

Developing a cost estimation model for packaging material

*Based on a multiple-case study within the
food packaging industry*

Mathias Dahlström & Jacob Peterson

MASTER'S THESIS

Packaging Logistics
Lund University





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Preface

This master thesis represents the last part of our education in Industrial Engineering and Management at the Faculty of Engineering, Lund University. The thesis corresponds to 30 ECTS credits and was written during the spring of 2013. The assignment was initiated by Tetra Pak Packaging Solutions AB, Lund, and conducted in collaboration with the Division of Packaging Logistics at the Department of Design Sciences, Faculty of Engineering, Lund University.

We would like to thank Tetra Pak, especially our supervisor at Tetra Pak, Fredrik Kuylenstierna, for his support and for giving us the opportunity to write this thesis together with a world leading company in the packaging industry. It has been both instructive and interesting. We would also like to thank Daniel Hellström, our supervisor at Division of Packaging Logistics, for his time, effort and guidance throughout this project. His ideas and comments have been very helpful.

We would also like to thank the employees at Oatly AB, Kiviks Musteri AB and Carlsberg Sverige AB Ramlösa (part of Carlsberg Breweries) for their help, explanations and all the information they have shared with us. A special thanks to Magnus Olin at Oatly AB, Christian Rosengren at Kiviks Musteri AB and Caroline Kullenberg at Carlsberg Sverige AB Ramlösa for their input. Without them this project would not have been possible to execute.

Finally, we would like to express our thankfulness to our families and friends for their support during our studies for nearly five years at Lund University.

Lund, Sweden, May 2013

Mathias Dahlström
Jacob Peterson

Abstract

Title: Developing a cost estimation model for packaging material - *Based on a multiple-case study within the food packaging industry*

Authors: Mathias Dahlström and Jacob Peterson

Supervisors: Fredrik Kuylenstierna (Tetra Pak Packaging Solutions AB) and Daniel Hellström (Lund University)

Background: Historically, the use of packaging has often been regarded as a necessary evil, associated with unnecessary costs, but needed to enable distribution of goods. Today many companies have begun to realise that the packaging can have a major impact on the supply chain. For Tetra Pak, it is of great importance to be able to offer deeper insights to the costs incurred by their packages, thus being able to increase the value proposition towards their customers.

Problem description: As of the current situation, Tetra Pak has limited insight into the costs that their packages incur for their customers in terms of the material used in the packages. The models in use at Tetra Pak today cannot be used to identify the costs incurred by Tetra Pak's products specifically in the material inventories of their customers.

Purpose: The purpose is to develop a material inventory cost estimation model for packaging material used for liquid food and beverages, which is able to estimate the cost of handling and storing 1000 units of packaging material in material inventory.

Objectives: The objectives of this thesis are to identify and define the process undertaken in material inventory, map the process to visualise and create an understanding of the material flow, develop a general cost estimation model and to draw conclusions from the findings of the study.

Method: The study is performed as a descriptive qualitative multiple-case study where mainly quantitative data has been used. The inductive approach was used, i.e. empirical data collected through observations during the case study.

Conclusions: The cost estimation model can be used to calculate the total cost as well as the cost per activity for 1000 units of material, enabling the user to identify which activities have greater or less impact on the total cost. However, when calculating the cost per 1000 units the consumption period of 1000 units is not taken into consideration which could lead to a misleading result. Another factor that

affects the result is the usage of different measurement units of the materials which make some of them hard to compare. The multiple-case study has also shown that the activities' impact on total cost differs both when comparing the same activities between cases and between different activities within the same case. Since the study is based on three cases the model cannot be used to draw statistically significant conclusions. However, since the model is to be used within the same context as the conducted case studies, chances are increased that the level of transferability is sufficient to fulfil its purpose. The authors believe that the cost estimation model can assist Tetra Pak in getting deeper insights into the costs incurred by their own packages in material inventory, enabling them to increase the value proposition towards their customers.

Keywords: Cost estimation model, material inventory, packaging material, Activity-Based Costing, multiple-case study, packaging logistics, process mapping.

Executive summary

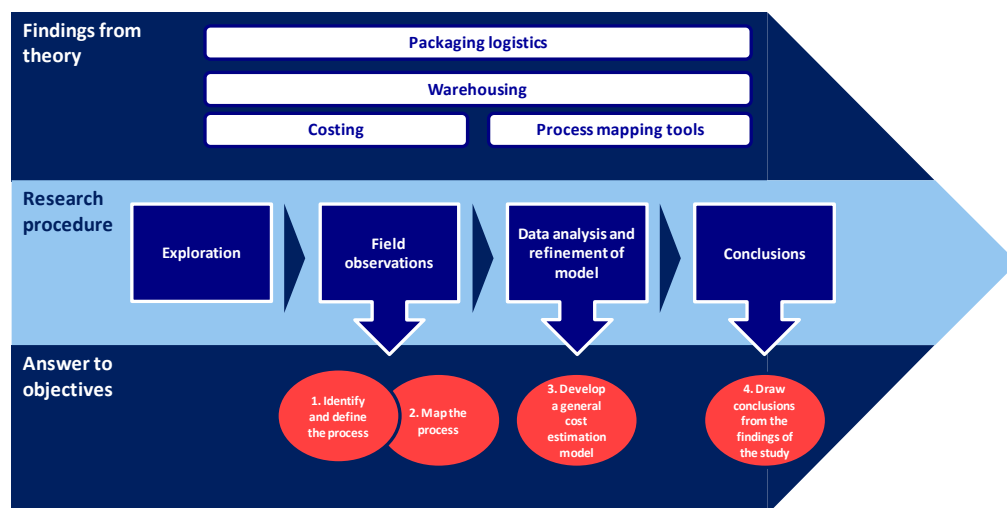
Background

Historically, the use of packaging has often been regarded as a necessary evil, associated with unnecessary costs, but needed to enable distribution of goods. Today many companies have begun to realise that the packaging can have a major impact on the supply chain. For Tetra Pak, it is of great importance to be able to offer deeper insights to the costs incurred by their packages, thus being able to increase the value proposition towards their customers.

Problem description and purpose

As of the current situation, Tetra Pak has limited insight into the costs that their packages incur for their customers in terms of the material used in the packages. The models in use at Tetra Pak today cannot be used to identify the costs incurred by Tetra Pak's products specifically in the material inventories of their customers. The purpose was therefore to develop a cost estimation model for packaging material able to estimate the total cost of handling and storing 1000 units of packaging material in material inventory.

The connection between the theory and the research procedure used, as well as how they answer to the objectives and thereby achieving the purpose, are presented in the figure below.



How the findings from the literature review and the research procedure should answer to the study's objectives.

Result

A multiple-case study, including three actors within the liquid food and beverages industry, was conducted. The activities performed in the companies' respective material inventories were identified and mapped using the flowchart technique, enabling the authors to develop three individual cost estimation models. Based on cross-case analysis of the results from the case companies, the authors were able to construct a general cost estimation model which could estimate the cost for handling and storing materials in inventory. The model can also be used for benchmarking purposes between different materials. The authors have further constructed the model so that the costs for the individual activities carried out in material inventory can be calculated and displayed separately as well as the total cost, according to the requirement. The model was constructed in this way to increase the user's understanding of where the costs arise.

Conclusion

The size of the impact of the individual activities differs from case to case according to the case study results. The authors' original intention was to exclude activities that turned out to have insignificant impact on the total cost, but since no unequivocal outcome was found of which activities should be regarded as insignificant, the original idea of excluding these activities was rejected.

Receiving and inbound loading is often, according to the case studies, a moderate impact activity while picking and outbound loading is more time consuming and therefore also more expensive. Picking is generally considered as a time consuming and expensive activity corresponding to a major part of the total costs in a warehouse. Despite of this, the case studies have shown great variations of impact on total cost from picking. Management and administration are two other activities where the impacts on total cost vary extensively. These variations can be derived from the differences in time spent on these activities and whether dedicated management and administration personnel are employed to handle material inventory. Another reason for the variations may be difficulties in estimating the time spent managing and administrating the material inventory. The amount of disposed goods has been considered as very low and has therefore not been seen as an important factor when estimating costs by the interviewees at the case companies. Yet, this activity has shown to have a very great impact at two of the case companies. Internal storage of goods is a very high impact activity in all cases conducted in the thesis. Based on the case studies, external storage tends to be cheaper than internal storage per pallet position and time unit. For this reason it

may be favourable to use external storage services, especially for materials that are stored for a long period of time. Further, by using an external warehouse with a flexible amount of pallet positions available the companies can achieve a high filling rate and deal with seasonal variance. The cost of using external storage should however be weighed against the cost of the transport between the external and the internal warehouse, which is not included in the scope of this study.

A low amount of units per pallet increases both the handling and storage cost per unit, thus increases the total cost per unit. This can particularly be seen for materials with low turn-over rates which also often are stored for a large number of days. Further, materials with a low turn-over rate tend to have a high value per unit, resulting in high capital costs, especially when applying a high internal rate.

The cost estimation model is based on three case studies and can therefore not be used to draw statistically significant conclusions. However, since the model is to be used within the same context as the conducted case studies, chances are increased that the level of transferability is sufficient. The authors believe that the cost estimation model can assist Tetra Pak in getting deeper insights into the costs incurred by their own packages in material inventory, enabling them to increase the value proposition towards their customers.

Future work

In order to verify the model and increase its transferability and accuracy it would be of interest to test the model further, both in terms of other packaging systems than the ones examined in this thesis and in terms of other companies. This would further allow for the possibility to draw general conclusions, since the risk is that the three case studies are not representative of all cases and that other important cost factors might exist that are not presented in the model. This statement does not imply that the work is lacking reliability for this specific project but rather the possibilities to generate statistically reliable results.

For future work it may be worth trying to find a better and more comparable alternative than to compare 1000 units of each material as this often gives misleading results since 1000 units of various materials correspond to different consumption periods.

During the authors' visits to the sites, all case companies expressed a need for a better understanding of material inventory costs in order to achieve higher efficiency and lower their costs. For this reason it would be interesting to investigate

further the possibilities to use the results from this thesis to optimise the different packaging systems and the activities connected to them. Since the purpose of this thesis was to investigate where the costs were incurred and the magnitude of them rather than exploring possible cost saving opportunities, the authors think that the findings from this project could be a good starting point to find possible improvements and lower the costs related to the packaging system. Investing these types of possible improvements could be a suitable project for another master thesis.

Further it would be interesting to compare the results from this study with cost aspects from other parts of the supply chain. For instance how does the cost allocation in material inventory differ from the one in the finished goods inventory? And how do the packaging-related costs that occur in the warehouse differ from other parts of the supply chain? A supply chain is a complex system where several aspects must be taken into consideration to achieve efficient and cost effective solutions. This is something that must be investigated further before initiating an improvement program based on the findings in this study in order to avoid sub-optimisation elsewhere in the supply chain. This is also aligned with the fundamental ideas of packaging logistics, combining logistics with packaging in order achieve an enhanced holistic view.

Glossary

Activity-Based Costing: A costing methodology that identifies activities in an organisation and strives to allocate costs depending on actual resource consumption.

Case study: A descriptive or explanatory analysis of a subject which is used to deeply describe a situation without affecting the studied object.

Cost estimation model: In this thesis the term refers to a mathematical model used to estimate the cost for handling and storing different materials in material inventory.

Cost of capital: Cost incurred by tying up capital, for example due to storage of material, since the capital otherwise could be invested or used elsewhere.

Flowchart: An illustration of a process which displays a logical order of how the input is transformed to output through a number of activities.

Material inventory: The part of the warehouse which is used to store and handle packaging material before the material enters production. Inventory and stock are used synonymously in this thesis.

Multiple-case study: A case study which consists of several case studies where the goal is to generalise the findings and draw cross-case conclusions.

Packaging logistics: A systematic approach used to combine the fields of logistics and packaging to obtain synergy effects by applying a holistic view.

Packaging material: Input material which is later used in a packaging system. Packaging material and material are used synonymously in this thesis.

Packaging system: Is defined as primary packaging, together with secondary- and tertiary packaging linked to a specific product.

Process mapping: A workflow diagram used to visualise and increase the understanding of a process.

Safety stock: A term used to describe a level of extra stock that is used to decrease the risk of shortage.

Supply chain: A system including organisations, people, activities, information and resources involved in transforming raw materials into finished products that are delivered from the supplier to the end customer.

Warehousing: Is defined as the process of storing goods within a storage facility. The process often includes activities such as material handling and material storage.

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1 Introduction

In this chapter an introduction of the study will be presented starting with the background. It will be followed by problem description, purpose, objectives and delimitations. It will also cover the target group of the study as well as a disposition to get an overview of the different chapters.

1.1 Background

Historically, the use of packaging has often been regarded as a necessary evil, associated with unnecessary costs, but needed to enable transportation and distribution of goods over long distances (Packforsk, 2000). For this reason, the importance of the packaging has often been overlooked, with the result that the packaging has been adapted to the already finished product instead of co-developed together with the product to create a better holistic solution. To achieve a world-class supply chain, different aspects of the supply chain must be taken into consideration in the product design process, not only the product design itself (Stank, et al., 2011). One reason for this is that once the design is completed, at least 80% of the product costs are set.

Today many companies have begun to realise that the packaging can have a major impact on the supply chain, which has had the consequence that the role of packaging has changed drastically and that it today is considered to be an important element for success in achieving an efficient logistics system. The packaging is no longer only used to facilitate the transport of the product but also used to achieve other positive effects such as increasing the fill rate, protecting the product and reducing the environmental impact (Packforsk, 2000). This is particularly noticeable in the food industry, which accounts for a large portion of the total consumption of packaging and where the packaging itself often represents a relatively large part of the product's total cost. For example, in 1996, the food industry in Sweden accounted for 50% of the total cost of the packaging material used in the domestic manufacturing industry (Packforsk, 2000).

The current market situation in the packaging industry is characterised by an ever increasing competition between the actors, which can partly be explained by an increasing demand for packaging development supporting sustainability (WPO, 2008). Packaging systems have to present high standards in all three aspects of sustainability, i.e. social, economy and environment. The economical aspect of sustainability hereby calls for cost-efficient packaging systems, both in order to generate revenue but also to contribute to sustainable development. These factors in their turn call for a greater demand for information flow and transparency.

As the competition becomes tougher and the demand for better and cheaper packages increases, especially from customers within the food industry, it becomes

increasingly important for Tetra Pak to offer its customers competitive packaging systems. This is also the background to this thesis which aims at developing a cost estimation model that can predict and compare the different costs which Tetra Pak's products generate for their customers. For Tetra Pak, it is of great importance to be able to offer deeper insights to the costs incurred by their own packages, thus being able to increase the value proposition towards their customers.

1.2 Problem description

Referring to the market situation and the call for greater cost-efficiency, not only the largest cost factors in the supply chain will play a crucial role in determining where cost reductions can be made. So will also smaller scale costs, such as costs incurred by material handling, i.e. costs arisen before the value adding manufacturing process takes place. In this thesis material is defined as empty packages, in other words the packaging material itself, and not the product or ingredients which the package is later filled with.

As of the current situation, Tetra Pak has limited insight into the costs that their packages incur for their customers in terms of the material used in their packages. For material specifically, Tetra Pak does not have any models to calculate the costs of keeping the materials in stock. There are a few other cost models in use at Tetra Pak today, but these are primarily internal models used for other parts of the supply chain, such as production cost models and models used for the finished goods inventories. These models cannot be used to identify the costs incurred by Tetra Pak's products in the material inventories of their customers.

This study will not be internally performed at Tetra Pak to consider material stock at Tetra Pak itself. For this reason three different companies have been chosen as subjects for the study. Two of the companies are currently customers to Tetra Pak and the third company is using different packaging systems than the ones provided by Tetra Pak. The reason for including both Tetra Pak customers and non-customers in the study is to obtain a more holistic view of the activities carried out in a food industry warehouse and to increase the ability of the findings to be applied more broadly and to additional empirical contexts, thus increasing the transferability.

1.3 Purpose

The purpose of this study is to develop a material inventory cost estimation model limited to material inventory, for packaging used for liquid food and beverages. The idea is to use the model to identify the costs differing between various packaging materials and thereby to make it possible to distinguish between different pros and cons connected to various packaging systems. The authors will identify and map the costs that are incurred within the material inventory rather than try to optimise the activities causing the costs.

1.4 Objectives

The objectives of this thesis are to:

1. Identify and define the process undertaken in material inventory.
2. Map the process to visualise and create an understanding of the material flow.
3. Develop a general cost estimation model.
4. Draw conclusions from the findings of the study.

1.5 Focus and delimitations

Since the model is intended to estimate the costs incurred in material stock, the analysis will be restricted to the activities and costs incurred by material stock operations. The scope of the study can be seen in *figure 1* below.

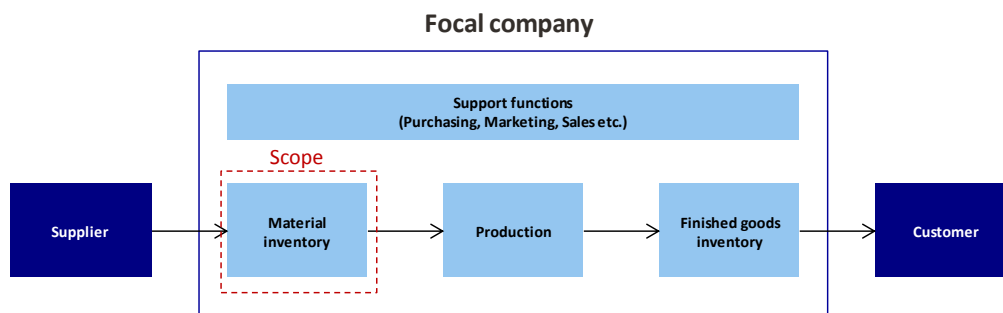


Figure 1: Scope of the study. The focus is on the costs and activities within the red rectangle.

The following aspects will be considered in the thesis:

- The model is to be able to predict the total cost of handling and storing 1000 units of various packaging materials in material inventory. This requirement was set by Tetra Pak.
- Only the activities within the packaging material inventory, including the total cost for external storage, will be taken into consideration.
- Overhead costs will be included but limited to indirect costs within the material inventory (such as the time the warehouse manager spends on handling material inventory).
- Safety stock will be included.
- The cost of material waste will be included.
- The model is to be compatible with existing cost models currently in use at Tetra Pak and the model will hence be developed using Microsoft Excel, which is the software employed at Tetra Pak as of now for the existing cost estimation models.

The thesis will be delimited by the following aspects:

- Costs incurred by business functions outside the warehouse such as support, marketing and purchasing will not be taken into account by the model.
- The cost for transportation to the internal warehouse and between the external and internal warehouse will not be included, since this activity is not carried out within the warehouse.
- Costs that occur after the packages reach the production will be excluded.
- Environmental fees will not be included.
- Return flow will not be excluded, for instance only material that pass the quality check upon arrival to the warehouse will be included in the cost model since the material that does not fulfil the quality criteria will be subject to claims and sent back to the supplier (or disposed and claimed).
- Shortage costs will be excluded since the effects of these will be hard to estimate.

1.6 Target group

The primary target group of the thesis is Tetra Pak, for whom the cost model will be developed and by whom it is going to be used. The cost model will be developed for internal use at Tetra Pak and is to be used within the organisation globally. The secondary target group will be the companies participating in the case studies. These companies will get a chance to review the results and the individual cost estimation model developed for their specific case study.

1.7 Company presentation

Tetra Pak AB (hereinafter referred to as Tetra Pak) is a worldwide actor within the multinational food packaging and processing industry (Tetra Pak, 2012). It all started in 1946 with Erik Wallenberg, employed by Åkerlund and Rausing, who came up with the idea of the tetrahedral form of packaging and with Ruben Rausing who backed the idea. Since then Tetra Pak has experienced significant growth and has been successful in the majority of the world's food packaging and processing markets. Today, Tetra Pak develops, manufactures and markets systems for processing, packaging and distribution of liquid food and beverages (Pak, 2012). In Sweden approximately 4000 people are employed by Tetra Pak of whom 3500 works in Lund. In 2011 Tetra Pak AB had a turn-over of 16.2 billion SEK (allabolag.se, 2013). Globally, the organisation spans more than 170 countries and employs more than 22000 people (Tetra Pak, 2012).

This thesis has been conducted in collaboration with the Tetra Pak Packaging Solutions AB, that develops and produces systems for processing and packaging of food. More specifically, the thesis has been carried out with members of the FACTS

(Financial Analysis Competence Tools & Support) function, which is a part of Tetra Pak Packaging Solutions AB. FACTS is a team of specialists with deep understanding of packaging material, packaging lines and value chain key drivers for Tetra Pak's and competitors' products (Tetra Pak FACTS, 2011). Within Tetra Pak Packaging Solutions AB, FACTS is responsible for developing and maintaining standard tools and methods for analysis. FACTS contributes to decision-making on product strategy and development projects in many ways, e.g. through Customer System Cost analysis which includes the costs that arise during storage and handling in material inventory for Tetra Pak's customers, which is the focus of this thesis. Customer System Cost is considered key to understanding competitiveness in the market.

1.8 Disposition

Chapter 1 – Introduction

The first chapter will describe the background and the current market situation. It will also cover the problem, purpose and goals as well as the focus of the thesis.

Chapter 2 – Methodology

The second chapter addresses various research methods. The research approach and procedure used in this thesis and the reason for this selection will be stated.

Chapter 3 – Literature review

In this chapter, relevant theory covering warehousing, cost allocation methods, packaging logistics and process mapping is explored. The literature review will be used as foundation for the theoretical framework used in this thesis. Finally, it will be explained how the theoretical framework and the research procedure will be used to answer to the study's objectives.

Chapter 4 – Case study description

The fourth chapter outlines the case studies conducted and the data collected during these. The different case study companies will be presented along with process maps of material inventory activities.

Chapter 5 – Case study results

In the fifth chapter the results from the case studies will be presented.

Chapter 6 – Single-case and cross-case analysis of case study results

In the sixth chapter the case study results are analysed in relation to the theoretical context. First, a case specific analysis for each of the individual cases will be presented. This will then be followed by a cross-case analysis where the similarities and differences between the different cases will be investigated, forming a basis for developing the cost estimation model and drawing conclusions.

Chapter 7 – Model description

In the seventh chapter the general cost estimation model, based on the findings from the case studies, will be presented together with the model's main features.

Chapter 8 – Conclusions

In this chapter the authors' conclusions based on the study will be presented.

Chapter 9 – Future work

The final chapter provides ideas and recommendations for future work.

2 Methodology

In this chapter the methodology used in the study will be described. Different methodologies, approaches and data collection methods are explained. This is followed with a discussion of different aspects of the reports credibility. The chapter ends with a description of research procedure and the different types of data collection methods used in this thesis.

2.1 Introduction to methodology

There are many different types of methodologies to choose from. Which working methods should be chosen depends on the nature and the goal of the work. Depending on the study's objective, the purpose of the methodology can be divided into four groups (Höst, et al., 2006):

1. **Descriptive:** The main purpose of descriptive studies is to identify and describe how something works or how it is carried out.
2. **Exploratory:** Exploratory studies are used to understand how things work and how they are performed at a deeper level.
3. **Explanatory:** Explanatory studies are designed to find the reasons and explanations behind how something works or is performed.
4. **Problem-solving:** The purpose with problem-solving is to find a solution to an identified problem.

The four most relevant methods when performing an applied science study (Höst, et al., 2006) will be explained below.

2.1.1 Survey

A survey is designed to compile and describe a situation's current state. Since the question to be answered often is broad, it is advisable to try to collect opinions and perspectives from a larger group of people. This can be done by using a questionnaire with a number of standardised questions which the group members should answer. The questions can either be quantitative, for instance "how often?" or "how long?", or qualitative which means that the questions are asked as statements and that the respondents rate how well the statements comply with their opinions. Regardless of the type of data used, the survey method is fixed and the questions cannot be changed when the survey has started, which makes it important to select the right questions from the start.

2.1.2 Case study

A case study is designed to deeply describe a situation without affecting the studied object. Case studies can for instance be used to understand how an organisation works. The method is flexible, which means that questions and the focus of the study can be changed over time. Data can be collected by using methods such as interviews, observations and archival analysis. This also makes the collected data mainly qualitative. Unlike a survey, where the samples are based on random

selection, a case study is based on a pre-determined case, often with a specific purpose. This means that case studies are often well suited to provide in-depth knowledge in a specific field, but that the method is less suited to draw general, statistically significant, conclusions.

According to Merriam (1994) factors such as the type of questions asked, the degree of control and the expected end result should be considered when deciding if a case study is the best option to investigate something of interest. A fourth and probably the determining factor is whether one can identify a specific system as the focus of the investigation. A case study is thus an examination of a specific phenomenon such as a program, an event, a person, an event, an institution or a social group. The limited or defined system is chosen because it is important and interesting or because there is some kind of hypothesis.

2.1.3 Experiment

In order to find links between cause and effect and explain different phenomena, more controlled methods than surveys and case studies are needed. Experiment is such a method. Experiments can be used to compare different technical solutions with each other by examining the effects of varying different parameters on the studied phenomenon and repeating the experiment. Experiments can also involve people and their behaviour. By allowing two or more groups to perform the same task in different ways, different factors can be examined. As a survey, an experiment is a fix method which makes it important to prepare well before the study begins. In order to draw general conclusions the subjects should be selected randomly. The data collected in an experiment is mainly quantitative but subjective assessments of the results, such as what is a properly completed task, may exist. The experiment can also be supplemented with qualitative data by examining how the test subjects experienced the different treatments.

2.1.4 Action research

For a study that aims to improve something while studying the situation, action research methodology can be used. Action research begins with observing a situation to identify or clarify the problem to be solved. The next step is to come up with a proposal on how the problem could be solved and thereafter to implement the solution. This is followed by an important but often neglected part, the evaluation of the solution, by observing it in context, and to analyse and reflect on how it worked. Action research is an iterative process that is repeated until the problem is solved. The method is primarily based on using qualitative data and the iterative process leads to a flexible design. Action research follows the same steps as the Shewart-cycle, which is a general method for improvement: plan, do, study, learn. The method aims to influence, observe and evaluate a situation at the same time. This could lead to problems with independence, since it is hard to critically

evaluate your own ideas, but by setting up criteria for evaluation a more objective assessment could be performed.

2.2 Research approach

One of the characteristics of an academic paper is altering between different levels of abstraction (Björklund & Paulsson, 2003). The paper should address issues of particular public interest, based on generally accepted practices and existing theories and relate the results to these theories. This alteration could be achieved using different approaches and could be divided into three categories (Björklund & Paulsson, 2003) that will be described below.

2.2.1 Inductive approach

When using an inductive approach, empirical data is collected without first studying existing theory related to the subject. The observations made in reality are used to make a generalisation which could be linked to theory, or in other words, the theory is formulated based on the empirical data collected.

2.2.2 Deductive approach

A deductive approach begins with using existing theory to make predictions or define hypotheses regarding different phenomena. The theories are then tested against the data collected to see if the hypotheses could be verified or not.

2.2.3 Abductive approach

Abduction means switching back and forth between theory and empirical data. The abduction approach is a mixture of the inductive and deductive approach.

2.3 Quantitative and qualitative study

Quantitative studies are studies that include information that can be measured or evaluated numerically (Björklund & Paulsson, 2003). However, everything is not possible to measure quantitatively, and it sets limits to the possibilities of knowledge generation through quantitative studies. Qualitative studies are used if you want to create a deeper understanding of a specific topic, a specific event or situation, but the possibilities of generalisation is lower than for quantitative studies. It is mainly the purpose of the study that determines whether a study is qualitative or quantitative. Observations and interviews are often more suitable for qualitative studies while surveys and use of mathematical models often are more suitable for quantitative studies, but in the end it is the practical approach that determines what kind of information that is obtained.

2.4 Data collection

When collecting data a distinction could be made between primary and secondary data. Primary data is data collected in order to be used in the current study, while

secondary data is based on information developed for other purposes (Björklund & Paulsson, 2003). A difference between primary and secondary data can also be distinguished according to whether the information has already been processed and interpreted or not. Primary data is information that has not previously been analysed, while secondary data is information based and dependent on primary data (Holme & S Krohn, 2003). This means that a primary source is preferable to a secondary source which is a retelling of the original information and might therefore have been revised along the way.

There are a variety of methods that can be used in the collection and processing of information and data. Some of the most common (Björklund & Paulsson, 2003) will be introduced in the following sections.

2.4.1 Literature study

All kinds of written materials, such as books, brochures and magazines, are defined as literature. The information obtained from the literature is secondary data. It is therefore particularly important to be aware that the information may be biased or not comprehensive. Similarly, the search routines used in the literature study, such as the databases and search terms used, might lead to an incomplete literature base.

2.4.2 Presentations

Participating in various forms of presentations might provide information of interest to the study. The form of these presentations can be very different. Common is that the information is secondary data and that it is important to consider to whom the information is primarily addressed and how this may have influenced its design.

2.4.3 Interviews

Interviews can be defined as different types of hearings that could be done by face-to-face or telephone contact, but also dialogues using email and SMS can be categorised as interviews. Interviews can be used to get access to primary data. There are many different types of interviews. The choice and number of respondents can be varied. All questions can be determined in advance or they can be formulated along the interview. The questions may be more or less leading and it is important that the person performing the interview is aware of how leading the questions are, as it is often best to avoid leading questions. Interviews may be conducted with one person or in a group. The interview can be recorded, written down or memorised.

2.4.4 Questionnaires

Questionnaires consist of a number of standardised predetermined questions and answers. The alternatives can for example be rated on a scale of 1 to 5 or 'yes' and

'no' options, but the respondent may also be able to provide more open and descriptive answers. To whom the questionnaires are sent, how they are distributed (via e-mail, regular mail etc.) and how many can be varied depending on what is considered appropriate in order to find answers to the kinds of questions asked.

2.4.5 Observations

Observations can be implemented in a variety of ways. Observers may participate in the investigated activity, known as participant observation, or observe the event from outside. The subject being observed can be informed about the observation in advance or it can be done without the subjects' knowledge. The observation could be performed using different types of measuring tools or it can be based on more subjective assessments.

2.4.6 Experiments

Experiments are based on the use of an artificial reality with given variables, which can be varied in a controlled manner. The environment is often a simplification of the reality. If the experimental method is not well established in the studied area, it is important to describe and justify the construction of the experiment, which variables to measure and how to do this.

2.5 Credibility

A study's credibility can be assessed based on different aspects; that the conclusions are well-founded (reliability), that the addressed phenomenon is being studied (validity), that the results are general (representativeness) and the extent to which values influence the study (objectivity) (Björklund & Paulsson, 2003; Höst, et al., 2006).

2.5.1 Reliability

The reliability is based on the precision of the data collection and the analysis. By stating how the work has proceeded the reader can make an assessment of the reliability. Allowing someone to check the data collection and analysis is a way to find weaknesses in the work that can be improved. Presenting the data in a compiled format to the respondents from the interviews is a way to ensure that the information gathered is correct. For quantitative studies, the use of static methods is central to the analysis. The selection process is also an important factor for reliability, for instance that the subjects were selected randomly from the population.

2.5.2 Validity

Validity concerns the connection between the object that is studied and what is actually measured. For example, if the goal is to measure peoples' experience by measuring the number of employment years, what the people did during those

years of employment should also be taken into account. To increase the validity of a study triangulation, studying the same object with different methods, can be applied.

2.5.3 Representativeness

The representativeness of the result depends to a large extent on the sample group. A survey and an experiment can only be generalised to the population from which the sample is taken from. One factor that contributes to good representativeness is that the lack of responses is not too large, or affecting a specific category of test subjects to a great extent. Case studies and action research is in principle not possible to generalise. On the other hand, if the context where the generalisation should be implemented in is similar to the one in which the study is conducted, it is more likely that the observed object behave similarly in the new context. A good and detailed description of the investigated context can help increase representativeness.

2.5.4 Objectivity

By clarifying and justifying the choices made in the study, the reader is given the opportunity to consider the study's results, thereby increasing the study's objectivity. Objectivity problems can arise when different types of summaries and abstracts are used. It is therefore important to reproduce the original content as objectively as possible. This means that the facts presented must be accurate, factual selection must not be biased and the use of emotive words should be avoided.

2.6 Method used in this thesis

The thesis's objective is to identify and provide a description of how and why costs occur in material inventory in the food and beverage industry, thus it is mainly a descriptive study. Due to the purpose of the thesis, case studies are appointed as a suitable choice of method. For this reason the case study method has been investigated more thoroughly and the findings are summarised below.

2.6.1 The case study method

A case study can be described by its special characteristics. These differ, but a case study often contains four essential characteristics (Merriam, 1994): they are particularistic (study focuses on a specific phenomenon), descriptive (the description of the studied phenomenon is extensive and thick), heuristic (the study can improve the reader's understanding of the phenomenon) and inductive (case studies are mainly based on inductive reasoning).

When it comes to case studies and research design five elements must be considered according to Yin (2003):

1. The study's questions. The form of the study questions might vary between different case studies but the case studies are often appropriate to use when trying to answer "how" and "why" questions.
2. The study's propositions, if any. The second component is related to the attention and the scope of the study. The "how" and "why" questions do not answer the question of what should be studied which means that propositions are needed to move the case study in the right direction.
3. The study's units of analysis. The third factor concerns the definition of the case and the primary units of analysis. When defining the case the main units should be at the same level as the research questions. By doing so it also becomes easier to compare the study with previous research in the area.
4. The logic link between the data and the propositions. The fourth component is connecting the empirical information to the theoretical propositions. This could for instance be done by trying to match the information to different patterns. Hopefully these patterns are diverse enough so that they can be interpreted as rival propositions.
5. The criteria for interpreting the findings. Since no exact way of interpreting the findings exist, the idea is to find significantly contrasting patterns so that the data can be matched with at least two rival propositions.

Case studies can be divided into single- or multiple-case studies with a holistic (single-unit of analysis) or embedded (multiple units of analysis) design (Yin, 2003), which can be seen in the *figure 2* below.

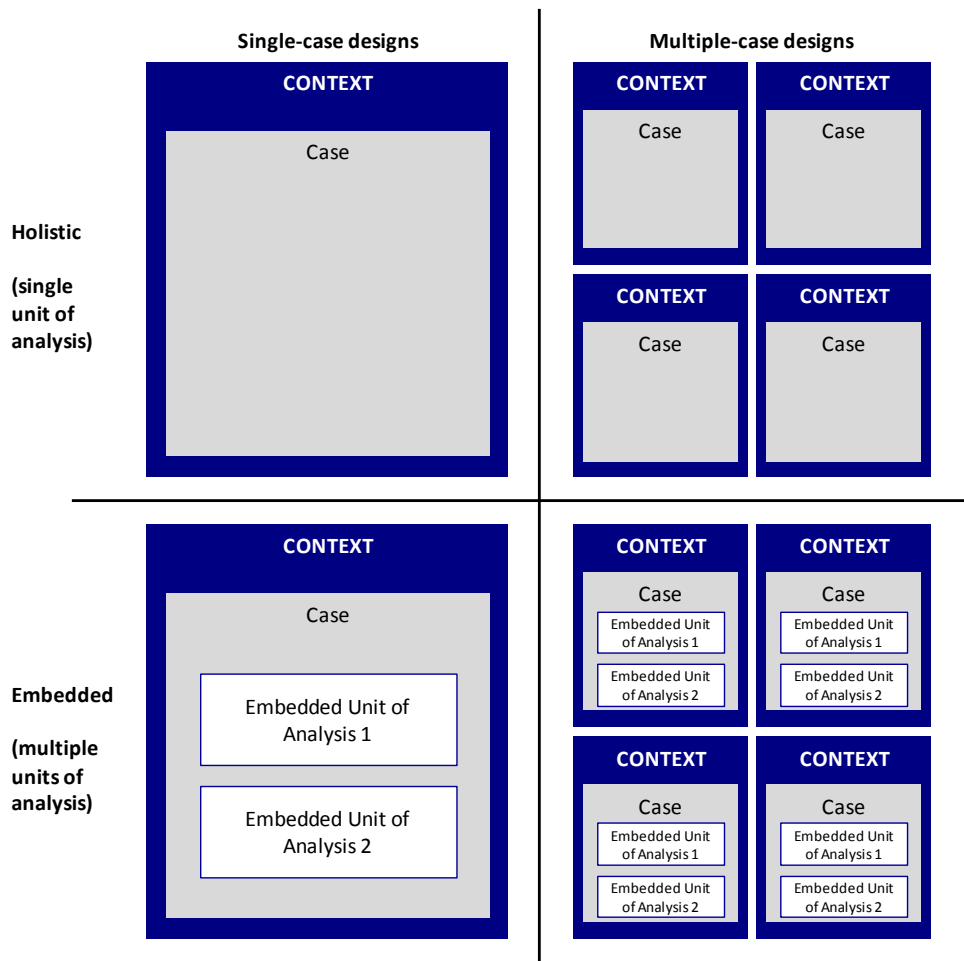


Figure 2: Basic design of case studies (Yin, 2003).

A single-case design is often less time consuming than a multiple design but using a single case as the base for the study also decreases the chances of generalisation. For this reason a single-case study could be a good option when critically testing an existing theory, studying a rare case or examining how a specific situation develops over time. A multiple-case design on the other hand is often the preferred choice if the possibilities and resources to conduct several case studies exist and the goal is to generalise the findings and draw cross-case conclusions, see *figure 3*.

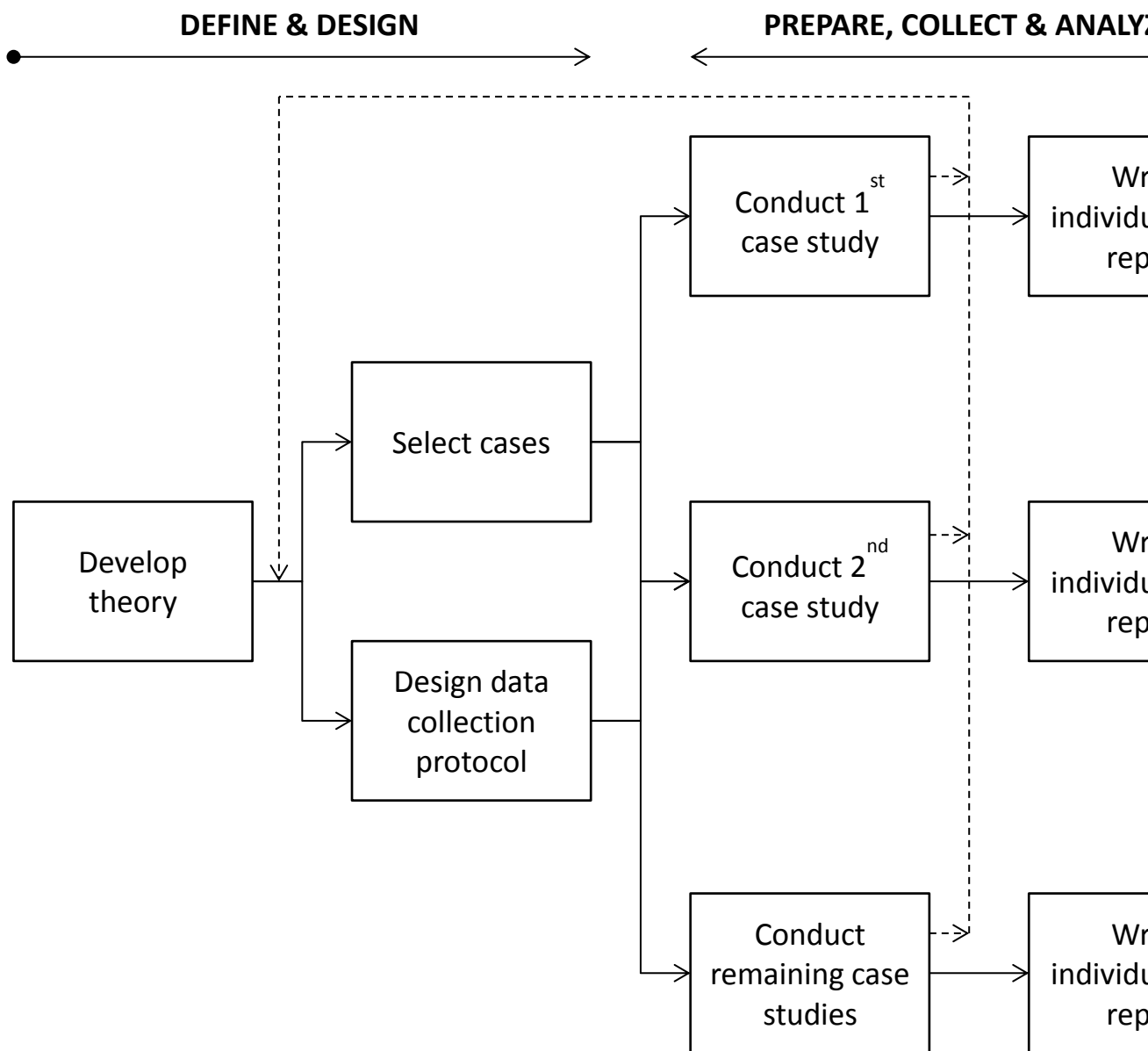


Figure 3: Case study method using multi-case design (Yin, 2003).

In both the single- and multiple-case the study design can be either holistic or embedded depending on the attention given to the different sub-units within the case. The main unit could for instance be an organisation as a whole and the smallest units could be the individual members. Studying the different sub-units can often lead to possibilities of deeper analysis but is also increases the risk of losing the holistic view if too much attention is given to the sub-units.

Before the case study is carried out a case study protocol should be established (Yin, 2003). The protocol should not only contain the instrument needed for the research but also the procedure and general rules that should be followed when using the protocol to ensure a high validity of the case study and to guide the investigator during the data collection. The specific content of the protocol might differ between different case studies but a general approach is including the following sections:

- An overview of the project (objectives, issues and relevant readings in the investigated topic).
- Field procedures (presentation of credentials, access to field sites, sources of information and procedural reminders).
- Case study questions (the specific questions used in the case study and potential sources for each question).
- A guide for the case study report (outline and format of data, other documentation used).

Case studies can be categorised in different ways depending on their purpose and structure (Yin, 2003), see *figure 4*.

Type of structure	Purpose of Case Study (single- or multiple case)		
	Explanatory	Descriptive	Exploratory
Linear-analytic	●	●	●
Comparative	●	●	●
Chronological	●	●	●
Theory building	●		●
"Suspense"	●		
Unsequenced		●	

Figure 4: Six structures and their application to different purposes of case studies, revised figure (Yin, 2003).

- **Linear-Analytic structure:** The general approach when composing research reports is the linear-analytic structure. This structure starts with a presentation of the problem being studied followed by prior theory covering the subject, methodology used, findings from collected data, analysis, conclusions and implications for further research based on the findings. Linear-analytical structure can be used for explanatory and descriptive as well as exploratory case studies.

- **Comparative structure:** A comparative study could be used when the same case study is carried out multiple times to compare various outcomes of the same case. By repeating the case study, different point of views and descriptions can be taken into consideration to find patterns to be fitted into existing models.
- **Chronological structure:** Since case studies often describe events over time case studies can be presented using a chronological order, for instance early, middle and late stages of the case.
- **Theory-building structure:** The theory-building structure means that the chapters follow a theory-building logic, in other words every chapter will contain a new part of the theoretical argument being made.
- **Suspense structure:** In contrast to the linear-analytic structure this structure starts with the outcome of the case, which is then followed by the reasoning behind the results.
- **Unsequenced structure:** This structure could be used if the different chapters do not have to be organised in a particular order. Since the individual chapters are considered equally important, the chapters could be altered without changing the descriptive value of the case study.

2.6.2 Revised case study method

The basic design of case studies as presented in the case study research section 2.6.1 was adapted for the specific case study conducted in this thesis. As seen in *figure 5* below, the case study in this thesis was a multiple-case study, performed at Kiviks Musteri AB, Oatly AB and Carlsberg Sverige AB Ramlösa (hereinafter referred to as Kiviks Musteri, Oatly and Ramlösa), with multiple embedded units of analysis. The context of the case study was defined as *Material inventory costs*, while the cases included in the case study were defined as *Material inventory costs Oatly*, *Material inventory costs Kiviks Musteri* and *Material inventory costs Ramlösa*. At last, the multiple embedded units of analysis were defined as the individual *packaging materials*, e.g. primary packaging material and secondary packaging material. In the figure these are referred to as *Packaging material 1*, *Packaging material 2*, etc.

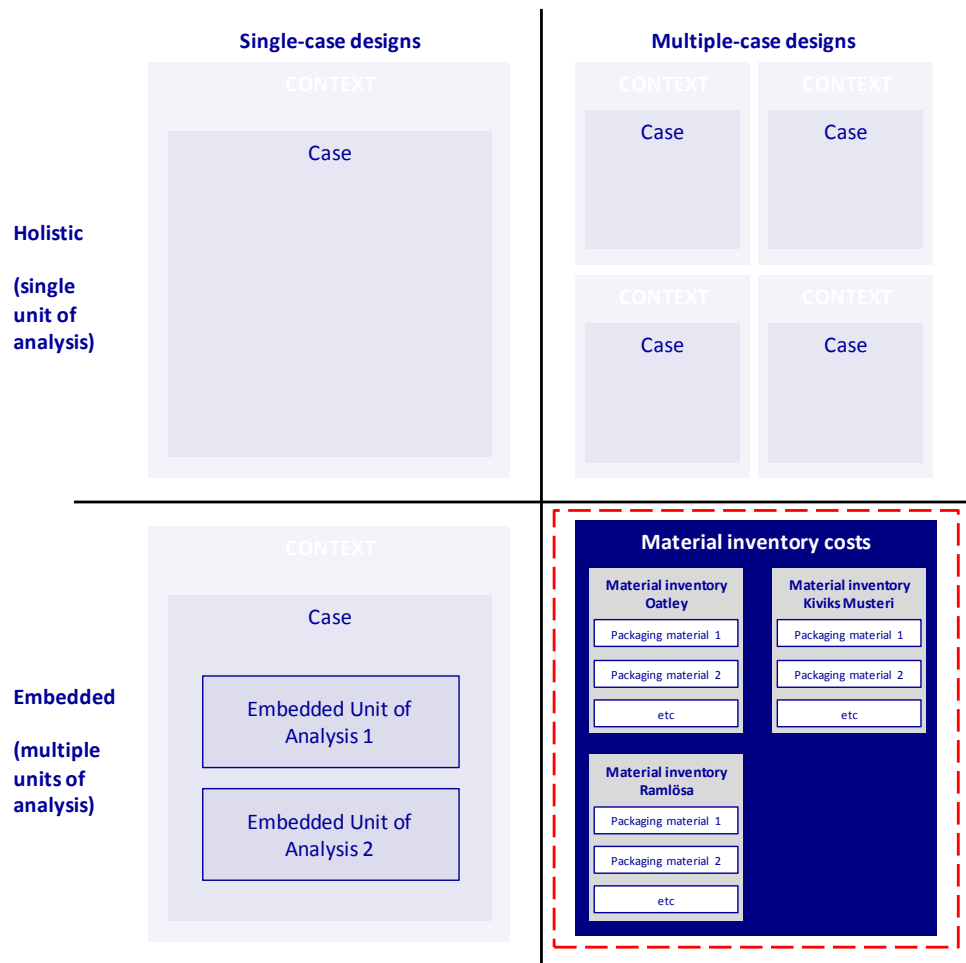


Figure 5: Context, cases and units of analysis for the case study, revised figure (Yin, 2003).

2.6.2.1 Purpose of the case study

Three case studies were performed in order to enable cross-case conclusions to be drawn based on the results from several different companies and still to complete the studies within the given time frame. Two cases were conducted at two of Tetra Pak's beverage manufacturing customers; Kiviks Musteri AB and Oatly AB. The third case was conducted at Ramlösa that is also in the beverage industry but uses other types of packages for their products, e.g. PET bottles, cans and glass bottles. By studying the costs that incurred in Ramlösa's material inventory and comparing these with Tetra Pak's customers' material inventory costs, differences and similarities were identified and analysed by using the cost estimation model. By incorporating another packaging system in the case study, the cost estimation model can be used for benchmarking purposes between different materials.

The purpose of this descriptive and interpretative case study was, in line with Brimson's (1991) view of the activity-based approach, to describe the combination

of people, technology, materials, methods and the environment that produces the companies' packaging systems in which to fill their products. This approach was oriented towards costing and tried to determine how the organisations worked at present. A quantitative approach was used due to the nature of the thesis, being a descriptive and interpretative case study trying to estimate the costs in material inventory. This was done through the collection of data at the company sites, followed by analysis and interpretation using the cost estimation model. All in all, the structure of this case study was a mix of the comparative and the linear-analytic structure as visualised in *figure 6* below.

Type of structure	Purpose of Case Study (single- or multiple case)		
	Explanatory	Descriptive	Exploratory
Linear-analytic	●	●	●
Comparative	●	●	●
Chronological	●	●	●
Theory building	●		●
"Suspense"	●		
Unsequenced		●	

Figure 6: Structure and application of the case study.

2.6.2.2 Purpose of the case study protocol

During the case studies a case study protocol was used. The purpose of the protocol was to establish:

1. A structured interview approach and guidance to the investigators during the data collection
2. A standardised agenda to ensure high objectivity and validity and comparison opportunities between the different case study companies.

Please see *Appendix B* for the case study protocol and the list of case study interview questions.

2.6.3 The inductive approach

The approach used in the thesis is inductive, i.e. empirical data collected through observations, which is also the main research approach for case studies in general according to case study theory (Merriam, 1994). Data collected through the cases is used to construct the cost estimation model, which is the theoretical output of the

inductive approach. Due to the limited amount of case studies performed, the case studies are used to provide in-depth knowledge and input data to create the cost estimation model based on theoretical transferability, rather than to form a basis for secure statistical conclusions.

2.6.4 Data collection

The authors have performed a qualitative study (case study), in order to examine the focus area thoroughly and create a deeper understanding of the specific topic, based on quantitative data. The case studies in this thesis have been conducted together with a number of chosen actors within the industry in order to understand how the activities affecting material inventory are organised and where the costs arise. Data was collected through interviews, on-site observations and using data provided by the case companies as well as through literature studies. Interviews and observations have mainly been used to gather qualitative data, while the numerical data and literature have been used as basis for quantitative data. To ensure the quality of the study and obtain a high credibility, uninterpreted primary data have been used to the extent this was possible, in order to avoid using biased data. In the cases for which only secondary data existed the authors have tried to collect data from several sources. For information that could have been misunderstood, for instance information gathered during interviews, the data was sent to the interviewees for verification.

2.6.5 Objectivity

Case studies are flexible and can be changed during the study. This might be a good thing since the case study can be adapted for the specific situation, but it can also lead to a low objectivity if researchers conducting the case study are affected by the object being studied. In order to increase the objectivity the authors have therefore used a case study protocol. This means that even if the different case studies have taken unexpected directions during the duration of studies, the authors have followed the predetermined steps as far as possible in order to reduce the risk of subjective assessments and also enhance the comparability of the different case studies and the ability to draw general conclusions. To gain a high objectivity and also to receive a holistic view, triangulation has been used and data and other information have been collected from multiple sources, including IT-system, individual and group interviews, printed material and observations. For the same reason people at both operational and tactical/strategic levels have been interviewed. By doing so the information has been gathered from several people with different points of view. Collecting data from more than one source has however not been possible for all the information used in this thesis and the risk of inaccurate information exists.

2.6.6 Validity

Another motive for using several sources and triangulation is to obtain a higher validity. The data collected from the different case companies' IT systems have therefore been complemented with both observations, where notes have been taken, and interviews, resulting in both quantitative and qualitative data being gathered. To make sure that the right data was collected, a questionnaire in form of an interview guide with all the questions needed to be answered, was used at all case studies.

2.6.7 Reliability

Reliability is about the precision of the data collection and the analysis. To achieve this and allow the reader to assess the work a research procedure, see section 2.6.9, and a case study protocol, see *Appendix B*, has been developed explaining the field procedure in detail. By following the interview guide in the case study protocol the data collection could be repeated in the same way again which increases the reliability. Processes and activities however tend to evolve over time which means that even if the data collection was to be performed in the same way in the future, the result and the outcome of the analysis might be different.

2.6.8 Representativeness

The case study companies have not been collected randomly and also only three case studies have been performed, which means that statistically significant results have not been obtained. On the other hand the model is to be used in a similar context as the case studies were performed in, which increases the chance of reaching a sufficient level of representativeness.

2.6.9 Research procedure

According to Yin (2003), the researcher has to develop an own research procedure due to the fact that there does not exist one single recipe on how to perform a case study that fits all case studies. The steps of the research procedure developed for the thesis is described in the following text.

- **Exploration:** Exploration of the field and theories usable to fulfil the purpose of the thesis. This is done through the literature review.
- **Field observations:** Case studies to be performed at case companies in order to map processes, collect data and form a foundation for the development of the cost estimation model. Development of case specific cost estimation models.
- **Data analysis and refinement of model:** Analysis of the data gathered during the case studies for the refinement and development of a general cost estimation model.
- **Conclusions:** Cross-case activity analysis and cross-case material analysis to enable conclusions to be drawn regarding both activities and materials.

3 Literature review

In this chapter, relevant theory covering warehousing, cost allocation methods, packaging logistics and process mapping is explored. The literature review will be used as foundation for the theoretical framework used in this thesis. Finally, it will be explained how the theoretical framework and the research procedure will be used to answer to the study's objectives.

3.1 Introduction to literature review

The purpose of this thesis is to create a cost estimation model for material inventory. The literature review of the thesis thereby covers different ways to calculate the costs incurred in material inventory, i.e. different ways to construct the foundation of the cost estimation model. The various approaches include absorption costing and traditional activity-based costing. For the latter, one must consider the definition of the term activity before making practical use of these methods.

Since the thesis does not cover optimising warehouse activities, there is no extensive review of the theories behind warehousing. The challenge lies within identifying *what* activities are undertaken and analysing what costs these activities give rise to, not *how* they are performed and how they can be *improved*. Although, a deeper understanding of the activities undertaken in material inventory is required in order to make the cost estimation model as realistic as possible. Therefore, theories on packaging logistics and material handling are useful in order to understand the reasons behind how and why things work in certain ways in the material inventories studied. As of today, the literature focusing specifically on material inventory is very limited. The existing theory mainly depicts a holistic view of warehousing. For this reason, the authors have applied general theories on warehousing and adapted them for material inventory.

At last, the theoretical framework requires a discussion on process mapping tools, which can be used in order to visualise the material flow in material inventory, thus creating a basis for the construction of the cost estimation model.

3.2 Costing

3.2.1 History of costing

Historically, direct labour and materials were the most important production factors in almost all manufacturing companies (Cooper & Kaplan, 1988). Due to the narrow range of products produced, these costs could easily be traced to specific products. Allocating overheads was a minor issue not causing much distortion.

Over time, production and marketing channels have multiplied, diminishing the share of the total costs which direct labour and materials constitute (Cooper & Kaplan, 1988). Instead, operations such as marketing, distribution, engineering and other overheads have taken its place as the major cost drivers. Although, even today

many companies are still allocating their overheads by their ever decreasing direct labour base. According to Cooper and Kaplan (1988) “Intensified global competition and radically new production technologies have made accurate product cost information crucial to competitive success”. This was the starting point for the development from a product oriented to an activity-based approach.

3.2.2 Absorption costing

When using the absorption costing method, the indirect costs are added using different cost centres, such as sales or production, to calculate the cost price (Skärvad & Olsson, 2008). The main purpose is to include all costs in the product cost. All costs incurred in the organisation are divided into direct or indirect costs, see *figure 7*, based on the following:

- **Direct costs:** Costs that can be directly attributed to cost drivers, e.g. packaging materials used to produce a product or wages for workers who directly work with the manufacturing of a product (Investopedia, 2013). Direct costs also include all overhead costs, such as costs for utilities used in the manufacturing of a product.
- **Indirect costs:** These are costs that can not be directly attributed to a specific cost driver, i.e. they are common to several cost drivers and should therefore be divided amongst these (Skärvad & Olsson, 2008). Examples may include costs of computers in the office, cleaning service for the factory etc.

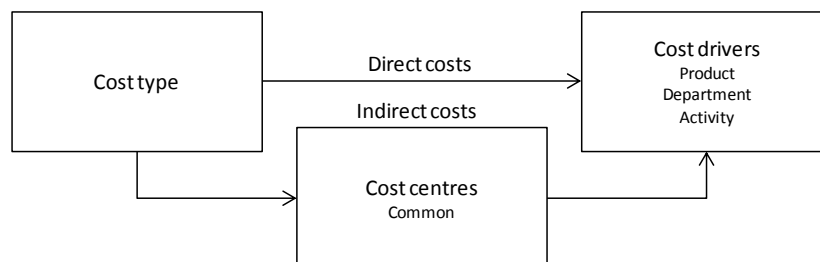


Figure 7: Main principles of absorption costing, revised figure (Gerdin, 1995).

3.2.2.1 Advantages and disadvantages of absorption costing

The primary advantages of the absorption costing method are that it is cheap to use and relatively simple to calculate, whereas the main disadvantage consist of the risk of making unjust allocations of indirect costs (Gerdin, 1995). The allocation of indirect costs is volume based, using scales as amount of products, salary, or machine hours. The size of the scales may be expressed as quantity, value or time. Due to these types of scales, large direct costs can lead to large indirect costs, e.g. when allocated according to amount of orders. Obviously, this can lead to unfair allocations of indirect costs.

In today's business landscape, indirect costs usually constitute a larger part of the total costs than earlier, which can primarily be explained by demands on customisation and automated manufacturing (Gerdin, 1995). Also, as companies over time have tended to grow larger and larger, the administrative costs of manufacturing products and supplying services have risen (Gerdin, 1995).

3.2.3 Activity-Based Costing

The factors above demand for a greater part of the total costs to be indirect and a need for better allocation of costs have arisen, which is the reason behind the development of the Activity-Based Costing method (ABC).

ABC is differentiated from traditional cost models primarily by means of being process oriented (Kaplan & Cooper, 1998). Traditional costing models assume that products consume resources, whereas ABC depicts that activities consume resources and products consume activities, see *figure 8*. Traditional costing models, as absorption costing discussed above, distribute the indirect costs with overheads. This often provides flawed cost information and many indirect costs get buried in diffuse overheads (Börjesson, 1994). ABC, on the other hand, strives to allocate costs depending on actual resource consumption. The activity-based approach treats a larger share of the total costs as variable, although fixed costs still exist.

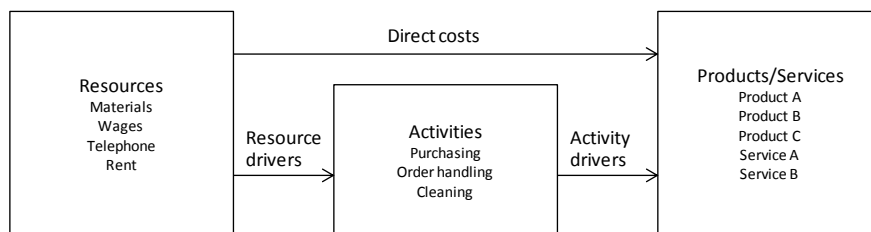


Figure 8: Main principles of ABC, revised figure (Gerdin, 1995).

3.2.3.1 Resources and resource drivers

Resources are economic elements which are utilised in order to perform activities (Börjesson, 1994). The resources can be either resources *consumed* to produce output from input (materials, energy etc.) or resources that *carry out* the activity (labour, machinery or automated processes). Use of resources cause costs which can be classified as either direct or indirect.

Resource drivers are used to allocate shares of resources consumed for performing activities (Börjesson, 1994). If it is not possible to determine a direct proportional relationship between a resource and an activity, the resource should as a 'rule of thumb' be allocated in proportion to the organisational unit's primary factor of production. Most often this factor is "time" for an indirect unit and for a direct unit "machine hours" is often highly relevant.

Of importance to notice is that an ABC approach is done with respect to resources *used*, not resources *supplied* (Börjesson, 1994). Thus only the actual resource requirements of a product are considered.

3.2.3.2 Activities and activity drivers

In an activity-based approach, the activity information necessary can be extracted from the questions: “*What activities take place in an organisation?*” and “*What resources do they consume and thereby what are their costs?*” (Börjesson, 1994).

According to Börjesson (1994), there is no formal definition of what an activity is, but the use of the concept for research purposes has been employed by a range of researchers. The following viewpoints from which various researchers observe activities can be mentioned:

- Activities from a strategic point of view, not primarily with cost measurement purposes. Highlighting strategically important activities to understand the behaviour of costs and to identify sources of competitive advantage (Porter, 1985).
- Activities as a mean of performing process analysis to enable business process improvements. Observing the key activities of a business, expressed so as to be measurable according to cycle time and cost (Harrington, 1991).
- Activities as “a combination of people, technology, raw materials, methods and environment that produces a given product or service” (Brimson, 1991). In this regard, an activity informs us about how a company utilises its resources and time (Börjesson, 1994). Furthermore, activities should be expressed in terms of a verb plus a noun, e.g. “load goods”, “receive order” or “handle materials”. This point of view states that activity analysis is about measuring time-use with the intention to determine cost activities’ cost and performance.

The process of developing activities for the ABC model typically begins with stating the following questions (Kaplan & Cooper, 1998):

1. What are the activities?
2. How much do they cost?
3. How many of each activity, and how long time, is needed to produce the company’s products or services?

The answer to the first question is normally given by interviews with employees (Kaplan & Cooper, 1998). The second question is easiest answered by asking the

finance department, for example to ask to see invoices. The third question is where the activity drivers come into the picture. An activity driver is the link between activities and cost objects such as a product or service (Kaplan & Cooper, 1998). An activity driver is a quantity, such as the number of transactions or the time required for an activity. The answer to the third question is given by asking the personnel responsible for performing the activity to estimate the time consumption of performing the activity and how many times it has to be done to finalise the product. To use time as an activity driver is often more accurate than how many times an activity has to be performed, but it is also more expensive due to extensive time consumption when measuring. For practical reasons, budget figures are used more often than time use (Börjesson, 1994).

Choosing what activity drivers to use is of vital essence for the outcome. This decision has to consider the availability of data and information and the possibilities of measuring it (Kaplan & Cooper, 1998). Activity drivers can be divided into the three following categories:

1. **Transaction drivers:** Consider the amount of transactions, which informs us how often an activity is undertaken.
2. **Duration drivers:** How long time an activity takes to carry out.
3. **Intensity drivers:** The amount of resources an activity consumes each time it is performed. Intensity drivers are only to be used when the time to carry out the activity varies each time or the activity is expensive to perform.

3.2.3.3 Activity information: Qualitative versus quantitative approach

Quantitative and qualitative information are complementary, although they can be collected and used separately for different purposes (Börjesson, 1994). Qualitative measures regard information such as interdependencies, activity triggers, root causes, performance measures etc. When activity information is used for costing purposes, the quantitative method, i.e. to identify activities and resource consumption, is sufficient.

3.2.3.4 Advantages and disadvantages of ABC

In order to stay competitive, companies often have to offer a wide range of products, a variety that affects the companies' costs (Thyssen, et al., 2006). Because of the ABC method's ability to map which activities are needed in order to deliver a product, the ABC method offers a clearer way to identify which products are profitable and which ones are not.

Simplistic approaches are no longer justified due to the increasing complexity of the competitive landscape (Cooper & Kaplan, 1988). The costs for product development, marketing, sales, engineering and other support functions have increased in size for

many companies (Börjesson, 1994). The implication of this is that the major performance improvement opportunities thereby lie among those costs. ABC offers, in several aspects, an effective and accurate way of finding costs as well as creating possibilities for cost reductions.

Many companies are critical to the use of ABC because it takes a lot of time to implement and is expensive to maintain (Kaplan & Anderson, 2004). In large companies, it is not uncommon for the company to have full-time employees dedicated to maintaining data, processing and reporting. On the other hand, if the ABC model is not updated frequently, because of the costs of reinterviewing and resurveying, it quickly becomes inaccurate. This highlights the importance of careful implementation and regular maintenance of an ABC model.

The availability of data is another issue, which largely determines the cost of developing an ABC system (Gerdin, 1995). Sometimes, data on the activity driver is already available in administrative and operational systems, e.g. a machine's operational time and downtime. When data does not exist, extensive measurement actions may be required.

Another critique against traditional ABC is regarding the detail versus complexity issue. The more detailed the model gets, the more complex it becomes to use, due to activities being split up into sub-activities, thus creating a greater amount of input data to be collected (Kaplan & Anderson, 2004).

Also, critique have arisen due to the opinion of the ABC model being too much focused on only costs, with too weak linkages to the revenue side (Gerdin, 1995). The demand for products is not taken into consideration by the ABC approach, thus risking to fall short on the overall picture. According to Gerdin (1995), the ABC model does not compose a solid decision base, due to the fact that it only provides a snapshot of historic events.

3.3 Packaging logistics

3.3.1 History of packaging logistics

The change from an agrarian society to today's modern industrial society has increased the demands for more sophisticated supply chains (Packforsk, 2000). A large part of the production that previously had been done locally for a local market was concentrated to a small number of efficient production units that could provide a greater geographic area with groceries. For this reason, packaging was needed to enable distribution and easier handling. As the shortage of labour increased in the 1950s this development took another step forward and led to that various forms of self-service solutions became more common in the grocery stores and that the

demand for better packaging systems increased even more. The result from this could today be seen at the local grocery retailer where products from around the world are accessible at the shelves.

In modern packaging logistics a systematic approach is used combining the otherwise separated fields of logistics and packaging to obtain synergy effects by applying a holistic view. Today many companies have begun to realise that the packaging can have a major impact on the supply chain, which has had the consequence that the role of packaging has changed drastically and that it today is considered to be an important element for success in achieving an efficient logistics system. The packaging is no longer only used to facilitate the transport of the product but also used to achieve other positive effects such as promoting the products, increasing the fill rate, protecting the product and reducing the environmental impact (Packforsk, 2000).

3.3.2 The packaging system

A packaging system could be divided into different packaging levels depending where in the distribution system the product is located (Packforsk, 2000). The primary packaging or the consumer packaging is the packaging which is in contact with the product and that the final consumer most often is in contact with. The secondary packaging or the retail packaging is designed to contain an appropriate number of primary packages and is used to make the handling at the retail store more efficient. A tertiary packaging or transport packaging is often used to assemble several primary or secondary packages on a load carrier, such as a pallet or a roll container, to protect the products and increase the handleability during transportation. The different levels of the packaging system could be seen in *figure 9*.

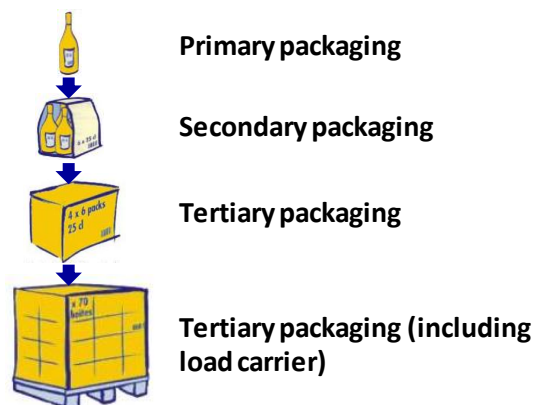


Figure 9: The packaging system (GS1, 2004).

3.4 Warehousing

Since this thesis does not aim to optimise the warehouse activities, extensive explanations on warehousing theory is not considered to be of importance. The challenge lies within identifying which activities are undertaken and analysing how they are performed in reality. To be able to understand, identify and analyse the activities, and due to the relatively uncharted area which this thesis covers, literature on the entire view of warehousing have to be used and applied to the specific activities in material inventory.

3.4.1 Material inventory

Inventory occurs at several stages in an organisation's value chain. *Figure 10* describes the stages of warehousing and highlights material inventory's position in the value chain.

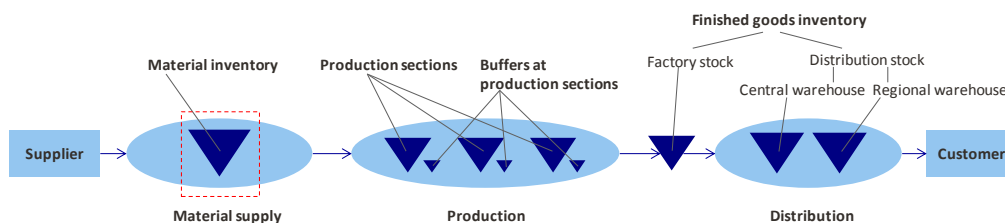


Figure 10: Material inventory highlighted in a typical value chain, revised figure (Oskarsson, et al., 2009).

The categorisation of activities undertaken in material inventory can be described in various ways. Following is a representation of two different means of distinguishing the activities that incur warehousing costs. According to Speh (2009), the activity framework can be organised as follows:

- **Handling:** Handling covers all expenses incurred due to moving products in the warehouse. The single largest component is the direct labour cost to move products in, around and out of the warehouse. Included in the direct labour is receiving, put-away, order selection and loading but may also include labour to re-storage, repackage and refurbish damaged goods if these activities exist. Also included are costs of trash disposal, fuel and electricity for use of equipment and depreciation of equipment costs.
- **Storage:** Storage costs are incurred due to goods at rest in the warehouse and are based on the cost of occupying the facility. Various departments of the company have differing views on storage. The sales department wants well filled stocks to be able to sell as much as possible at all times, whereas the finance department prefers low rates of frozen capital, thus the lowest possible storage levels. Lower storage levels demand more effort from

warehouse workers. Every time storage is required, warehouse workers are necessary for handling, registration etc. Also, it may incur a need for equipment such as forklifts and automation robots and shelves and storage area.

- **Operations administration:** These costs are based on the support of the operations of the warehouse and include clerical operations, information technology, supervision, supplies, insurance, taxes etc.
- **General administration:** These are general costs, not incurred in the warehousing operations, and include for instance general management, non-operating staff and general office expenses. They have to be allocated accordingly either by absorption costing or ABC.

Another way to describe the warehousing activity framework is offered by Oskarsson et al. (2009):

- **Goods reception:** This activity includes the unloading of incoming goods. Sometimes it also includes reloading, e.g. reloading bulk material onto pallets for more efficient handling. Normally, arrival reporting is done in conjunction with goods reception. This typically consists of registration in data system and marking goods with goods labels.
- **Incoming inspection:** In general some sort of control is made at arrival. To what extent this inspection is done is often decided by the goods' criticality and how the supplier has performed earlier. The quality control is often dependent on the cost of the goods. Expensive goods are often controlled rigorously while inspection of cheaper goods often can be done with samples. Many companies today make quality controls at their suppliers, which ultimately mean that fewer resources need to be used for inspections when goods arrive. Also, regular quantity controls are important to make sure the inventory balance is correct.
- **Inbound loading:** After goods reception and incoming inspection the goods are moved to a buffer zone or a picking location. Two main ways of how to position goods exist. A *fixed location system* means that each article or product has a predetermined spot in the warehouse, which is reserved for only this type of article or product. This method requires less administration but also a great warehouse space. Furthermore, this method does not favour the FIFO picking system (First In – First Out) which gives rise to a

higher risk of in obsolescence due to longer storage times. A *flexible positioning system* means that goods are placed at a free space in the warehouse according to some prioritisation system. This requires a relatively advanced system for administration, where to keep track of the good and the spot where it is being stored. By always emptying a pallet instead of stocking up pallets with new incoming goods, FIFO is easier to comply with and the risk of obsolescence decreases. A third way of positioning goods is a mix of the fixed location system and the flexible positioning system. This means having fixed picking locations while the buffer locations are flexible, which requires relatively simple administration and results in high utilisation of warehouse volume. The mixed system is commonly used in un-automated warehouses.

- **Storage:** The picking location is primarily determined by the following three parameters:
 - **Picking rate; how often the picking location is visited:** To determine picking locations depending on picking rate is very complex but may contribute to high picking efficiency. Goods with a high picking rate should be placed easily reachable, while goods with low picking rate should be placed further up and away. Often, only a small share of the total amount of articles have high picking rate while most articles have a low picking rate.
 - **Picking quantity; the amount of units picked at each occasion:** Goods with high picking quantity may cause long queues even though it may have a low picking rate.
 - **Goods volume and weight:** The volume and weight should be taken into consideration when determining at which place in the racks to position the goods.

- **Re-storage:** The movement of goods from a buffer zone to the picking location.

- **Picking:** Picking can be done manually or automatically by the use of picking robots. Picking is often considered as one of the most important processes in a warehouse due to the fact that it consumes the most labour and determines the level of service towards customers (Bartholdi & Hackman, 2011). Picking can be divided into three principles, namely order picking, zone picking and article picking:

- **Order picking:** The picker finishes one or several entire orders.
 - **Zone picking:** The order is divided into sub-orders to be picked in different zones in the warehouse, by pickers dedicated to one zone each.
 - **Article picking:** An amount consistent with e.g. one day's need is picked. The assortment into different orders is done at a later stage.
- **Packaging, labelling and shipment:** It is important that goods that are sent into production is packaged appropriately and labelled correctly. The requirements are although often lower than if the goods are to be sent to customers.

3.5 Process mapping

A process can be described in a variety of ways, depending on the purpose of the description (Skärvad & Olsson, 2003). The purpose will depict the level of description needed and what aspects of the process to include. Davenport (1993) describes a process as “a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure for action”. Damij and Grad (2006) state that “a business process is defined as a structured, measured set of activities designed to produce a specified output for a particular customer or market”. Many other definitions of a process exist, but the fundamentals are all the same. A process can be broken down into sub-processes, which are built up by a number of activities, which in their turn consist of a number of tasks according to *figure 11* below.

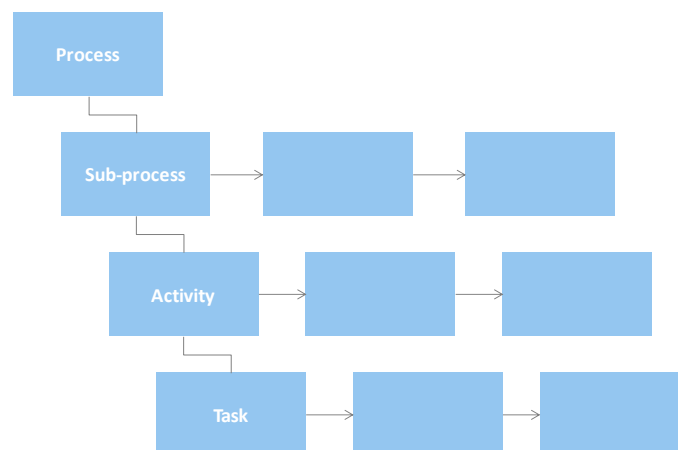


Figure 11: Process hierarchy (Kalman, 2002).

The main purpose of process mapping is to improve human performance and reduce error variance (Kalman, 2002). The benefits of developing a process map include simplified work flow, reduced cycle time, eliminate unnecessary costs and improved

job satisfaction. According to Kalman (2002), “The value of a graphical representation is its power to show an overall plan of how activities and tasks fit together”. Process mapping can be used to *understand existing processes* and is both an analytical tool and a process intervention tool. As an analytical tool, process mapping is a method of visualising processes in terms of sub-processes, activities and/or tasks. As a process intervention tool process mapping engages in dialogue and acts as a facilitator for change. Of importance to remember is that process maps are not the solutions to a given problem, but rather a way of understanding where in the process to focus the improvement efforts (Aguilar-Savén, 2004). As Damij and Grad (2006) state: “A model is a representation of a business process, which reflects its reality by capturing all necessary information on process behaviour”.

Process mapping is not intended to split work tasks, but rather to provide a holistic picture of processes (Aguilar-Savén, 2004). Often difficulties to access data from supply chain actors outside the focal company exist, but this may also be true inside the focal company, especially when it comes to defining costs that arise along a process (Hines & Rich, 1997). Using the right model involves to consider the purpose of the analysis and knowledge of available tools (Aguilar-Savén, 2004). In the following paragraphs, some of the possible ways to map a process will be described.

3.5.1 Terminology

Various terms are used interchangeably in the literature, e.g. process mapping (Kalman, 2002) and business process modelling (Aguilar-Savén, 2004). For consistency in this thesis the authors have chosen to use the term process mapping exclusively.

3.5.2 Eight steps of how to map a process

To enable an efficient procedure and minimise the risk of mistakes for the development of a process map, it is useful to apply a structured methodology (Ljungberg & Larsson, 2012). Otherwise, the risk of making mistakes such as overlapping activities, too much focus on details and extensive time consumption may occur. In the literature, various ways of mapping a process exist. The authors have chosen to adopt the eight step procedure declared by Ljungberg and Larsson (2012):

1. Define the purpose of the process and its start- and end point.
2. Hold a brainstorm session to identify the process’s possible activities.
3. Arrange the activities in the correct order.
4. Merge and add activities.
5. Define objects in and objects out to all activities.
6. Make sure the activities are linked via the objects.

7. Control that the activities are described on a common and suitable detail level and that they are provided with appropriate names.
8. Correct until a satisfying description of the process is obtained.

3.5.3 Flowchart

The illustration of processes is often done with flowcharts, which display a logical order of how the input is transformed to output through a number of activities (Skärvad & Olsson, 2003). The materials are moved between stages through various flows, which can be illustrated in a flowchart. Sometimes, the materials are also stored between the stages. Physical flows are depicted with arrows, whereas storage is illustrated with triangles and the processing stations as rectangles, see *figure 12*. Also included in the flowchart are information flows, containing information steering the process. Information flows are often depicted with dashed arrows. Decision points may as well be illustrated, often with a diamond shape. What shapes to include and how to define them can be adapted to the specific needs of the situation. An example of a flowchart can be seen in *figure 13*.

The main advantages of flowcharts are that they are easy to use and communicate and that they provide high flexibility (Aguilar-Savén, 2004). Depending on the process which the flowchart depicts, the flowchart may though be very large and too flexible for one to easily be able to identify process boundaries. Another drawback is that a flowchart provides no description of responsibilities or performers.



Figure 12: Commonly used symbols in flowcharts, revised figure (Aguilar-Savén, 2004).

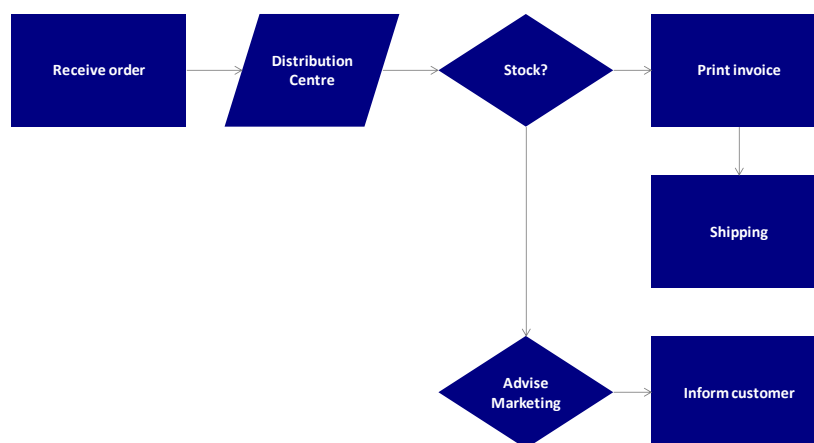


Figure 13: Example of flowchart (Aguilar-Savén, 2004).

3.5.4 Activity table

An activity table is another way of mapping a business process. An activity table is constructed as follows. Column number one represents business processes, while column number two represents work processes included in the business processes. In case even procedures are included in the work processes, these are shown in column number three. Column number four depicts the activities. In the remaining columns entities, i.e. users or group of users, are described. This way of conducting an activity table makes it possible to visualise a clear picture of every business process, the work processes involved and the procedures and activities included in the work processes.

To make a real world depiction by the use of activity tables, there are both vertical and horizontal linkages between the activities (Damij & Grad, 2006). Vertical linkages are employed to show the order in which the activities are performed. Every activity except the first one are linked to predecessor activities and all activities except the last one are linked to successor activities. Horizontal linkages connect each one of the activities with the entities involved in it. The entity that starts the activity is called the source entity, while the entity that receives the activity's output is called the target entity. It is possible that one activity is only connected to one entity. This happens when the same entity performs an activity and uses its output. It is also possible that one activity is connected to more than two entities, which is the case when several entities receive the output of the activity, or when several entities perform the same activity. In order to visualise the linkages on the vertical and horizontal axes, one can make use of different symbols.

- Symbol □ means that an entity is a resource of an activity.
- Symbol ◇ means that an activity is a decision activity. These types of activities start with different alternative paths and are succeeded by various alternative successor activities.
- Symbol → is used to vertically and horizontally connect the activities. The arrow symbol also shows the flow from the source entity to the target entity.
- Symbol ■ indicates that the activity is the end activity for the specific business process.

Provided below, in *figure 14*, is an example of an activity table for a process performed at hospitals, the same course of action is used for mapping a business process with an activity table.

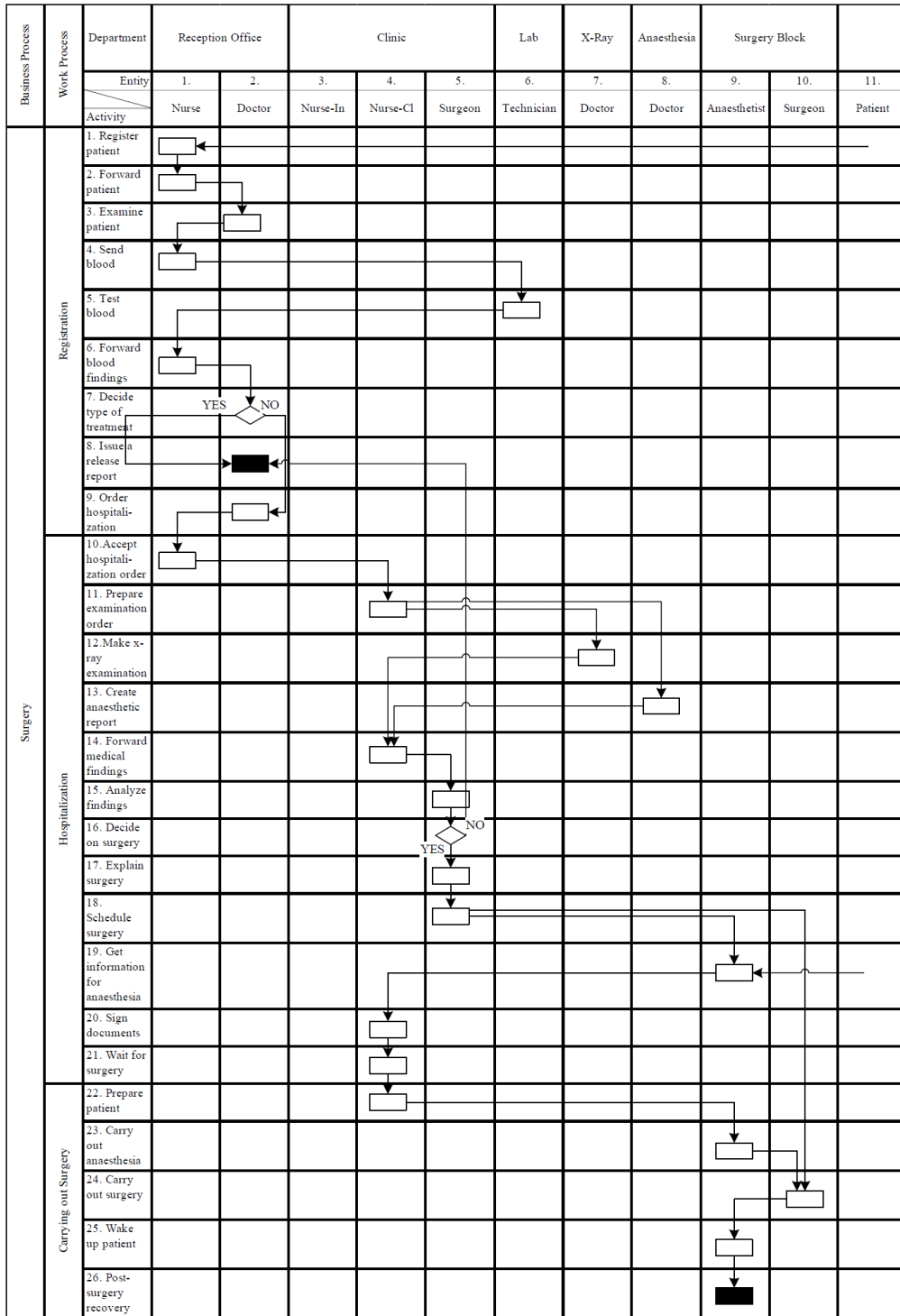


Figure 14: Example of an activity table (Damij & Grad, 2006).

Also needed to develop a solid process map is a property table, which can be developed simultaneously as the activity table (Damij & Grad, 2006). The property table serves as to give a detailed description of the activities and is constructed as follows. In column number one the activities are represented and in the subsequent columns various characteristics for each activity are described. These characteristics are description, resource (entity), time, role, input/output and cost., see *figure 15*.

Characteristic Activity	Description	Resource	Time	Rule	Input/ Output	Cost
1. Register patient	Nurse in Reception Office accepts patient's medical card, Doctor's order, registers her/him	Nurse	10 min	Check medical card validity	Doctor's order, Medical card	
2. Forward patient	Forward the patient and patient's documents to the doctor	Nurse	5 min		Medical card	
3. Examine patient	Doctor in Reception Office examines the Patient	Doctor	10-20 min	Check patient medical record	Medical record	
4. Send blood	Nurse in Reception Office takes patient's blood sample and send it to Laboratory	Nurse	10 min	Indicate needed blood examination order	Blood examination order	
5. Test blood	Technician in Laboratory tests blood example and sends results back to reception office	Technician	30 min	Check blood examination order	Blood exam. order, Blood findings	
6. Forward blood findings	Nurse in Reception Office prints patient's blood findings and gives it to Doctor	Nurse	5 min		Blood findings	

Figure 15: Example of property table (Damij & Grad, 2006).

In comparison to flowcharts, activity tables are not as good as the flowchart in terms of visualisation capability. Also, to use activity tables is not as easy as to use flowcharts, due to difficulties to gather all necessary information to make a comprehensive activity and property table (Damij, 2007). The activity table has its main advantage when a business process contains hundreds of activities. In these events, one can more easily identify the entire path of the process since the whole process is presented in one table.

3.6 Theoretical framework

From the literature review the authors have developed a theoretical framework including concepts and theories to be used to achieve the purpose of the thesis. These selections are presented and motivated below and together they shape the theoretical framework for the proceeding work. In combination with the research procedure developed, presented in section 2.6.9, the theoretical framework is intended to achieve the objectives of the thesis.

3.6.1 Costing

An ABC approach to resource cost estimation is undertaken, as discussed above, with respect to resources *used*, not resources *supplied*. This serves the authors well in their strive to create a model that estimates actual resource consumption in material inventory. The ABC approach is also process oriented and depicts that

activities consume resources while products consume activities. To identify and analyse the exact activities performed in material inventory, the authors believe, will be more accurate than to allocate costs according to overheads as done with absorption costing which often leads to flawed cost information as mentioned earlier.

The ABC approach used in this thesis will be the one of Brimson's (1991), since this approach is of a more operational nature, focusing on *how* activities are undertaken, not *what* activities are needed to achieve a strategic goal. This approach is oriented towards costing and tries to determine how an organisation works at present, rather than the approaches suggested by Porter (1985) and Harrington (1991) where activities are considered as tools for strategic decisions and business process streamlining.

Only some of the activities performed in the material inventory will be of relevance, in line with the requirements for the cost estimation model set up by Tetra Pak, when constructing the cost estimation model. Therefore, not all activities of them will be taken into account by the model. To identify activities performed in material inventory, the method of Kooper and Caplan (1988) will be adopted, i.e.

1. What are the activities?
2. How much do they cost?
3. How many of each activity, and how long time, is needed to produce the company's products or services?

The critique of ABC being too much focused on only costs, with too weak linkages to the revenue side, will not be a concern in this thesis. The purpose of this thesis is to estimate costs in material inventory, not provide an overall picture taking product demand into account.

3.6.2 Packaging logistics

The different concepts used in packaging logistics, such as primary-, secondary- and tertiary packaging materials, will be used throughout the thesis and the development of the cost estimation model to group different packaging materials in a systematic and logical way as well as to comply with prevailing terms in the field of packaging logistics. By integrating a logistic and a packaging approach, a better holistic view could be obtained and a more efficient supply chain could be achieved.

3.6.3 Warehousing

The activity frameworks reviewed above will be redefined in the cost estimation model according to the individual case studies in this thesis, so as to define the activities in a suitable way. The lists may differ between cases depending on how the

case company's activities in material inventory most appropriately can be described. The detail level of the activities will be discussed with Tetra Pak and the case companies so as to serve their and the thesis's purposes. These discussions will lead to a final list of activities, presented in section 4.1, with appropriate activity detail levels to be used for the construction of the cost estimation model.

3.6.4 Process mapping

The main purpose of including process mapping in this thesis is to visualise the material flow through the activities performed in the material inventory. Therefore, a flowchart, with its greater visualisation capability that displays a logical order of the material flow, serves this purpose better than an activity table. Since there is a rather small amount of activities performed in material inventory, activity tables are not very beneficial and the problem with too extensive flowcharts will not be an issue. Also, descriptions of responsibilities are superfluous since the majority of the activities in material inventory are performed by the warehouse workers. Consequently, shifts of responsibility will not be needed to be displayed in the process maps. At last, due to the limited time scope of the case study and the difficulties of gathering all data to make a comprehensive activity and property table, flowchart constitute the most beneficial option for this thesis's purpose.

The focus of this thesis, material inventory, will be defined as a sub-process within the overall process of manufacturing. The activities included in this sub-process will be identified during the case study. According to Kalman (2002), the benefits of process mapping involves mainly improvement efforts. However, the purpose of this thesis is not to provide input to improvement efforts. Mapping the activities conducted in material inventory will rather act as an analytical and visualisation tool to understand the existing processes and to form the basis for the cost estimation model. The process map will form a baseline and structure for how to construct the cost estimation model, i.e. which activities to include and how to structure them.

More tools than the ones described in the process mapping sections do exist, e.g. value stream mapping and swim lane flowchart diagrams, but due to the vast nature and purposes of process mapping only a few relevant ones were chosen for this thesis in order to achieve high relevance. Value stream mapping was not chosen due to the activities in material inventory not being value adding activities. Swimlane flowchart diagram mapping was not selected due to the fact that the sub- process of material inventory does not involve many, if any, transfers of responsibility.

3.7 Achieving the objectives of the study

Figure 16 explains how the findings from the literature review and the research procedure should answer to the study's objectives. For the reader's convenience the steps of the research procedure and the objectives of the thesis are first revisited.

Research procedure in this thesis:

- **Exploration:** Exploration of the field and theories usable to fulfil the purpose of the thesis. This is done through the literature review.
- **Field observations:** Case studies to be performed at case companies in order to map the processes, collect data and form a foundation for the development of the cost estimation model. Development of case specific cost estimation models.
- **Data analysis and refinement of model:** Analysis of the data gathered during the case studies for the refinement and development of a general cost estimation model.
- **Conclusions:** Cross-case activity analysis and cross-case material analysis to enable conclusions to be drawn regarding both activities and materials.

Objectives for the study:

1. Identify and define the process undertaken in material inventory.
2. Map the process to visualise and create an understanding of the material flow.
3. Develop a general cost estimation model.
4. Draw conclusions from the findings of the study.

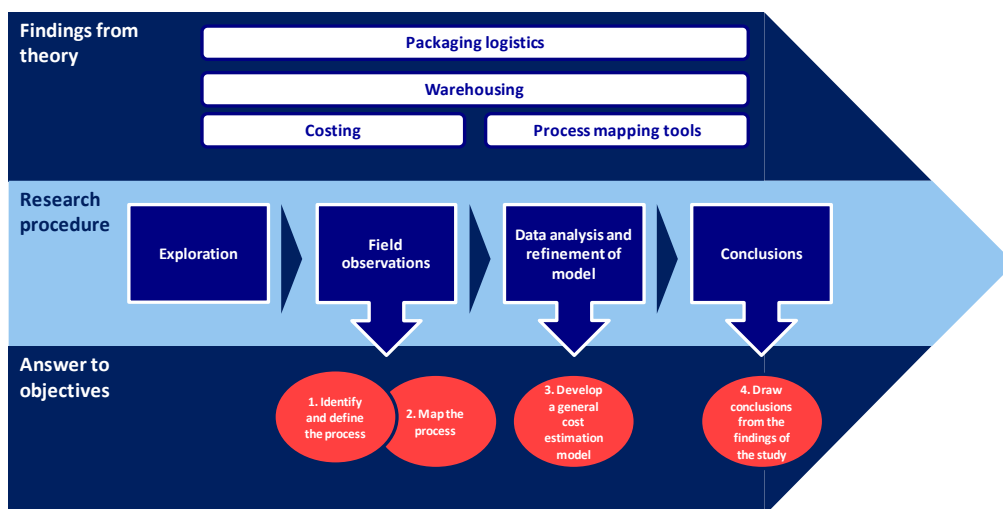


Figure 16: How the findings from the literature review and the research procedure should answer to the study's objectives.

4 Case study description

The fourth chapter outlines the case studies conducted and the data collected during these. The different case study companies will be presented along with process maps of material inventory activities.

4.1 Conducting the case study

The case study has been conducted according to the revised case study method, presented in section 2.6.2. The steps to achieve the purpose of the case studies were undertaken as follows:

1. Map the process in material inventory to identify activities.
2. Gather organisational data as input to the cost estimation model.
3. Test the model and evaluate its accuracy.
4. Form a basis for refinement of the model.

Step 1 above was addressed at each company throughout an initial brainstorm session according to the following steps:

- 1.1 Define the purpose of the process and its start- and end point.
- 1.2 Hold a brainstorm session to identify the process's possible activities.
- 1.3 Arrange the activities in the correct order.
- 1.4 Merge and add activities.
- 1.5 Define objects in and objects out to all activities.
- 1.6 Make sure the activities are linked via the objects.
- 1.7 Control that the activities are described on a common and suitable detail level and that they are provided with appropriate names.
- 1.8 Correct until a satisfying description of the process is obtained.

The following definitions were agreed upon between the authors and each case company according to the steps above:

- The purpose of the process was defined as all handling and storage of goods in material inventory before entering production, excluding transportations occurring outside the warehouse, e.g. between external and internal warehouse and return flows.
- The starting point was defined as the point of time when goods are received at either the internal or external warehouse depending on the case.
- The end point was defined as the point of time when the goods enter production.
- Since production is not included in this thesis, objects in and objects out are the same in the material inventory.
- Based on the warehousing theories describing activity frameworks, section 3.4.1, and steps 1.1-1.8 above, a revised case specific version of the activity

framework have been developed. The activities undertaken in material inventory at the case companies were described in the following common way with appropriate names and detail levels, thereby answering the first objective of the study. This information is then used to map the different processes in material inventory, displayed in the case specific flowcharts below, see *figure 19*, *figure 22* and *figure 25*, answering the second objective.

- **External storage of goods:** Warehouse used for storing material located at another site than the internal warehouse and owned by another operator. Rent is paid per pallet position utilised per month in the external warehouse.
- **Receiving and inbound loading of goods:** Activity performed to receive goods arriving to the internal warehouse, either directly from the supplier or from the external warehouse. The transportation from the supplier and the external warehouse to the internal warehouse is excluded in the analysis since the focus of the thesis involves only the activities carried out in the internal material inventory and the costs incurred by the utilisation of the external warehouse. Receiving and inbound loading typically involve the utilisation of forklifts. This activity may include labelling of goods or pallets before the placing the goods at their storage position.
- **Quality control (incoming inspection):** Quality control is performed in conjunction with receiving and inbound loading to control the quality of the received goods. Administration occurs after the quality control in order to register received goods in the business management software or to make a complaint towards the supplier due to insufficient quality of the received goods.
- **Internal storage of goods:** Activity that occurs after the inbound loading of goods, counted from the point of time when goods are placed at their storage position in the warehouse until they are picked for transportation into production. This activity consumes time but not man-hours.
- **Picking and outbound loading of goods to production:** Activity that involves goods being collected from their storage position and transported into production. Different material have different picking rates (how often the picking location is visited) and picking quantity (the amount of units picked at each occasion). This activity may include

repackaging and labelling before goods being sent to production. Further, administration may occur to update the balance in the business software management.

- **Disposal of goods:** Not an actual activity in itself, but results in loss of goods value (purchase price) which affect the total cost. May occur during any of the above stated activities.
- **Management of material inventory:** This activity involves only the direct management of the material inventory, e.g. the time that the warehouse manager focuses on material inventory matters. Often the managers do not spend all of their time focusing only on material inventory, but rather a fraction of their total time.
- **Administration of material inventory:** Administration may occur after goods reception and quality control and when goods are picked to be sent into production etc.
- **Other activities in material inventory:** This may include stocktaking in material inventory and other activities not included in any of the above stated activities.
- **Cost of capital:** Both during internal and external storage, cost of capital will occur. Therefore, this will be classified as an activity even though one could argue this is not an actual step performed in material inventory.

Step 2, to gather organisational data as input to the cost estimation model, was conducted according to the steps:

- 2.1 Observations at internal and external warehouse.
- 2.2 Several individual interviews with employees on different levels and positions in the companies.
- 2.3 Several group interviews with employees on different levels and positions in the companies.
- 2.4 Data extracted from reports, business management software and invoices.

The vast range of data sources serves the authors' in their pursuit of reliability. In the second step, based on the theory on Activity-Based Costing, section 3.2.3, transaction drivers (how often an activity is undertaken) and duration drivers (how long time each activity consumes each time it is performed) were identified. This information was then used to estimate the cost for the different activities. Intensity

drivers were not included due to workers having estimated the average time consumption for each activity, thus the times to carry out an activity do not vary from time to time. To raise validity, the same questions have been given to several employees and answers to these questions have been double checked for validation. Also, the number of years that the interviewees have worked for the companies and their previous positions are displayed at each case to increase validity.

Step 3 was handled in collaboration with employees at the case companies, with whom the authors tested the model and evaluated the model's accuracy. This step was conducted according to the steps:

- 3.1 Model tested by the authors.
- 3.2 Model evaluated by the authors.
- 3.3 Model sent to the contact person at each case company who then verified or commented on the model's alignment with their views of material inventory costs.

Step 4 was conducted by the authors with the employees' input after each case study, to refine the model for the next case study to be performed. The fourth step was conducted according to:

- 4.1 Consider feedback given in step 3.3 to identify issues with the current version of the model.
- 4.2 Incorporate adjustments to update the model.

After the last step, the information and data collected was regarded as sufficient and appropriate by the authors and the case companies representatives, enabling the authors to finalise the general cost estimation model, presented in *chapter 7*.

4.2 Case study at Kiviks Musteri AB

4.2.1 Company background

Kiviks Musteri AB is a customer of Tetra Pak and subsidiary of the Kivik Holding Group (Kiviks Musteri, 2011). Kiviks Musteri AB owns the brands Kiviks Musteri, Åkesson och Åkesson Kronovalls Vinslott. Their business idea is to refine fruits and berries (Kiviks Musteri, 2011). In 2011, the turn-over of the company was 470 million SEK and 103 people were employed by the company (Kiviks Musteri, 2012). During 2010, the production volume of their Tetra Brik Aseptic (TBA) line was 58.6 million (Kiviks Musteri, 2011). Kiviks Musteri uses an external warehouse where they have a flexible amount of pallet positions available for their usage.

4.2.2 Name of sites and contact people

Data was collected during two visits at Kiviks Musteri's warehouse and production site in Kivik, Sweden, on the 27th of March and 18th of April 2013. Employees at Kiviks Musteri involved in the case study are listed in *table 1* below.

Name	Position	Previous positions	Number of years in the company
Christian Rosengren	Production manager	-	3
Karin Almedal	Material planner	Warehouse administrator	25
Mats Jakobsson	Accountant manager	-	5
Peter Nävik	Purchaser	Purchasing and logistics	6
Benny Jönsson	Production planner	Warehouse worker	45

Table 1: Interviewees at Kiviks Musteri.

4.2.3 Field study

Due to Kiviks Musteri's vast product assortment, two products were selected as the focus for the case study, namely Pärondryck 1.5 liter and Fläderblomsdryck 0.20 liter. As seen below in *figure 17*, both of these packages are Tetra Brik Aseptic.



Figure 17: Pärondryck 1.5 liter and Fläderblomsdryck 0.20 liter (Kiviks Musteri, 2013).

All activities undertaken in material inventory linked to these two products were identified and can be observed in the case specific figure below, *figure 18*. The figure is a revised version of the main principles presented in the literature review on Activity-Based Costing, section 3.2.3.

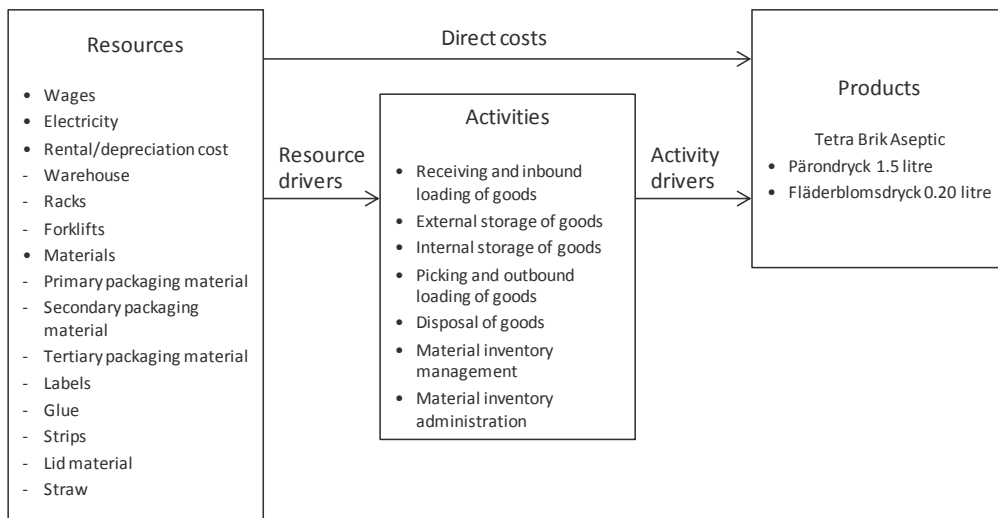


Figure 18: Main principles of ABC applied at Kiviks Musteri, revised figure (Gerdin, 1995).

4.2.4 Flowchart of material inventory activities

The activities in material inventory at Kiviks Musteri AB were identified throughout steps 1.1–1.8 in section 4.1 above and mapped in a flowchart, see *figure 19*, using the same symbols as suggested in the literature review on process mapping, section 3.5.3. Material flow is depicted with solid arrows, information flow with dotted arrows and return flow with red arrows (return flows are not included in the analysis).

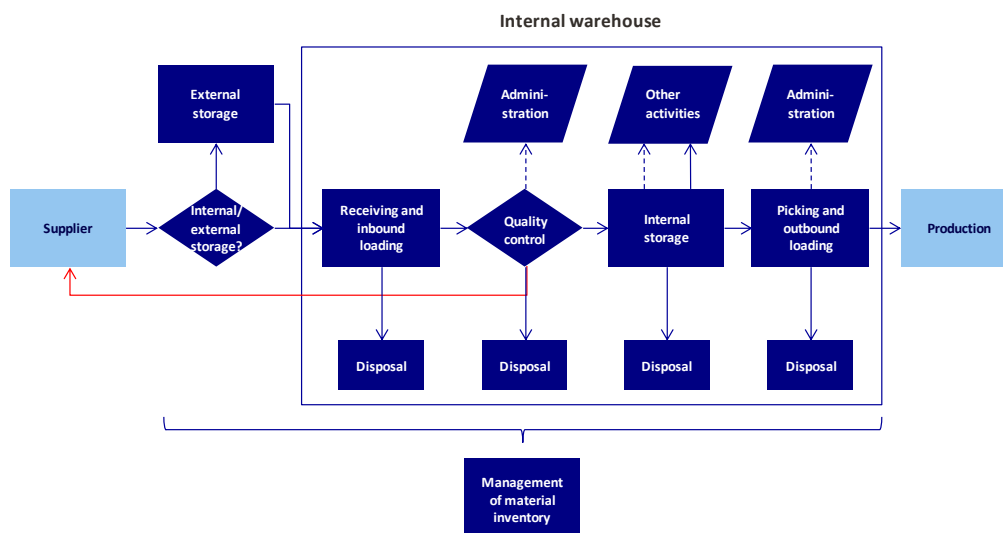


Figure 19: Flowchart of material inventory activities, Kiviks Musteri.

4.3 Case study at Oatly AB

4.3.1 Company background

Oatly is an oat drink producer with its headquarter in Landskrona, Sweden. The company employs 46 people and has experienced a steady growth of 20% annually in the recent years (Olin, 2013). The company's annual turn-over in 2011 was 182 million SEK (allabolag, 2012). In 2012 they produced 22 million Tetra Brik Aseptic packages (Olin, 2013). Oatly uses an external warehouse where they have a flexible amount of pallet positions available for their usage.

4.3.2 Name of sites and contact people

Data was collected during four visits at the warehouse and production site on the 22nd of March, 4th of April, 15th of April and 3rd of May 2013. Employees at Oatly involved in the case study are listed in *table 2* below.

Name	Position	Previous positions	Number of years in the company
Magnus Olin	Supply Chain manager	-	4
Andreas Bergstaf	Accountant manager	-	6
Vlade Veljanovski	Production Controller	-	5
Håkan Axenklev	Warehouse manager	-	6

Table 2: Interviewees at Oatly.

4.3.3 Field study

Four products were selected as the focus for the case study, namely Oat Drink Enriched 1 L, Havredrikk Sjokolade Økologisk 1 L, iMat 0.25 L, Hafer/Haver Calcium BIO 0.25 L. The reason for selecting four different products is to see how the number of days in stock affects the total cost. This was done by comparing the package with the highest sales volume to the package with the lowest sales volume within the same package size, i.e. comparing Oat Drink Enriched 1 L with Havredrikk Sjokolade Økologisk 1 L and comparing iMat 0.25 L with Hafer/Haver Calcium BIO 0.25 L. As seen below, in *figure 20*, the packages used for these products are Tetra Brik Aseptic.



Figure 20: Oat Drink Enriched 1 L, Havredrikk Sjokolade Økologisk 1 L, iMat 0.25 L, Hafer/Haver Calcium BIO 0.25 L (Oatly, 2013).

All activities undertaken in material inventory linked to these two products were identified and can be observed in the case specific figure below, *figure 21*. The figure is a revised version of the main principles presented in the literature review on Activity-Based Costing, section 3.2.3.

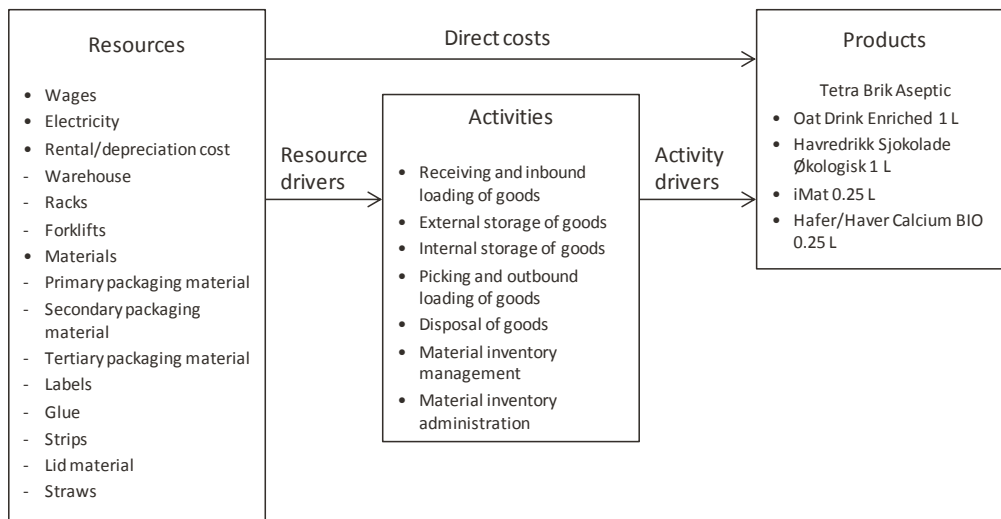


Figure 21: Main principles of ABC applied at Oatly, revised figure (Gerdin, 1995).

4.3.4 Flowchart of material inventory activities

The activities in material inventory at Oatly were identified throughout steps 1.1–1.8 in section 4.1 and mapped in a flowchart, see *figure 22*, using the same symbols as suggested in the literature review on process mapping, section 3.5.3. Material flow is depicted with solid arrows, information flow with dotted arrows and return flow with red arrows (return flows are not included in the analysis).

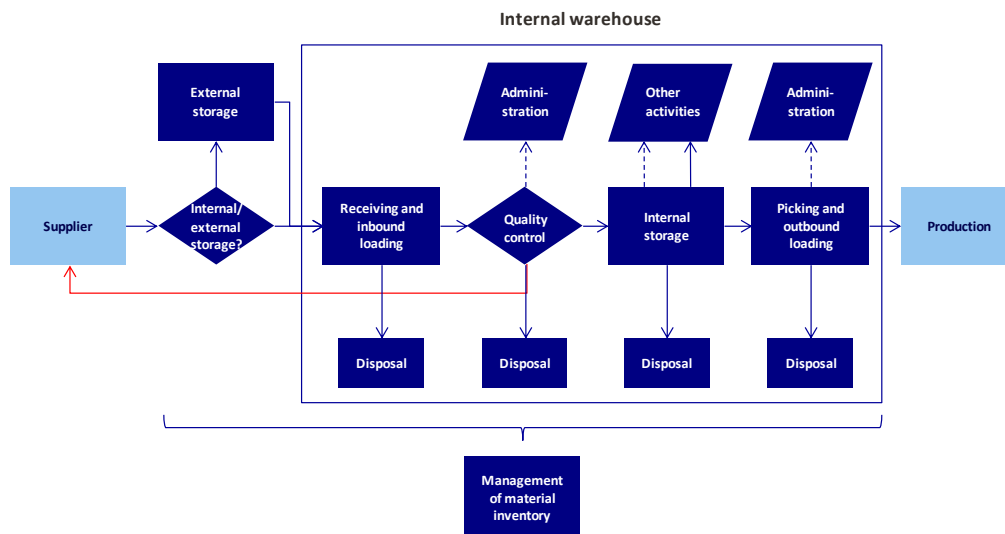


Figure 22: Flowchart of material inventory activities, Oatly.

4.4 Case study at Carlsberg Sverige AB Ramlösa

4.4.1 Company background

Ramlösa, owned by Carlsberg Sverige AB, is a producer of mineral water located outside of Helsingborg, Sweden. The water is pumped up from two different sources before it is filtered, carbonated, flavoured and filled in different packages. The company offers mineral water filled in aluminium cans, glass bottles and PET bottles of various sizes. During 2012 28.7 million PET 0.5 liter and 21.5 million PET 1.5 liter were produced. The company currently employs 72 people.

4.4.2 Name of sites and contact people

Data was collected during two visits at the warehouse and production site on the 24th and 25th of April 2013. Employees at Ramlösa involved in the case study are listed in *table 3* below.

Name	Position	Previous positions	Number of years in the company
Caroline Kullenberg	Material planner	-	2
Amelie Wranning	Director of organisational development	-	1
Anders Rosqvist	Warehouse coordinator	Warehouse worker	20
Juha Kärkäinen	Warehouse worker	-	20

Table 3: Interviewees at Ramlösa.

4.4.3 Field study

Two products were selected as the focus for the case study, namely Ramlösa Original 1.5 liter and Ramlösa Original 0.5 liter. As seen below, in *figure 23*, the packages used for these products are 1.5 liter and 0.5 liter PET bottles.



Figure 23: Ramlösa Original 1.5 liter and Ramlösa Original 0.5 liter (Mat.se, 2013).

All activities undertaken in material inventory linked to these two products were identified and can be observed in the case specific figure below, *figure 24*. The figure is a revised version of the main principles presented in the literature review on Activity-Based Costing, section 3.2.3.

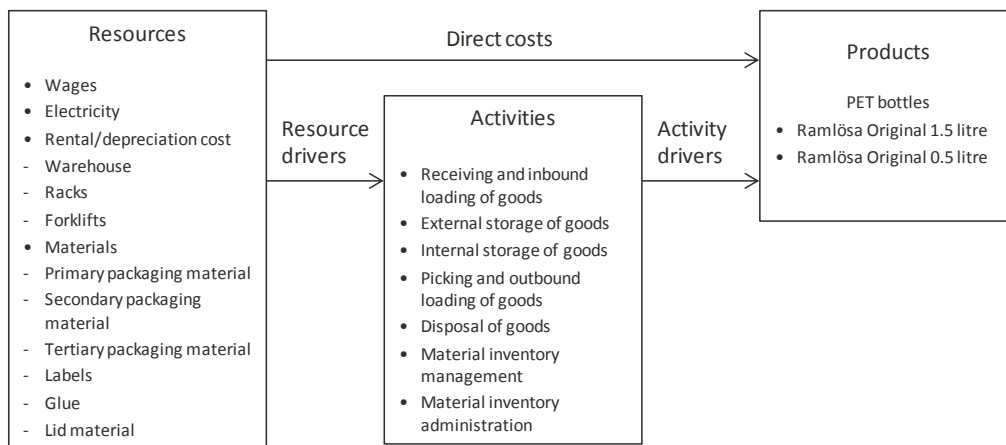


Figure 24: Main principles of ABC applied at Ramlösa, revised figure (Gerdin, 1995).

4.4.4 Flowchart of material inventory activities

The activities in material inventory at Ramlösa were identified throughout steps 1.1–1.8 in section 4.1 and mapped in a flowchart, see *figure 25*, using the same symbols as suggested in the literature review on process mapping, section 3.5.3. Material flow is depicted with solid arrows, information flow with dotted arrows and return flow with red arrows (return flows are not included in the analysis). Unlike Kiviks Musteri and Oatly, Ramlösa does not employ external warehousing services.

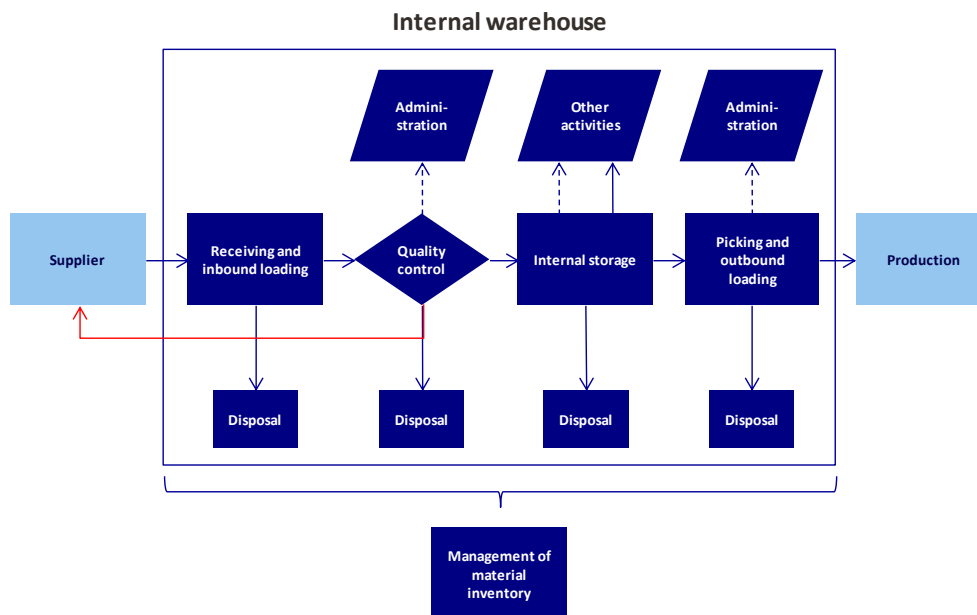


Figure 25: Flowchart of material inventory activities, Ramlösa.

5 Case study results

In the fifth chapter the results from the case studies will be presented.

Based on the revised activity framework, section 4.1, and the packaging logistics concepts, presented in section 3.3, the individual cost per material and activity as well as the total cost per material were calculated using the cost estimation model, in order to provide an answer to the question “how much do the activities cost”. This is the fundamental objective of Activity-Based Costing, see section 3.2.3. For each case, these results are presented in the tables below, see *table 4*, *table 5* and *table 6*, along with pie charts, see *figure 26*, *figure 27* and *figure 28*, displaying the fraction of total cost per activity for each material.

5.1.1 Results from the case study at Kiviks Musteri

MATERIAL	External		Internal								Sum
	External storage cost per 1000 units	Cost of capital (external storage)	Internal storage cost per 1000 units	Cost of capital (internal storage)	Receiving and inbound loading cost per 1000 units	Picking and outbound loading cost per 1000 units	Management cost per 1000 units	Administration cost per 1000 units	Costs for other activities per 1000 units	Cost of disposed goods per 1000 units	
-1.5 liter primary package	0,8	1,2	1,5	0,5	0,8	5,0	1,1	0,1	0,0	0,9	11,9
-0.20 liter primary package	0,3	0,7	0,7	0,4	0,2	1,1	0,2	0,0	0,0	0,3	4,0
-Corrugated board (1.5 liter primary packages)			13,8	0,6	15,3	92,4	21,1	1,0	0,6	1,8	146,6
-Corrugated board (0.20 liter primary packages)			7,8	0,3	11,5	69,4	15,9	0,7	0,4	1,1	107,1
-Stretch film	112,7	99,1	155,2	32,5	34,4	207,4	47,4	2,2	1,3	20,6	712,8
-Top sheet	56,8	44,0	145,0	26,7	37,8	227,9	52,1	2,4	1,4	19,9	614,1
-Label (secondary packaging)			0,3	0,1	0,1	0,3	0,1	0,0	0,0	0,1	0,9
-Label (pallets)			10,6	1,4	0,4	2,3	0,5	0,0	0,0	0,1	15,5
-Glue (straw)			1260,7	230,1	76,6	461,5	105,5	4,8	2,9	40,0	2182,1
-Glue (secondary packaging)			264,7	60,9	41,9	252,6	57,8	2,6	1,6	27,6	709,6
-Glue (lid material)			1151,9	254,9	70,0	421,7	96,4	4,4	2,6	44,3	2046,2
-Strip (LS)	43,7	0,0	198,8	0,0	33,9	204,3	46,7	2,1	1,3	0,0	530,8
-Strip (IS)	1064,5	631,0	4473,6	631,0	271,8	1637,8	374,5	17,0	10,2	109,6	9220,9
-Strip (Pull tab)	2,1	1,8	9,0	1,8	0,7	3,9	0,9	0,0	0,0	0,4	20,6
-Recap 2 white	0,2	0,1	0,0	0,0	0,2	1,1	0,3	0,0	0,0	0,1	2,0
-U-straw black	0,5	0,2	0,1	0,0	0,1	0,6	0,1	0,0	0,0	0,0	1,6
-U-straw transparent	0,2	0,1	0,0	0,0	0,1	0,6	0,1	0,0	0,0	0,0	1,1

Table 4: Results from the case study at Kiviks Musteri.

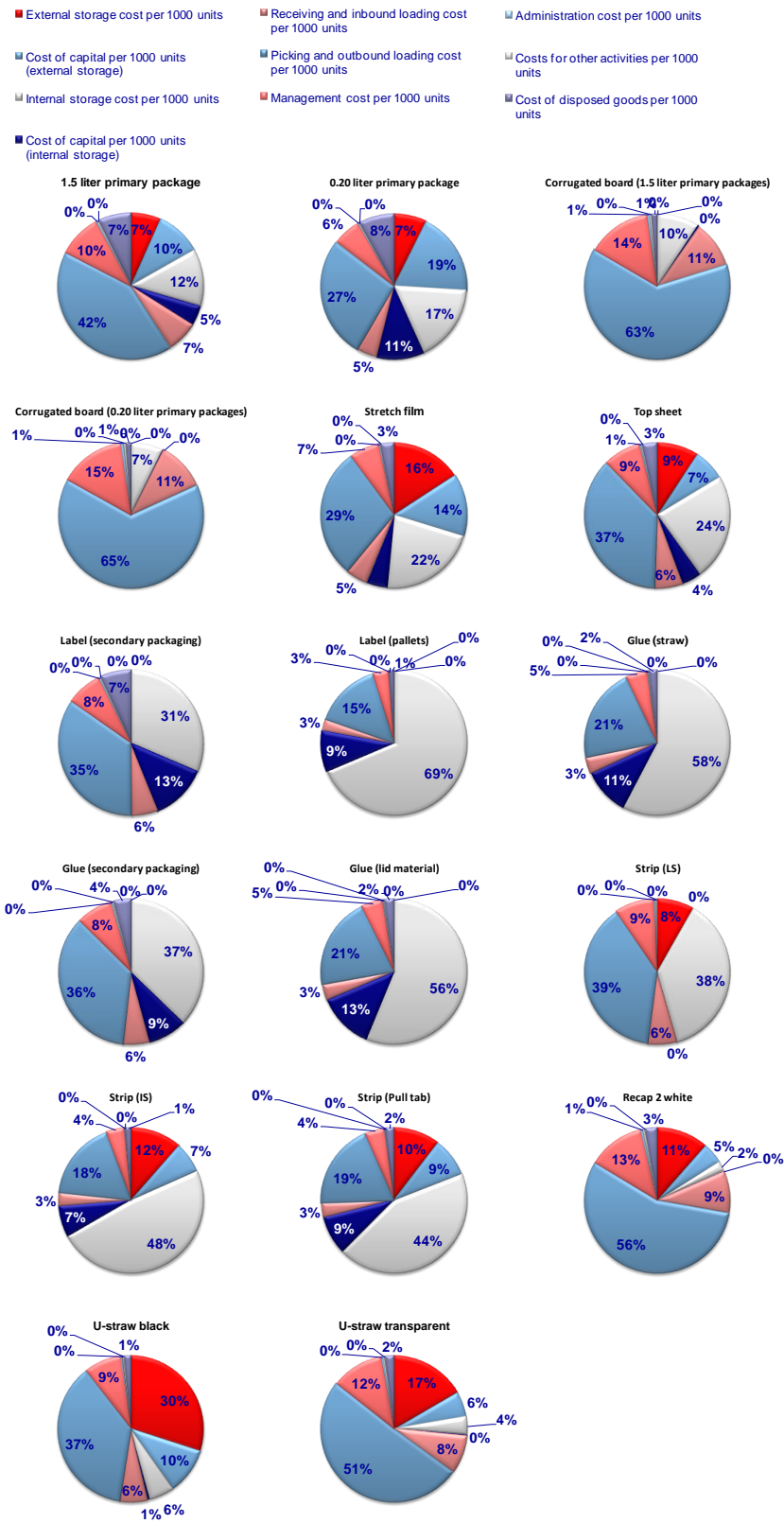


Figure 26: Fraction of total cost per activity at Kiviks Musteri.

5.1.2 Results from the case study at Oatly

MATERIAL	External		Internal								Sum
	External storage cost per 1000 units	Cost of capital per 1000 units (external storage)	Internal storage cost per 1000 units	Cost of capital per 1000 units (internal storage)	Receiving and inbound loading cost per 1000 units	Picking and outbound loading cost per 1000 units	Management cost per 1000 units	Administration cost per 1000 units	Costs for other activities per 1000 units	Cost of disposed goods per 1000 units	
-1 liter primary package (largest sales volume)	2,4	13,0	0,2	0,8	0,4	0,8	0,3	0,4	0,0	8,5	26,8
-1 liter primary package (smallest sales volume)	16,5	51,9	1,3	3,3	0,7	1,3	0,6	0,7	0,1	8,5	84,9
-0.25 liter primary package (largest sales volume)	0,9	5,4	0,1	0,4	0,2	0,3	0,1	0,2	0,0	4,3	11,9
-0.25 liter primary package (smallest sales volume)	5,5	16,0	0,7	1,6	0,4	0,7	0,3	0,4	0,0	4,3	29,9
-Corrugated board (1 liter primary packages)			17,4	3,8	18,8	37,5	15,6	18,8	1,4	21,3	134,5
-Corrugated board (0.25 liter primary packages)			5,9	2,1	6,3	12,6	5,3	6,3	0,5	11,9	50,9
-Stretch film			154,1	305,2	20,2	40,3	16,8	20,2	1,5	208,2	766,4
-Top sheet			13733,2	15316,3	1363,6	2727,3	1136,4	1363,6	102,3	7929,7	43672,3
-Label (secondary packaging; 1 liter primary packages)			2,0	3,3	0,1	0,1	0,1	0,1	0,0	0,6	6,2
-Label (secondary packaging; 0.25 liter primary packages)			1,7	3,2	0,1	0,2	0,1	0,1	0,0	1,0	6,5
-Label (pallets)			15,2	21,6	0,3	0,5	0,2	0,3	0,0	1,9	39,8
-Glue (straw)			12535,2	3686,3	300,0	600,0	250,0	300,0	22,5	460,0	18154,0
-Glue (secondary packaging)			413,1	561,2	24,0	48,0	20,0	24,0	1,8	170,0	1262,2
-Glue (lid material)			521,7	589,2	39,1	78,1	32,6	39,1	2,9	230,0	1532,7
-Strip (LS)			328,2	0,0	37,4	74,7	31,1	37,4	2,8	0,0	511,5
-Strip (IS)			1783,2	3236,7	137,9	275,9	114,9	137,9	10,3	1305,4	7002,3
-Strip (Tab)			2,4	9,6	0,2	0,4	0,2	0,2	0,0	4,1	17,0
-SlimCap			1,0	1,1	0,2	0,3	0,1	0,2	0,0	1,0	3,9
-Straw			1,6	0,5	0,2	0,4	0,2	0,2	0,0	0,3	3,3

Table 5: Results from the case study at Oatly.

- External storage cost per 1000 units
- Receiving and inbound loading cost per 1000 units
- Administration cost per 1000 units
- Cost of capital per 1000 units (external storage)
- Picking and outbound loading cost per 1000 units
- Costs for other activities per 1000 units
- Internal storage cost per 1000 units
- Management cost per 1000 units
- Cost of disposed goods per 1000 units
- Cost of capital per 1000 units (internal storage)

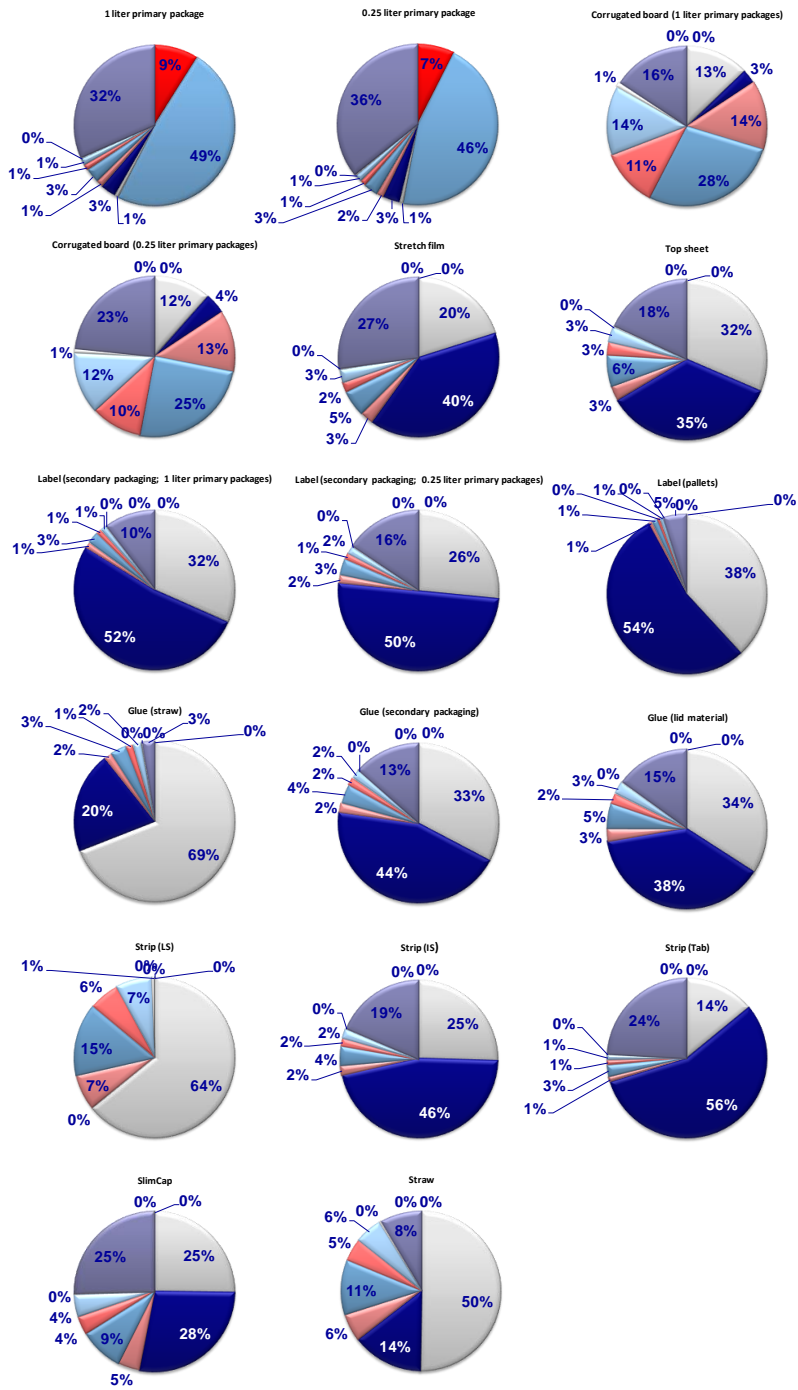


Figure 27: Fraction of total cost per activity at Oatly.

5.1.3 Results from the case study at Ramlösa

MATERIAL	Internal								Sum
	Internal storage cost per 1000 units	Cost of capital per 1000 units (internal storage)	Receiving and inbound loading cost per 1000 units	Picking and outbound loading cost per 1000 units	Management cost per 1000 units	Administration cost per 1000 units	Costs for other activities per 1000 units	Cost of disposed goods per 1000 units	Total cost per 1000 units
-1.5 liter primary package	2,3	1,1	2,2	2,7	7,3	0,7	0,3	2,9	19,4
-0.5 liter primary package	1,8	0,1	1,2	1,5	3,9	0,4	0,2	0,2	9,1
-Corrugated board (1.5 liter primary packages)	3,2	0,7	2,8	3,5	9,5	0,9	0,4	1,9	22,9
-Corrugated board (0.5 liter primary packages)	7,3	1,1	11,6	14,5	39,0	3,5	1,6	5,0	83,6
-Stretch film (1.5 liter primary packages)	206,0	186,5	34,8	43,5	117,5	10,7	4,9	90,5	694,4
-Stretch film (0.5 liter primary packages)	91,4	81,3	35,4	44,3	119,5	10,9	5,0	90,5	478,4
-Shrink wrap	14,0	27,7	14,9	18,6	50,2	4,6	2,1	84,4	216,4
-Shim (1.5 liter primary packages)	28,5	7,0	20,6	25,7	69,4	6,3	2,9	14,5	174,8
-Label (pallets)	1,3	1,3	0,5	0,6	1,7	0,2	0,1	1,4	7,1
-Label (primary packaging 1.5 liter original)	0,1	0,0	0,1	0,1	0,2	0,0	0,0	0,1	0,6
-Label (primary packaging 0.5 liter original)	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,1	0,3
-Glue (labels)	463,4	375,6	52,6	65,7	177,4	16,1	7,4	122,4	1280,7
-Glue (secondary packaging)	212,3	284,5	44,4	55,4	149,7	13,6	6,3	170,8	936,9
-Lids (original)	0,2	0,1	0,3	0,4	1,0	0,1	0,0	0,3	2,3

Table 6: Results from the case study at Ramlösa.

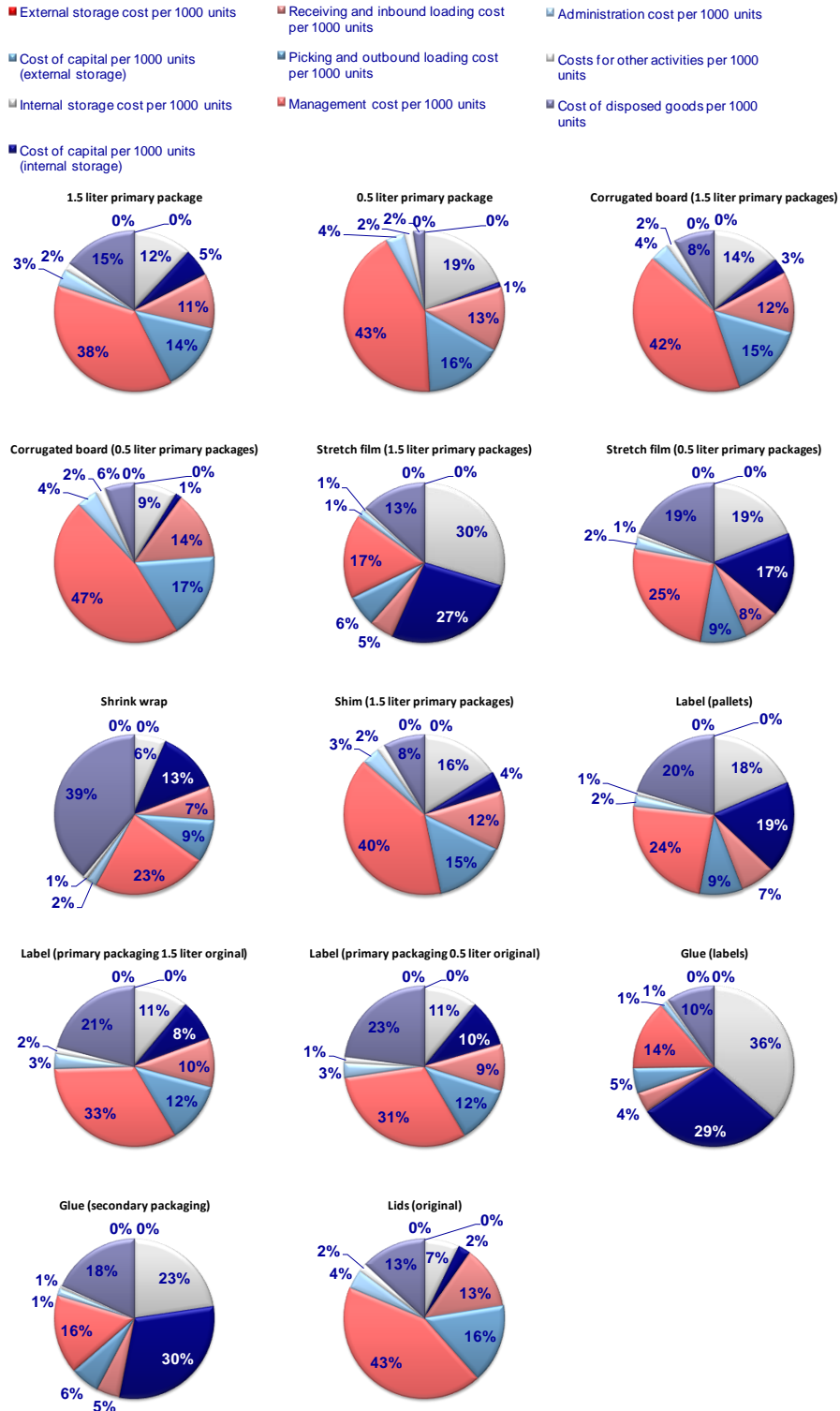


Figure 28: Fraction of total cost per activity at Ramlösa.

6 Single-case and cross-case analysis of case study results

In this chapter the case study results are analysed in relation to the theoretical context. First, a case specific analysis for each of the individual cases will be presented. This will then be followed by a cross-case analysis where the similarities and differences between the different cases will be investigated, forming a basis for developing the cost estimation model and drawing conclusions.

6.1 Introduction to case study analysis

The analysis have been conducted in line with the multiple-case study design by Yin (2003), presented in section 2.6.1, where individual case analysis of activities have been conducted followed by cross-case analysis on activities and materials. The analysis have also been performed using the packaging logistics concepts, presented in section 3.3, dividing the materials into different groups, such as primary packaging material, secondary packaging material etc.

The first step of the analysis was, within each individual case, to examine and interpret the activities' relative impact on the total cost incurred in material inventory. By identifying the various activities' cost impact on the total cost, the authors could draw conclusions on which activities that had greater or less impact on material inventory costs, independently of the material. No analysis of absolute numbers between different materials was conducted at this stage, since these are measured using different units such as meters, kilograms and pieces, which make them impractical, or even impossible, for comparison. For instance it would be inappropriate to compare a thousand kilograms of glue, which last for several years, with a thousand pieces of primary packages, which often equal less than one day's usage. Another reason for this is that the amount of units that can be stacked on a pallet varies largely between various materials. Therefore, also the handling costs per 1000 units will differ drastically.

To determine the relative impact of the activities on total cost, the activities have been divided into different categories depending on the highest result obtained from any material. The categories are displayed in the table below, see *table 7*. The different intervals are determined according to what the authors consider to be appropriate based on the variety of the results from the various case studies.

Percentage interval	Impact
0-1%	Insignificant
2-10%	Low impact
11-20%	Moderate impact
21-30%	High impact
31-100%	Very high impact

Table 7: Categorisation of activity impact on total cost.

The second step was to make a cross-case analysis where the same materials, e.g. primary packages, were compared between the different case studies. In this step also the costs in absolute terms (per pallet and in some cases also per time unit) of the individual activities were analysed and compared between the different case studies. This enabled the authors to draw cross-case conclusions, which in their turn formed the basis for the general cost estimation model.

The outcome of the case study analysis was then used to construct the general cost estimation model using input from the individual case studies.

6.2 Analysis of the case study at Kiviks Musteri

The results indicate that the impact on total cost for some activities span wide ranges, which can be observed in *table 8*. This is dependent upon several factors such as varying lead times, different amount of units per pallet and the value (purchase price) of each unit.

Activity	Impact (% of total cost)
External storage cost	High impact (7-30%)
Cost of capital (external storage)	Moderate impact (5-19%)
Internal storage cost	Very high impact (2-69%)
Cost of capital (internal storage)	Moderate impact (0-13%)
Receiving and inbound loading cost	Moderate impact (3-11%)
Picking and outbound loading cost	Very high impact (15-65%)
Management cost	Moderate impact (3-15%)
Administration cost	Insignificant (0-1%)
Costs for other activities	Insignificant (0-0%)
Cost of disposed goods	Low impact (0-8%)

Table 8: Relative impact of different activities on total cost at Kiviks Musteri.

Below is provided a thorough analysis of the individual activities' impacts on total cost:

- **External storage of goods:** Kiviks Musteri has a relatively low cost for external storage of goods per day compared to internal storage. A relatively large amount of days in stock still makes the external storage a high impact activity on total cost. The wide range within this activity depends to a great extent on varieties in the number of units stacked on one pallet.
- **Cost of capital (external storage):** A relatively large amount of days in stock but a rather low internal rate of return makes this a moderate impact activity. The wide range depends on differences in value (purchase price) and days in stock.
- **Internal storage of goods:** The internal storage cost per pallet position per day is four times higher than the external, which makes this a very high impact activity. The wide range within this activity depends to a great extent on varieties in the number of units stacked on one pallet and a great difference between days in stock.
- **Cost of capital (internal storage):** Some of the materials spend a large amount of days in stock. Combined with a rather low internal rate of return

this makes it a moderate impact activity. The wide range depends on differences in value (purchase price) and days in stock.

- **Receiving and inbound loading:** Kiviks Musteri has a rather low cost per pallet for receiving and inbound loading, which places the activity in the lower region of the moderate impact span. The varieties in the results mainly depend upon the number of units stacked on one pallet.
- **Picking and outbound loading:** A high cost per pallet makes this a very high impact activity. The wide range of results can be explained by the great difference in the amount of units per pallet.
- **Management:** Handling and planning the material inventory flow require several hours from the management staff every day which classify this as a moderate impact activity. The varieties in the results mainly depend upon the number of units stacked on one pallet.
- **Administration:** The time spent on this activity is low at Kiviks Musteri which leads to this activity being categorised as insignificant. Although the amount of units per pallet varies widely between materials, this has almost no impact due to the low time usage for this activity.
- **Other activities:** The only other activity identified at Kiviks Musteri is stocktaking which requires very low time usage, which leads to this activity having insignificant impact. For the same reason the result span is narrow.
- **Disposed goods:** No systematic waste occurs in material inventory and the percentage of disposed goods is estimated to be approximately 0.1%. This makes it a low impact activity. Some varieties in the results can however be seen, which can be explained by differences in purchase prices per unit for different materials.

6.3 Analysis of the case study at Oatly

The relative impact of different activities on total cost at Oatly have been analysed and the result is summarised in *table 9*.

Activity	Impact (% of total cost)
External storage cost	Low impact (7-9%)
Cost of capital (external storage)	Very high impact (46-49%)
Internal storage cost	Very high impact (1-69%)
Cost of capital (internal storage)	Very high impact (0-56%)
Receiving and inbound loading cost	Moderate impact (1-14%)
Picking and outbound loading cost	High impact (1-28%)
Management cost	Moderate impact (0-11%)
Administration cost	Moderate impact (1-14%)
Costs for other activities	Insignificant (0-1%)
Cost of disposed goods	Very high impact (0-36%)

Table 9: Relative impact of different activities on total cost at Oatly.

Below is provided a thorough analysis of the individual activities' impacts on total cost:

- External storage of goods:** Due to a low external storage cost per pallet position per day, external storage is a low impact activity, even though goods are stored for an extended period of time at the external storage. The low variation can be derived from the fact that only the primary packages, which constitute only a small fraction of the materials used, are being stored externally.
- Cost of capital (external storage):** Even though the value of the goods stored at the external warehouse is relatively low, this activity has very high impact on total cost due to the high internal rate. The low variation can be derived from the fact that only the primary packages, which constitute only a small fraction of the materials used, are being stored externally.
- Internal storage of goods:** This being a very high impact activity depends on a mismatch between what is measured in the case study and the annual consumption. Glue used for attaching the straws to the primary package is bought at an annual rate of 50 kilograms, while the model estimates the cost of storing 1000 kilograms, which equals to 20 years consumption. Further, some materials are stocked for extended periods of time. The large variation

originates from great differences in amount of units per pallet and amount of days in internal storage, as mentioned above.

- **Cost of capital (internal storage):** This is considered to be a very high impact activity because great average number of days in stock for materials with high unit prices. The high internal rate also contributes to the very high impact. Large variations of purchase price and days in stock can be seen in the great variation of impact.
- **Receiving and inbound loading:** The price per pallet for receiving and inbound loading is rather low, but since the amount of units stacked per pallet for some of the materials also is low, this lead to receiving being a moderate impact activity. The variation originates from differences in amount of units per pallet.
- **Picking and outbound loading:** Compared to receiving and inbound loading, the picking and outbound loading price per pallet is twice as high. This makes it a high impact activity. The variation stems from differences in amount of units per pallet.
- **Management:** The price per pallet for management is low to medium, which is a result of only a small amount of time being dedicated to this activity, but since the amount of units stacked per pallet for some of the materials also is low, this lead to management being a moderate impact activity. The variation originates from differences in amount of units per pallet.
- **Administration:** The price per pallet for administration is low to medium, which is a result of only a small amount of time being dedicated to this activity, but since the amount of units stacked per pallet for some of the materials also is low, this leads to administration being a moderate impact activity. The variation derives from differences in amount of units per pallet.
- **Other activities:** The only other activity identified at Oatly is stocktaking which requires very low time usage, which makes it an insignificant impact activity. For the same reason the result span is narrow.
- **Disposed goods:** No available data on disposed goods exists, but the amount of waste was estimated to be approximately 1%. Since this is an average percentage used for all materials, the disposal of materials with high unit prices becomes rather expensive. This makes disposal a very high impact

activity. The lack of correct data may however lead to a misleading rate of impact for this activity. Varieties in the results can be explained by differences in purchase prices per unit for different materials.

6.4 Analysis of the case study at Ramlösa

The relative impact of different activities on total cost at Ramlösa have also been analysed and the result is summarised in *table 10*.

Activity	Impact (% of total cost)
External storage cost	N/A
Cost of capital (external storage)	N/A
Internal storage cost	Very high impact (6-36%)
Cost of capital (internal storage)	High impact (1-30%)
Receiving and inbound loading cost	Moderate impact (4-14%)
Picking and outbound loading cost	Moderate impact (5-17%)
Management cost	Very high impact (14-47%)
Administration cost	Low impact (1-4%)
Costs for other activities	Low impact (0-2%)
Cost of disposed goods	Very high impact (2-39%)

Table 10: Relative impact of different activities on total cost at Ramlösa.

Below is provided a thorough analysis of the individual activities' impacts on total cost:

- **External storage of goods:** Ramlösa does not use an external warehouse for handling their packaging material.
- **Cost of capital (external storage):** Ramlösa does not use an external warehouse for handling their packaging material.
- **Internal storage of goods:** Low amount of units stacked per pallet of the most expensive materials make this a very high impact activity. Great differences in the amount of units stacked per pallet and variations in average number of days in stock are the reasons behind the impact span.

- **Cost of capital (internal storage):** A relatively high internal rate in combination with high unit prices for some of the materials places this within the high impact category. Differences in unit price and variations in average number of days in stock are the reasons behind the impact range.
- **Receiving and inbound loading:** Low to medium receiving and inbound loading cost per pallet in combination with differences in the number of units per pallet for different materials place the activity in the lower region of the moderate impact category. The impact interval can also be explained by the differences in the amount of units per pallet.
- **Picking and outbound loading:** Low picking and outbound loading cost per pallet in combination with differences in the number of units per pallet for different materials place the activity in the lower region of the moderate impact category. The impact interval can also be explained by the differences in the amount of units per pallet.
- **Management:** Managers at Ramlösa spend a relatively large amount of their time managing the material inventory flow. This leads to a high cost per pallet and puts this activity in the very high impact group. The impact interval can be explained by the differences in the amount of units per pallet.
- **Administration:** The price per pallet for administration is low, which is a result of only a small amount of time being dedicated to this activity. This leads to administration being a low impact activity. The variation derives from differences in amount of units per pallet.
- **Other activities:** The only other activity identified at Ramlösa is stocktaking which requires low time usage. This makes it a low impact activity. For the same reason the result span is narrow.
- **Disposed goods:** No available data on disposed goods exists, but the amount of waste was estimated to be approximately 0.5%. Since this is an average percentage used for all materials, the disposal of materials with high unit prices becomes rather expensive. This makes disposal a very high impact activity. The lack of correct data may however lead to a misleading rate of impact for this activity. Varieties in the results can be explained by differences in purchase prices per unit for different materials.

6.5 Cross-case analysis

6.5.1 Cross-case activity analysis

- **External storage of goods:** At both Kiviks Musteri and Oatly the materials that are stored externally are stored for a relatively long period of time. Although, at Kivik the activity is classed as a high impact activity but at Oatly it is classed as a low impact activity. The reason for this is that Oatly stores only the primary packages, where a large number of units are stacked per pallet, at the external warehouse. Meanwhile, Kiviks Musteri stores several of their materials at the external warehouse, some of them stacked with a lower amount per pallet, which result in a broader impact span and a higher cost per unit for those materials. Ramlösa does not use an external warehouse for handling their packaging material.

For Kiviks Musteri, the cost for external storage is 2.0 SEK per pallet position per day. For Oatly, the cost is 1.6 SEK. The external storage cost is 25% higher at Kiviks Musteri than at Oatly, but both of the costs are lower than the internal storage costs. However, one should keep in mind that using an external warehouse will give rise to additional transportation costs. As stated in the delimitations of this thesis, these costs are not included in the study.

- **Cost of capital (external storage):** At Kiviks Musteri this is classified as a moderate impact activity, while at Oatly it is ranked as a very high impact activity. This can partly be explained because Kiviks Musteri applies an internal rate of 5% and Oatly 10%. Further, Oatly stores the materials for longer periods of time at the external warehouse than Kiviks Musteri, which results in a higher cost of capital. Ramlösa does not use an external warehouse for handling their packaging material.

The cost of capital depends on the internal rate but also on the purchase price of the materials, the number of units purchased of each material and the number of days in stock. With this said, the cost of capital is material specific and no uniform cost per pallet exists.

- **Internal storage of goods:** This activity is a very high impact activity at all cases. Also, the variation is high at all three companies. Both the very high impact and the large impact span mainly depend on that some of the materials are stacked at a low amount per pallet for a long time period. Another reason is that the model calculates the cost for 1000 units independently of how long time it is going to take to consume this amount.

The cost for internal storage is 8.0 SEK per pallet position per day for Kiviks Musteri, 2.1 SEK for Oatly and 2.0 SEK for Ramlösa. Oatly and Ramlösa have low internal storage costs since Oatly uses a tent for internal storage and Ramlösa's warehouse already is depreciated.

- **Cost of capital (internal storage):** This activity has moderate impact at Kiviks Musteri, very high impact at Oatly and high impact at Ramlösa. For all three cases this activity's impact span is wide, which can be explained by differences in purchase price, amount purchased and number of storage days. The big difference between the three cases is the internal rate ranging from 5% at Kiviks Musteri to 8% at Ramlösa and 10% Oatly.

The cost of capital depends on the internal rate but also on the purchase price of the materials, the number of units purchased of each material and the number of days in stock. With this said, the cost of capital is material specific and no uniform cost per pallet exists.

- **Receiving and inbound loading:** This activity is classified as a moderate impact activity in all three cases. The time use for this activity is consistently low in all cases which leads to a low receiving and inbound loading cost per pallet. The reason why this activity being classified as a moderate instead of a low impact activity is because of the variations caused by different amount of units stacked per pallet depending on the material.

The cost for receiving and inbound loading is 18.0 SEK per pallet for Kiviks Musteri, 15.0 SEK for Oatly and 19.0 SEK for Ramlösa. The narrow span of these numbers indicates that the time use for this activity does not differ substantially and that this is a reasonable cost for receiving pallets.

- **Picking and outbound loading:** This is a very high impact activity at Kiviks Musteri, a high impact activity at Oatly and a moderate activity at Ramlösa. At Kiviks Musteri it consumes a significant amount of time to handle each pallet, which is the reason for the high impact value. At Oatly and Ramlösa less time is spent to handle each pallet, classifying the impact of the activity as lower than at Kiviks Musteri.

The cost for picking and outbound loading is 111.0 SEK per pallet for Kiviks Musteri, 30.0 SEK for Oatly and 23.0 SEK for Ramlösa. The wide span indicates differences in how efficient this activity is performed, but other factors such as the layout of the warehouse also affect this result.

- **Management:** This activity has moderate impact at Kiviks Musteri, moderate impact at Oatly and very high impact at Ramlösa. Time use by management and the total amount of pallets handled together determine the management cost per pallet. At Kiviks Musteri management spend a relatively large amount of time managing the material flow, but at the same time the number of pallets handled is high, resulting in a moderate cost per pallet. At Oatly time spent by management is low and so is the number of pallets handled, which lead to a moderate cost per pallet. At Ramlösa a considerable amount of time is spent by management and the pallet flow is rather low, which result in a high cost per pallet.

The cost for management is 25.3 SEK per pallet for Kiviks Musteri, 12.5 SEK for Oatly and 62.5 SEK for Ramlösa. As mentioned above, the cost is a consequence of the time spent and the total amount of pallets handled. The time spent varies depending on whether the company employs management personnel dedicated for handling the material inventory or not. Another aspect worth to consider regarding management is this activity's interactions with other activities. For instance a high management cost might lead to more efficient flow throughout the material inventory.

- **Administration:** This is an insignificant impact activity at Kiviks Musteri, a moderate impact activity at Oatly and a low activity at Ramlösa. All case companies spend a low amount of time on this activity. Differences in impact levels mainly depends on the total amount of pallets handled. Kiviks Musteri handles the highest number of pallets annually and Oatly the lowest.

The cost for administration is 1.1 SEK per pallet for Kiviks Musteri, 15.0 SEK for Oatly and 5.7 SEK for Ramlösa. As mentioned above, the cost is a consequence of the time spent and the total amount of pallets handled.

- **Other activities:** This activity has insignificant impact at Kiviks Musteri, insignificant impact at Oatly and low impact at Ramlösa. The only activity identified at all three cases as other activities is stocktaking. This activity is performed on rare occasions and does not consume large amount of time, resulting in low impact values.

The cost for other activities (stocktaking) is 0.7 SEK per pallet for Kiviks Musteri, 1.1 SEK for Oatly and 2.6 SEK for Ramlösa. The differences depend

on the time spent, the personnel who performs the activity and the total amount of pallets handled.

- **Disposed goods:** This activity has low impact at Kiviks Musteri, very high impact at Oatly and very high impact at Ramlösa. Since no available data or systematic waste exist at any of the three case companies, they have all estimated the percentage of goods disposed. Given that the percentage is the same for all materials and since some of the materials have high purchase price per unit, even small changes in the percentage could have great impact on the disposal cost.

The percentage of disposed goods is estimated to be 0.1% at Kiviks Musteri, 1% at Oatly and 0.5% at Ramlösa. The cost of disposed goods depends on the estimated percentage of disposed goods and the purchase price. This means that the cost of disposed goods is material specific and no uniform cost per pallet exists.

6.5.2 Cross-case material analysis

In this section a cross-case material analysis is carried out. However, the reader should keep in mind that even though materials are categorised in the same material group (e.g. primary packaging material, lid material etc.) they are not the same packages and therefore they may differ in size and shape. For instance, the material needed for a 1 liter primary package might be less than the material needed for a 1.5 liter primary package which could lead to a lower purchase price for the 1 liter primary package. This means that all the materials in the same material group may not be strictly comparable, but due their resemblance and similar attributes an analysis could still be conducted with a reasonable result. In some cases, even within the same material group, all materials might not be used by all case companies (this is marked with “N/A” in the tables) or are not measured with the same unit (this is stated as “Incomparable” in the tables), which make them incomparable. The number of materials differ between each material group which results in empty cells in the tables (this is marked with “–” in the tables).

The total cost estimated by the model for each material for all case companies are summarised in *table 11* below.

Kiviks Musteri		Oatly		Ramlösa	
Material	Total cost per 1000 units (SEK)	Material	Total cost per 1000 units (SEK)	Material	Total cost per 1000 units (SEK)
Primary packaging material					
1.5 liter Tetra Brik Aseptic (pieces)	11,9	1 liter Tetra Brik Aseptic (largest sales volume) (pieces)	26,8	1.5 liter PET (pieces)	19,4
-	-	1 liter Tetra Brik Aseptic (smallest sales volume) (pieces)	84,9	-	-
0.20 liter Tetra Brik Aseptic (pieces)	4,0	0.25 liter Tetra Brik Aseptic (largest sales volume) (pieces)	11,9	0.5 liter PET (pieces)	9,1
-	-	0.25 liter Tetra Brik Aseptic (smallest sales volume) (pieces)	29,9	-	-
Secondary packaging material					
Corrugated board (1.5 liter primary packages) (pieces) (pieces)	146,6	Corrugated board (1 liter primary packages) (pieces)	134,5	Corrugated board (1.5 liter primary packages) (pieces)	22,9
Corrugated board (0.20 liter primary packages) (pieces) (pieces)	107,1	Corrugated board (0.25 liter primary packages) (pieces)	50,9	Corrugated board (0.5 liter primary packages) (pieces)	83,6
Tertiary packaging material					
Stretch film (kg)	712,8	Stretch film (kg)	766,4	Stretch film (1.5 liter primary packages) (kg)	694,4
-	-	-	-	Stretch film (0.5 liter primary packages) (kg)	478,4
Top sheet (kg)	614,1	Topsheet (pieces)	43672,3	Topsheet	N/A
Shrink wrap	N/A	Shrink wrap	N/A	Shrink wrap (kg)	216,4
Shim	N/A	Shim	N/A	Shim (1.5 liter primary packages) (pieces)	174,8
Label					
Label (secondary packaging) (pieces)	0,9	Label (secondary packaging; 1 liter primary packages) (pieces)	6,2	Label (secondary packaging)	N/A
-	-	Label (secondary packaging; 0.25 liter primary packages) (pieces)	6,5	-	-
Label (primary packaging)	N/A	Label (primary packaging)	N/A	Label (primary packaging 1.5 liter original) (pieces)	0,6
-	-	-	-	Label (primary packaging 0.5 liter original) (pieces)	0,3
Label (pallets) (pieces)	15,5	Label (pallets) (pieces)	39,8	Label (pallets) (pieces)	7,1
Glue					
Glue (straw) (kg)	2182,1	Glue (straw) (kg)	18154,0	Glue (straw)	N/A
Glue (secondary packaging) (kg)	709,6	Glue (secondary packaging) (kg)	1262,2	Glue (secondary packaging) (kg)	936,9
Glue (lid material) (kg)	2046,2	Glue (lid material) (kg)	1532,7	Glue (lid material)	N/A
Glue (labels)	N/A	Glue (labels)	N/A	Glue (labels) (kg)	1280,7
Strips					
Strip (LS) (kg)	530,8	Strip (LS) (kg)	511,5	Strip (LS)	N/A
Strip (IS) (kg)	9220,9	Strip (IS) (kg)	7002,3	Strip (IS)	N/A
Strip (Pull tab) (meter)	20,6	Strip (Pull tab) (meter)	17,0	Strip (Pull tab)	N/A
Lid material					
Recap 2 white (pieces)	2,0	SlimCap (pieces)	3,9	Lids (original) (pieces)	2,3
Straws					
U-straw black (pieces)	1,6	Straw (pieces)	3,3	Straw	N/A
U-straw transparent (pieces)	1,1	-	-	Straw	N/A

Table 11: Total cost (SEK) per 1000 units per material.

The average number of days in stock for each material for all case companies have been summarised in a table, see *table 12*.

Kiviks Musteri		Oatly		Ramlösa	
Material (unit)	Average number of days in stock	Material (unit)	Average number of days in stock	Material (unit)	Average number of days in stock
Primary packaging material					
1.5 liter Tetra Brik Aseptic (pieces)	13,0	1 liter Tetra Brik Aseptic (largest sales volume) (pieces)	59,5	1.5 liter PET (pieces)	8,5
-	-	1 liter Tetra Brik Aseptic (smallest sales volume) (pieces)	237,5	-	-
0.20 liter Tetra Brik Aseptic (pieces)	23,5	0.25 liter Tetra Brik Aseptic (largest sales volume) (pieces)	50,0	0.5 liter PET (pieces)	12,0
-	-	0.25 liter Tetra Brik Aseptic (smallest sales volume) (pieces)	150,5	-	-
Secondary packaging material					
Corrugated board (1.5 liter primary packages) (pieces) (pieces)	2,0	Corrugated board (1 liter primary packages) (pieces)	6,5	Corrugated board (1.5 liter primary packages) (pieces)	9,0
Corrugated board (0.20 liter primary packages) (pieces) (pieces)	1,5	Corrugated board (0.25 liter primary packages) (pieces)	6,5	Corrugated board (0.5 liter primary packages) (pieces)	5,0
Tertiary packaging material					
Stretch film (kg)	40,5	Stretch film (kg)	53,5	Stretch film (1.5 liter primary packages) (kg)	47,0
-	-	-	-	Stretch film (0.5 liter primary packages) (kg)	20,5
Top sheet (kg)	22,5	Top sheet (pieces)	70,5	Top sheet	N/A
Shrink wrap	N/A	Shrink wrap	N/A	Shrink wrap (kg)	7,5
Shim	N/A	Shim	N/A	Shim (1.5 liter primary packages) (pieces)	11,0
Label					
Label (secondary packaging) (pieces)	12,0	Label (secondary packaging; 1 liter primary packages) (pieces)	185,5	Label (secondary packaging)	N/A
-	-	Label (secondary packaging; 0.25 liter primary packages) (pieces)	116,5	-	-
Label (primary packaging)	N/A	Label (primary packaging)	N/A	Label (primary packaging 1.5 liter original) (pieces)	9,0
-	-	-	-	Label (primary packaging 0.5 liter original) (pieces)	9,5
Label (pallets) (pieces)	61,0	Label (pallets) (pieces)	425,5	Label (pallets) (pieces)	21,0
Glue					
Glue (straw) (kg)	36,5	Glue (straw) (kg)	292,5	Glue (straw)	N/A
Glue (secondary packaging) (kg)	14,0	Glue (secondary packaging) (kg)	120,5	Glue (secondary packaging) (kg)	38,0
Glue (lid material) (kg)	36,5	Glue (lid material) (kg)	93,5	Glue (lid material)	N/A
Glue (labels)	N/A	Glue (labels)	N/A	Glue (labels) (kg)	70,0
Strips					
Strip (LS) (kg)	25,0	Strip (LS) (kg)	61,5	Strip (LS)	N/A
Strip (IS) (kg)	73,0	Strip (IS) (kg)	90,5	Strip (IS)	N/A
Strip (Pull tab) (meter)	61,0	Strip (Pull tab) (meter)	85,0	Strip (Pull tab)	N/A
Lid material					
Recap 2 white (pieces)	12,0	SlimCap (pieces)	40,0	Lids (original) (pieces)	4,5
Straws					
U-straw black (pieces)	47,5	Straw (pieces)	63,5	Straw	N/A
U-straw transparent	19,5	-	-	Straw	N/A

Table 12: Average number of days in stock (internal and external storage).

The purchase price ratio and units per pallet ratio for each material for all case companies have also been summarised in a table, see *table 13*.

	Kiviks Musteri	Oatly	Ramlösa	Kiviks Musteri	Oatly	Ramlösa	Kiviks Musteri	Oatly	Ramlösa
Primary packaging material									
Material	1.5 liter Tetra Brik Aseptic (pieces)	1 liter Tetra Brik Aseptic (pieces)	1.5 liter PET (pieces)	0.20 liter Tetra Brik Aseptic (pieces)	0.25 liter Tetra Brik Aseptic (pieces)	0.5 liter PET (pieces)	-	-	-
Purchase price ratio	170%	150%	100%	900%	1080%	100%	-	-	-
Units per pallet ratio	260%	450%	100%	660%	570%	100%	-	-	-
Secondary packaging material									
Material	Corrugated board (1.5 liter primary packages) (pieces)	Corrugated board (1 liter primary packages) (pieces)	Corrugated board (1.5 liter primary packages) (pieces)	Corrugated board (0.20 liter primary packages) (pieces)	Corrugated board (0.25 liter primary packages) (pieces)	Corrugated board (0.5 liter primary packages) (pieces)	Shrink wrap	Shrink wrap	Shrink wrap (kg)
Purchase price ratio	530%	560%	100%	130%	120%	100%	N/A	N/A	100%
Units per pallet ratio	150%	100%	830%	100%	150%	100%	N/A	N/A	100%
Tertiary packaging material									
Material	Stretch film (kg)	Stretch film (kg)	Stretch film (kg)	Top sheet (kg)	Top sheet (pieces)	Top sheet	-	-	-
Purchase price ratio	130%	120%	100%	Incomparable	Incomparable	N/A	-	-	-
Units per pallet ratio	100%	150%	100%	Incomparable	Incomparable	N/A	-	-	-
Label									
Material	Label (secondary packaging) (pieces)	Label (secondary packaging; 1 liter primary packages) (pieces)	Label (secondary packaging) (pieces)	Label (pallets) (pieces)	Label (pallets) (pieces)	Label (pallets) (pieces)	Label (primary packaging) (pieces)	Label (primary packaging) (pieces)	Label (primary packaging) (pieces)
Purchase price ratio	120%	100%	N/A	100%	110%	170%	N/A	N/A	100%
Units per pallet ratio	140%	100%	N/A	150%	130%	100%	N/A	N/A	100%
Glue									
Material	Glue (secondary packaging) (kg)	Glue (secondary packaging) (kg)	Glue (secondary packaging) (kg)	Glue (straw) (kg)	Glue (straw) (kg)	Glue (straw)	Glue (lid material) (kg)	Glue (lid material) (kg)	Glue (lid material)
Purchase price ratio	190%	100%	200%	100%	100%	N/A	220%	100%	N/A
Units per pallet ratio	100%	140%	110%	480%	100%	N/A	100%	120%	N/A
Strips									
Material	Strip (LS) (kg)	Strip (LS) (kg)	Strip (LS)	Strip (IS) (kg)	Strip (IS) (kg)	Strip (IS)	Strip (Pull tab) (meter)	Strip (Pull tab) (meter)	Strip (Pull tab)
Purchase price ratio	100%	100%	N/A	100%	100%	N/A	100%	100%	N/A
Units per pallet ratio	120%	100%	N/A	100%	160%	N/A	100%	270%	N/A
Lid material									
Material	Recap 2 white (pieces)	SlimCap (pieces)	Lids (original) (pieces)	-	-	-	-	-	-
Purchase price ratio	100%	170%	100%	-	-	-	-	-	-
Units per pallet ratio	160%	140%	100%	-	-	-	-	-	-
Straws									
Material	U-straw (pieces)	Straw (pieces)	Straw	-	-	-	-	-	-
Purchase price ratio	100%	100%	N/A	-	-	-	-	-	-
Units per pallet ratio	230%	100%	N/A	-	-	-	-	-	-

Table 13: Comparison of purchase price and units per pallet, index 100.

- **Primary packaging material:** For both primary packaging sizes, the lowest purchase price and the lowest amount of units stacked per pallet are found at Ramlösa. The low amount of units per pallet results in a relatively high total cost in spite of the low purchase price. The highest total cost is however found at Oatly, which indicates high costs for handling and long storage periods. The effect of the large number of days in stock can also be seen in the comparison between the most and least frequently used primary package. Kiviks Musteri has the most expensive large packaging material and the second most expensive small packaging material but has the lowest total cost for both of these packages, which can partly be explained by the high amount of units per pallet, but also indicates an efficient material inventory flow.
- **Secondary packaging material:** Ramlösa has the lowest purchase price for the corrugated board used for the larger size of primary packages. For this corrugated board, Ramlösa also has the, by far, highest number of units per pallet. This is because this corrugated board consists solely of one sheet while the corrugated board used for the larger TBA packages is designed as an open-top box. Therefore, the total cost for this corrugated board is only one sixth compared to the other options. For the corrugated board used for the smaller size of primary packages, Ramlösa still has the lowest price but the prices are more alike. Although, Oatly has the highest amount of units per pallet, resulting in the lowest total cost.

Corrugated board is a rather standardised material, which can be seen in the similar purchase prices (except for Ramlösa which was explained above) and the total cost for handling and storage, taking the amount of units per pallet into account. The material is frequently used for several materials which also be seen by the low average number of days in stock for all three case companies.

- **Tertiary packaging material:** Stretch film is the only tertiary packaging material used at all three case companies. This is a rather standardised material which can be seen by the relatively equal purchase price and units per pallet ratios, as well as in the total cost. The average number of days in stock is also similar for all three case companies.

Top sheets are used at Kiviks Musteri and Oatly but different units of measurement, i.e. purchase units, are applied which makes the purchase price and units per pallet ratios incomparable. One unit at Kiviks Musteri equals one top sheet, while at Oatly one unit is equivalent to one roll

containing 250 top sheets. The effect of this is that the total cost per 1000 units becomes more than 70 times higher at Oatly, even though the actual cost of handling and storing one top sheet is not 70 times higher at Oatly than at Kiviks Musteri.

- **Label:** Secondary packaging labels are only used at Kiviks Musteri and Oatly and the purchase price ratio and units per pallet ratio are quite the same at the two companies. Despite of this the total costs are very different. The main reason for this is large differences in the number of days in storage. Since primary packaging labels are only used at Ramlösa, these will not be analysed.
- **Glue:** Glue for straws is priced at an equal level at Kiviks Musteri and Oatly. The average number of days in stock is eight times higher at Oatly and the amount of units per pallet is one fifth of the amount at Kiviks Musteri. This results in an eight times higher total cost at Oatly. Of importance to notice is that the annual consumption of glue for straws at Oatly is 50 kilograms while the total cost is calculated for a 1000 units, thus corresponding to 20 years consumption. At Kiviks Musteri, 1000 kilograms of glue for straws equal to four years usage.

The purchase price for glue for secondary packaging material is half the price compared to the other case companies. Oatly also has the highest number of units per pallet. Despite of this Oatly has got the highest total cost, which can be explained by the number of days in stock being nine times higher than at Kiviks Musteri and three times higher than at Ramlösa.

Glue for lid material is priced higher at Kiviks Musteri than at Oatly and stacked with a lower amount of units per pallet, resulting in a 30% higher total cost, even though the amount of days in stock is three times higher at Oatly.

Glue for labels is only used at Ramlösa and will therefore not be analysed.

- **Strips:** Strip (LS) is included in the primary packaging material price, which means that no cost of capital can arise by storing this material. Oatly has a lower amount of units per pallet and a greater amount of days in stock than Kiviks Musteri. Despite of this the total cost is slightly lower at Oatly, which indicates higher handling costs at Kiviks Musteri.

When it comes to strip (IS) and strip (Pull tab) the purchase price is the same at Kiviks Musteri and Oatly, but the amount of units per pallet is significantly higher at Oatly. This leads to a lower total cost at Oatly even though the number of days in stock is slightly higher than at Kiviks Musteri.

- **Lid material:** SlimCap, used by Oatly, has the highest purchase price and the largest number of days in stock, resulting in a higher total cost despite the higher number of units per pallet. When comparing the lid materials used at Kiviks Musteri and Ramlösa, the lid materials are priced at the same level but the one used at Kivik has a higher units per pallet ratio while the average number of days is lower at Ramlösa, resulting in a similar total cost.
- **Straws:** Straws are only used at Kiviks Musteri and Oatly and the purchase price ratio are quite the same at the two companies. In spite of this, the total costs are very different. The main reason for this is large differences in the number of days in stock and units per pallet ratio.

7 Model description

In this chapter the general cost estimation model, based on the findings from the case studies, will be presented together with the model's main features.

Based on the analysis of the case study results, the authors were able to construct the general cost estimation model, answering to the study's third objective. The cost estimation model should, according to Tetra Pak's requirements, be able to calculate the total cost for handling and storing 1000 units of different materials in material inventory. The results can also be used for benchmarking purposes between different materials. The authors have further constructed the model so that the costs for the individual activities carried out in material inventory can be calculated and displayed separately, as well as the total cost according to the requirement. The model was constructed in this way to increase the user's understanding of where the costs arise.

In this section a fictive company, Company X, has been used to display what the outcome might look like when using the general material inventory cost estimation model constructed based on the cross-case analysis. A manual describing how the model is to be used could be found in *Appendix A*.

7.1 Dashboard

The Dashboard is used to show a summary of the materials' total costs per 1000 units estimated by the model. An example of the Dashboard sheet can be seen in *figure 29*.

Costs per material (1000 units)		
Material	Article name	Total cost (per 1000 units)
-1 liter primary package	Material A	10,5
-0.20 liter primary package	Material B	4,3
-1 liter primary package	Material C	6,5
-Corrugated board (0.20 liter p	Material D	75,4
-Stretch film	Material E	580,1
-Top sheet	Material F	431,3
-Label (secondary packaging)	Material G	0,8
-Label (pallets)	Material H	10,5
-Glue (straw)	Material I	1727,9
-Glue (secondary packaging)	Material J	568,5
-Glue (lid material)	Material K	1390,1
-Strip	Material L	10,3
-Lid	Material M	4,2
-Straw	Material N	1,6

Figure 29: *Dashboard* sheet in the cost estimation model for Company X.

7.2 Input materials

In this sheet the user fills in data for the materials to be analysed. The data includes quantity purchased, delivery intervals and safety stock. An example of the Input materials sheet can be seen in *figure 30*.

MATERIAL (Make selection in drop-down list)	Unit	Quantity purchased (annual)	Delivery interval to external warehouse (number of days between deliveries)	Safety stock in external warehouse (days)	Delivery interval to internal warehouse (number of days between deliveries)	Safety stock in internal warehouse (days)
-1 liter primary package	pieces	2200000	20	4	10	0
-0.20 liter primary package	pieces	930000	30	5	15	0
-1 liter primary package	pieces	800000	0	0	5	0
-Corrugated board (0.20 liter primary packages)	pieces	550000	0	0	5	0
-Stretch film	kg	13000	60	0	20	0
-Top sheet	kg	13000	30	0	15	0
-Label (secondary packaging)	pieces	5000000	0	0	25	0
-Label (pallets)	pieces	200000	0	0	120	0
-Glue (straw)	kg	1200	0	0	70	0
-Glue (secondary packaging)	kg	5700	0	0	30	0
-Glue (lid material)	kg	1600	0	0	70	0
-Strip	meter	200000	25	0	25	5
-Lid	pieces	6000000	70	0	25	15
-Straw	pieces	4000000	60	0	15	5

Figure 30: *Input materials sheet in the cost estimation model for Company X.*

7.3 Activities

Based on the findings from the case studies, the following activities are undertaken in material inventory and therefore included in the model:

- External storage of goods
- Cost of capital (external storage)
- Internal storage of goods
- Cost of capital (internal storage)
- Receiving and inbound loading
- Picking and outbound loading
- Management
- Administration
- Disposed goods

To enable the user to include other activities than the ones observed during the case studies a tenth activity has been added in the *Activity* sheet:

- Other activities (e.g. stocktaking)

For a detailed description of the activities, see section 4.1.

In the Activity sheet the resources needed to handle and storage the materials are to be filled in by the user. Resources include factors such as time use and energy consumption. Other variables to be filled in include internal rate, rental and

depreciation costs among others. Based on the case studies the authors have estimated average values for the majority of the required input, which are prefilled in the general cost estimation model, but could easily be changed by the user to fit the specific case. An example of the Activity sheet can be seen in *figure 31*.

Activities and resources		Value
Universal input		
Internal rate	=	5%
Working days per year	=	245
Number of storage days per year	=	365
Total amount of pallets handled (annual)	=	10000
Electricity cost (SEK/kWh)	=	0,6
Percentage disposed goods of purchased goods	=	0,10%
External storage of goods		
External storage cost per pallet position (annual)		720
Number of storage days per year	/	365
External storage cost per pallet (per day)	=	2
Receiving and inbound loading of goods		
Time use per day (man-hours)		5
Labour cost (per hour)	*	210
Cost per day	=	1050
Working days per year	*	245
Annual cost	=	257250
Total amount of pallets received (annual)	/	10000
Receiving cost per pallet	=	26
Internal storage of goods		
Rental, depreciation and maintenance costs		
Warehouse depreciation cost or rent (annual)		300000
Racks depreciation cost or rent (annual)	+	40000
Maintenance cost (annual)	+	0
Forklifts and other machines used for handling (used in material inventory) depreciation cost or rent, (annual)	+	50000
Forklifts and other machines used for handling (used in material inventory) maintenance cost (annual)	+	15000
Computer and IT-system cost (used in material inventory) (annual)	+	35000
Other rental, depreciation and maintenance costs (used in material inventory) (annual)	+	0
Total rental, depreciation and maintenance costs (annual)	=	440000
Energy consumption		
Heating		
Electricity		
Heating electricity consumption (kWh/m ²)		110
Storage area (m ²)	*	600
Total heating energy consumption (kWh, annual)	=	66000
OR		
Other source of energy used for heating		
Energy consumption cost used for heating in material inventory (annual)		
Energy consumption cost used for heating in material inventory (annual)	=	0
General electricity consumption		
General electricity consumption (kW)	*	5
Time usage per day (h)	*	24
Number of working days (annual)	*	245
Total general electricity consumption (kWh, annual)	=	29165
Forklifts electricity consumption		
Number of electric counterbalance forklift		
Number of electric counterbalance forklift		1
Time usage per day (h)	*	4
Daily electricity consumption (kWh)	=	72
Number of electric pallet truck		
Number of electric pallet truck		1
Time usage per day (h)	*	4
Daily electricity consumption (kWh)	=	24
Number of electric roll gripper		
Number of electric roll gripper		1
Time usage per day (h)	*	4
Daily electricity consumption (kWh)	=	6
-		
Time usage per day (h)	*	
Daily electricity consumption (kWh)	=	0
Total daily forklift electricity consumption (kWh)	=	102
Number of working days (annual)	*	245
Total forklift electricity consumption (kWh, annual)	=	24931
Sum energy consumption cost		
Total electricity consumption (kWh, annual)	=	120096
Electricity cost (SEK/kWh)	*	0,60
Total electricity cost (annual)	=	72058
Total energy cost (annual)	=	72058

Activities and resources		Value
Sum internal storage cost		
Total internal storage cost (annual)	=	512058
Total number of pallet positions available for packaging material	/	300
Internal storage cost per pallet position (with 100% utilization, annual)	=	1707
Total number of pallet positions used for packaging material		250
Total number of pallet positions available for packaging material	/	300
Utilization (average filling rate)	=	83%
Internal storage cost per pallet position (with 100% utilization, annual)		1707
Utilization (average filling rate)	/	83%
Actual internal storage cost per pallet position (annual)	=	2048
Number of storage days (annual)	/	365
Actual internal storage cost per pallet position (per day)	=	6
Picking and outbound loading of goods to production		
Time use per day (man-hours)		10
Labour cost (per hour)	*	210
Cost per day	=	2100
Working days per year	*	245
Annual cost	=	514500
Total amount of pallets sent to production (annual)	/	10000
Picking and outbound loading cost per pallet	=	51
Material inventory management costs		
Time use per day (man-hours)		2,0
Labour cost (per hour)	*	300
Cost per day	=	600
Working days per year	*	245
Annual cost	=	147000
Total amount of pallets handled (annual)	/	10000
Management cost per pallet	=	14,7
Material inventory administration costs		
Time use per day (man-hours)		0,5
Labour cost (per hour)	*	210
Cost per day	=	105
Working days per year	*	245
Annual cost	=	25725
Total amount of pallets handled (annual)	/	10000
Administrative cost per pallet	=	2,6
Other activities in material inventory		
Time use per day (man-hours)		0,5
Labour cost (per hour)	*	210
Cost per day	=	105
Working days per year	*	245
Annual cost	=	25725
Total amount of pallets handled (annual)	/	10000
Cost for other activities per pallet	=	2,57

Figure 31: Activities sheet in the cost estimation model for Company X.

7.4 List of materials

In this sheet the materials and their respective units, purchase price per unit, purchasing currency, quantity per pallet and type of carrier have been listed by the authors. If cost estimations for other materials are to be performed, the list can be extended or modified by the user. An example of the List of materials sheet can be seen in *figure 32*.

MATERIAL	Unit	Purchase price per unit	Currency	Quantity per pallet	Type of carrier
Primary packaging material					
-1 liter primary package	pieces	1,00 SEK		22000	TP PALLET
-0.20 liter primary package	pieces	0,50 SEK		100000	TP PALLET
Secondary packaging material					
-Corrugated board (1 liter primary packages)	pieces	2,00 SEK		1000	EURO PALLET
-Corrugated board (0.20 liter primary packages)	pieces	1,00 SEK		1500	EURO PALLET
Tertiary packaging material					
-Stretch film	kg	24,00 SEK		500	EURO PALLET
-Top sheet	kg	23,00 SEK		500	EURO PALLET
Label					
-Label (secondary packaging)	pieces	0,10 SEK		350000	EURO PALLET
-Label (pallets)	pieces	0,20 SEK		50000	EURO PALLET
Glue					
-Glue (straw)	kg	45,00 SEK		200	EURO PALLET
-Glue (secondary packaging)	kg	30,00 SEK		400	EURO PALLET
-Glue (lid material)	kg	50,00 SEK		300	EURO PALLET
Strips					
-Strip	meter	0,50 SEK		30000	EURO PALLET
Lid material					
-Lid	pieces	0,10 SEK		100000	EURO PALLET
Straws					
-Straw	pieces	0,05 SEK		190000	EURO PALLET

Figure 32: List of materials sheet in the cost estimation model for Company X.

7.5 List of forklifts

This sheet has been prefilled by the authors in the general model and includes information on electricity consumption for commonly used forklifts. In case a specific forklift cannot be found in the list, the user may insert this manually in the list. An example of the List of forklifts sheet can be seen in *figure 33*.

Forklifts	Voltage (Volt)	Current (Ampere)	Power (Kilo Watt)
-	0	0	0
Electric pallet truck	24	250	6
Electric stacker	24	375	9
Electric roll gripper	12	120	1,44
Electric counterbalance forklift	24	750	18

Figure 33: List of forklifts sheet in the cost estimation model for Company X.

7.6 Calculations

According to what has been filled out by the user in the previous sheets this sheet calculates, per material, the number of pallets and the average number of days in stock in the external and internal warehouse. This information is then used as input when calculating the costs in the Results sheet. An example of the Calculations sheet can be seen in *figure 34*.

MATERIAL (Make selection in drop-down list)	Unit	Purchase price/unit	Quantity per pallet	Number of pallets (annual)	Average number of days in stock in external warehouse	Average number of days in stock in internal warehouse
-1 liter primary package	pieces		1	22000	100	5
-0.20 liter primary package	pieces		0,5	100000	10	7,5
-1 liter primary package	pieces		1	22000	37	2,5
-Corrugated board (0.20 liter primary p	pieces		1	1500	367	2,5
-Stretch film	kg		24	500	26	10
-Top sheet	kg		23	500	26	7,5
-Label (secondary packaging)	pieces		0,1	350000	15	12,5
-Label (pallets)	pieces		0,2	50000	4	60
-Glue (straw)	kg		45	200	6	35
-Glue (secondary packaging)	kg		30	400	15	15
-Glue (lid material)	kg		50	300	6	35
-Strip	meter		0,5	30000	7	17,5
-Lid	pieces		0,1	100000	60	27,5
-Straw	pieces		0,05	190000	22	12,5

Figure 34: Calculations sheet in the cost estimation model for Company X.

7.7 Results

The cost per activity and material is displayed in the Results sheet. The individual activity costs are then summarised in the *Total cost per 1000 units* column, which is the same information presented in the Dashboard. An example of the Results sheet can be seen in figure 35.

MATERIAL	External		Internal							Sum	
	External storage cost per 1000 units	Cost of capital per 1000 units (external storage)	Internal storage cost per 1000 units	Cost of capital per 1000 units (internal storage)	Receiving and inbound loading cost per 1000 units	Picking and outbound loading cost per 1000 units	Management cost per 1000 units	Administration cost per 1000 units	Costs for other activities per 1000 units		Cost of disposed goods per 1000 units
-1 liter primary	1,3	1,9	1,3	0,7	1,2	2,3	0,7	0,1	0,1	1,0	10,5
-0.20 liter primary	0,4	1,4	0,5	0,5	0,3	0,6	0,2	0,0	0,0	0,5	4,3
-1 liter primary			0,6	0,3	1,2	2,4	0,7	0,1	0,1	1,0	6,5
-Corrugated board			9,4	0,3	17,2	34,3	9,8	1,7	1,7	1,0	75,4
-Stretch film	118,4	98,6	112,2	32,9	51,5	102,9	29,4	5,1	5,1	24,0	580,1
-Top sheet	59,2	47,3	84,2	23,6	51,5	102,9	29,4	5,1	5,1	23,0	431,3
-Label (secondary)			0,2	0,2	0,1	0,2	0,0	0,0	0,0	0,1	0,8
-Label (pallets)			6,7	1,6	0,5	1,0	0,3	0,1	0,1	0,2	10,5
-Glue (straw)			982,0	215,8	128,6	257,3	73,5	12,9	12,9	45,0	1727,9
-Glue (secondary)			221,5	61,6	67,7	135,4	38,7	6,8	6,8	30,0	568,5
-Glue (lid material)			736,5	239,7	96,5	192,9	55,1	9,6	9,6	50,0	1390,1
-Strip	0,9	0,9	3,4	1,2	0,9	1,8	0,5	0,1	0,1	0,5	10,3
-Lid	0,7	0,5	1,5	0,4	0,3	0,5	0,1	0,0	0,0	0,1	4,2
-Straw	0,3	0,2	0,4	0,1	0,1	0,3	0,1	0,0	0,0	0,1	1,6

Figure 35: Results sheet in the cost estimation model for Company X.

7.8 Assumptions and delimitations of the model

The following assumptions and delimitations were made during the construction phase of the cost estimation model:

- Since return flows are delimited from the thesis, the number of pallets received is assumed to be the same as the number of pallets sent to production subtracted with the amount of pallets disposed.
- The only waste cost that is included is the cost of lost goods value (i.e. the purchase price) since it has shown to be difficult to estimate how much of each material is wasted and the weight of this, as well as the time it takes to handle waste. Handling costs of disposed goods are therefore not included.

- All materials are assumed to be handled using pallets, since the cost for all activities are calculated per pallet.
- The cost of pallets is not included due to the fact pallets are not considered consumable goods but are instead reused over and over again. Further, the cost of pallets is difficult to allocate correctly to material inventory specifically since they are also used in production and finished goods inventory.
- It is assumed that electric forklifts are used, since the model is to be used within the food industry. For this reason the *List of forklifts* sheet only includes electric forklifts.
- The data collected during the case studies and used to construct the general model are based on annual values.

7.9 Limitations of the model

The cost estimation model is based on three case studies and can therefore not be used to draw statistically significant conclusions. However, since the model is to be used within the same context as the conducted case studies, chances are increased that the level of transferability is sufficient.

The data used is based both on primary data from the case companies' IT-systems and on estimations made by the interviewees. The latter may affect the model's accuracy negatively. If more primary data would have been available this could have increased the accuracy.

Another limitation of the model is that it calculates the total cost of 1000 units independent of the measurement unit (kilogram, meter, piece) of the material or the length of the consumption period for 1000 units. The requirement of calculating the total cost for 1000 units was given by Tetra Pak, but is also considered to be a limitation by the authors.

Furthermore, since the model does not contain information regarding how many units per material is required for different products (i.e. assembled packages), which means that the model cannot calculate the total material inventory cost for one finished product. This also means that different packaging systems cannot be compared with each other. However, Tetra Pak does possess information on how many units per material is required for different products and therefore the model could be updated by including this information.

8 Conclusions

In this chapter the authors' conclusions based on the study will be presented.

In this chapter, the conclusions from the study are presented, answering to the fourth and last objective of the study.

As mentioned in the literature review, material inventory is a relatively uncharted research area and few papers have been written in the field. The theoretical contribution of this thesis is therefore considered by the authors to be deeper insights to processes and costs that occur in material inventory.

The activities identified at the case companies correspond well with the findings from the theory chapter describing warehousing. However, the size of the impact of the individual activities differs between cases according to the case study results. The authors' original intention was to exclude activities that turned out to have insignificant impact on the total cost, but since no unequivocal outcome was found of which activities should be regarded as insignificant, the original idea of excluding these activities was rejected. If a need arises to add an activity in the model, this could be done either by simply adding the activity to the list or by using the *Other activities* section. If an activity in the model is regarded as unnecessary, the values for this activity could be set equal to zero or the activity could be deleted from the list. The conclusions drawn from the case studies regarding the activities and materials as well as the cost estimation model itself are described below.

A large amount of days in stock has a great impact on total cost. This can especially be observed in the case of Oatly. Even though they have similar or even cheaper purchase prices for some of the materials and/or higher units per pallet ratios they end up having a higher total cost for these materials due to their large number of days in stock.

Receiving and inbound loading is often, according to the case studies, a moderate impact activity while picking and outbound loading is more time consuming and therefore also more expensive. As stated in theory by Bartholdi & Hackman (2011), picking is generally considered as a time consuming and expensive activity corresponding to a major part of the total costs in a warehouse. Despite of this, the case studies have shown great variations of the cost impact from picking.

Management and administration are two other activities where the impacts on total cost vary extensively. The variations in the case studies in this thesis can be derived from the differences in time spent on these activities and whether dedicated management and administration personnel are employed to handle material inventory. Another reason for the variations may be difficulties in estimating the

time spent managing and administrating the material inventory. These difficulties could occur also for the rest of the activities.

The internal rate has shown to play an important role for the total cost. This can clearly be seen when comparing the Oatly case (which has the highest internal rate) to Kiviks Musteri (which has the lowest internal rate), where materials with similar purchase prices, units per pallet ratios, handling costs and average numbers of days in stock tend to be more expensive at Oatly.

The amount of disposed goods has been considered as very low and has therefore not been seen as an important factor when estimating costs by the interviewees at the case companies. Yet, this activity has shown to have a very great impact at two of the case companies. No reliable data on the percentage of disposed goods has existed on any of the case companies and has therefore been estimated by the employees. This could mean that the actual cost of disposed goods could be either lower or higher than estimated by the model, but the results still indicate that this activity possibly will have a large impact.

Internal storage of goods is a very high impact activity in all cases conducted in the thesis. Based on the case studies external storage tends to be cheaper than internal storage per pallet position and time unit. For this reason it may be favourable to use external storage services, especially for materials that are stored for a long period of time. Further, by using an external warehouse with a flexible amount of pallet positions available the companies can achieve a high filling rate and deal with seasonal variance. The cost of using external storage should however be weighed against the cost of the transport between the external and the internal warehouse, which is not included in the scope of this study. Since the goods will pass the activities carried out within the internal warehouse either way, the cost of distribution between the warehouses might lead to a higher total cost for goods with a low number of days in stock.

The number of units stacked per pallet has also turned out to be an important factor when calculating the total cost. A lower amount of units per pallet increases both the handling and storage cost per unit, thus increases the total cost per unit. This can particularly be seen for materials with low turn-over rates which often are stored for a large number of days. Further, materials with a low turn-over rate tend to have a high value per unit which leads to high capital costs.

One reason for the large differences in purchase price per unit, and in the end the total cost, is the usage of different measurement units, for instance it is hard to compare the cost for material measured in kilograms with material measured in pieces or meters. For example, one kilogram of glue will likely not correspond to the

same consumption period as one piece of primary package and therefore the total costs of these will not be comparable. Different measurement units are even sometimes used for the same materials, e.g. for top sheets where one unit (pieces) at Oatly equals to multiple units (kilograms) at Kiviks Musteri. Also the differences, in sizes and shapes, between materials within the same material group decrease the possibilities of accurate comparisons between materials. For example, Kiviks Musteri uses 1.5 liter primary packages while the equivalent material in use at Oatly is 1.0 liter primary packages.

The instructions given by Tetra Pak was not to develop a model that calculates costs for specific periods, but instead to create a model which calculates the total cost for 1000 units independent of the corresponding consumption period. This is however regarded as a limitation of the model by the authors. Furthermore, since the model does not contain information regarding how many units per material is required for different products (i.e. assembled packages), which means that the model cannot calculate the total material inventory cost for one finished product. This also means that different packaging systems cannot be compared with each other. However, Tetra Pak does possess information on how many units per material is required for different products and therefore the model could be updated by including this information.

The cost estimation model is based on three case studies and can therefore not be used to draw statistically significant conclusions. However, since the model is to be used within the same context as the conducted case studies, chances are increased that the level of transferability is sufficient for Tetra Pak's requirements. This assumption is based on the fact that the activities within material inventory at the three case companies are identical or very similar. Furthermore, according to Tetra Pak, the information and data gathered and the structure of the model are appropriate to be used for calculating material inventory costs for their customers. The model might also be applicable in other contexts, although this was not included in the scope of the study and this possibility has therefore not been investigated. The authors believe that the cost estimation model can assist Tetra Pak in getting deeper insights into the costs incurred by their own packages in material inventory, enabling them to increase the value proposition towards their customers.

9 Future work

The final chapter provides ideas and recommendations for future work.

The cost estimation model is based on three different case studies which were performed together with three different companies in the food industry. In order to verify the model and increase its transferability and accuracy it would be of interest to test the model further, both in terms of other packaging systems than the ones examined in this thesis but also in terms of other companies. This would further allow for the possibility to draw general conclusions, since the risk is that the three case studies are not representative of all cases and that other important cost factors might exist that are not presented in the model. This statement does not imply that the work is lacking reliability for this specific project but rather the possibilities to generate statistically reliable results. By conducting more case studies in the same industry it would be possible to discover more similarities and differences between companies within the food industry. For the same reason it would also be interesting to study companies outside the food business to see if the findings in this thesis could be used in other contexts and if the relative impact of the cost categories differs between different industries or if they would remain almost the same. For future work however, it may be worth trying to find a better and more comparable alternative than to compare 1000 units of each material as this often gives misleading results since 1000 units of various materials correspond to different consumption periods.

During the authors' visits to the sites, all case companies expressed a need for a better understanding of material inventory costs in order to achieve higher efficiency and lower their costs. For this reason it would be interesting to investigate further the possibilities to use the results from this thesis to optimise the different packaging systems and the activities connected to them. Since the purpose of this thesis was to investigate where the costs were incurred and the magnitude of them rather than exploring possible cost saving opportunities, we think that the findings from this project could be a good starting point to find possible improvements and lower the costs related to the packaging system. Investing these types of possible improvements could be a suitable project for another master thesis.

Further it would be interesting to compare the results from this study with cost aspects from other parts of the supply chain. For instance how does the cost allocation in raw material inventory differ from the one in the finished goods inventory? And how do the packaging-related costs that occur in the warehouse differ from other parts of the supply chain? A supply chain is a complex system where several aspects must be taken into consideration to achieve efficient and cost effective solutions. This is something that must be investigated further before initiating an improvement program based on the findings in this study in order to

avoid sub-optimisation elsewhere in the supply chain. This is also aligned with the fundamental ideas of packaging logistics, combining logistics with packaging in order to achieve an enhanced holistic view.

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11 Appendix A: Manual for *Cost Estimation Model*

Colour codes for cells

Different colour codes are used in the cost estimation model depending on the type of data used in the specific cell. The colour codes can be seen in *figure 36*.





	Input data – These cells require the user to input data (please see below for optional data input)
	Linked cell – These cells are linked to other cells and are not to be changed by the user
	Calculation - These cells contain calculations formulas and are not to be changed by the user
	Result - These cells contain results calculations and are not to be changed by the user

Figure 36: Colour codes used in the cost estimation model.

Seven individual sheets

The model contains seven Excel sheets according to:

1. Dashboard
2. Input materials
3. Activities
4. List of materials
5. List of forklifts
6. Calculations
7. Results

Below is a description of the individual sheets and the logical flow between them.

Dashboard

This sheet displays the main results *after* all data input have been inserted in the following sheets.

Input materials

In this sheet the user fills out data on internal and external parameters per material type:

Quantity purchased (annual)

- Delivery interval to external warehouse (number of days between deliveries)
- Safety stock in external warehouse (days)
- Delivery interval to internal warehouse (number of days between deliveries)
- Safety stock in internal warehouse (days)

The data is used as input in the sheet 'Results' to calculate the cost for the various activities for 1000 units per material type.

Activities

The data to be inserted in this sheet is *not* to be specified per material type but per activity:

- **Universal input:** Information that is used for the cost estimation of several of the activities.
- **External storage of goods:** Calculates the cost of storing goods at an external warehouse.
- **Receiving and inbound loading of goods:** Calculates the cost of receiving and the inbound loading of goods.
- **Internal storage of goods:** Calculates the cost of storing goods at an internal warehouse. Consist of the following:
 - **Rental, depreciation and maintenance:** Costs for the physical warehouse and racks and the maintenance of these, forklifts, computers and IT-system and other rental, depreciation or maintenance costs.
 - **Energy consumption:** Costs for heating, general electricity consumption and forklifts electricity consumption
- **Picking and outbound loading of goods to production:** Calculates the cost of picking and the outbound loading of goods to production
- **Material inventory management costs:** Calculates the cost of management, i.e. the costs incurred by the time used by management on managing the material inventory.
- **Material inventory administration costs:** Calculates the cost of administration, i.e. the costs incurred by the time used for administrative

tasks such as registration of received goods and registration of goods sent to production.

- **Other activities in material inventory:** For the model to be general, the user may here insert time use and labour cost for other activities occurring in his or her material inventory than the ones listed above.

For each activity, the cost per pallet or the cost per pallet position per day is calculated. This information is used as input in the 'Results' sheet to calculate the cost per 1000 units per material type.

List of materials

The data contained in this sheet does not have to be changed, unless the user wishes to change it. The data is per material type and the sheet contains:

- Unit (pieces, kg or meter)
- Purchase price per unit
- Currency
- Quantity per pallet
- Type of carrier

The data is used as input to calculate the cost of capital for internal and external storage per material type in 'Results'.

List of forklifts

The data contained in this sheet does not have to be changed, unless the user wishes to change it. The data inserted in this sheet is linked to the sheet 'Activities', where the user can select a *type* of forklift, *how many* entities of this type of forklift are in use and for *how many hours* this type of forklift is in use per day. Hereafter the amount and cost of electricity for running this type of forklift are calculated. The data contained in the sheet 'List of forklifts' is per forklift type:

- Voltage (Volt)
- Current (Ampere)

Which after multiplication give us:

- Power (Kilo Watt)

Calculations

This sheet requires no input of data. 'Calculations' calculates the following per material type:

- Number of pallets (annual)
- Average number of days in stock in external warehouse
- Average number of days in stock in internal warehouse

The output of these calculations are thereafter used as input in the calculations of the results in the 'Results' sheet.

Results

This sheet requires no input of data, but calculates and displays the following results per material type according to the input in the previous sheets:

- External storage cost per 1000 units
- Cost of capital per 1000 units (external storage)
- Internal storage cost per 1000 units
- Cost of capital per 1000 units (internal storage)
- Receiving and inbound loading cost per 1000 units
- Picking and outbound loading cost per 1000 units
- Management cost per 1000 units
- Administration cost per 1000 units
- Costs for other activities per 1000 units
- Cost of disposed goods per 1000 units

The above stated costs are then summed per material type into:

- Total cost per 1000 units

12 Appendix B: Case study protocol

Purpose

The purpose of this project is to develop a material inventory cost estimation model limited to material inventory, for packaging used for liquid food and beverages, which is able to predict the total cost of handling and storing 1000 units of various packaging materials in material stock.

Objectives

1. Identify and define the process undertaken in material inventory.
2. Map the process to visualise and create an understanding of the material flow.
3. Develop a general cost estimation model.
4. Draw conclusions from the findings of the study.

Field procedures

- Map the process.
- Individual and group interviews:

Name	Position	Previous positions	Number of years in the company

- Collect data from IT-systems and other relevant sources.

Case study questions

The focus of the case study is to investigate the storage cost of material in material inventory. We are going to exemplify this with two products, as a suggestion the two largest products in terms of sales volume. We define *packaging systems* as primary packaging, e.g. Tetra Brik Aseptic, together with secondary- and tertiary packaging linked to this product. Further, we define *material* as the all materials that are parts of the packaging system, that is to say both the material used for the primary packaging as well as the material used for the secondary- and tertiary packaging, e.g.

corrugated cardboard for the secondary packaging and stretch film for the tertiary packaging.

For the questions below that deal with quantitative aspects we would be thankful to receive data for these, preferably for at least a year in order to be able to make an overall assessment of the annual material flow.

Packaging material

- Which materials for aseptic packages do you store in the material inventory?
- Which materials are input of each product (i.e. which materials are included in primary-, secondary- and tertiary packaging for each product)?
- Type of input for each material (i.e. kg, pieces, metres etc.)?
- What size is the average order for each material?
- Quantity of each material per pallet?
- What type of pallet is used for each material?
- Season variations for different products?
- Queuing system used (FIFO, LIFO)?
- Purchasing price for each material (i.e. the price for material in primary-, secondary- and tertiary packaging for each product)?

Receiving of goods

- How many employees work with receiving and quality control?
- How long time do these activities consume on average?
- What is the hourly or monthly rate of these workers?
- How many pallets, containing the materials stated above, arrive on average each time?
- How many units of each material go through quality control?
- Are there any administrative or managerial costs linked to the receiving of goods and quality control?

Inbound loading of goods (after quality control until material is placed at its position in the warehouse)

- How many employees work with inbound loading of goods?
- How long time does the inbound loading consume on average?
- What is the hourly or monthly rate of these workers?
- Are there any administrative or managerial costs linked to the inbound loading of goods?

Storage

- Which internal rate is used to calculate the accumulation of capital?
- What is the average storing period for each material?
- How many square meters is the material inventory?
- How many square meters of storing area is there in the entire warehouse?
- What percentage of the total warehouse area is dedicated for storage of the above stated materials?
- How many pallet positions are available?
- How many pallet positions are used by the above stated materials on average?
- Average filling rate in material inventory?
- How are pallets stored (on the floor vs. in racks)?
- What percentage of the pallets are handled more than once and how long time does this consume?
- Are dedicated or flexible pallet positions used?
- What is the hourly or monthly rate of the storage personnel?
- Are there any administrative or managerial costs linked to the storage of goods?

Loading (to production)

- How many pallets are sent to production on average each week containing the above stated materials?
- How many pallets are sent to production in total each week?
- How many workers are working with the loading of goods?
- How long time does the loading of goods consume on average?
- What is the hourly or monthly rate of these workers?
- How long time do the pallets stay on the loading area on average?
- Are there any administrative or managerial costs linked to the loading of goods?

Disposal

- What is the amount of disposed units for each material?
- What percentage do each material constitute of the total amount of disposed goods, including the reason for disposal and at what activity this occurs?
- Are there any administrative or managerial costs linked to the disposal of goods?

Waste handling

- What is the average weight of waste?
- What is the cost per kilo gram to handle waste?
- How much time does waste handling consume for internal labour?
- What is the hourly or monthly rate of these workers?
- Are there any administrative or managerial costs linked to the waste handling?

Indirect and other costs

- How many forklifts and other handling machinery are used in material inventory?
- What is the operational cost of forklifts and other handling machinery in material inventory (fuel and service)?
- What is the depreciation or rental cost for forklifts and other handling machinery?
- What is an appropriate way of allocating costs between FVL, production and material inventory, in case the forklifts and other handling machinery are used in more than material inventory?
- What are the electricity costs for the material inventory? How to allocate costs if electricity consumption is not separated on the invoice?
- What is the depreciation cost of rental cost of the material inventory?
- What is the maintenance cost for material inventory?
- Other administrative or managerial costs linked to material inventory?
- Do you have more activities than the above stated (receiving/quality control, inbound loading, storage, loading) that affect the costs for running the material inventory?
- Other costs?