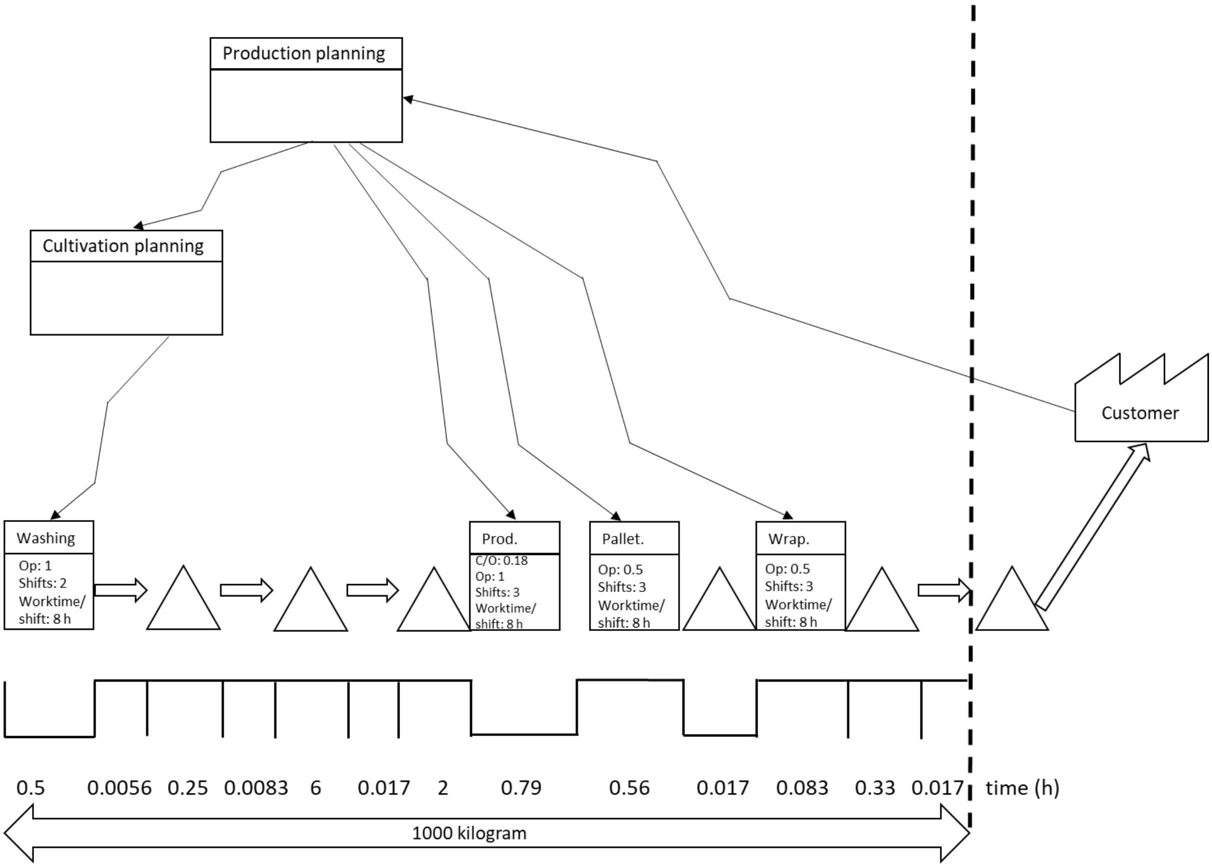

Figure 4.16 VSM of Washed material transported in pallets to production.

Table 4.6 Processes for Washed material transported in pallets to production.

Action	Time (h)	VAT/NVAT
Washing	0.5	VAT
Transportation to waiting area 1	0.0056	NVAT
Waiting to get transported to waiting area 2 from waiting area 1	0.25	NVAT
Transportation to waiting area 2	0.0083	NVAT
Waiting to get transported to waiting area 3 from waiting area 2	6	NVAT
Transported to waiting area 3 from waiting area 2	0.017	NVAT

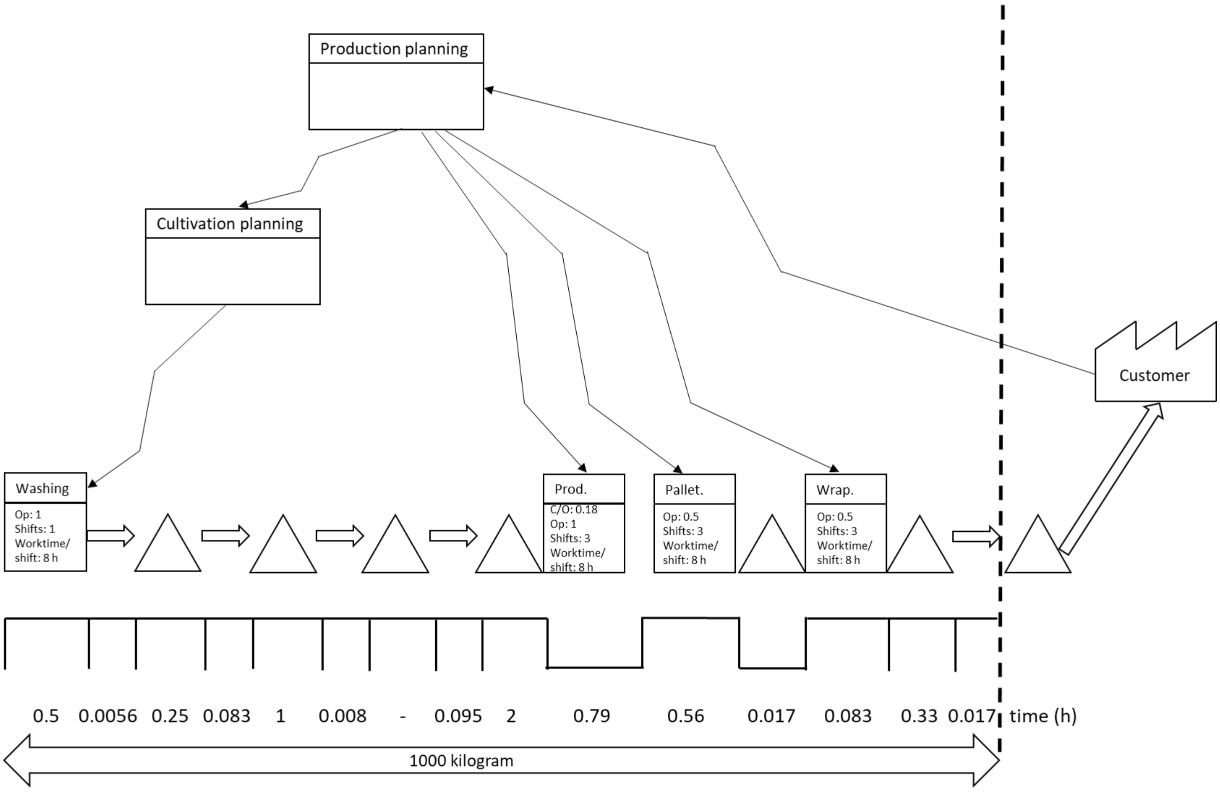

Figure 4.17 VSM of Washed material stored in pallets in fridge before transported to production.

Table 4.7 Processes for Washed material stored in pallets in fridge before transported to production.

Action	**Time (h)**	**VAT/NVAT**
Washing	0.5	VAT
Transportation to waiting area 1	0.0056	NVAT
Waiting to get transported to waiting area 2 from waiting area 1	0.25	NVAT
Transportation to waiting area 2	0.0083	NVAT
Waiting to get transported to fridge storage from waiting area 2	1	NVAT
Transported to fridge storage from waiting area 2	0.008	NVAT
Fridge storage	-	NVAT
Transported to waiting area 3 from fridge storage	0.095	NVAT

4.7 Key Performance Indicators

The company can be divided into three different areas where different KPIs are used. These areas are the wash line, the production line and the logistics department. There are more departments within the company that uses different types of KPIs but for the purpose of this study it is irrelevant to investigate them further. Hence, only the KPIs used in the previously presented departments will be presented below.

4.7.1 Wash line

The cultivation manager sets the different KPIs for this department. Listed below are the KPIs currently measured and followed up.

- Crops per hectare

The cultivation manager also tries to keep track of volumes of dirt in the raw material deliveries and the quality of delivered raw materials, but no documentation is at place.

4.7.2 Production line

The factory manager sets the different KPIs for the production department. Listed below are the KPIs currently measured and followed up.

- Overall Equipment Efficiency (OEE)
- Maintenance related stops
- Volume produced per hour
- Product waste

4.7.3 Logistics department

The logistics manager sets the different KPIs for the warehouse. Listed below are the KPIs currently measured and followed up.

- Warehouse turnover rate
- Backorders
- Stock value
- Obsoletes

5. Analysis

In this chapter, the data received from the company will be analysed. First the production pattern for each product family is presented, then the waste generated by each family. In addition, the issues identified during Gemba walks in the wash line and the production line are further described.

The analysis of the current state was based on empirical findings from observations and interviews as well as secondary data obtained from the company MS Excel file together with data from the company information system. Worth noting is that some mistakes in the secondary data were identified, which potentially could make the results of the analysis less trustworthy.

The data in the Excel file is manually filled by the company, which can be a reason for errors in the data. The few values below zero was sorted out during the analysis.

Another identified mistake in the data was in the comment section where the reasons behind high levels of waste are explained. This is presented in Section 5.4 and one of the comments state waste above 60% when the waste in fact was just around 55%.

5.1 Sales patterns

The sales for each product family were analysed and can be seen in Figure 5.1-Figure 5.4. The x-axis shows the months that the family was produced, and the y-axis shows the volumes in kilograms. As there was no data available further back than July 2019, the sales patterns over a one-and-a-half-year period were analysed. As the company mainly plans their production on customer orders, the sales pattern can give an idea of the demand pattern. As previously presented and found in literature, the demand for the agri-food industry is uncertain. This was also indicated during interviews and in the data analysis.

When comparing the sales volumes of 2019 to 2020 for Family A, the sales are somewhat similar during three months of the available period. For the other three months, the sales volumes are very different. The available sales volumes for Family A can be seen in Figure 5.1.

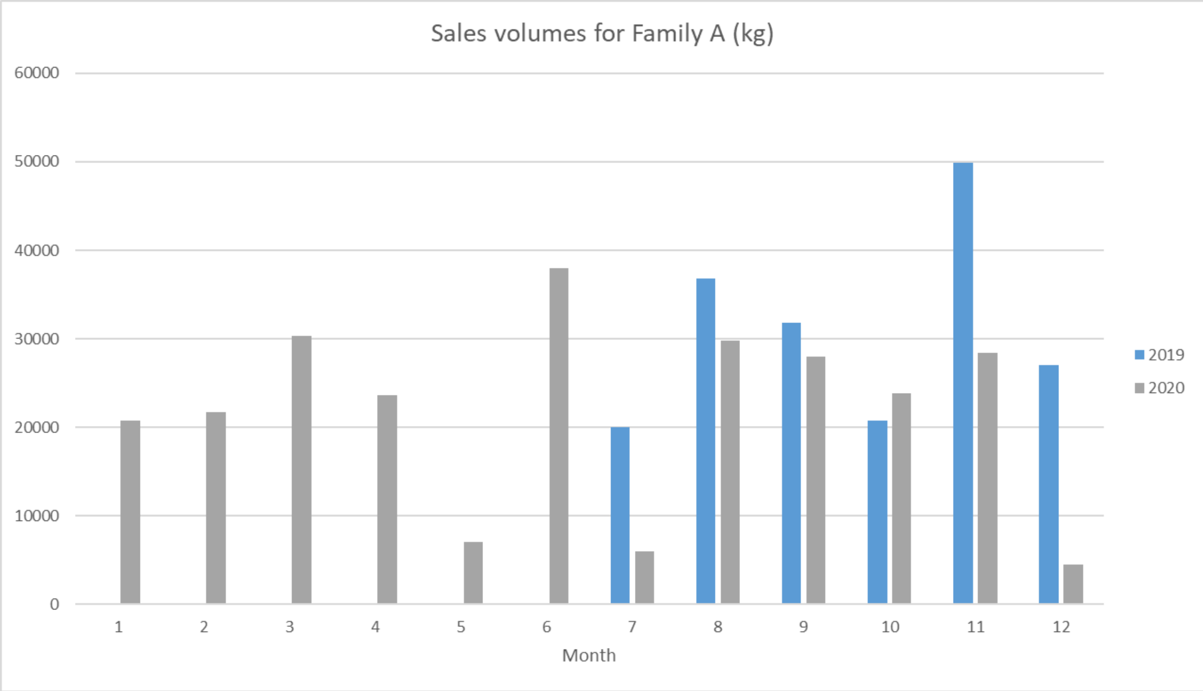

Figure 5.1 Sales pattern for Family A.

For Family B, the sales volumes are very different for every month of the available period. The available sales volumes for Family B can be seen in Figure 5.2.

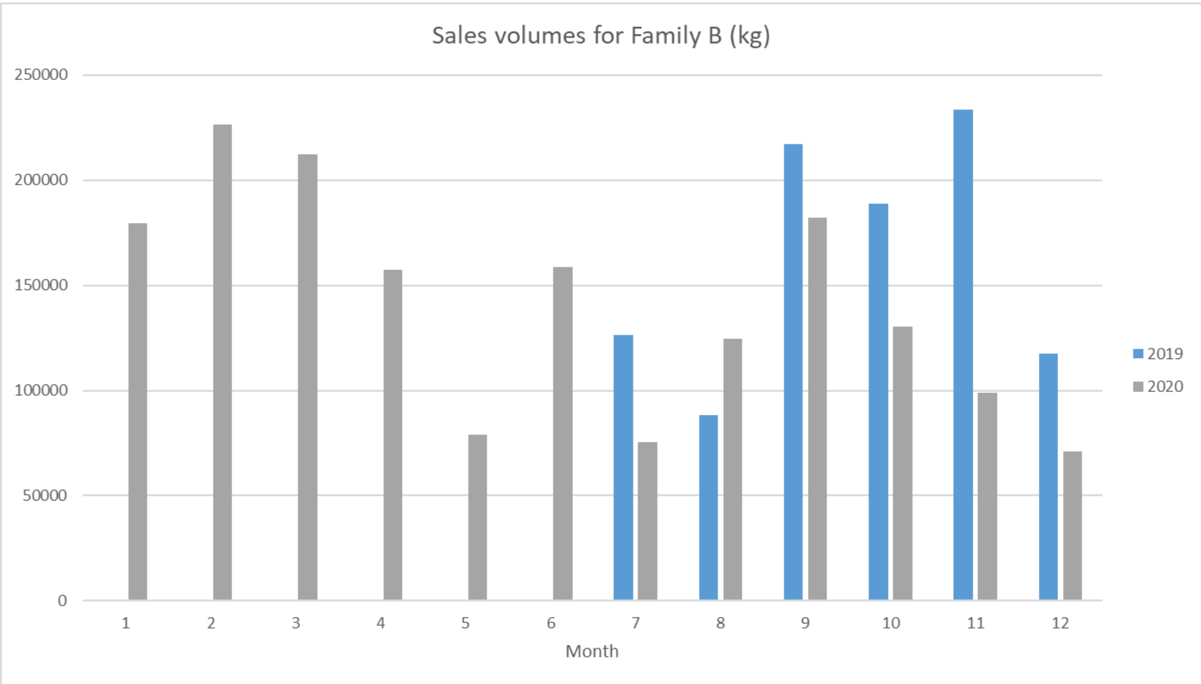

Figure 5.2 Sales pattern for Family B.

For Family C, the sales are somewhat similar in August and October of the two years. For the other months, the sales volumes are very different. It can also be seen that there is no seasonal pattern for the available time period, i.e., the volumes vary a lot from month to month as well as from year to year. The available sales volumes for Family C can be seen in Figure 5.3.

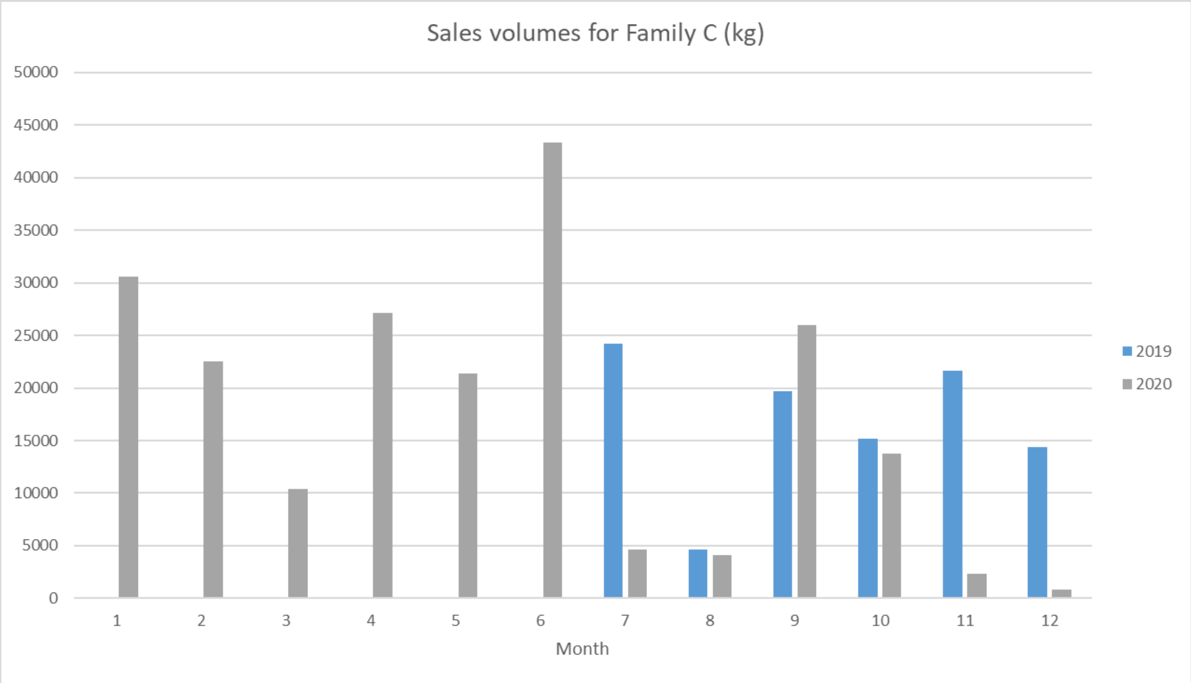

Figure 5.3 Sales pattern for Family C.

For Family D, the sales are somewhat similar in most of the comparable months i.e., July to December 2019 and 2020, respectively. Compared to the other families, Family D has less variation from month to month. The available sales volumes for Family D can be seen in Figure 5.4.

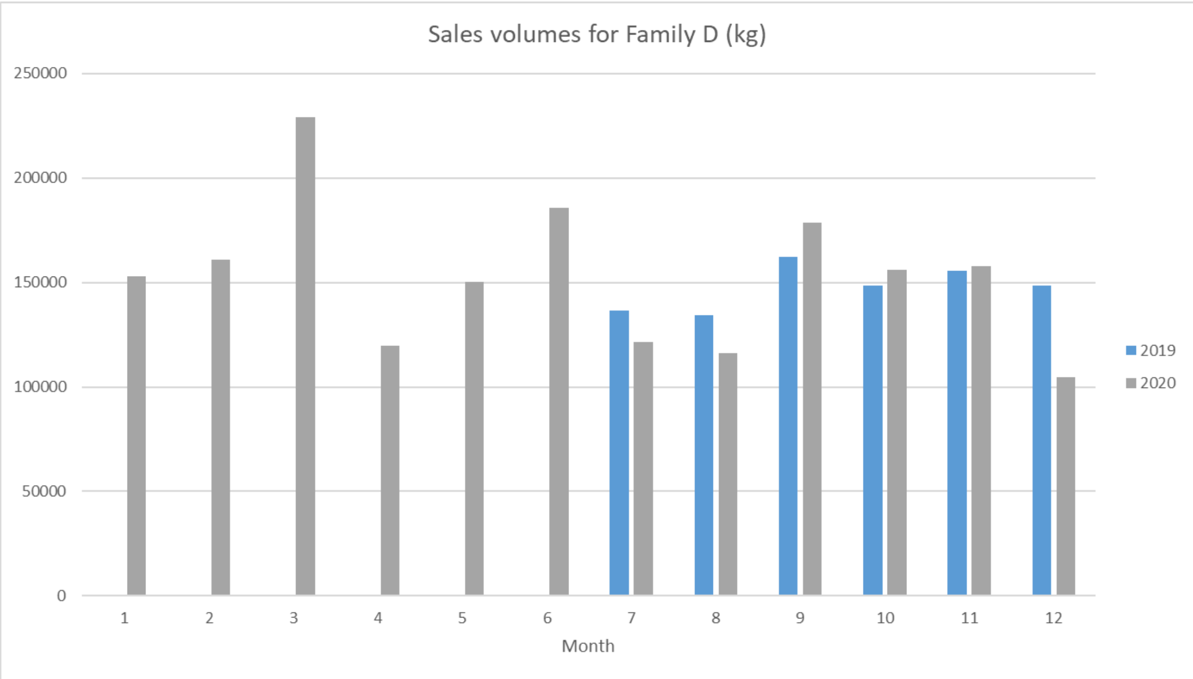

Figure 5.4 Sales pattern for Family D.

5.2 Production patterns

In theory it was found that the agri-food industry is impacted by seasonality. This was proven during interviews and the seasonality affects the company in the sense that there are only certain time-periods in a year when crops can be harvested. In Table 5.1 the different harvesting periods for each product family are presented.

Table 5.1 Different harvesting periods for the product families.

Product family	Harvest period
A	September-November
B	September-November
C	All year
D	September-November

Below is an illustration of the volumes produced during 2019 and 2020 for each product family. For this part of the analysis, data was available for all of 2019 and 2020. There is a small indication that the different families are produced around the same weeks over the two-year period. However, the different product families are produced on weeks both close to as well as far away from the harvest period. The production volumes can be seen in Figure 5.5-Figure 5.8 and the y-axis shows the produced volumes in kilograms and the x-axis displays weeks.

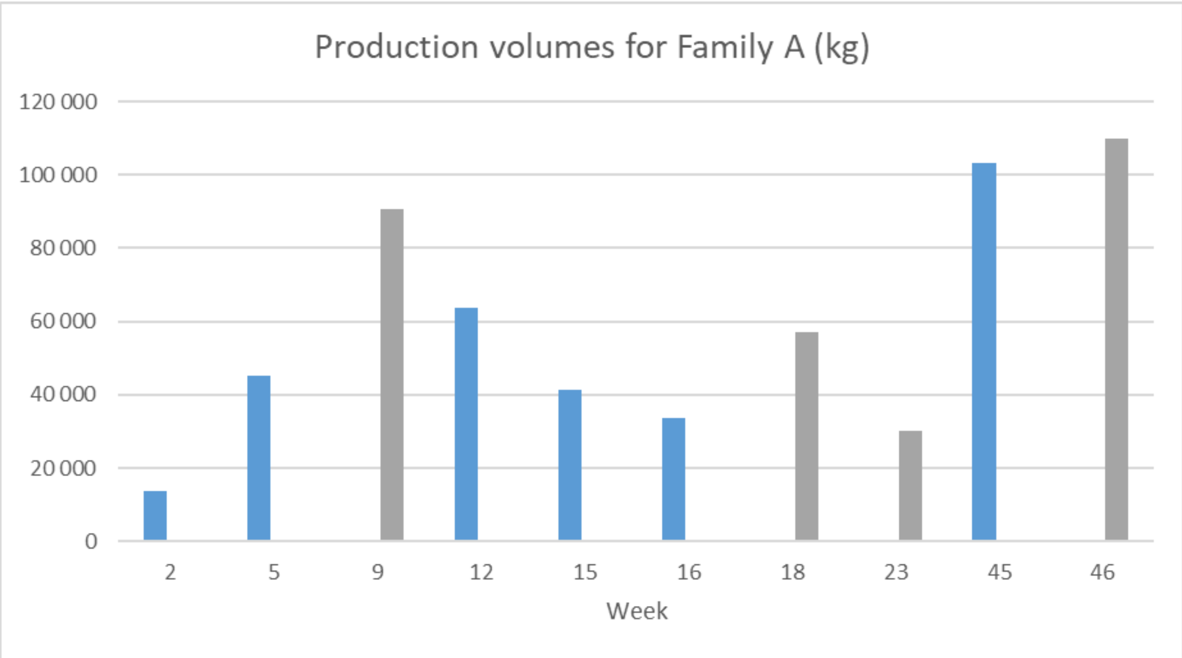

Figure 5.5 Production volumes per week for Family A over a two-year period.

For Family A, the production has not occurred during the exact same week in the two-year period. However, there are only a couple of weeks difference between the two years. In 2019 the total production volume of Family A was around 300 tons, and in 2020 the production volume was 287 tons.

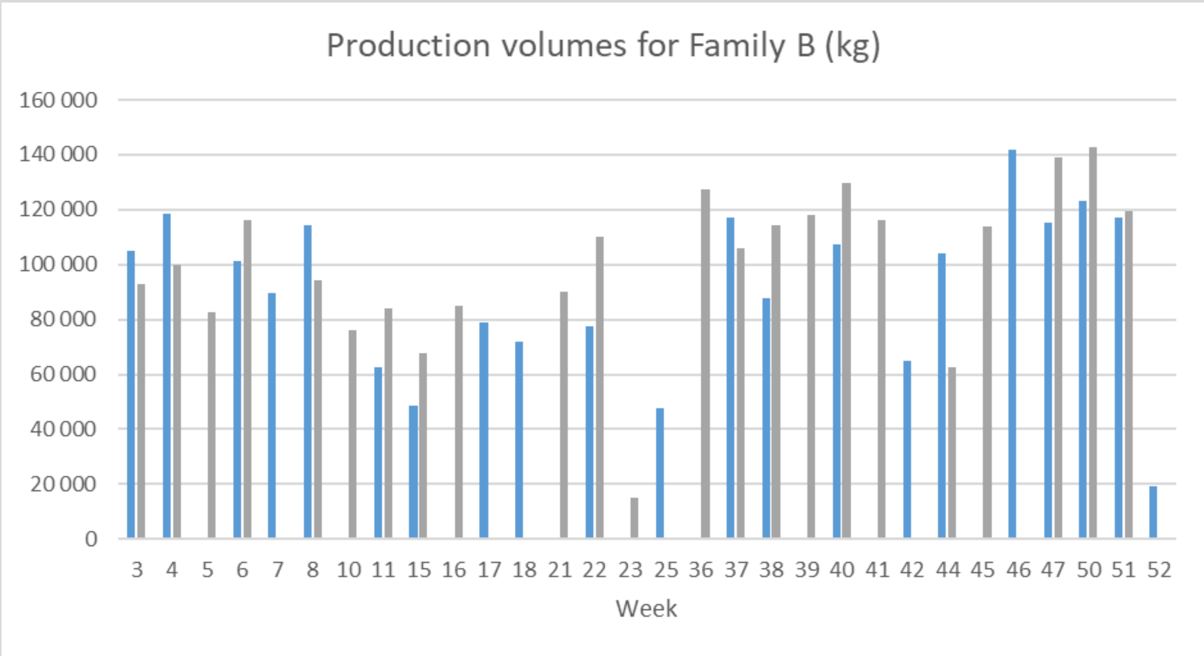

Figure 5.6 Production volumes per week for Family B over a two-year period.

For Family B, production occurred on the exact same week in 14 out of 30 production weeks. When production did not occur on the exact same week, the difference was only one or two weeks for a majority of the time. In 2019 the total production volume for Family B was 1914 tons and in 2020 the production volume was 2303 tons.

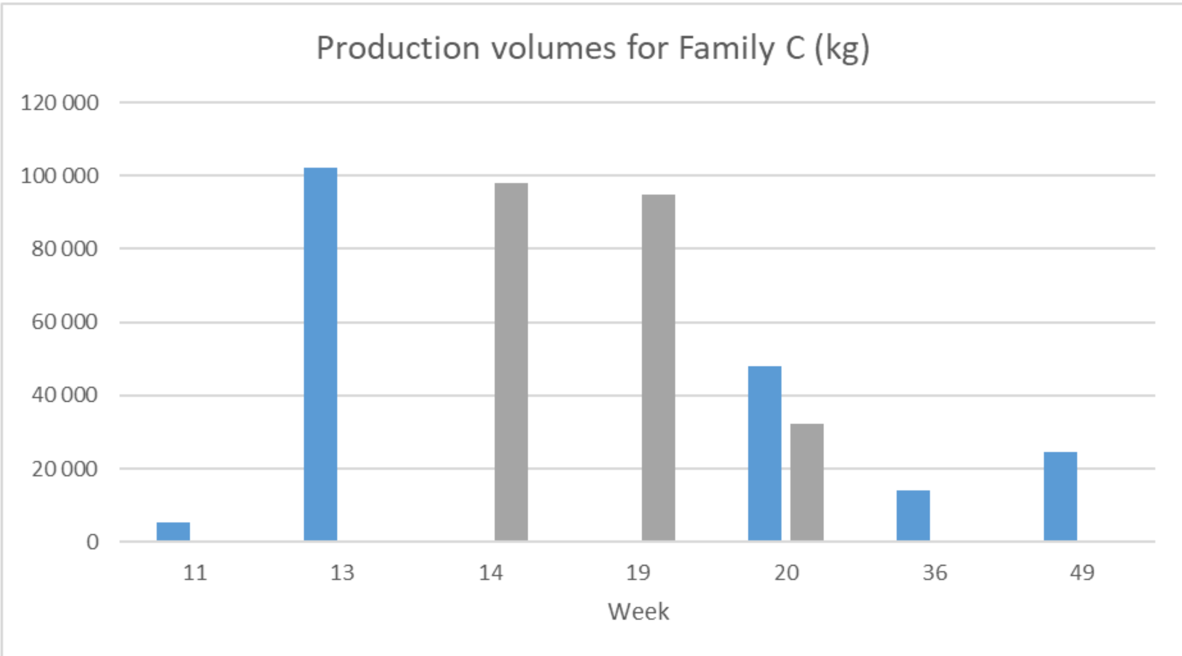

Figure 5.7 Production volumes per week for Family C over a two-year period.

During week 20, both in 2019 and in 2020, the company produced product Family C. The other times that this product family was produced varies a lot between the two years. The reason behind this could be the previously mentioned demand uncertainty since the company mainly produces its products based on customer orders. In 2019, the total production volume of Family C was 193 tons and in 2020 the total production volume was 225 tons.

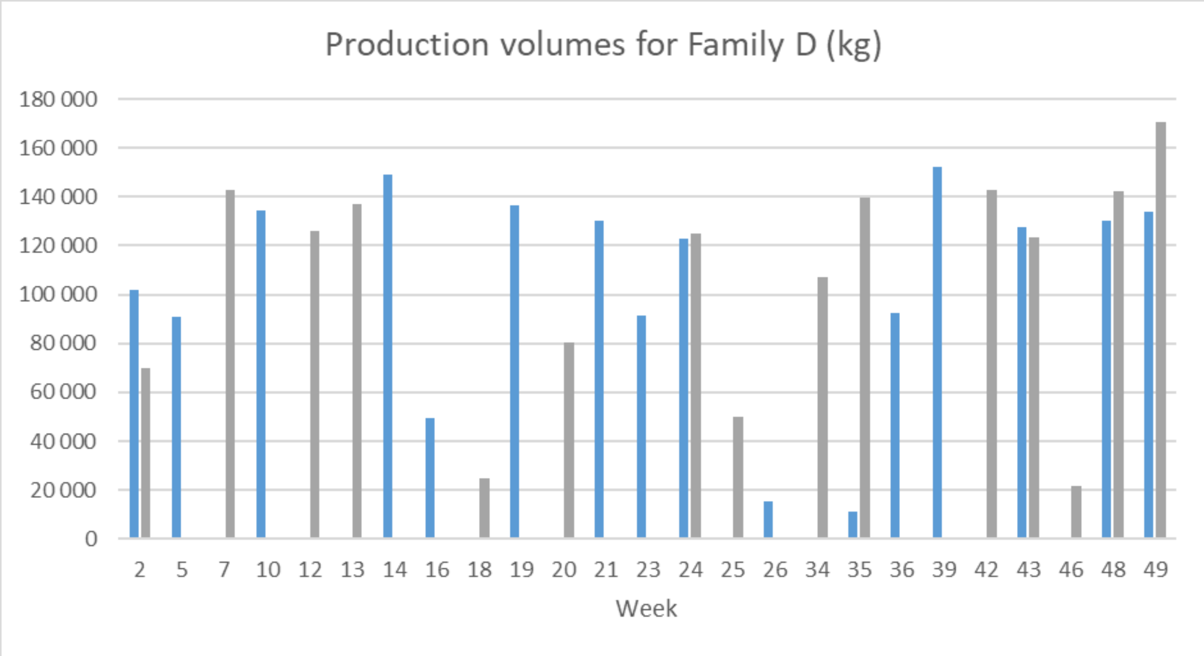

Figure 5.8 Production volumes per week for Family D over a two-year period.

For product Family D, the production occurred on the exact same week 6 times over the two-year period. When comparing the other production weeks, they only differ with 1-3 weeks for the majority of the time. In 2019 the total production volume of product Family D was 1700 tons and in 2020 the total production volume was 1603 tons.

5.3 Planning

The planning is currently done based on customer demand and on-shelf availability of finished products. The planning department does not have any insight to the stock levels of raw materials which leads to a more complicated planning process. Before the pandemic, the production planner was able to speak to the cultivation manager on-site to get the required information regarding the stock levels of raw materials. This has changed with the pandemic and the home-office policy, the production planner is currently working remotely and therefore does not have the possibility to get information quickly from the cultivation manager. In addition, the lack of sufficient computer systems to assist the planning makes the process more time consuming and complex.

The demand in the agri-food industry is uncertain and high demands of certain products can occur when least expected. Some of the company's customers have promotions on the products which is notified to the company in advance, however, these promotion notifications are often of little to no help for the company since it usually does not provide them with volume forecasts. Even if a customer were to provide a volume forecast these are rarely accurate.

5.4 Waste in production

During the production process, raw material not meeting the quality requirements is sorted out and hence regarded as waste. The amount of waste varies with the characteristics of the raw material such as size, appearance and quality, but also varies with product family and cut. The main problem identified related to waste of raw material was waste due to bad product quality. This issue was discovered through observations as well as in interviews. Figure 5.9-Figure 5.12

illustrate the waste per product family on the days that it occurred during 2019, 2020 and the first weeks of 2021. The highest, lowest and average waste per product family can be seen in Table 5.2.

Table 5.2 Waste per product family

Product family	Lowest waste (%)	Highest waste (%)	Average waste (%)
A	4.71	53.59	30.75
B	3.16	72.23	30.37
C	4.91	75.27	30.37
D	4.95	57.28	30.9

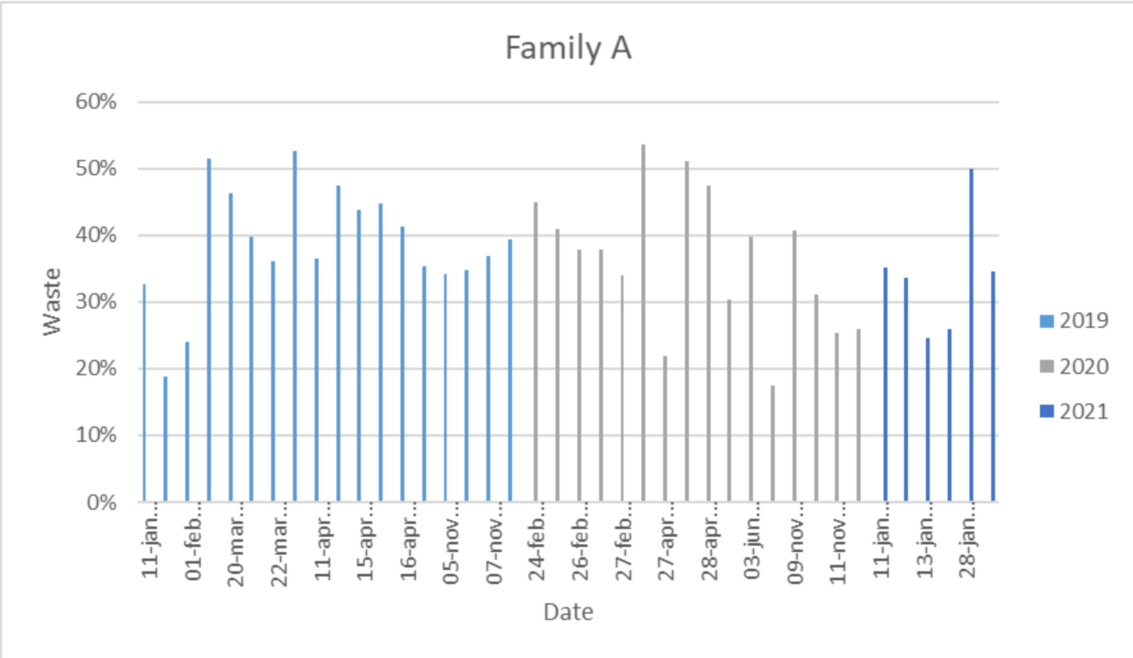

Figure 5.9 Waste per day for Family A from 2019 to 2021.

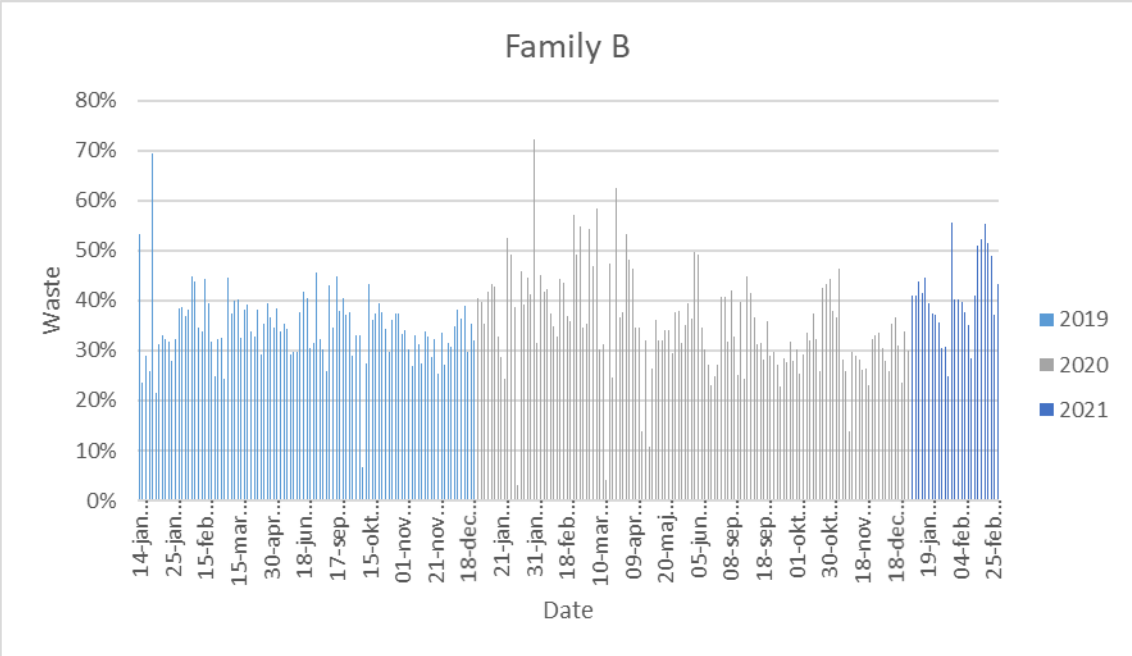

Figure 5.10 Waste per day for Family B from 2019 to 2021.

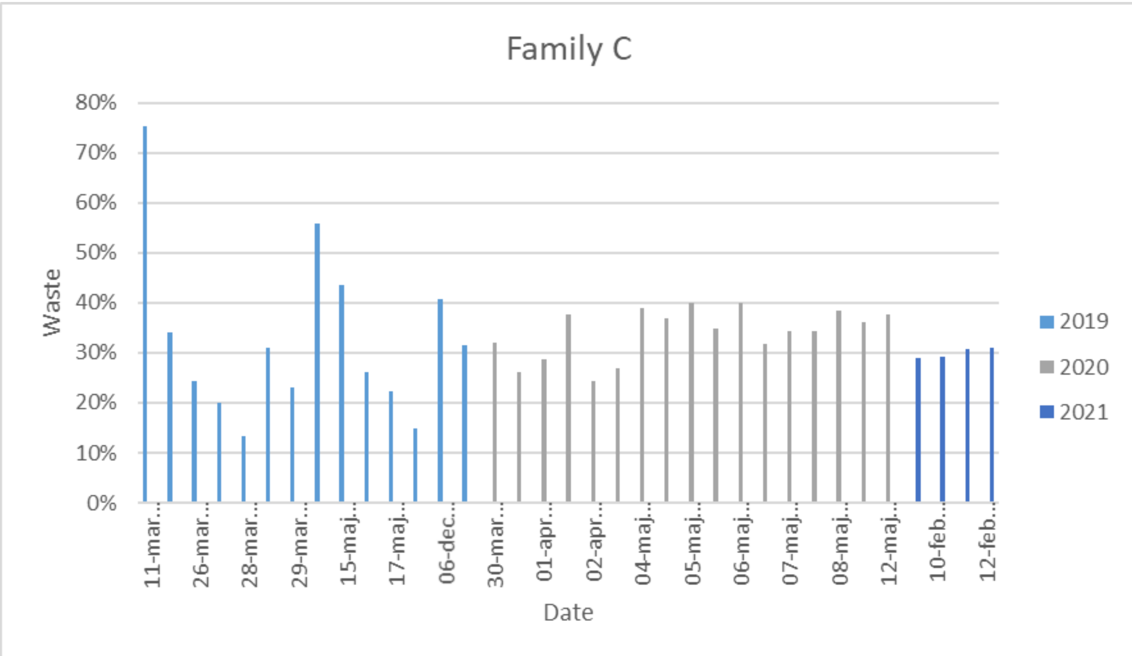

Figure 5.11 Waste per day for Family C from 2019 to 2021.

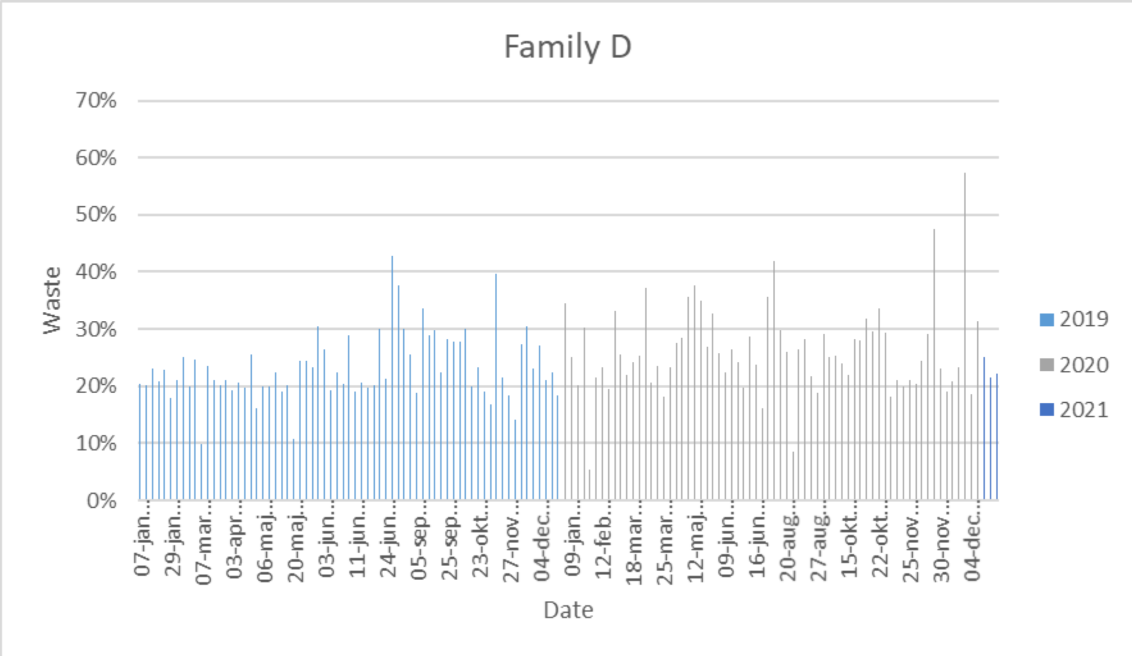

Figure 5.12 Waste per day for Family D from 2019 to 2021.

Independently of product family, the waste of raw material is very inconsistent. There is no significant difference between the families. To investigate the reasons behind the high waste percentages, all production orders with waste above 50% were further analysed and are presented in Table 5.4. Note that the data presented in Table 5.4 except for the cost, is extracted from the company's own documentation. Hence, one comment states "waste above 60%" when the recorded data gives around 54% waste. In addition, there are some inconsistencies in the expressions used. Table 5.3 shows the fraction of total production volume of each family in comparison with fraction of order with waste above fifty percent. Noticeable is that Family D stands for a large part of the production volume, but a has very low fraction of orders with above fifty percent waste. One potential reason could be that the sales volumes for Family D are the most even ones. Since the company is producing based on customer orders, a stable sales volume could result in less time spent in storage for raw materials from Family D. Family B seems critical with a very large share of orders with over 50% waste and at the same time stands for close to half of the total production.

Table 5.3 Production volumes and waste above fifty percent.

Family	**Percent of total production volume**	**Percent of total orders with waste above 50%**
A	6.9	17.4
B	49.5	69.6
C	4.9	8.7
D	38.7	4.3

Table 5.4 Production orders with waste above fifty percent.

Date	Family	Production Volume out (kg)	Waste (%)	Comment	Direct cost (SEK)
2019-01-14	B	1800	53.38		2 188
2019-01-17	B	960	69.35		3 748.88
2019-03-11	C	5300	75.27		30 664
2019-03-19	A	4620	51.54		4 711
2019-04-10	A	7860	52.60	Poor quality of raw material.	8 888
2019-05-14	C	2400	55.83	Stop in drains	3 605
2020-01-23	B	13680	52.59	Poor quality of raw material. Change of knives.	15 451
2020-01-31	B	6400	72.23	Change of gasket in steam peeler	30 207
2020-02-20	B	13860	57.16	Poor quality of raw material	23 162
2020-02-28	A	10460	53.59	Ammoniac pump stopped	12 954
2020-03-02	B	12540	54.89		17 411
2020-03-05	B	12940	54.32	Poor quality of raw material	17 103
2020-03-09	B	10760	58.26	Steam peeler gasket broken	19 570
2020-03-13	B	3000	62.50	Poor quality of raw material	7 410
2020-04-07	B	11880	53.25	Poor quality of raw material	14 271
2020-04-28	A	10840	51.17	Poor quality of raw material	10 646
2020-12-03	D	960	57.28		1 618
2021-02-01	B	14400	55.48	Very poor quality of raw material. Waste is over 60%.	21 006
2021-02-18	B	17640	50.94	Very poor quality of raw material. Waste is over 50%.	16 917
2021-02-19	B	13040	52.14	Very poor quality of raw material. Waste is over 50%	14 112
2021-02-22	B	14880	55.31	Very poor quality of raw material. Waste is over 55%.	21 403
2021-02-23	B	10540	51.54	Very poor quality of raw material. Waste is over 50%.	6 396
2021-02-23	B	6300	51.50	Very poor quality of raw material. Waste is over 50%.	10 747
				Sum	314 201

As seen in Table 5.4, the comments made were mostly regarding the quality of the raw material. Some comments were, however, regarding equipment failure. During interviews, it was found that the poor quality was due to the fact that the raw material had been stored in the fridge for too long. In addition, the poor quality could also be the reason behind the equipment failures.

Running the production line with raw material of poor quality leads to direct costs in forms of pure waste of material, labour costs, equipment costs and other production costs. The costs and incomes were based on an average calculated by the company. It was estimated that the waste goes through two thirds of the production, before being sorted out. Despite no exact numbers, the calculation gives an indication of how much the company loses when the waste is high. Based on these calculations, the company has lost a total of 304 201 SEK when waste is above fifty percent between January 2019 and February 2021.

Above the direct costs of running the production with raw material of poor quality, there are other problems related to this. A common problem with production using raw material of poor quality, is that the production plan changes. When it is realised that raw material has been stored in the fridge for too long resulting in poor quality, it is often decided to change the production plan and use the material of poor quality earlier than planned. This results in an occupied production line instead of producing the planned product that the company could get a higher output from. There is no clear prioritization in the production as for when this happens. Furthermore, there is no clear prioritization list for when the raw material should be stored in the fridge, when it should be stored outside, or when it should go direct to the washing line. There is neither a prioritising list for what raw material the production should use or any information regarding where it has been stored, or for how long the material has been stored.

Since the company produces products based on customer orders, certain product families might not be ordered for a long time. Hence, the raw material is stored for a long time. As most of the product families have a limited time period for harvest, most raw material must be taken to the company between September and December. Taking this into consideration, it becomes clear that it is a difficult task to plan the production of all the different cuts within a product family without having any raw materials of poor quality.

5.5 Wash line

In this section, all the identified problems within the wash line are presented. The times presented are based on timing of each task during the Gemba walks. To calculate the total time for a day or a shift, data from the MS Excel file have been used in combination with data from the interviews.

Loading of wash line: Raw material placed in the outdoor storage area generates several travels with the wheel loader to fill the wash line. The operator can only take two trips at a time, with about 1.5 ton of raw material each trip. When the two trips are completed, the operator must leave the wheel loader and go to the wash line to make sure that it is operating correctly. The operator might need to even out the washed material placed in pallets or on the trailer to make sure no product falls out. If a lot of smaller raw material has been delivered, the operator also has to make sure that a container placed underneath the brushes is not full. If that is the case, the operator must use the forklift to empty the container with material on to the wash line again.

Due to lack of recorded data at the company, it is hard to get an understanding of the average amount of travels made between the outdoor storage and the wash line. To estimate this, data records of the volumes tipped into the production was used. Based on that data, it was estimated that it takes an average of 22 trips between the outdoor storage and the wash line to satisfy the production volumes for one day. This means that the operators spend around 35 minutes travelling between the outdoor storage and the wash line every day that material is needed form that location. In addition, the lack of documentation makes it hard to know how often raw material is placed in the outdoor storage. Based on the Gemba walks it was estimated that raw material is taken from the outdoor storage 60% of the time.

Lack of space: The wash line is located in a separate building from the production. The building is currently leased from another company. The area where the wash is located is small and there is not much space for the operators to use when operating the forklift. Every time a pallet or a trailer is full, as well as when the layer of washed raw materials in the trailers need to be evened out, the operator must use the forklift. This results in movements of the forklift that can be considered unnecessary. Even though the limited space is obvious close to the wash line, the company still stores old machinery in that area. This makes the available space to operate in even smaller.

Double handling: Due to the current facility layout, a lot of double handling occurs around the wash line. When a pallet is full, it is taken to waiting area 1 and then replaced by a new pallet. When there are 4 pallets placed in waiting area 1, the operator takes 2 pallets to waiting area 2. On the way back, the operator collects two empty pallets and brings them to the wash line. The pallets left in waiting area 2 are placed there only to later be moved once again, to the fridge storage or to waiting area 3. Since the wash line operates in a faster pace than the production line, full trailers are placed in waiting area 1 until the production foreman can collect them.

When the pre-wash is used, a full pallet is moved to a waiting area close by and a new pallet is placed underneath the pre-wash. As the number of full pallets in the waiting area increases, two pallets at a time are taken to the fridge storage.

Facility layout: The outdoor storage is located about 70 meters from the start of the wash line, the travels needed to load the wash line are therefore long and the volumes that can be loaded are limited.

Waiting area 2 and the fridge storage are located about 90 meters from the wash line. Since there is no automated transportation from the wash line to waiting area 2 or the fridge storage and the space close to the wash line is limited, many travels with a long distance are required.

The production line is located around 150 meters from the wash line. This also leads to many and long travels to refill the production line with washed raw material.

Inadequate machinery: In the first step of the wash line, raw material is cleaned from dirt by rotating brushes. In this step, small raw material falls through the brushes and lands in a small container placed underneath. These products are still usable and are therefore, as the container is full, placed back on the wash line by the operator. This task is time consuming and complicated due to the limited space available to operate the forklift. It takes around 2 minutes for the operator to put raw material back on the wash line and when a delivery includes a lot of small raw material, this task must be done at least once an hour. This results in 16 minutes spent in this task each shift.

Bad fridge storage: Through interviews it was discovered that the current fridge storage has lacking capacity. During the first couple of months of harvest, when it is still warm outside, it is not possible to store any raw material in the fridge storage. This because the capacity of the coolers is too low and therefore it is impossible to get the fridge to the right temperature. The raw material that is delivered to the company then has to be produced within a short period of time so that the quality of the raw material does no decrease while it is stored in the outdoor storage.

Operator waiting time: The wash line is quite automated and the tasks for the operator are pretty much limited to three tasks; loading wash line, moving full trailers and pallets as well as replacing them with empty ones and even out the layers of washed raw material in pallets and trailers. This leads to a lot of time spent waiting and watching the line, in case something where to happen.

Waiting time for delivered raw material: When raw material is to be taken immediately to the wash line upon delivery, the driver sometimes must wait for offloading. This, because the wash line is occupied by another type of raw material or raw material from a different grower.

5.6 Production line

In this section, all the identified problems within the production line are presented. The times presented are based on timing of each task during the Gemba walks. To calculate the total time for a day or a shift, data from the MS Excel files have been used in combination with data from the interviews.

Distance to printer: For every pallet produced, a label is needed. The operator must walk around 50 meters within the production facility to reach the printer. When the label is printed, the operator walks back to the wrapping station to place the label on the pallet. This task must be done at least twice every hour and it takes about 3 minutes. This results in a total of 2 hour and 24 minutes spent on this task every day.

Transportation to wrapping and warehouse: When a pallet is full, it is automatically transported out of the robot cage to an area which makes it accessible to the operator. The operator then takes a forklift to bring the pallet to the wrapping station, the pallet is left at the wrapping station as the operator removes the forklift and goes to print a label. The operator returns with the printed label and starts the wrapping station. As the pallet is fully wrapped, the operator puts on the label and gets the forklift. The pallet is then transported to the adjacent warehouse. It takes a total of around 3.7 minutes to complete the wrapping process. The transportation and wrapping process takes around 3 minutes and the transportation to the old warehouse takes 40 seconds.

Storage of packaging materials: The packaging material is stored in a different building. The foreman must drive a forklift about 100 meters to collect the packaging material from the other building and then bring it back to the packaging part of the production line. This is done a couple of times a week.

Packaging material: During Gemba walks it was noticed that the packaging material used is not adequate. The large rolls of plastic bags would work properly until around 1/6 of the material was left on the roll. At that point the material would start to tear up as it went through the cutting machine, making it unusable. One reason could be that the material is winded too tightly on the rolls. The company has recently returned a total of 516 kilograms of packaging material, that has been gathered over the last six months.

Defect bag labeling machine: One task that the operator has is to make sure that the labeling machine do not stamp labels on the transportation band. This was found to be a common issue and the staff must use screwdrivers to remove the labels from the transportation band.

Dropped bags: During Gemba walks it was noticed that the machine that fills the 20 kg bags was not operating properly. The machine dropped several bags to the ground which then could not be reused and had to be thrown away.

5.7 Communication and information sharing

The company have a lot of documents accessible for all relevant employees in a SharePoint, however, during this study it was found that some important information is missing. Mainly, information regarding the storage of raw materials. The only found data related to the deliveries and stock keeping of raw materials was in the company’s information system. In the system, data regarding supplier, quantities and delivery dates can be found. However, it is not possible to find if the received raw material has been placed in any of the two available storage facilities. This impacts the production planning and in the end the amount of waste generated. If the production planner had access to the raw material stock levels, when it was stored and how the quality of the stored goods was, a lot of waste could potentially be avoided.

Another issue found regarding communication is the one between the wash line and the production. Currently, the company does not have a good way of communicating which raw materials to use. This leads to double handling of pallets by the wash line. The wash line operators place the material that is to be used when the cut is changed at waiting area 2 until it is time to use it. Then, when it is time to use the material, the operator transports the material to waiting area 3, where the production foreman then can retrieve the material for production.

5.8 VSM in the agri-food industry

To understand similarities and differences between the case company, the agri-food industry and the automotive industry, a comparison of the identified characteristics presented in Table 3.2 was made. It was found that the company shares many characteristics with those typical for the agri-food industry, which can be seen in Table 5.5. This makes the company a good foundation for the comparison in RQ3: *How does the use of VSM in the agri-food industry differ from a previously (well) studied industry?*. Important to remember is that having one company represent an entire industry cannot give the full picture. However, it can give an idea of how applicable VSM is in the agri-food industry.

Table 5.5 Characteristics of the agri-food industry compared to the company and the automotive industry.

Characteristic	**Agri-food industry**	**The company**	**Automotive industry**
Product variety	High	High	Low
Shelf life	Short	Short	Long
Profits margins	Low	Low	High
Seasonality	High	High	High
Perishable goods	Yes	Yes	No
Overall economic dependency	Low	-	High
Digitalization	Low	Low	High

The use of VSM during this study has proven to be a good tool to visualize the complicated routes that the material at the company takes. It has showcased which operations that are value adding and which are not. Moreover, during the process of creating the map, bottlenecks in how the company operates could be discovered. This has been one of the key takeaways as the use of VSM forces the users to look thoroughly into the processes.

During the study, it was found that the use of VSM is best coupled with other lean tools and at a company that operates after the lean philosophy. As the main idea with the philosophy is to work continuously to reduce waste, it can be valuable to have implemented this type of thinking before VSM is used. This would make it easier to the create the map and hence a future state map, a work plan and implementation. E.g., with a Kaizen-mindset, changes will be easier to implement. With the lean philosophy being a keystone of a company, major problems would already be detected and acted upon and the VSM would mainly provide identification of smaller improvements needed.

The lean philosophy is only implemented in a small part of the company. This was identified as one of the differences of the use of VSM in the agri-food industry compared to a (well) studied industry as the automotive industry. The automotive industry is an industry where the lean philosophy is often implemented, making the use of VSM a natural step to improve operations. At the company, VSM has also been proven to be a good tool. However, instead of finding small improvements that are easy to implement, the tool has visualised bigger problems the company has, e.g., issues related to the layout.

During the creation of the VSMs in this study, there have been difficulties related to the complicated and inconsistent routes the raw material takes after delivery. Inconsistent routes can give a false picture of the reality as the VSM generate a static result. The same goes for the variations of processing and waiting times. This is something the researcher need to take into account when conducting a VSM in the agri-food business. To give a better picture of the reality, historical data of processing and waiting times could be used. This was only possible in parts of this study, as there is lack of documentation at the company. In the automotive industry, however, there is an ongoing rise and importance of information, technology and communication – digitalisation of the industry. This makes for another difference between the industries. In a digitalised business, there will be better access to documentation and more historical data. Hence, this makes it easier to create a VSM with a more accurate representation of the reality.

6. Recommendations

In this chapter, suggestions to solve or ease the identified problems are presented. The suggestions are divided based on which part of the company they will impact, either the wash line or the production line. This is followed by a risk analysis of the suggestions where the implementation effort and impact of the implementation has been assessed on a scale from low to high.

To summarize the identified problems, the department or area it was found in as well as the type of waste it generates, Table 6.1 was created. A few of the identified problems could not be linked to any of the seven commonly defined types of waste.

Table 6.1 List of identified problems and the type of waste it generates.

Department/area	Identified problem	Type of waste	Section
Wash line	Loading of wash line	Transport	6.1.3
Wash line	Lack of space	Transport	6.1.1
Wash line	Double handling, Communication issues	Transport, waiting	6.1.2
Wash line	Facility layout	Transport	6.1.5
Wash line	Inadequate machinery	Inappropriate processing	6.1.4
Wash line	Low-capacity fridge	Inappropriate processing, defects	6.1.6
Production line	Long distance to printer	Transport	6.2.1
Production line	Storage of packaging material	Transport	6.2.2
Production line	Transportation to wrapping and warehouse	Transport	6.2.3
Production line	Packaging material	Defects	6.2.4
Production line	Defect bag labelling machine	-	6.2.4
Production line	Dropped bags	-	6.2.4
Raw material storage	Lack of documentation and lack of KPIs	-	6.1.7 & 6.1.8
Production planning	No planning assistance from information system	Inappropriate processing	6.2.5

6.1 Wash line

In this section, the identified improvement suggestions within the wash line are presented. To calculate the costs for a day, a shift or a year, the previously calculated times were multiplied with the personnel costs.

6.1.1 Clearing of space near wash line

The space at the end of the wash line is inadequate due to both storage of old machinery and poor facility layout. To clear space near the wash line, the company is recommended to sell or discard the equipment not needed in accordance with 5S and sort. The equipment and material still needed should be organised so that it is easy to access and takes less space as in systemisation within 5S. If this is done, the company can save time during the end of washing operations as the forklifts will be easier to operate and more pallets can be stored near the wash line.

6.1.2 Reduce double handling and communication issues

Pallets to be taken from waiting area 1 to waiting area 3 are driven first to waiting area 2 to later be taken to waiting area 3. This creates double handling that could easily be reduced by driving the pallets straight from waiting area 1 to 3. The reason this has not been done before is the lack of communication between the production and the wash line. The suggestion is that information about what raw material to use each shift is given by the management to the production foremen.

6.1.3 Loading of wash line

When raw materials arrive for use a few days after delivery, it is offloaded in the outdoor storage. By planning the arrival of material day by day rather than week by week, material could be offloaded directly at the wash line. This could reduce the cost of manual labour at the inbound with 34 500 SEK per year.

6.1.4 Build adequate machinery

It is recommended for the company to start investigating ways of rebuilding the machinery. By rebuilding the machinery so that small material does not fall through, time could be saved as the operator would not need to spend time on refilling the wash line with material that has fallen out. Making these changes would result in time savings of 16 minutes each shift those small raw materials are washed. The cost savings are hard to determine since there is no documentation of how frequent deliveries of small raw material are.

6.1.5 New facility layout

The company has plans to make changes to the facility layout. The current plan is to eventually move the wash line so that it is connected to the production line. This could be beneficial since it would reduce the time spent by the foreman to collect raw material from waiting area 1. It would also reduce the time spent on collection and transportation of raw material to and from waiting area 2 as well as the fridge storage. However, there are some aspects that still needs to be addressed even if the wash line is moved.

Loading of wash line – if raw material arrives and cannot be processed in the wash line immediately, it needs to be placed somewhere. The current outdoor storage would then be located just as far away, if not further away from the new wash line. This results in the same issue as the company is currently facing. Therefore, it is suggested to consider moving the outdoor storage closer to the new wash line as well as investing in a transportation system from the outdoor storage to the wash line. This in order to eliminate the long and time-consuming travels currently conducted. Another solution could be to invest in a new type of wheel loader with larger capacity, this to reduce the number of travels needed to load the wash line. If the short-term solution presented earlier related to this problem is implemented, there might not be a need for the company to invest in this long-term solution.

Lack of space – if a new wash line facility is built, it is important to build it with well thought-through dimensions. The current wash line lacks space to operate properly, hence this is very important to consider when building a new facility.

Double handling – much of the double handling that is occurring at the company currently is due to the facility layout. If a new facility is built, all previously used waiting areas would be removed, and the washed raw material could be transported immediately into production or to the adjacent fridge storage.

Reduce traffic at the most occupied area – it is recommended to investigate the routes of the raw material deliveries at the company's facilities as a new layout is created. It would be beneficial for the company if the new layout removed traffic from the street between the wastewater treatment plant and the production. That street is used by personnel to get to another office building, inbound deliveries to the warehouse, inbound deliveries of raw material as well as hired personnel such as electricians.

6.1.6 Increase fridge cooling capacity

If a new facility is built, it will also include a new fridge. However, if a new building is not built it is important for the company to act upon the existing fridge storage. A new fridge would enable the company to place raw materials in the fridge earlier in the season than it is currently possible to do. This could lead to lower obsolete products since raw material stored in the fridge will deteriorate at a slower pace compared to raw material that has to be stored in the outdoor storage.

6.1.7 Increase documentation

This issue can and is recommended to be addressed immediately. The existing documentation should be shared with the rest of the company or at least the planning department. In addition, the documentation of raw materials should include the following information:

- Date of arrival
- Place of storage
- Quantity
- Size of raw material
- Quality of raw material upon arrival, based on a classification system
- Level of processing (raw, pre-washed or washed)
- Date of outtake of raw material and quality at that time, based on the classification system

With proper documentation at place, problems could be easier identified and analyzed. Furthermore, the documentation is needed to start measuring KPIs and hence make improvements. In addition, Axsäter (2006) states that the total investment in inventories is enormous, and the control of capital tied up in raw material, work in progress, and finished goods offers a very important potential for improvement. The presented documentation will hence help the company to gain control over the raw material inventories.

6.1.8 New KPIs

As there are no KPIs related to the processes before the raw material enters the production, it is suggested that the company starts to measure operations related to the wash line. This, to get a better understanding of the current state, but also to see the impact of the suggested changes. The new KPIs identified, that the company should start tracking, are presented in Table 6.2 below. When measuring the raw material quality, an ABC-classification system should be used. The letter indicates an estimate of how many months the raw material could be stored before turning obsolete. Each letter and its corresponding shelf life can be seen in Table 6.3.

Table 6.2 New KPIs to introduce at the company.

Responsible	Task	Unit
Cultivation manager	Storage inventory level	kg
Cultivation manager	Storage inventory turnover	Days/months
Cultivation manager	Raw material quality	Scale (ABC)
Cultivation manager	Obsoletes	kg

Table 6.3 Classification system of raw material.

Class	Time before obsolete
A	5-6 months
B	3-5 months
C	1-3 months

6.2 Production line

In this section, the identified improvement suggestions within the production line are presented. To calculate the costs for a day, a shift or a year, the previously calculated times were multiplied with the personnel costs.

6.2.1 Reduce distance to printer

If the labelling printer needed at the end of the production line were moved to be in connection to the wrapping, time could be saved. There is a computer near the wrapping, meaning that no extra equipment would be needed. Above the savings in time, this would mean that the operator never would have to leave the packing area. This would reduce the risk of production stops due to the fact that the operator was not around to fix it. This would result in a yearly saving of 211 000 SEK.

6.2.2 New storage location for packaging material

It is recommended for the company to move the storage of packaging material for the production line, from the area marked in black to the area marked in green in Figure 6.1. This would decrease each retrieval of packaging material with more than 100 meters. The time savings would be 6 minutes for each retrieval of new packaging material.

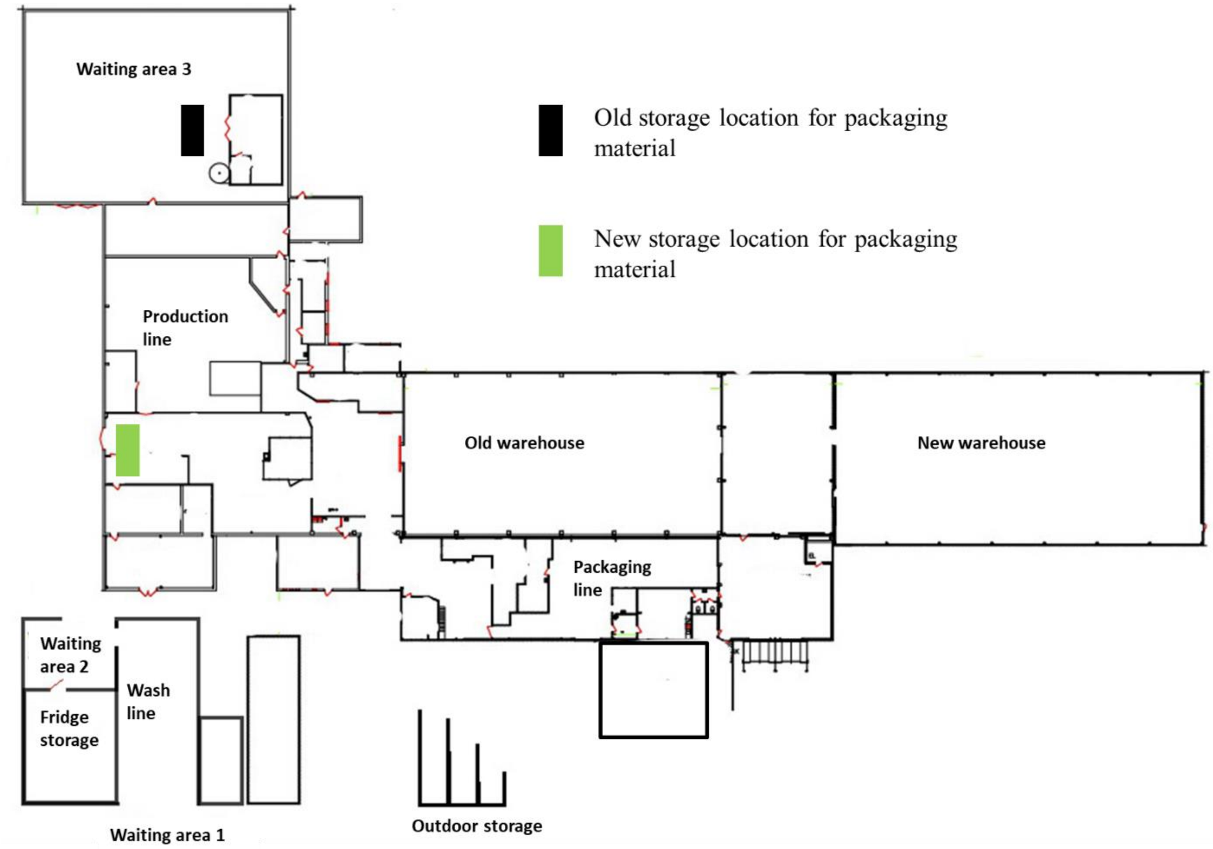

Figure 6.1 Illustration of the old and new storage location for packaging material.

6.2.3 Transportation to wrapping and warehouse

The manual work required to wrap pallets and transport them to the warehouse is small. However, it becomes time consuming due to the small space. Therefore, it is recommended that the company investigates the possibility to install an automatic transportation band that brings the pallet from the palettizing area to the wrapping and then to the warehouse. This would save the company almost 60 minutes of labour each shift and 258 720 SEK yearly in manual labour. If the labelling process would be automated as well, this would save the company an addition of 48 minutes each shift. The time savings generated by these two changes equals a yearly saving of around 470 000 SEK.

6.2.4 Identify root causes

The packaging material becoming inadequate can have two possible reasons. The first is that the material is poor, resulting in that 1/6 of the plastics bags needs to be thrown out. The other explanation is that the knives are not good enough, which tears the packaging material so that it cannot be used.

The issue with the bag labelling machine and the issue with dropped bags are quite frequent problems since both are part of the operator’s daily routine. It is hard to determine the time spent on these tasks since there are no records of it.

The company is advised to investigate in the reason behind these three issues by starting to document every time these problems occur to get an overview of the frequency. The operator should also note how much is left of the roll when the packaging material cannot be used.

Furthermore, the company should document every time the knives are changed, to see if this correlates with the packaging material becoming inadequate.

Based on this documentation it is possible to calculate the average time spent on these issues as well as the average time spent on resolving the consequences and the costs of lost material. The next step would be to repair the machines so that these issues become less frequent. The other options could be to invest in new machines or change supplier of packaging material.

6.2.5 New information system

It is recommended for the company to research new information systems that could be valuable for them. The main thing that the current system is lacking, is production planning assistance. Investing in an information system that can assist in production planning would save the planner a lot of time currently spent on retrieving information from many different sources. This would make the planning more adequate, resulting in a more efficient production. It can also be useful to add the raw material storage to the new information system to make that information accessible for more employees. In addition, this could potentially reduce obsoletes as it is easier to keep track of raw material inventories. Another reason to investigate a new information system is that it will provide a better way of tracking KPIs compared to the current system.

6.3 Risk analysis

To determine the hierarchy of the final recommendations and in which order the company should prioritize to implement the suggestions, a risk analysis was completed. The identified risks during and after implementation as well as the mitigations for each suggestion related to the wash line are presented in Table 6.4. The identified risks during and after implementation as well as the mitigations for each suggestion related to the production line are presented in Table 6.5. In addition to the risks presented in Table 6.4-Table 6.5, there could be more risks not identified by the authors. It is therefore recommended for the company to complete their own risk analysis as a complement before implementing any of the suggestions.

Table 6.4 Suggestions for the wash line alongside identified risks and mitigations.

Suggestion	Risk(s)	Mitigation
Clearing of space near wash line	Difficulties getting rid of old machinery. New things placed at the location.	Make a thorough plan and make sure the machinery is disposed in a correct manner. Inform and set up rules for what can be placed in the area. Create designated areas for pallets and forklifts.
Reduce double handling and communication issues	Wrong material used in production.	Clear instructions about the new process to operators. In the beginning, notes on the pallets can be used to ensure that the right material is used.
Loading of wash line	Not getting the sizes needed at each delivery. Growers not able to do frequent deliveries.	More contact with growers, make better use of the fridge storage. -
Build adequate machinery	-	-
New facility layout	Interruptions to work processes. Higher costs and longer time than estimated.	Thorough implementation plan.
Increase fridge cooling capacity	No fridge storage during implementation. Not possible due to leased.	Utilize the outsourced fridge storage facilities. -
Increase documentation	Employees reluctant to change. Risk of incorrect input.	Educate employees in why the documentation is needed, have clear instructions of what to document and when. Management commitment.
New KPIs	-	-

Table 6.5 Suggestions for the production line alongside identified risks and mitigations.

Suggestion	Risk(s)	Mitigation
Reduce distance to printer	-	-
New storage location of packaging material	Lack of space.	Check the current inventory and remove what is not necessary. Create a dedicated area for the packaging material.
Transportation to wrapping and warehouse	Implementation interrupts the work process and production stops.	Plan most of the rebuild to take place during cleaning and/or weekends. It is vital that the rebuild does not cause several days of stop in production.
	Limited accessibility.	Build staircase above the transportation band.
Identify root causes	Not finding the root cause.	-
New information system	Current system offline during change.	Plan for the data transfer, consider if the implementation should be carried out step by step or as a "big bang".
	Incorrect choice of system.	Make sure that the system includes all vital information and has appropriate features.

Each suggestion has been analysed based on the level of implementation effort and the impact. The result of this analysis is illustrated in Figure 6.2. Level of implementation effort in this case is based on how time consuming, costly, and complex the suggestion is. Impact is based on how big of a difference, based on cost and time savings, the implemented suggestion would provide. The suggestions were analysed in relation to each other.

Level of implementation effort

Impact	Low	Medium	High
High	Reduce distance to printer	Increase documentation	New facility layout Transportation to wrapping and warehouse New information system
Medium	Reduce double handling and communication issues	Loading of wash line Build adequate machinery	Increase fridge cooling capacity
Low	Identify root causes New KPIs	New storage location for packaging material Clearing of space near wash line	

Figure 6.2 Matrix of the implementation effort and impact of the suggestions on the business.

6.4 Future state map

Based on the previously presented recommendations related to the material flow, a future state map has been created. In Table 6.6-Table 6.7 the new times are presented alongside the old ones. The first table illustrates the times when raw material is taken in pallets to the production. The second table illustrates the times when raw material is taken to the production via the fridge storage. In this section, the route taken when raw material is placed in trailers is not presented since the changes of the future state map does not impact that route. The map is presented in Figure 6.3 and in the future state, waiting area 2 has been removed in order to reduce double handling. In addition, the future state map does not utilize the outdoor storage since that led to a lot of time spent on travelling back and forth to the wash line with the wheel loader. Only the material aimed for the pre-wash process should be placed in the outdoor storage, the rest of the delivery should be placed directly on the wash line.

Table 6.6 New times for the different steps when material is transported in pallets to production.

Action	**New time (h)**	**Old time (h)**	**VAT/ NVAT**
Waiting for washing	8	8	NVAT
Washing	0.5	0.5	VAT
Transportation to waiting area 1	0.0056	0.0056	NVAT
Waiting to get transported to waiting area 2 from waiting area 1	0	0.25	NVAT
Transportation to waiting area 2	0	0.0083	NVAT
Waiting to get transported to waiting area 3 from waiting area 2	0	6	NVAT
Transported to waiting area 3 from waiting area 1	0.017	0.017	NVAT
Total time (h)	**8.52**	**14.78**	

Table 6.7 New times for the different steps when material is transported in pallets via fridge storage to production.

Action	**New time (h)**	**Old time (h)**	**VAT/ NVAT**
Waiting for washing	8	8	NVAT
Washing	0.5	0.5	VAT
Transportation to waiting area 1	0.0056	0.0056	NVAT
Waiting to get transported to waiting area 2 from waiting area 1	0	0.25	NVAT
Transportation to waiting area 2	0	0.0083	NVAT
Waiting to get transported to fridge storage from waiting area 1	0.25	1	NVAT
Transported to fridge storage from waiting area 1	0.0083	0.008	NVAT
Fridge storage	-	-	NVAT
Transported to waiting area 3 from fridge storage	0.095	0.095	NVAT
Total time (h)	**8.86**	**9.87**	

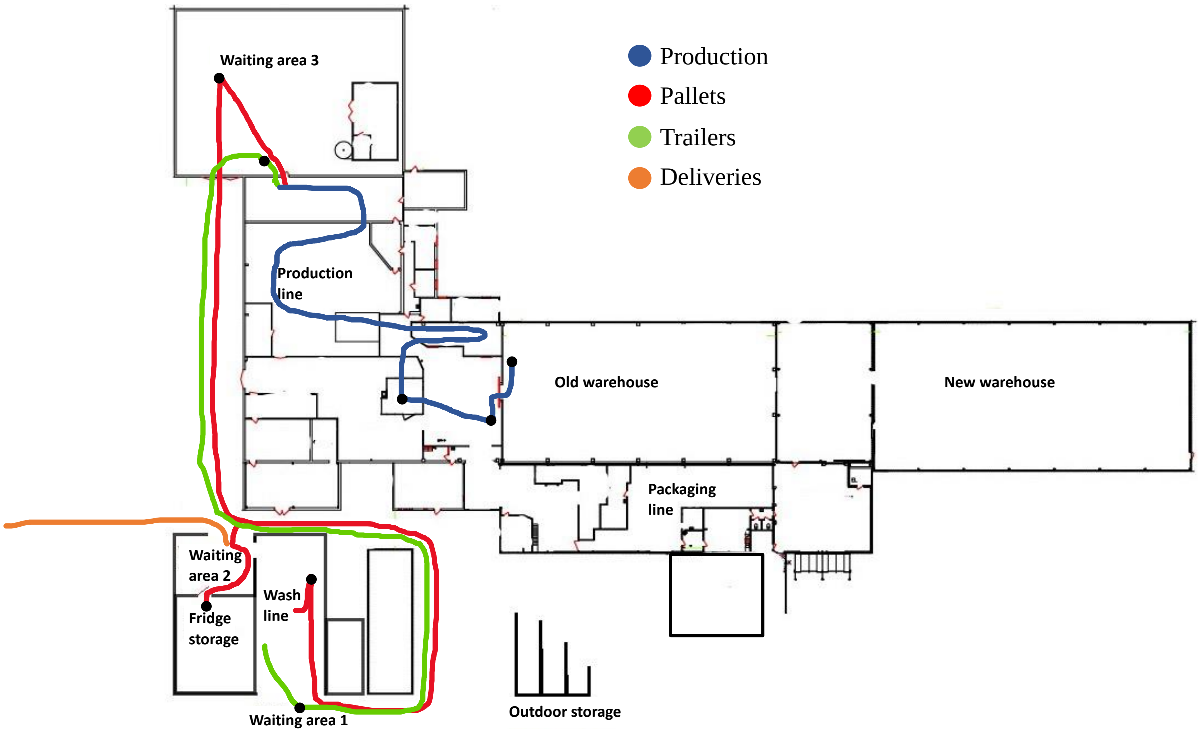

Figure 6.3 Future state map.

7. Conclusions

In this chapter, the findings in the study are summarized. The recommendations are ranked, and the research questions answered with the aim to clarify and concretise the findings of the analysis. This is followed by a discussion of how the study can contribute to further studies and research.

7.1 Ranked recommendations

Based on the analysis in Section 6.3, the recommendations have been ranked in implementation order. The order was based on how high of an impact the implementation would provide combined with the implementation effort required. Highest ranking was given to the suggestions that had a high impact and a low implementation effort. The ranking order decreases as the implementation effort is higher and as the impact is lower.

1. Reduce distance to printer
2. Increase documentation
3. Reduce double handling and communication issues
4. Identify root causes
5. New KPIs
6. Loading of wash line
7. Build adequate machinery
8. New storage location of packaging material
9. Clearing of space near wash line
10. Transportation to wrapping and warehouse
11. New facility layout
12. New information system
13. Increase fridge cooling capacity

7.2 Revisit research questions

RQI What waste can be identified by VSM and how does that affect the business?

During this study several sources of waste were identified during the Gemba walks and completion of the VSMs. According to the different types of waste described by Hines and Rich (1997), the identified waste at the company can be divided into the following categories: waiting, transportation, inappropriate processing and defects.

The identified waiting was mainly for the operators working on the wash line. The waiting means unutilized capacity for the company. Another type of waiting identified was washed raw material waiting to get transported to production. The waiting time leads to longer lead times for the company. The reason behind the waiting time is that the wash line can operate at a faster pace than the production line. A faster pace on the wash line is necessary when the products are sorted in order to provide the production line with the required volumes.

Identified waste characterized as transportation was both for products and employees. The methods of transporting material to and from the wash line results in double handling as well as unnecessary, time-consuming routes. This leads to high costs and inefficient work for the company. Within the production line, there were several tasks included in the daily operations that required travels (walking and forklift) ranging from 50 to over 100 meters, summing up to hours spent on travelling a day.

Inappropriate processing was a source of waste that led to increased costs and defect raw material. In the wash line, the inappropriate processing was the brushes that caused raw material to fall off the transportation band, this led to extra work for the operator which then resulted in increased costs. The low capacity of the fridge causes raw material to become obsolete earlier, which leads to defects. Lastly, the lack of planning assistance in the information system leads to a time-consuming task, especially since the planning is changed frequently.

RQ2 How can the identified waste be reduced?

During the Gemba walks and the analysis, a lot of effort was placed to find the root cause of the identified waste. Based on the root cause, several suggestions that could potentially reduce the waste were identified. The suggestions were then discussed, between the authors as well as with some employees and the most suitable suggestions were further analysed. It turned out that a couple of the found suggestions could mitigate more than one identified source of waste. The suggestions that turned out to be less suitable were often too time-consuming or costly, therefore, they were discarded. Suggestions include both processes and layout as well as the flow of both material and information. The final recommendations are presented in depth in Chapter 6 and listed in Section 7.1.

RQ3 How does the use of VSM in the agri-food industry differ from a previously (well) studied industry?

As previously discussed in Section 5.8, the company can be considered representative of the agri-food industry. However, since only one company has been studied it is hard to generalize for the entire industry. It was found that VSM was useful in the sense that different types of waste could be identified but since the company does not have any other lean tools implemented, some of the identified sources of waste requires changes or implementations that are time consuming and costly. In addition, the lack of documentation at the company made it impossible to calculate the average time that raw material spends in the storage, which can be considered essential to get a full and overarching understanding of the lead times.

Another issue with using VSM at the company was that there are so many different routes that the raw material can take and mapping all these areas for different product families was both time consuming and challenging. Compared to the automotive industry where the production operations generally have a linear structure, the routing is more complex.

In the agri-food industry, consideration to the harvesting seasons must be taken. This means that raw material must spend several months in storage before a demand occurs and during this time, the products can potentially become obsolete. This is very different compared to the automotive industry where components can be produced and delivered as needed. In addition, the components have a much longer shelf life and rarely becomes obsolete.

7.3 Contributions

In this study it was confirmed that VSM in combination with spaghetti diagrams constitute a good set of principles in order to identify waste. The use of the two tools in combination provides a thorough understanding of all examined processes and hence, provides the opportunity to identify waste. Both tools are, however, very time-consuming and it is believed that having someone “from the outside” could potentially be more valuable as they are less likely to overlook certain sources of waste just because “that is how it has always been”.

To find feasible improvement suggestions, 5S-thinking was used. Through the recommendations, solutions that provide a standardized and sorted way of working was found. However, little literature actually explains which actions to take in order to reduce the identified waste. It was found that looking at other improvement suggestions, from studies applying VSM, could assist in determining some of the actions needed to reduce the waste.

This report will contribute to future research within the agri-food industry. Based on the found literature related to VSM, to the best of our knowledge no report has previously been written about applying VSM to a company this closely involved in the agricultural business. In addition, this report provides a comparison of using VSM within the agri-food industry which can be valuable for future research within the field. It highlights differences that are important to take into consideration when conducting a similar type of research.

7.4 Future research

In this study, it was concluded that VSM can be used to successfully identify waste in an agri-food business. However, this study was limited by both time and case company, meaning there are additional areas to be further studied. As the case company does not have the lean philosophy implemented, it would be interesting to conduct a case study at an agricultural business already applying several lean principles. In this way, it could be found if the use of VSM differs depending on if lean is implemented or not.

Another area of future research would be to investigate the relationship between harvesting seasons, demand fluctuations and obsoletes in the agri-food business. This was found to be an issue at the case company and is likely to cause problems in the industry as well.

As the authors have only covered parts of the company, a suggestion is for future studies to focus on the packaging line and/or the warehouses. Lastly, the company has plans to implement many of the suggestions and will use the authors findings as a basis for further analysis.

Appendices

Appendix A

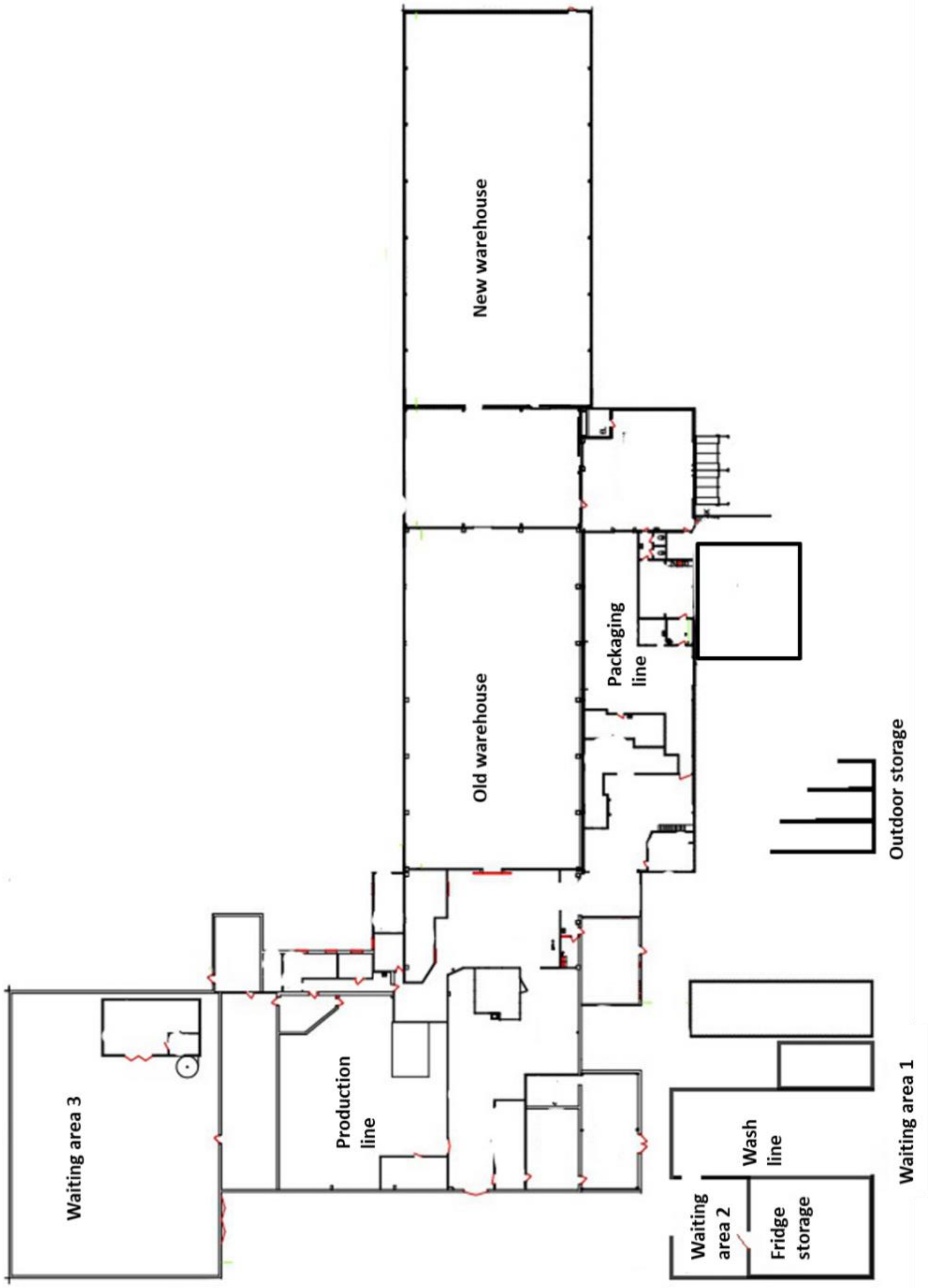

Figure 1 Enlarged illustration of the facility layout.

Appendix B

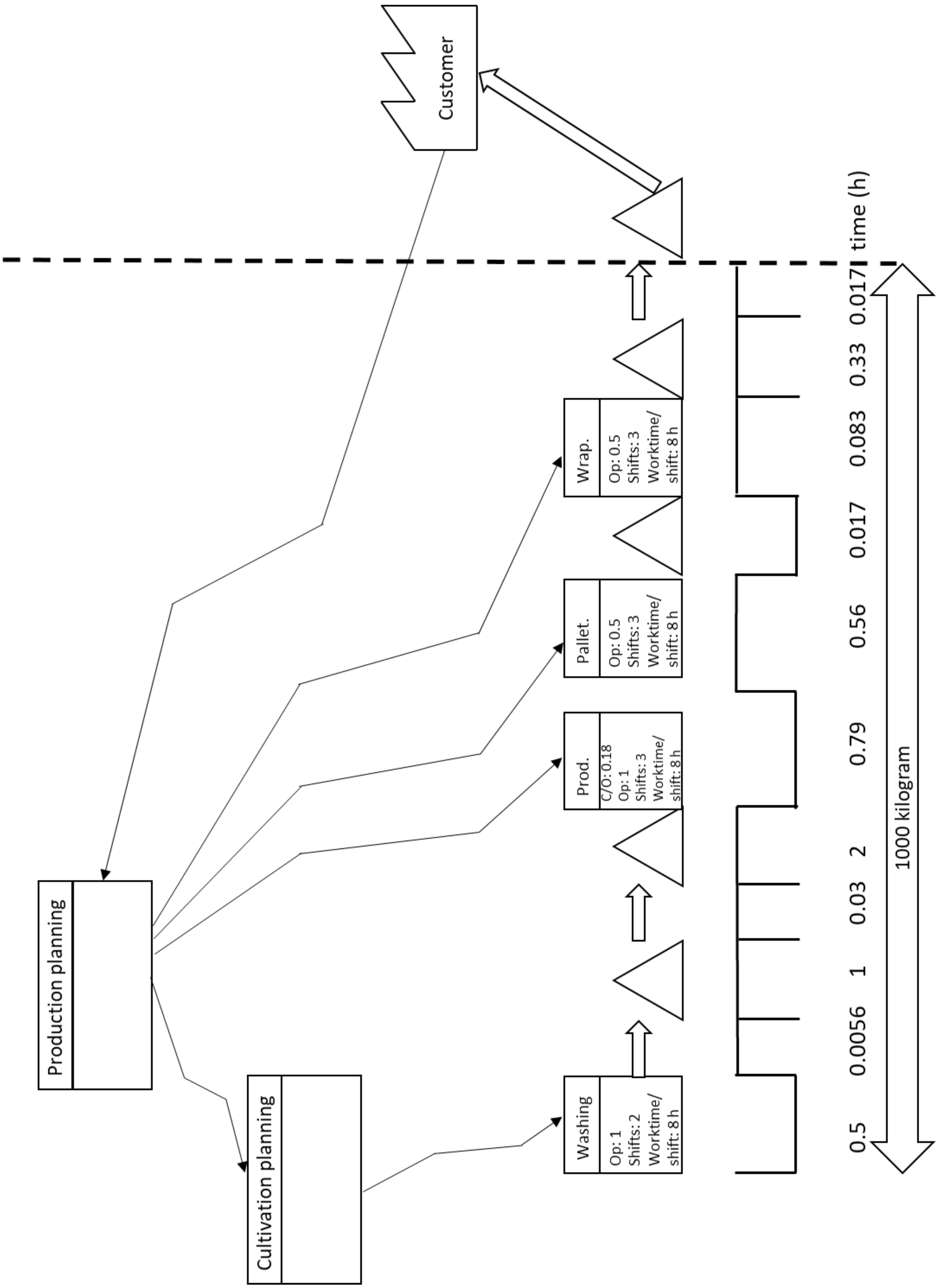

Figure 2 Enlarged illustration of Figure 4.15.

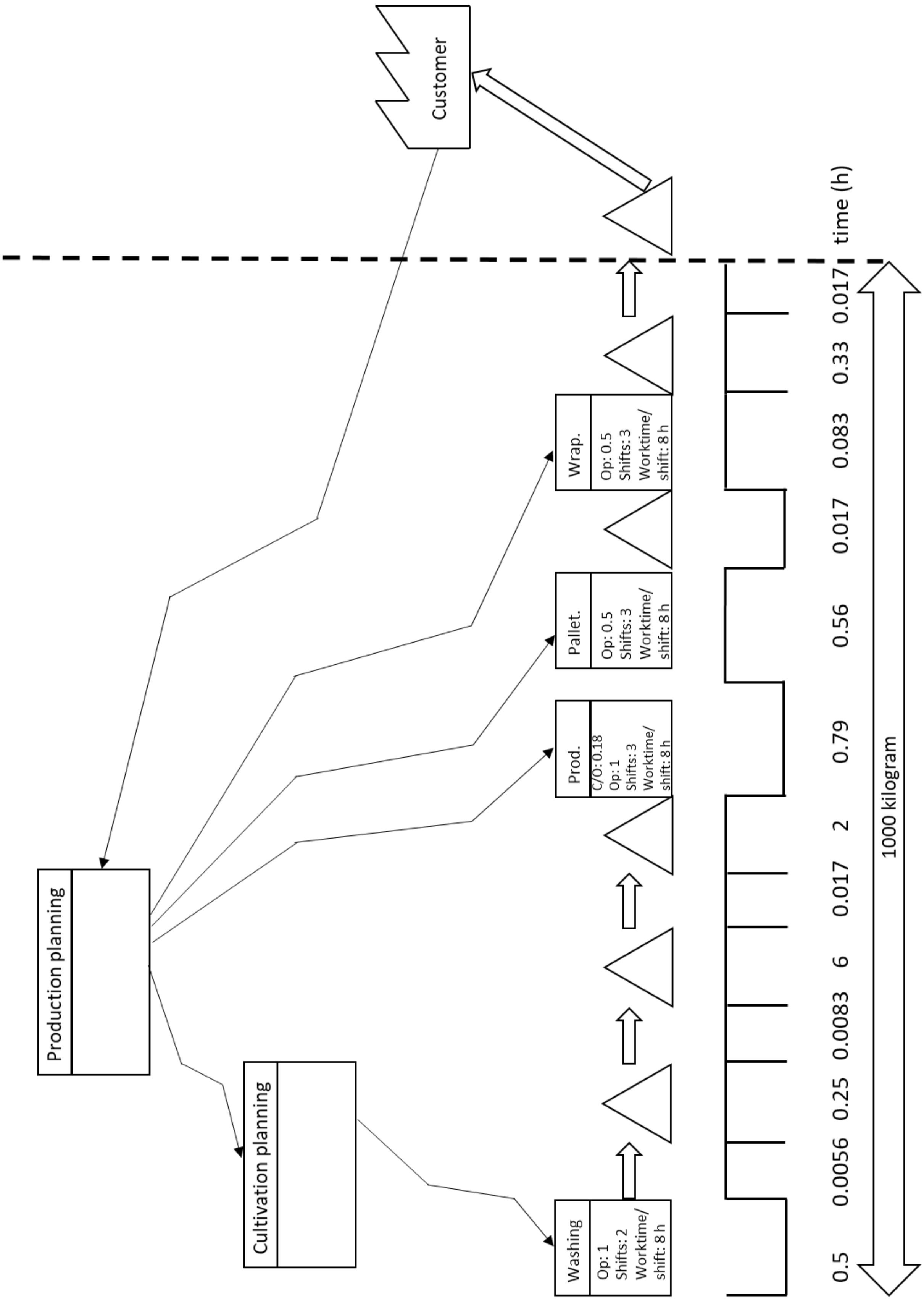

Figure 3 Enlarged illustration of Figure 4.16.

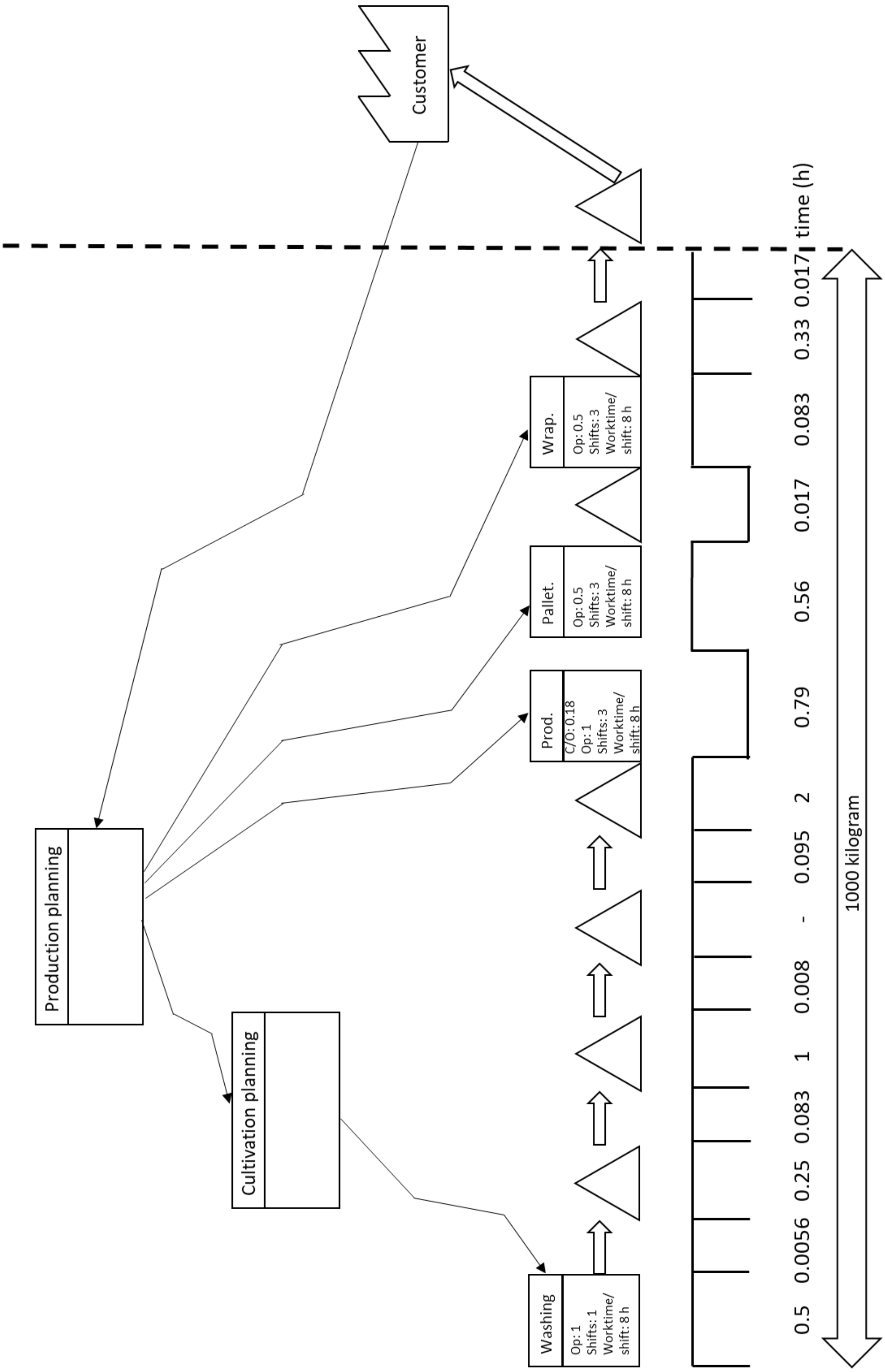

Figure 4 Enlarged illustration of Figure 4.17.

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