Linnæus University
Sweden

Master thesis in Business Process Control and Supply Chain Management (15 credits)

Logistics driven packaging for efficient and sustainable road freight

A case study on a global export company

Authors: Elisabeth Salenborg, Robin Persson, Samuel Shirpey

Supervisor: Petra Andersson
Examiner: Åsa Gustavsson
Semester: Spring 2020
Course code: 4FE25E
Date: 2020-05-28

Linnæus University
Sweden

Abstract

Packaging plays a crucial role in logistics as it has a significant effect on the efficiency of transportation. The shape and dimensions of packaging material has considerable impact on transport performance, whereas an optimal packaging system for products enables for improved utilization of the total volume on a load carrier. As a result of improved freight performance, transportation costs can be reduced. Improved vehicle utilization for shipments also has a positive impact on environmental aspects, as increased vehicle fill rate can lead to less required transports which ultimately lowers the overall carbon emissions caused by transports. Therefore, an optimization of the packaging model can lead to substantial benefits, both economically and environmentally.

The purpose of this study was to create a cost estimation model for the company Machine Corporation that would illustrate what effects a new packaging strategy would have on transportation costs, fill rate and environmental aspects. To achieve this purpose, relevant data have been collected from the company together with suitable metrics found in the literature. The collected data was thereafter used to create a cost estimation model that served as a tool to determine the total costs and the potential savings. The outcome results of the model showed that Machine Corp. would have made a yearly saving of 2 341 353 SEK. The implementation of a new packaging strategy was estimated to increase the volume-based fill rate for truck loads by approximately 54% which enabled for a reduction of transportation costs by 32%. Furthermore, the results showed a positive impact on environmental aspects as the total amount of road freight shipments needed per year was estimated to reduce by 32% as well and the total tonnes-km per year would decrease by 31%.

Keywords: Environmental impact, fill rate, packaging, road freight, transportation, vehicle utilization

Acknowledgements

This thesis represents our final work and last part of the Masters Programme in Business Process Control and Supply Chain Management at Linnaeus University. The thesis corresponds to 15 credits and has been conducted at the Department of Management Accounting and Logistics.

There were many people involved in the process of writing this thesis that made our experience more enjoyable. We would like to thank everyone and express our gratitude to those who made the study possible. First and foremost, we would like to thank everyone involved at the case company for giving us the opportunity to take on this project and for giving us their support during the whole study. Furthermore, we would like to send a special thanks to Roger Stokkedal at Linnaeus University who guided us through extensive data management. At last, we would like to thank our supervisor Petra Andersson for her insightful feedback through the course of the study.

Elisabeth Salenborg, Robin Persson & Samuel Shirpey, May 2020.

Table of contents

List of figures

List of tables

List of abbreviations

CE	Central Europe
DC	Distribution Centre
EMS	European Modular System
FTL	Full Truck Load
LDM	Loading Meter
LTL	Less Than Truckload
OECD	The Organisation for Economic Co-operation and Development
MT	Metric Tonnes
SW	Sweden

1 Introduction

In this chapter a background of the theoretical concepts will be provided. The background will provide a foundation for the research questions and will start by discussing the need for green logistics and the role of packaging and vehicle fill rate. The research problem will be discussed by identifying the gap in research on the effects of packaging and fill rate in transportation efficiency. In the end of the chapter, the purpose, delimitations and disposition of the thesis will be presented.

1.1 Green logistics

Climate change and an increasingly deteriorating environment is pressuring firms to reduce their environmental impact and today many global organizations work with sustainability aspects as a part of their business strategy. There has been a growing trend in research and practice that addresses the development of green logistics operations, due to the fact that the transport sector accounts for the fastest growing source of greenhouse gas emissions (Nilsson et al., 2013). Many shipping firms have responded to the environmental concerns by embracing practices for greener shipping. These practices relate to resource conservation and waste reduction in regards to handling and distribution of shiploads (Mariano et al., 2016). Common actions are to count the carbon footprints for shipping routes and replace existing transport equipment with other alternatives that have a lower environmental impact. Road freight in particular plays a significant role in regards to the growing CO2 emissions, and some of the large hauliers and express carriers like DHL, UPS, TNT and FedEx, have developed various programs to face the environmental challenges in the industry. These programs aim to expand the movement for greener logistics from big actors to less developed markets and countries. Arvis et al. (2014) sees logistics performance as an increasingly important and complementary aspect to sustainability and therefore, there is a great need to assess the CO2 emissions in the transport industry.

A large contributor to the negative environmental impact in the transport sector is low fill rate in vehicles and load carriers. The problem often arises in low stackability of goods or poor design of packaging material, which reduces the overall weight and volume utilization of transports. Hellström & Nilsson (2011) describes that packaging materials' have a large effect on logistical processes when it comes to environmental impact and do not only affect financial aspects for companies, in terms of material and material handling costs related to the packaging of products.

1.2 The role of packaging and vehicle fill rate

The role of packaging in logistics and supply chains is vital, and will influence the economic and environmental performance of a supply chain. From a logistics perspective, packaging influences every logistics activity, such as the efficiency of warehousing and transportation. The shape and dimension of packaging will affect cube utilization in transports, hence environmental performance can be measured from how well companies utilize sustainable packaging decisions (Pålsson et al., 2013). In the face of the ongoing climate change, sustainability continues to receive a lot of focus and there is a lot of pressure for companies producing and using packaging, to consider optimizing the packaging systems. As packaging plays a crucial role in supply chains, an optimization of the packaging model can lead to a substantial decrease in emissions (Laia et al., 2008).

Road bound truck freight remains the most used transport mode in Europe and the sector also accounts for the largest environmental impact in terms of CO_2 emissions (Swedish Transport Agency, 2011). Fill rate optimization and load consolidation has the potential to reduce carbon intensity and reduce the negative environmental effects. Fill rate refers to space utilization, specifically considering volume and weight efficiency. The fill rate measure refers to the ratio of the actual amount of goods carried on transport compared to how much that could have been carried (Piecyk, 2010; McKinnon, 2018). In order to achieve higher fill rates in general, companies have to find an arrangement to which a larger proportion of space in transports are utilized. This will in turn contribute to sustainable development as companies continue to strive to reduce ecological footprint, as well as economic benefits as a result of increased transportation efficiency. Previous research shows that there are significant implications related to both fill rate and packaging systems, thus the role of the two factors are highly relevant for research purposes (Hellström & Olsson, 2017).

1.3 Problem discussion

The selected case company has requested to remain anonymous for the study, which means that specific information that can compromise their anonymity will be considered confidential. The company will therefore be referred to as “Machine Corp.” throughout this study.

Machine Corp. delivers products to customers located all over Europe. Insights drawn from the company indicates that there is a need to optimize the transport utilization for shipments, in order to increase transportation efficiency, customer satisfaction and reduce environmental impact. Today, the products shipped from Sweden to Europe do not have any tertiary packaging arrangement, instead they are only mounted onto pallets. Although this approach is cost effective in regards to a lower budget required for packaging of products, it has resulted in a wastage of the truck space for shipments, as the fill rate is not optimized. Therefore, the ambition of Machine Corp. is to implement a new packaging system that has the potential to increase the fill rate for road freight transports. The aim is to customize packaging to enable stacking of shipped products, thus increasing the volume utilization of the load carriers. Further benefits the company sees with a new packaging system is increased customer satisfaction as a result of the products being more protected during transportation, as well as a decrease in carbon emissions as higher vehicle fill rate can enable for less shipments required, hence mitigating the environmental impact. However, the implication of adopting a new packaging system will be reflected in significantly increased costs for packaging materials and additional labour costs related to the packaging process.

Gustafsson et al. (2005) has shown that companies have successfully reduced the number of trucks/shipments by redesigning their packaging and as a result achieving more efficient transportation. The choice of packaging influences the load factor and fill rate, as shapes, dimensions and stackability are reflected in the vehicle utilization (Pålsson et al., 2013; Edwards et al., 2010). However, the fill rate concept can be looked at from different perspectives, both economic and physical, and from different viewpoints of companies, customers, government and the general public - which has led to a large diversity in the perception and measures of fill rate. There is currently no standardized measure for calculating the fill rate that could be applicable in all situations, instead it is dependable on the specific situation and goal with the measure. Santén & Rogerson (2018) provides a detailed study regarding fill rate which includes empirical measures based on volume and weight for road freight, but most research only consider fill rate as a part of general logistics performance measures and does not provide further details (Lama & Schofer, 2019; Lai et al., 2004; Mentzer & Konrad, 1991). To clarify the perception of fill rate for this study, the term will refer to the fullness of the vehicle, in other words available loading capacity compared to used loading capacity.

Despite the crucial importance of packaging and fill rate in transportation efficiency, there is lack of research in this area. The studies mentioned above have investigated either the role of packaging or fill rate in logistics, but no empirical studies have been found that explores implementation of a new packaging system to improve vehicle fill rate. Furthermore, few studies take into consideration the costs of improving packaging and fill rate. Therefore, this study aims to bridge the gap between practical and academic research regarding the interplay between packaging and fill rate - considering both physical and economic impact.

1.4 Purpose

The purpose of this paper is to create a cost estimation model that will illustrate what effects a new packaging strategy will have on transportation costs, fill rate and environmental aspects. This will be achieved by answering the following research question and sub-research questions:

RQ: What are the cost implications and potential savings of adopting the new packaging strategy?

SRQ1: How does the new packaging strategy affect vehicle fill rate?

SRQ2: How does the new packaging strategy affect environmental aspects?

1.5 Delimitations

The scope of the study was delimited to cover shipments for the European market only, since non-European shipments already have a packaging model. As Machine Corp. is a global company that operates all over the world, the study will only cover data for two specific locations, the distribution sites in Sweden and Central Europe. As Machine Corp. has a broad product portfolio with many different dimensional characteristics, the scope of study was limited to only cover packaging of the five most shipped products on the European market.

1.6 Disposition

Introduction
- This section presents the setting of the study. Firstly, the subject is presented followed by a problem discussion where the case study company is introduced. Thereafter, the purpose and research questions are presented followed by delimitations and the disposition of the study.

Method
- This section presents the methodological choices, case study design, data collection and data analysis used in order to answer the purpose and research questions of this thesis.

Theoretical framework
- This section presents a literature review of the four main focus areas of the study; road freight transportation, fill rate, packaging and the connected environmental aspects.

Case company
- This section presents the reader with a background of the company and important knowledge of the logistics processes of the company. Furthermore, the main focus areas of the study are presented with more detailed data.

Cost estimation model
- In this section the cost estimation model is presented, which was constructed based on the theoretical and empirical findings. The model's main features and including metrics are described, and lastly the limitations are discussed.

Results and analysis
- In this section, the findings from the case study and the cost estimation are presented and analyzed. All the calculations for packaging, fill rate, transport costs and environmental impact are explained and the outcome results are presented.

Discussion
- This section contains a discussion about the findings of the study, where the results are more closely compared to the theoretical framework Furthermore, limitations with the scope of the thesis is discussed followed by a discussion about opportunities for future research.

Conclusion
- This section presents the concluding remarks of the thesis and answers the research questions.

2 Methodology

In this chapter the methodological choices of the study are explained. Firstly, the research process is presented which describes our approach of study. The thesis was conducted through a deductive approach and a single case study in order to provide an in-depth understanding of the identified research gap and company problem. Furthermore, collection of data, data analysis and research quality will be described and discussed.

2.1 Research process

The main purpose of this study is to investigate what effects a new packaging strategy would have on vehicle fill rate, transportation costs and environmental impact. Considering the purpose, the process of this study is reflected in figure 2.1. and the research was performed accordingly.

The first step is the selection of research, where the authors were given access to a company project. Then the research questions were formulated to suit the objectives of the project, which resulted in one main research question followed by two sub questions, mentioned in details in section 1.4. After clarifying the research topic, the research method and strategy was established. Thereafter, primary and secondary data was collected. After that, all presented data was analysed with the help of a cost estimation model - which ultimately led to the concluding remarks of the study.

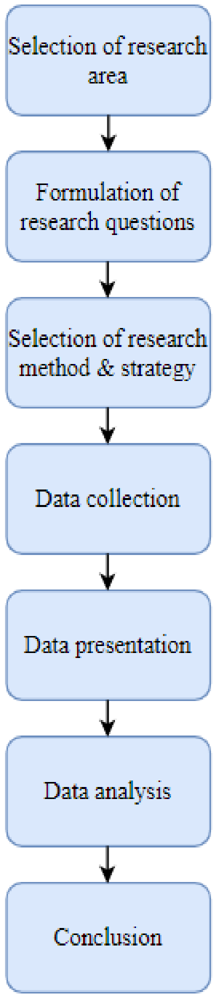

Figure 2. 1: The research process

2.2 Research approach

When conducting a research, it is essential to state the worldview of the authors, because this will naturally influence the study. Creswell (2014) highlights *postpositivism*, *constructivism*, *transformative* and *pragmatism*, which are widely discussed in the literature. The main approach of this study and the author's set of beliefs can be reflected in the pragmatism view. Pragmatists can be characterized by emphasizing the purpose and questions of the research by using all available approaches to understand the problem. The research looks for different approaches for collecting and analysing data, rather than restricting to a single approach (Creswell, 2014). This study aims to solve a company problem which required the authors to collect and analyse both quantitative and qualitative data.

In order to answer the research questions, a theoretical framework has been constructed based on an extensive review of literature, to enable for collection and analysis of data. According to Bryman (2018) the relation between theory and practical research is decided by three different approaches, *deductive*, *inductive* or *abductive*. This study will align with the deductive research approach which represents the most common view about the relationship between theory and practice in social science (Bryman, 2018). The characterization of the approach is that the theoretical framework dictates the research. General theories and previous empirical findings are used in order to draw conclusions based on an individual case (Ahrne & Svensson, 2015).

2.3 Research method

A distinction is often made by researchers between two types of research methods, qualitative and quantitative, and the selected method should be based on research questions and purpose of the study (Bryman, 2018). However, the nature of the company problem and the necessity of a pragmatism view, allows the study to be conducted through a mixed research method. A mixed research method is typically characterized by combining elements of qualitative and quantitative data (Johnson et al., 2007). A mixed approach integrates or links the two forms of data in tandem by embedding one within the other, or by having one build on the other

(Creswell & Plano Clark, 2007). The purpose of this study is to examine if the incorporation of a new packaging strategy is economically viable. Thus, the approach of this study requires collection and analysis of qualitative data in order to understand the subject problem. Furthermore, collection and analysis of quantitative data is required in order to calculate and visualize if the investment is financially sustainable.

2.4 Research strategy

When conducting a study there are different research strategies that can be used and the most common according to Bryman (2018) are surveys, case studies and experimental investigations. Research strategies focus on different frameworks and bases for collecting and analysing data. A research strategy is thus a reference frame for the generation of evidence that is chosen to answer the research questions of the paper. This study will investigate a specific company case and will therefore be conducted through a case study.

According to Collis & Hussey (2014) a case study is defined as a "methodology that is used to explore a single phenomenon (the case) in a natural setting using a variety of methods to obtain in-depth knowledge". The case study is usually associated with qualitative research methods, in regards to unstructured interviews and observations. However, case studies often involve the application of both qualitative and quantitative methods. Furthermore, the case study aims to elucidate the specific case in a detailed way - and that distinction is what enables the research strategy to be differentiated from any other approach. Therefore, the case study is appropriate for our research, since the objective is to solve and explain a specific company problem.

2.4.1 Case study design

According to Collis & Hussey (2014) there exist different forms of case studies, and this paper will be constructed through a mix of a *constructionist case study* and an *opportunist case study*. The former is performed by researchers who can be seen as constructionists and the aim of the research is to provide "a rich picture of life and behaviour in organizations or groups"

(Easterby-Smith et al., 2018). This type of case study takes advantage of interviews and observations to provide insights in the unit of analysis. Opportunist case studies often arise when there is an opportunity to examine a phenomenon because the researchers have access to a specific company, business, person or other case (Collins & Hussey, 2014). A case study can as well be conducted either as a single or multiple case study (Yin, 2003). This study has the ambition to explain a unique case and will therefore be conducted through a single case study to create an in-depth understanding of the concepts and the outcome of the results (Merriam, 2002).

The use of case studies has had several criticisms, the main concern is the limited ability to generalize the findings and outcomes. Moreover, the use of single case studies has the potential to lead to biased views that will influence the outcome of the study (Merriam, 1998; Yin, 2003). The authors of this paper are fully aware of these criticisms and in order to get a holistic view to a relatively specific problem situation, the authors will not exaggerate or simplify any of the elements. The use of three authors also will minimize the risk of generalizing, as interviews and data collection conducted by three people ensures that there is different perspective and that a high degree of rigor is attained throughout the study.

2.4.2 Selected case company

The selected case company is a global technology actor that operates in about 400 locations in more than 50 countries. They have a large portfolio of products and also provide services to their customers such as installation, support and maintenance. Machine Corp. considers themselves to be one of the market leaders in their industry and they employ approximately 17,000 people across the world. As Machine Corp. is such a big organization, the scope of this investigation has been limited to only cover two of the 400 locations, which consists of a manufacturing site in Sweden and a distribution terminal in Central Europe. The thesis topic originated from a subject in need of investigation which was identified by Machine Corp. As a result of this, the authors were requested to conduct a study regarding the subject. The company was potentially evaluating to introduce a new packaging strategy for the European market, but lacked resources to support the investigation. Stakeholders in the company were keen on finding out the potential benefits that a new packaging strategy could result in.

2.5 Data collection

The data collection consisted of primary data that was collected through interviews and observations of the packaging process. The secondary data consisted of statistics from the Company databases. The interviews were a part of the preliminary investigation, where the project scope and all necessary information was presented by the company. Although, further interviews were also conducted by the authors during the course of the study to gather necessary inputs and information from people within the company (Bryman & Bell, 2017). In terms of the secondary data collection, the company provided the authors with an Microsoft Excel file consisting of 2019 years total shipped quantity for the five products included in the project scope. Due to the complete accessibility, a non-disclosure agreement was signed by the authors which ensured that the company's internal data would not be shared with external parties.

Observations

Observations can be carried out in different ways, namely qualitative and quantitative (Saunders et al., 2016). In the case of this study, the observations were made in order to collect quantitative data. In order to determine the labour cost and the total packaging cost, it was necessary to measure the time it took to complete the packaging process of the products included in the scope, which was done by one of the authors together with the warehouse employees. During the observations, the employees performing the specific tasks were also subject for unstructured interviews in order to gain a better insight of the packaging process.

Interviews

Interviews are a useful method for collecting data (Merriam, 2009) and in our case, the information provided from the interviews were important in terms of understanding and formulating the study subject. Due to the non-disclosure agreement signed with the company, the company requested to remain anonymous and therefore the semi structured interview and corresponding responses will not be provided. When conducting the semi-structured interviews, the authors prepared formulated questions that gave the interviewee freedom to develop their answers and speak in detail and elaborate their answers (Denscombe, 2010). During the interviews, academic terms were operationalized to ensure that the interviewees understood the various supply chain terminologies and hence attain the right answers to the questions. The interviewees were carefully selected and had different positions in the company: Transportation manager, strategic buyer, project manager, and shop floor staff dealing with packaging of the products. During the interviews, quantitative data was also analysed together with the company based on the weekly output results provided by the authors.

Data from secondary sources

The authors were given complete access to the data necessary for the project scope. As previously mentioned, the secondary data provided from the company originated from their databases. The following data was included in the Microsoft Excel file given to the authors:

Data	Specifications
Total shipping volumes for the five products included in the project scope	Including total quantity, total loading meter (LDM) and total weight.
Pricing list for European shipments	Including the total chargeable weight for 2019 and price per/kg for each country in EU
Complete list of all packaging types (modular boxes)	Including LDM, dimensions and procurement prices for each box type

Table 2. 1: Secondary data specifications

The shipping volume and price list included data from both the Sweden site and Central European distribution terminal. The freight pricing list can be found in appendix 2. All the secondary data provided was essential for the project scope and enabled the authors to perform all the calculations necessary.

Literature review

The other source of secondary data used in the thesis consisted of scientific articles, literature together with various reports and documents that encircled our project scope and thesis purpose. Since the scope of the study object is directed towards a specific field of area, the secondary data used in this study has been carefully reviewed to ensure a high level of quality (Kothari, 2004). However, the literature search started with a wide approach to later be narrowed as the purpose of the study became clearer to the authors.

The literature review and theoretical framework was conducted by searching for scientific articles using the databases Google Scholar, LNU OneSearch and Business Source Premier. To ensure a high level of quality of the data in accordance with Merriam (2009), all searches were filtered to only cover scientific journals and publications. The ambition was to gather the most recent publications to keep up to date with recent literature findings, however our search field included a fair amount of sources that were applicable regardless of publication year. The keywords used in the literature search were the following: *Packaging logistics, packaging optimization, tertiary packaging, fill rate, vehicle utilization, road freight performance, road freight pricing, environmental impacts of logistics, environmental impacts of transportation.*

2.5.1 Summary of data collection

Table 2.2 below summarizes all interviews and observations during the study. In the first initial meeting with the company, the different stakeholders were informed of the project scope. Resources within different roles of the company were then assigned to ensure that every stage of the process was well represented.

Week	Stage	Goal	Department representative	Interview type
13	Pre-study	Briefing on transport figures and the case	Transport manager	Unstructured
14	Pre-study	Briefing on packaging models, pricing, material types	Strategic buyer	Unstructured
15	Case study	Review of the packaging process	Project manager	Observation
16	Case study	Project meeting to review the proposed cost model	Transport manager	Unstructured
17	Case study	Present final cross-matching for modular boxes and products	Project manager	Unstructured
18	Case study	Observation of packaging times and estimation on fill rates	Shop floor staff (outbound distribution)	Observation / Semi-structured
19	Case study	Follow up meeting on SW distribution costs	Transport manager	Unstructured
20	Case study	Follow up on CE distribution costs	Transport manager	Unstructured
21	Case study	Follow up meeting on packaging prices	Sourcing manager	Email
22	Case study	Presentation of the cost estimation model	All representatives	

Table 2. 2: Interviews and observations conducted during the case study

2.6 Data analysis

Data analysis is the process of research when the authors examines, cleanses and discovers which data to be used in the study (Bryman & Bell, 2017). This study used *pattern matching* as an analysis tool, which is a system where researchers can expect a certain outcome or result depending on the theoretical choices (Cao, 2007). In this case, the expected result was that the adoption of a new packaging strategy would lead to substantial benefits, as stated in the literature.

Furthermore, data triangulation was achieved through collection of data from different sources, in terms of the interviews, observations and secondary data of the study. According to Yin (2009) this minimizes the risk of bias and establishes validity. The analysis of the secondary data was mostly done by using Microsoft Excel which later were extracted and included in the paper. The quantitative analysis involved four different categories of data, namely packaging costs, transportation costs, fill rate and environmental metrics. In appendix 1, an extraction from the calculations made in Excel are presented to give an example of how the measures were conducted for packaging and transportation costs.

Packaging costs

In order to evaluate the effect of additional packaging operations, the cost for packaging material and labour were analysed. Furthermore, each different product dimension was grouped and cross-referenced into two main groups of packaging material, namely modular boxes made of either *plywood* or *cardboard*. There were 13 different types of modular boxes and each specific type had an individual price. When the total quantity of all products were matched against a suitable modular box, it was possible to establish a total cost for packaging material. Moreover, the time it takes to package each product on a modular box was also taken into consideration. The cardboard and plywood boxes required different packaging operations and therefore the packaging time varied. The time measures were established through observations, as mentioned earlier. The total packaging costs for both material and material handling could then be calculated.

Transport costs

The main determinant for the transportation costs, was to calculate the estimated fill rate increases that would be enabled by the modular boxes. The company established estimations on increased fill rates based on their non-European shipments that already included packaging with the same type of modular boxes. The proposed degree of fill rate provided by the company was then used to determine the reduction in LDM per product with corresponding modular box. The new LDM per modular box and product was then taken into consideration when determining the new chargeable weight, which is a determinant when calculating freight prices. The new chargeable weight was then applied to the existing price per/kg negotiated with the haulier (displayed in appendix 2). This calculation was applied to the total volume of 2019 for the shipped products, which ultimately showed the new total transportation cost.

Environmental impact

In order to evaluate the environmental effects of the new packaging strategy, the number of vehicles needed to ship the new amount of LDM were calculated. Furthermore, the most trafficked route between SW and CE terminal was investigated to determine the difference in tonnes-km travelled. As the total LDM was reduced as a result of the estimated fill rate increases, fewer vehicles would be needed for shipments on this route. Due to data complexity, only one route was chosen, however the selected route accounted for 45% of the products total volume shipped during 2019. The specific calculation for tonnes-km is explained in later parts of the study.

2.6.1 Model creation

Based on the above explained aspects, a cost estimation model was created to evaluate the costs and potential savings of adopting of a new packaging system, which included all the specific measures necessary. Creating a cost estimation model would be beneficial for the company in providing valuable information as to the viability of taking up the project (Blais, 2011). Furthermore, developing the cost model would serve to test theoretical knowledge and contribute to research in business logistics. The model was created accordingly based on packaging costs, fill rate measures and transportation costs. However, environmental aspects were also included. The total costs were measured dependent on the specific variables and comparisons were done in assessing the viability of the project. This was presented in the form of estimated new costs, net savings and potential benefits for the company. As the company data was very unique with internal company specifications, weekly meetings were held with relevant stakeholders to ensure all important aspects were addressed. A detailed description of the model is presented in chapter 5.

2.7 Research quality

According to Williamson (2002) the quality of research can be affected by the way authors handle the collection of empirical and theoretical data. Attempting a high degree of internal validity, external validity and reliability is essential and should always be taken into account in scientific reports and studies (Björklund & Paulsson, 2014).

2.7.1 Internal validity

Internal validity refers to the coherence between collected empirical data and theory used in the research (Bryman & Bell, 2017). Furthermore, internal validity refers to what degree the empirical data and theoretical sources used in the study is sincere and accurate (Merriam, 2009). According to Hernon & Schwartz (2009) internal validity describes to what extent the tools used to measure the study object actually measures what it is intended to. It also takes into consideration whether the authors have taken into account different variables that could have affected the results of the findings in the research study. Strengthening the internal validity has been done in this study by critically examining the collected data used in the research, thus ensuring consciousness of variables that could affect the findings of the study (Powell & Conway, 2004). Another way to strengthen validity in this thesis was done with the help of a triangulation method. Triangulation allowed the authors to collect data on a variety of methods and the triangulation was done by complementing the primary data with secondary sources (Björklund & Paulsson, 2014).

2.7.2 External validity

External validity is to what extent the results of the research study can be generalized over different places, times and conditions beyond the particular study context in which the study was made (Bryman & Bell, 2017). Since this research is a case study, the level of generalizability might be lower due to a smaller sample size than a multiple case study for example. An important context when discussing the transferability of a case study is that the scope of the study needs to be narrowed down to an intense part of the studied object. It was therefore of importance that the authors focused on giving so-called *thick descriptions,* thus enabling readers to fully understand the circumstances and details that were examined in the study (Björklund & Paulsson, 2014). Since this study was made as a single case study with a narrowed scope, developing a *thick description* was important to increase the level of generalizability.

2.7.3 Reliability

Reliability refers to what extent the methodology used in the report can be used by other authors and still provide similar results (Ejvegård, 2009). Ensuring a high reliability of the research study demands that selected methodology is well documented, in order for others to be able to follow in the same steps as previous researchers (Yin, 2009). It has however been argued by authors that even if a research has been well documented, there can still be differences in the results due to the fact that people and times are not static and could therefore provide different answers (Bryman & Bell, 2017). This study has put great focus on carefully documenting and explaining all choices made and methods used. Furthermore, all metrics have been explained in detail to allow future researchers and readers to use and apply the same elements.

2.8 Ethical considerations

The ethical aspects of a study are always of significant importance and Bryman (2018) mentions four essential ethical issues; voluntariness, integrity, confidentiality and anonymity. Voluntariness means that all concerned parts of the study are informed about the purpose of the research and are aware that their participation is voluntary. The concerned parts also have the right to be enlightened about which parts of the study they are participating in. Integrity implies that the participants themselves decide about their level of participation and the confidentiality term means that all collected data must be processed with the maximum amount of trust and secrecy. Personal data must be preserved in a manner so that no unauthorized part has any access to it, and it must be ensured that all information is used for research purposes only (Bryman, 2018). Furthermore, information about participants cannot affect the concerned company, the individual or be used for commercial purposes (Ahrne & Svensson, 2015). The participants also have the right to complete anonymity if desired.

This study was conducted in accordance with the ethical aspects, and the subject company along with all involved participants choose to stay anonymous. The company that is providing the data and information used in this paper is being referred to as Machine Corp., a fictional name. Everyone involved in the study through interviews are also anonymized, and their names are replaced with the name of their working department. These actions ensure the confidentiality and anonymity of the study. Furthermore, the purpose of study and the general guidelines of the paper have been assigned to the authors by the company, thus the integrity and voluntariness aspects are ensured as well. A last important notion is that all data presented have been manipulated due to confidentiality reasons. However, the results of the study will still reflect the actual outcome, even though the data has been manipulated.

2.9 Methodological summary

The chapter started with an explanation and illustration of the research process to present the approach taken by the authors, and to conclude, the chapter ends with a summary of all the methodological choices made, visualized in table 2.2.

Areas of method	**Methodological choices**
Research approach	Pragmatic view, deductive approach
Research method	Mixed methods approach
Research strategy/design	Single case study
Data collection	Primary & secondary data
Data analysis	Pattern matching, data triangulation
Research quality	Internal & external validity, reliability
Ethical considerations	Voluntariness, integrity, confidentiality and anonymity

Table 2.2: Methodological summary

3 Theoretical framework

This chapter starts with a presentation of the prerequisites for road freight together with important aspects of freight operations and road freight pricing. Further on, this chapter elaborates about the aspects of vehicle utilization and fill rate followed by the role of packaging in logistics operations, and the effects on the environment.

3.1 Road bound truck transportation

In order to be able to deliver products from a producing unit to a consuming unit, a transportation method must be selected. Usually, the shipments from manufacturers are ordered via a third party logistics (3PL) provider, also called a haulier, which means that the transportation process is outsourced to another actor (Santén, 2017). When ordering transports from a haulier there are four major modes of transport available, which are road, rail, air and sea freight (Jonsson & Mattson, 2016). The selection of transportation methods depends on what type of logistical goal the buyer of the transport wants to achieve, e.g. high customer service, low lead time, cheap or environmental friendly. The most common way of distributing goods between suppliers, producers and customers is by road bound truck traffic. Truck transportation by road offers very high flexibility as road infrastructure is accessible almost everywhere in most countries. It has the ability to reach out directly to the customer from the start of the delivery point and is preferable to use when shipping to customers on a widespread market (Jonsson & Mattson, 2016). Under the past half-century, the truck traffic has significantly increased due to increased demands for fast and effective transports (Lumsden, 2012). European road truck transportation will be the highlighted freight method in this study.

The prerequisite for road freights is that vehicles used in commercial transports have a technical attribute which purpose is to carry a load bearing unit, which could be a trailer, container or another form of loading carrier (Jonsson & Mattsson, 2016). The technical attribute of the loading carrier heavily depends on the physical dimensions of the transported goods, but also on the quantity of goods to be shipped (Lumsden, 2012). Furthermore, the European road freight directives set by the European Commission also dictates the design and choice of the load bearing unit. The directives are set to ensure that transportations within the EU are regulated to maximum dimensions and loading weights of the truck and loading carrier combination. These regulations are set to ensure safety and security for both commercial traffic and private traffic throughout the EU (European Commission, 2015).

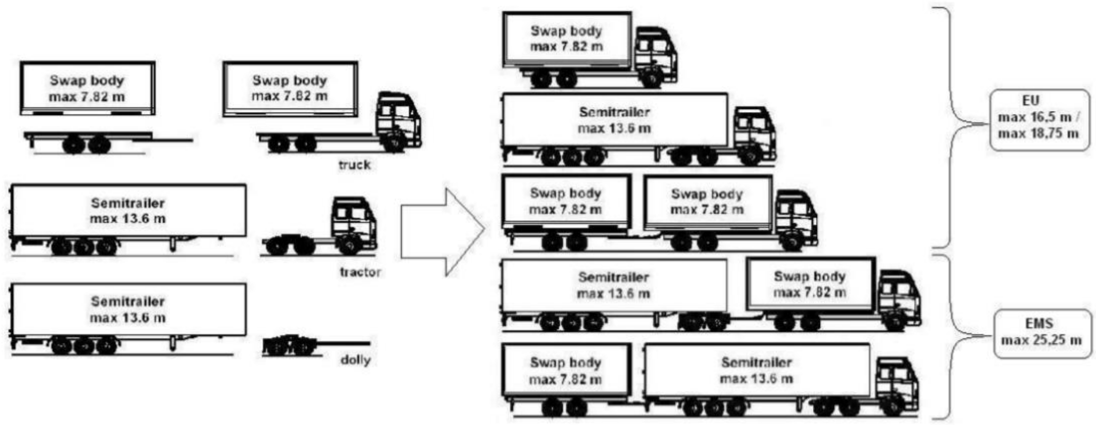

Figure 3. 1: Road freight vehicle combinations EU (Åkerman & Jonsson, 2007).

In Figure 3.1 different vehicle combinations are presented, the different combinations can be used to increase or decrease load capacity for transports depending on required capacity for the given situation.

No	Type of Truck	Max Weight	Vehicle Length	Load Capacity Carrier			
		[Ton]	[M]	[Ton]	[Pallets (EUR)]	[m]	[m3]
1	Truck With Swap Body	26	12	15	24	7,8	44
2	SemiTrailer	40	16,5	26	33	13,6	92
3	Truck With Swap Body + Swap Body	40	18,75	26	33	15,6	94
4	Truck With Swap Body + Semitrailer	60	25,25	40	52	21,4	140
5	Truck With Semitrailer + Swap Body	60	25,25	40	52	21,4	140

Figure 3. 2: Vehicle combination specifications provided by Lumsden (2012).

In Figure 3.2 the total dimensions and maximum load capacity for each combination is presented. Allowed vehicle combinations in the EU are set to standards included in vehicle combination 1-3 in figure 3.2. Vehicle combination 4-5 is a European Modular System (EMS) which allows a larger combination but which are only allowed in Sweden and Finland so far. The reason for it to be allowed only in Sweden and Finland is due to the quality and space of the roads having a higher standard than the rest of the EU (Lumsden, 2012).

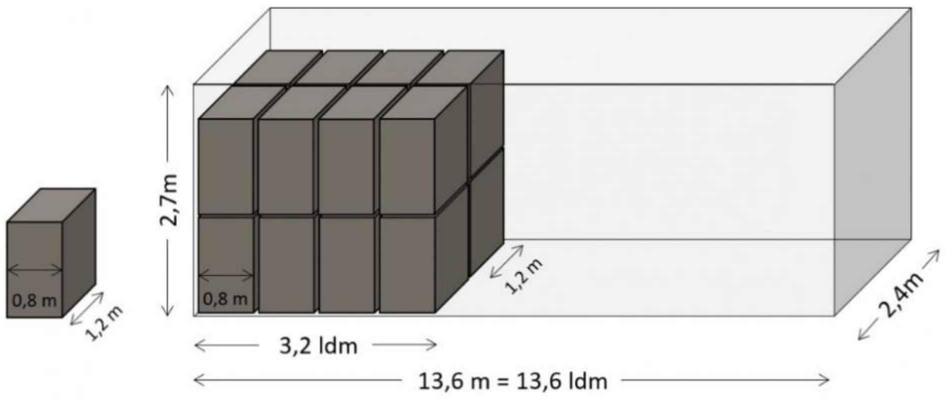

Figure 3. 3: European Semi Trailer Standard (Hänel, 2018).

An important aspect when considering the loading process of products before shipment, is that the products are loaded on standardized loading carriers. A load carrier is a unit which is being used to pack finished products on, in order to increase the ability to stabilize, secure and improve cargo safety during shipments (Gustavo, et al, 2017). There are today several different forms of load carriers, some of the most recognizable forms of load carriers are the traditional containers, sea pallets and in Europe, the standardized euro pallets. The reason for the use of standardized pallets is to simplify the material handling when moving and loading goods onto vehicles (Jonsson & Mattsson, 2016). The two of the most used combinations of euro pallets come with the dimensions of 800 · 1200 mm which is called a "whole pallet" and 600 · 800 mm which is called a "half pallet" (Lumsden, 2012). The measures for each pallet dimension is also a representation of how much loading metre (LDM) it will occupy on the loading carrier. The LDM is calculated using the following formula:

$$LDM = Length \cdot Width \div 2{,}4$$

The LDM for the standard whole EU pallet equals 0,4 and the half pallet 0,2. Figure 4.5 visualizes a loading carrier with whole pallet goods. The standard EU trailer can load a maximum amount of 13,6 LDM which equals 33-34 whole pallets. One LDM in load carrier or trailer has a maximum weight capacity of 1850 kg according to European standards (Lumsden, 2012).

3.1.1 Road freight pricing

According to Lumsden (2012) and Sudalaimuthu & Anthony Raj (2009) there are several different methods for hauliers to determine the price for a transportation, depending on characteristics of the transported goods different parameters can be used as a base in the pricing method to determine the cost of a transportation.

Chargeable weight: The determination of chargeable weight is made by multiplying the total LDM for a single load carrier with the maximum weight per LDM. The standard maximum weight per LDM for EU transports is 1850 kg. In European road freight standards this calculation would give following chargeable weight for a semi-trailer:

$$\text{Chargeable weight for semi-trailer} = 13{,}6\ LDM \cdot 1850KG = 25\ 160\ kg$$

Chargeable weight multiplied by price per kg: This pricing method is based on two parameters. First is the cost for distance of the transport, meaning that the price will vary depending on what total distance that is going to be needed to transport the products, longer distance results in a higher cost per kg. The second factor is based on the chargeable weight of the transport, meaning that the price per kg will be multiplied with the total chargeable weight of the transport

Minimum charge: This pricing method is commonly used when smaller quantities are going to be shipped. If the transport buyer has a small order with a low chargeable weight or volume the hauliers will set a higher price for the transport in order to keep the transport profitable for them.

Full Truckload (FTL): This pricing method allows the haulier to bound a transportation to one single customer, the price per kg will be lower when the transport buyer has enough goods to fill a whole truckload.

Less Than Truckload (LTL): If the transport buyer lacks goods to order a full truckload, the haulier will have to search for consolidation options in order to increase the truckload. This pricing method will result in a higher price per kg for the transport buyer.

A beneficial aspect for the transport buyer to consider is to always strive for achieving cost efficiency for the transportations, this is done by trying to fill the loading carrier as much as possible, thus striving for FTL. Having a FTL reduces the cost per unit compared to the costs for a transport with a LTL (Lumsden, 2012). The reason for a LTL to be more expensive for the transport buyer than it would have been for a FTL, is that the haulier will need to fill the unused capacity by consolidating the shipment on other places of the distribution network, which requires additional effort.

3.2 Vehicle utilization

Measuring the performance of transport operations is always relevant for companies in order to evaluate the progress and to support decision making. Improving transportation performance, has gained a strong foothold during the past years as the overall importance of good logistics performance for economic growth and competitiveness has been widely recognized (Fawcett & Cooper, 1998; Mariano et al., 2016). The primary goal of transportation and physical distribution is to move goods from place of supply to place of final sale, and to do so in alignment with the organizational goals (Mentzer & Konrad, 1991). By delimiting the literature review to focus specifically on road freight performance there are different perspectives to be found regarding transport operations. Improving vehicle utilization is one of the most attractive distribution measures for companies according to McKinnon & Edwards (2010), because of the substantial economic and environmental benefits that it generates. The rising transportation costs and oil prices gives companies strong incentives to manage and improve their vehicle loading. A common way to achieve a higher vehicle utilization, is to improve the packaging of the goods transported, to optimize the fill rate. Fill rate refers to the vehicle utilization and can be explained as how much of the available capacity of a certain resource (or resources) a vehicle is using. Measuring fill rate indicates how efficiently the freight sector is transporting goods in their vehicles (European Environment Agency (EEA), 2010).

$$\text{Vehicle utilization (fill rate)} = \text{utilized capacity} \div \text{available capacity}$$

McKinnon et al. (2003) suggests modifying the design and dimensions of handling equipment and to change packaging and pallet-wrapping systems to increase stackability. If vehicle fill rate can be improved through better packaging and making better use of the vehicle's capacity, then the same amount of goods can be shipped, but with less vehicles and less travelled kilometres. This assists in reducing total freight vehicle traffic, thus leading to less congestion, emissions and other environmental impacts caused by road freight transports (EEA, 2010).

The following part of the literature review aims to develop a greater understanding about the roles of fill rate, packaging and environmental impacts in road freight and outbound delivery performance.

3.3 Fill rate

Fill rate has different dimensions, and can be looked at through different perspectives and levels. From a viewpoint of government and policy makers, fill rate is attractive due to the potential of reducing transport volumes thus enabling a more effective use of infrastructure and reducing environmental impact. From a company perspective, the prospect of fill rate is appealing in order to increase freight efficiency and thus decreasing transportation costs (McKinnon & Edwards, 2010). A haulier can earn more money by adding more goods to an unfilled vehicle, since it can reduce the number of trucks used and total fuel consumption. The same goes for the transport buyers, it is possible for them to reduce the amount of shipments with an increased fill rate, as well as they can take advantage of reduced cost per unit by ordering FTL instead of LTL for example (Lumsden, 2012).

Calculating fill rate is accordingly a very useful distribution measure, due to the substantial economic and environmental benefits that it generates. The general aspects of fill rate can therefore be seen in both an economic and environmental perspective, which is visualized in figure 3.4 below.

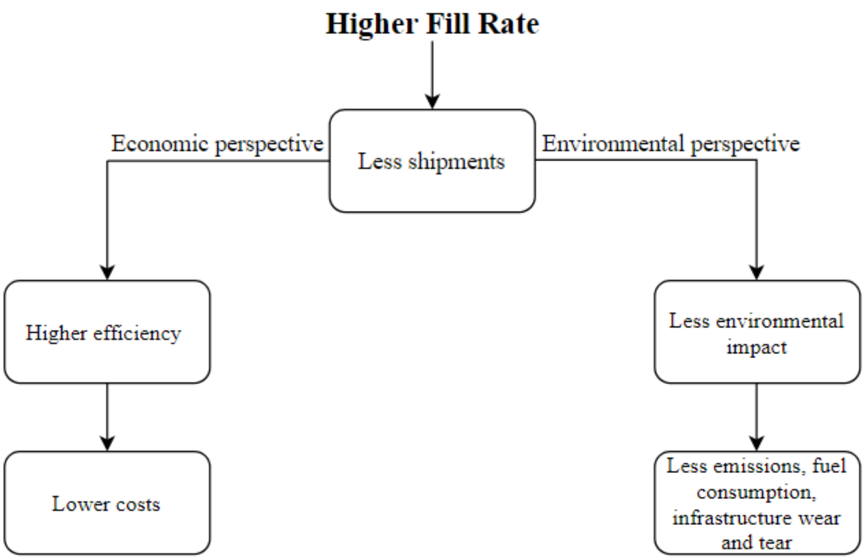

Figure 3. 4: The economic and environmental aspects of fill rate. Own illustration.

3.3.1 Measuring fill rate

In regards to logistics operations, fill rate is a commonly applied measure used to evaluate specific goals that relates to logistics efficiency. As mentioned, fill rate is the ratio between what a transport actually carries and the maximum load it is allowed to carry. However, there is no standardized way of measuring fill rate according to McKinnon & Ge (2004) and several terms have also been used to describe the measure in previous literature, like filling rate, fill ratio, load factor, load fill and vehicle loading etc. Although the definition of fill rate is clear, independent of the term used, measuring it can be somewhat more complicated.

If the fill rate in passenger transportation were to be compared with the fill rate in freight transportation, the measure becomes very different. The available capacity and the occupied capacity can easily be measured since every passenger is assigned to a seat each (Kasilingam, 1996). But measuring the available and occupied capacity in freight transport, is not as simplified. Another aspect in public transportation, is that the passenger usually returns to the starting destination again, making the capacity to be utilized in both directions of the transportation route. However, in freight transportation the goods are usually shipped from a producing unit to a consuming unit, causing the vehicle to run empty when returning (McKinnon & Ge, 2006). Empty running has a negative effect on vehicle utilization and is a challenging aspect in freight transportation. Therefore, fill rate is not the only way to determine vehicle utilization, empty running can be applied as well and could also be combined with fill rate for laden trips to include the whole journey. When it comes to measuring fill rate specifically in road freight transportation, there are generally a few different dimensions used which includes parameters for *weight*, *volume*, *deck area*, *empty running* or *tonnes-kilometres*.

Weight: The most commonly used measure to determine the fill rate is weight as a dimension. Ülkü (2012) expresses the fill rate in the perspective of weight as “the ratio of the actual weight of goods carried to the maximum weight that could have been carried on a laden trip”.

Volume: Volume is a 3-dimensional measure for the percentage of space occupied by a vehicle load (length · width · height). In regards to unitized loads (pallets, cages etc.), the actual number of units carried can be divided by the maximum number to calculate the fill rate. However, the assessment should include the average height of the unit loads as well, to provide a more accurate percentage of the volume-based fill rate. The height is often restricted for loaded units, so the height utilization should rather be based on the restriction, than on the height of the trailer/load carrier. Assessing this measure at industry level is still very problematic though, because there is a lack of systematic collection of volumetric road freight data (McKinnon & Edwards, 2010).

Deck area: The deck area is a 2-dimensional measure that can be defined as the percentage of used floor space. The utilized capacity is defined by the number of units carried set against the number of units that could have been carried (Santén & Rogerson, 2018).

Empty running: The definition of empty running is the proportion of vehicle-kms that run empty. Empty running is an inevitable consequence of one-way freight transports due to the issue of balancing a freight flow for the opposite direction. Empty journeys are incredibly inefficient from an economic perspective and very wasteful in terms of environmental impact. However, during the past 30 years, the amount of empty truck running has steadily decreased, which has resulted in both economic and environmental benefits (McKinnon & Edwards, 2010).

Tonnes-kilometres: Tonnes-kms is generally a productivity measure for the freight sector and is calculated by multiplying the weight of the transported goods in tons with the transport distance in kms. The last-half century has seen a significant increase in tonnes-kms carried by the average truck, which is mainly due to increases in maximum truck weights and vehicles in motion for more hours per day. McKinnon & Edwards (2010) argues that tonnes-kms is a rather limited measure in terms of fill rate, because it gives no indication of actual vehicle utilization or potential to increase fill rates. However, it can be used as an indicator of sustainability and environmental impact for the road freight sector.

3.3.2 Combining weight-based and volume-based fill rate

The fill rate measure is therefore depending on the dimension used for calculating the rate, and measuring different dimensions, will generate different results (Santén & Rogerson, 2018). Using occupied deck area as a dimension for example, can indicate a 100% fill rate if the pallet space is fully utilized, even if the pallets are empty. On the other hand, a weight-based fill rate can achieve a rate of 100% if the weight capacity is maximized, but then the utilization of floor space is not being considered. Therefore, to provide a better picture about the total fill rate, more than one dimension could be included in the measure. As previously mentioned, fill rate is generally based on weight, mostly due to the lack of volume data and the fact that weight is more easily measured than volume (McKinnon & Leonardi, 2008).

Santén & Rogerson (2018) argues that a combination of both weight and volume is the most optimized measure to determine the fill rate, because both dimensions can restrict the maximum load. McKinnon (1999) also conducted a survey that included vehicle utilization in the UK food supply chain, where the key performance indicator for fill rate was measured by weight, number of pallets and pallet height. The food chain shipments are rather constrained by volume than weight because of the low density of the products, therefore adding a dimension for pallet height enables the estimation of volume to some extent. The results of the survey showed a notable variation in terms of fill rate for weight and volume. The average transport utilization considering weight was 56%, whereas the volume utilization was 78%. Santén and Rogerson (2018) explains that it is important to gain a perspective on the fill rate that embraces both weight and volume, and a high fill rate is achieved when the used capacity and the available capacity are balanced in terms of volume and/or weight.

3.3.3 Factors for improving fill rate

There are several methods that can be used to allow for an increase in fill rate. Jordan (2011) discusses the loading of vehicles, to allow for more freight carried per trip and maximizing every inch of the load carrier. It is suggested to load the vehicle starting with the largest and heaviest goods, to then fill up with the smaller units, thus the amount of weight carried can be increased. It could also be beneficial to reorganize how the cargo is boxed and packaged -

eliminating excess and superfluous packing material can increase the number of units that can be fitted into the vehicle, increasing space utilization. However, the safety aspects must still be considered. Jordan (2011) also mentions that deliveries should be rescheduled to reduce the frequency. Rescheduling to the minimum amount possible will result in larger freight carried by each vehicle and waste from unutilized space will reduce.

As a result of a study conducted by McKinnon et al. (2003), it was discovered that there is a lot of potential for increased vehicle utilization and the following suggestions for improvements were made:

- Increase the degree of load consolidation.
- Change the design and dimension of handling equipment to allow for compatibility.
- Selection of vehicles with less carrying capacity and lower height to match the average size and weight of the carried load. Also enhances the fuel and aerodynamic efficiency.
- Use of double-deck vehicles that can carry two layers (stacked) of pallets and cages.
- Change packaging and pallet-wrapping systems to increase stackability.

3.4 Packaging

Packaging has been defined as a coordinated system of preparing goods for transport and distribution, it is a means of ensuring the safe delivery to the final customer in good condition at a minimum cost. Packaging is a critical process that is aimed at minimizing costs of delivery while maintaining profitability (Paine, 1981). It has been generally divided into two types; consumer packaging and logistical packaging. Moreover it’s been classified in accordance with the different levels as primary, secondary or tertiary (Jönsson, 2000).

1. Primary: The packaging that is in direct contact with the product.
2. Secondary: Contains several primary packaging and is mainly designed for retailer packaging.
3. Tertiary: Packaging that is for logistics and transportation.

The composition of packaging may change along the distribution channel, in some cases only the primary packaging is involved and in some may integrate all the three types of packaging (Hellström & Nilsson, 2011). For the purposes of this thesis, packaging refers to the tertiary packaging and mainly in relation to transportation. Examples of tertiary packaging are cardboard, wooden material and pallets.

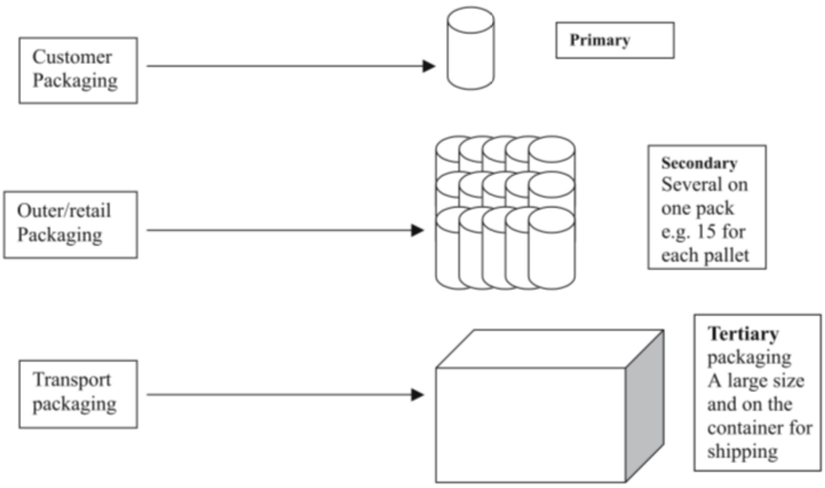

Figure 3. 5: Packaging levels (Johansson & Westström, 2002).

3.4.1 The interface of packaging and logistics

In recent years a new philosophy of the packaging role in supply chain has emerged. Traditionally, packaging has been viewed as a means of protection of goods during transportation (Chan et al., 2006). The need to fully utilize packaging systems in order to increase the effectiveness of the total system and improve distribution efficiency has brought forth packaging logistics (Wills, 1990). Logistics has been defined as one of the supply chain processes that plans, implements the efficient and effective flow of goods from the point of origin to the point of consumption. Thus, packaging logistics is defined as the interaction and relations between the logistics and the packaging system that improve add on values to the entire supply chain (Chan et al., 2006).

Throughout the supply chain there are many interactions of packaging and logistics and thus to avoid sub optimization, the integration of both would lead to increase in supply chain performance (Tompkins et al., 2010). Packaging is an important component that could increase competitiveness (Zheng et al., 2009). It affects the costs and the efficiency of many of the logistic activities such as transport (Lambert et al., 1998). Other aspects of logistics such as damages, cargo handling are dependent on the performance of packaging. Thus, packaging logistics has been recognized as a core competence leader to superior performance.

3.4.2 Costs linked to packaging logistics

Packaging could affect a wide array of logistic activities and the cost and efficiency of the supply chain. Supply chain nodes such as manufacturing activities related to inhouse factory productivity, warehouse operations and transportation are dependent on the efficiency and optimization of packaging. In the past decade, the role of packaging in the supply chain has been disregarded and seen as a minor subset of the supply chain (Chan et al., 2006). However, as the role of packaging becomes critical to the overall supply chain performance, businesses begin to evaluate the costs and efficiency of packaging operations to avoid the risk of sub-optimization (Sjöström, 2000). Today, businesses focus on improving product packaging operations in order to minimize the costs related to equipment and labour through minimizing the volume of material used, rationalizing the number and types of packaging operations (Lee & Lye, 2003). Since the costs for packaging processes in a manufacturing company is related to the labour cost and salary and the time it takes to fulfil all activities that need to be included to physically handle the products that are going to be delivered (Kulinska, 2014).

Packaging material and material handling cost

Direct labour and material account for a substantial portion of a product's manufactured cost (Lee & Lye, 2003). Material costs include the cost of packaging material, and the cost of necessary packaging accessories. The major type of packaging materials used in the manufacturing industry are paper, paperboards and wood. Material handling costs involves the cost of packing and all the operations necessary prior to the state to which product is considered fully packaged. Depending on the type of products the number of operations within packaging will vary to comply with industry standards (Gustafsson et al., 2005). Improving and increasing the efficiency of material handling has the potential to reduce the overall packaging costs and enhancing supply chain performance.

Transportation cost

The packaging function has a direct link to transportation cost, the dimensions and weights of packaging material will affect transportation costs. The quality of packaging is also critical in minimizing damages during transportation, there is a direct trade off of packaging costs and transport cost (Gourdin, 2001). Depending on the mode of transport, the packaging material must be suitable to avoid transport related damages. Rail and road transport require more robust packaging material in order to withstand impact during transport. Statistics show that the frequency of damages are three times higher in cross border transport than domestic transport. Therefore, companies must make the right adaptation necessary for cross border road freight (Lumsden, 2012).

3.4.3 Packaging logistics impact on transportation

Packing logistics has become an integrated system that improves the efficiency of supply chain leading to efficient transport and reduction of transportations costs (Garcia-Arca., 2006). Standardized packaging is fundamental in transportation and has played a central role in shaping logistics and increasing handling and transport efficiency. For instance the shape and dimensions of packaging affects cube utilization during transport. Previous studies carried out by ECR Europe (1997) indicate that supply chains could cut costs by approximately 1.2 percent of sales value from improved utilization of vehicles, better space utilization and reduced transportation costs (Nilsson & Pålsson, 2006). Boxes differ depending on product size and palletizing boxes enables the optimization of transport and the lack thereof will lead to increased space usage and consequently decreasing transportation costs (Abdou & Yang, 1994). Box modularity aims to develop standards for packaging sizes in order to rationalise packaging dimensions and hence increase space utilisation. The degree of stackability will directly affect costs as this is likely to increase utilisation and hence lead to increased fill rates and transport cost reduction (Kye et al., 2013). The choice of modular box packaging is crucial and loading multiple size boxes on pallets to maximize space usage will lead to increased efficiency and reduce transportation costs (Pennington & Tanchoco, 1988).

3.4.4 Packaging logistics impact on the environment

In OECD countries, transportation represents about 30 percent of CO2 emissions (ITF, 2010) and depending on the degree of optimisation of volume and weight of packaging this will affect transport efficiencies as unutilized spaces will in turn have high environmental impact (Pålsson, 2018). Factors such as shape and dimension of packaging will affect cube utilisation during road transport and thus have environmental consequences (Hellström & Nilsson 2011). Volume and weight of packaging are seen as top three supply chain initiatives in reducing emissions in the supply chain (Doherty & Hoyle, 2009). Therefore the choice of packaging is key when environmental issues are addressed in logistics (Penman & Stock, 1994). The degree of cube utilization is dependent on the design of the product and the choice of packaging. Sub optimised packaging will limit cube utilisation by creating empty spaces between units during transportation. Empty spaces arising from low fill rates will also lead to increased movement during transportation and lead to increased risk of damaged goods (Hellström & Nilsson, 2011).

The environmental impact of tonne per km is relative to the degree of cube utilization. An increase in cube utilization will lead to fewer vehicles on the road thus lower carbon emissions. The total impact from low packaging fill rate in road freight will lead to increased CO2 and cost intensity per km (Hellström & Nilsson, 2011). Higher cube utilization in transport will reduce environmental impact of transport. Hence the environmental impact of packaging optimization is of concern (European Environmental Agency, 2005).

4 Case company

This section gives an introduction to the case company and its operations regarding transportation and packaging in order to provide a deeper understanding of the main focus areas in this study. The section is based on the gathered information from interviews, observations and secondary data to describe the business and present the relevant figures for packaging and transportation. All numerical and statistical data presented below is based on figures for 2019 and the shipped volumes only consider the five products included in the thesis scope.

4.1 The European logistics process at Machine Corp.

Machine Corp. has a complex supply chain network with different supply chain nodes managing the transactional flow, physical goods flow and payment flow. Machine Corp. ships approximately 200 000 units of products with varying dimensions and weights annually. The weights range from around 60 kg to 2000 kg. The total load shipped from the distribution centres to European customers for the year 2019 was around 7000 Metric Tonnes (MT). However, the scope of the study will only focus on the physical flow of goods from the Swedish (SW) distribution centre (route one) and the Central European (CE) distribution centre (route 2), visualized in figure 3.1. The European customers account for 48% of the total sales with diverse shipment dimensions. The total transportation costs accounts for the largest component of logistic costs in terms of Machine Corp's operations; therefore, the company is constantly looking for opportunities to reduce these costs. One of the ways in which the company works with reducing transportation costs is through negotiating low prices with their existing haulier. The freight rates and prices for transports from SE and CE can be found in appendix 2.

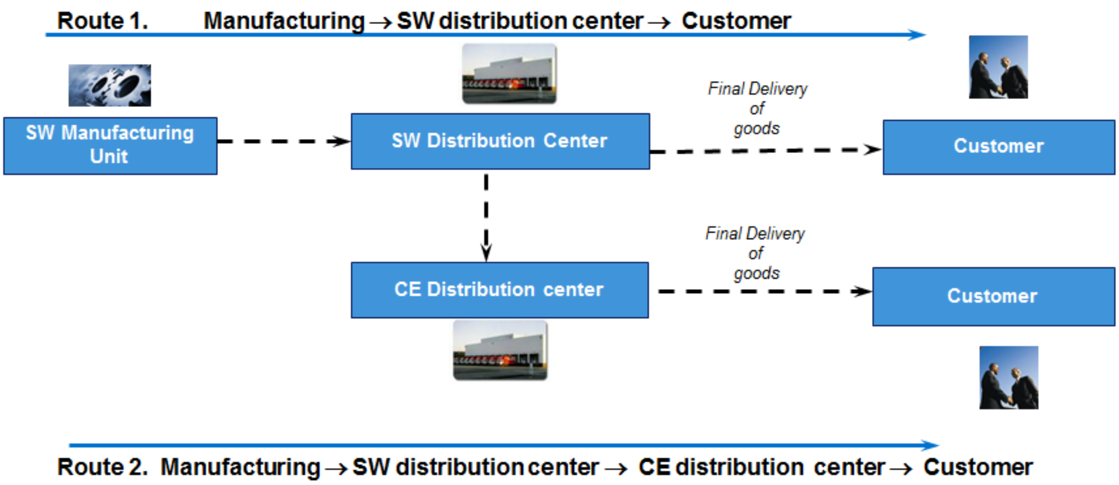

Figure 4. 1: Machine Corp distribution system. Own illustration

From a logistics perspective, Machine Corp's transport operations are quite complex as they have a wide portfolio of products with varying dimensions and weights. This makes it extremely challenging in striving to maintain high transport efficiency while keeping service levels high and transportation costs low. Logistics is a critical process in the supply chain operations of Machine Corp. and in order to ensure that the company is managing its operations effectively, various performance metrics are measured on a quarterly basis to identify any opportunities for improvement as well to ensure that costs are within budget allocations. The pre-study conducted at Machine corp. provided an overview and understanding of how the packaging and logistics operations at Machine corporation are carried out. The authors acquired knowledge about the company's products, business process and overall knowledge that was necessary in order to understand what aspects to consider in evaluating the cost model.

4.2 The current packaging strategy

The current packaging strategy for the European market today, does not involve any tertiary packaging of the products, as the products are only mounted onto pallets. Products shipped outside of Europe however, are packaged in either plywood or cardboard boxes. Machine Corp. has discovered that the shipments outside of Europe are more efficient, as the packaging for this market enables stackability of the products. The packaging material used outside of Europe is ensured to meet sustainability standards and Machine Corp. requirements include standards for dimensions and material specifications, such as 90% recycled material and minimal percentages of virgin fibre. All costs related to the packaging process are costs that occur at Machine Corp's manufacturing site in Sweden since it is the only place where the products are being packaged.

Visualized in table 4.1 are all the modular boxes that will be used to package the five products that the scope of this study covers. Each of the modular boxes has a specific LDM characteristic that will determine which pallet size that will be used to mount the product on. The average weight for the plywood and cardboard boxes combined is approximately 4kg. The plywood packaging is generally used for the heavier products whereas the cardboard boxes are used for the lighter products. The material cost visualized in table 5.1 is the procurement cost for each modular box, the pallet cost is the cost for a single pallet used in order to mount both product and modular box on. The pallet cost will not be further considered in the project scope since this cost will remain the same for all shipped products, regardless of packaging method.

Modular box type	LDM	Pallet cost SEK	Material cost SEK
001 Plywood	0,7	316,95	1003,08
002 Plywood	0,5	248,40	866,91
003 Plywood	0,4	173,48	543,05
004 Plywood	0,5	248,4	839,33
005 Plywood	0,4	273,77	594,23
006 Plywood	0,4	173,48	669,21
007 Plywood	0,4	173,48	628,83
008 Plywood	0,5	248,40	1379,46
009 Plywood	0,7	316,95	1210,64
010 Plywood	0,9	726,66	1592,45
011 Plywood	0,5	248,40	870,68
012 Cardboard	0,4	188,85	299,12
013 Cardboard	0,2	139,10	229,86

Table 4. 1: Characteristics of the modular boxes

Table 4.2 visualizes the cost for material handling, which means the cost for the time it takes to prepare a product with the right modular box. The material handling cost is calculated by the time it takes to mount a modular box onto a pallet containing a product, which thereafter is multiplied with the hourly labour cost which consists of direct worker salary and indirect overhead costs.

Modular box type	Packaging time (h)	Material handling cost SEK
001-011 Plywood	0,25	215,63
012-013 Cardboard	0,13	115

Table 4. 2: Packaging time and material handling cost

The lack of tertiary packing for the products has led to certain problems, where the main problem is found in terms of low vehicle utilization, as the products cannot be stacked on top of each other without any proper packaging. This creates a waste in terms of unused LDM, higher transportation costs and a higher number of trucks used which results in a larger environmental impact in terms of fuel consumption and CO2 emissions. The lack of tertiary packaging has also resulted in an increase in damages during transport. These damages are often small and in most cases the customer ends up making the repair work for the damages occurred during transportation. The company believes the lack of tertiary packaging results in a higher propensity of occurring damages. During transportation, the products lack a supporting frame and therefore are unable to withstand potential impacts. In the long term this is likely to affect the service levels of the company and consequently lead to a lower customer satisfaction than desired.

4.3 Transport operations

4.3.1 Fill rate measures

There is today no existing strategy on how to measure vehicle fill rate at Machine Corp. The measurements that are being taken into consideration when ordering transports from the haulier to their European customers, is today only the maximum weight and deck area (LDM) capacity for each shipment ordered. The motivation at Machine Corp. is to start measuring vehicle fill rate once the new packaging system for the European market is implemented. Visualised in table 4.3 is the total shipped volumes for 2019 regarding the five products that this study is focusing on. The total trucks required in table 4.3 is a theoretical measure based on 2019 years volume for the five products.

	Total weight (tonnes)	Total LDM	Trucks required	Average truck load weight (tonnes)
Prod. shipped on pallets	5811,55	4854,60	357	16,27

Table 4. 3: Total shipped volumes for European market 2019

4.3.2 Freight pricing and costs

Machine Corp. uses the same haulier for all deliveries both in SW and CE, which means that all pricing is consistent. Furthermore, every shipment for the European market is road freight-based, and the standard EU semitrailer displayed in Figure 3.1 by (Åkerman & Jonsson, 2007) is always ordered from the haulier. The pricing agreements between Machine Corp. and the haulier are based on a chargeable weight multiplied by price per kg pricing method, as explained by Sudalaimuthu & Anthony Raj (2009). For the transportations to customers within Europe, there is a fixed price list based on postal code and travel distance. There is today a step based price list for the total amount of kilos that is going to be shipped, if the weight of the transported goods is higher, the price per kg will be lower. Visualised in appendix 2 is a list of average prices/kg for shipments to all countries. The price list considers shipments sent from both SW and CE. Table 4.4 displays the chargeable weight and total transportation costs for SW and CE for the European market (shipped on pallets only) for 2019.

Distribution location	Current total chargeable weight (kg)	Current total transportation cost (SEK)
Sweden	7 642 072,5	6 180 016,50
Central Europe	5 829 442,5	22 949 388,80

Table 4. 4: Current chargeable weight and transportation costs for SW and CE

4.4 Environmental aspects

There is today a general understanding within the transportation department at Machine Corp. that the utility rate for the European market is underutilized due to the lack of tertiary packaging and stackability for deliveries that exist in their current outbound transportation system. Therefore, there is a thought and belief that the number of trucks needed to distribute goods from Machine Corp. is higher than necessary. The environmental concerns due to this, is that the emissions from the current outbound transportation system to customers in the European market are too high. The numbers of trucks needed to distribute goods from the production plant in Sweden and from the terminal in France is displayed in table 4.5. The number of trucks required is based on theoretical calculations where the total amount of LDM distributed under 2019 has been divided with the maximum LDM capacity a semi-trailer can carry. The results from this calculation have provided a theoretical indication on how many trucks that would have been needed to carry the total sum of LDM for all five products.

	Distance (km)	Total LDM	No. of trucks	Total distance (km)	Total weight (tonnes)	Average weight/truck	Total tonnes-km
Prod. shipped on pallets	1476	2181,6	161	237636	2553,0	15,86	606 685 896

Table 4. 5: Data for shipped volumes (SW → CE Terminal)

5 The cost estimation model

This section presents a description of the cost estimation model based on the findings of the theoretical framework and the empirical data provided by the company, which specifically relates to packaging costs, transportation costs and environmental impact. The model's main features will be presented together with a description of the applicable metrics. The final section will present the limitations of the model.

5.1 Description of the cost estimation model

In order to answer the purpose of the thesis, a cost estimation model was created to calculate what costs were likely to be affected by the adoption of the new packaging strategy. The management of the company requested a model displaying if there was a possibility of lowering transportation costs through the adoption of a new packaging strategy. The implementation of a new packaging strategy was due to increase the packaging costs, therefore the model would be used by the company to assess if the savings achieved in transportation costs could potentially cover the additional packaging costs. The model has been constructed by focusing on each of the costs separately, namely packaging costs and transportation costs, and finally comparing the results derived from both. The two types of costs are each influenced by different elements and activities which are described thoroughly in this section.

5.2 Overview of elements derived from the case company database

From the data provided by the company it was necessary to know what elements and activities that affected the respective costs in order to develop a holistic model. The raw data from Machine Corp. provided details that were necessary to develop a general understanding of the company's supply chain operations. The complete set of data provided is presented below in table 5.1, and can also be found in table 2.1.

Data	Specifications
Total shipping volumes for the five products included in the project scope	Including total quantity, total loading meter (LDM) and total weight.
Pricing list for European shipments	Including the total chargeable weight for 2019 and price per/kg for each country in EU
Complete list of all packaging types (modular boxes)	Including LDM, dimensions and procurement prices for each box type

Table 5. 1: Data specifications

The raw data consisted of approximately 100,000 order lines in the itemized rows which was sorted into two categories; packaging and transportation. The factors for fill rates and environmental aspects were based on the above mentioned categories. As mentioned earlier, all the numerical data and results presented in the next chapter will be manipulated due to confidentiality reasons.

5.2.1 Packaging costs

The elements that directly affected the packaging costs were material costs and material handling costs, displayed in table 5.2. The products dimensions were cross referenced against the dimensions of the modular boxes to determine the suitable fit. Then, the material costs were calculated based on the procurement price for each modular box multiplied with the number of the times each box was used. The labour costs per hour as a part of the material handling costs, were calculated using the hourly rates for direct worker wages and indirect overhead costs, which were provided by the company. This was then multiplied with the total time it would take to pack the total amount of products. As mentioned earlier, the packaging times were measured during an observation.

Metrics	**Description**
Material cost	Total material cost for modular boxes
Material handling costs	Labour cost per hour (packaging operations)

Table 5. 2: Packaging metrics

5.2.2 Transportation costs

The elements that were necessary in order to calculate the transportation costs are listed below in table 5.3. All calculations were based on the entire volumes for all of the five products shipped under 2019. Based on the new fill rate estimations provided by the company, new transportation costs that included the modular boxes were calculated with the help of the metrics presented in table 5.3.

Metrics	**Description**
Loading Meter (LDM)	Standard unit of measurement for road freight pricing
Chargeable weight	A chargeable weight based on the amount of LDM shipped
Price per kg	The chargeable weight multiplied by price per kg
Volume-based fill rate	Maximum volume capacity on a load carrier / utilized volume
Weight-based fill rate	Maximum weight capacity on a load carrier / utilized volume

Table 5. 3: Transportation metrics

5.2.3 Environmental impact

To measure the environmental impact of implementing the new packaging strategy, the metrics displayed in table 5.4 were chosen. By scanning the literature and the empirical data provided by the company, it was found that the metrics below were suitable as they were possible to be applied on the data provided in this specific case study.

Metrics	**Description**
Vehicles required	Amount of shipments needed with estimated fill rate increases
Tonnes-km	Total weight in tonnes shipped multiplied by total travel distance

Table 5. 4: Environmental metrics

5.3 Summarized table with calculations

Metrics	**Calculation**
LDM of a load unit	*Length · Width ÷2,4*
Chargeable weight	*LDM · 1850 kg*
Transport cost	*Chargeable weight · price/kg/country*
LDM after new fill rate estimations (75%)	*Existing LDM · (1÷1.75)*
LDM after new fill rate estimations (33%)	*Existing LDM · (1÷1.33)*
New chargeable weight	*New LDM ·1850 kg*
New transport cost	*New chargeable weight·price/kg/country*
Transport saving	*Current total transport - New total transport cost*
Total number of trucks required/year	*Total LDM÷13,6*
Material handling cost	*Packaging time (h) · Labour cost (h)*
Material cost	*Price per modular box*
Total material handling cost/year	*(Packaging time (h) · Labour cost (h)) · Annual volume*
Total material cost/year	*Price per modular box · Annual volume*
Total packaging cost/year	*(Total material handling cost + material cost) · Annual volume*
Tonnes-kilometres	*Total weight shipped/year · Total kms/year*

Table 5. 5: Summarized calculations

5.4 Limitations of the model

The cost estimation model has not taken into consideration other costs directly related to transportation in the supply chain than those presented. The scope of the model has only covered transport and packaging costs in relation to each other. Furthermore, the model is based on the data from one case study and therefore the results cannot be used to derive generic conclusions, however if the data is applicable to similar companies with similar prerequisites, then the level of generalization can be increased. Moreover, the cost model is based on secondary data provided by the case company and this data is specific to the company's operations in one geographical setting and specifically one segment in the global company's business operations. The company has operations in 400 locations and as the data is limited to include one area of business operations of the case company, it would pose limitations as the results may be different in other business segments and locations within the company. Due to the large volume of data that would otherwise be required, the scope of study was limited to five product assortments, the selection was based on the products that are best sellers and have high shipment volumes. Furthermore, the scope of the study was limited to the highest market shares in Europe and thus small markets within Europe with infrequent deliveries and low volumes were not taken into consideration.

6 Results & analysis of the cost estimation model

In this section, the results of the cost estimation model will be presented. All calculations made will be analysed and explained in detail. In appendix 1 – an extraction of calculations made in Microsoft Excel are displayed to give an example of the data analysis process for packaging costs and transportation costs.

6.1 Packaging costs

Implementing a new packaging strategy for the European market could come with many potential benefits for Machine Corp. However, it will result in increased costs for both packaging material and material handling. During 2019, over 9000 units of the 5 products covered in this report were shipped on the European market on pallets only. Mounting modular boxes onto all of these products will have a significant effect on costs for packaging operations, mainly considering equipment/material and labour costs as Lee & Lye (2003) mentions. The packaging time presented in table 6.1 is based on the average time it takes for each material type (plywood or cardboard) to be mounted on a pallet containing a product. The material handling cost for the packaging of products considers the labour costs and the packaging time (Kulinska, 2014). The material handling cost in table 6.1 explains the total cost of packaging for one product, depending on modular box type.

Material handling cost = packaging time (h) · labour cost (h)

Modular box type	Packaging time (h)	Material handling cost SEK
001-011 Plywood	0,25	215,63
012-013 Cardboard	0,13	115

Table 6. 1: Packaging time and material handling cost

Table 6.2 presents what the total cost for mounting modular boxes onto the products would have been based on the shipped quantity for 2019. Each product has been matched with a modular box that fits the specific dimension of that product. The total cost of the modular boxes is based on the procurement price for each type of box (plywood 001-011 and cardboard 012-013) multiplied with the number of times each box was used. The price list for modular boxes can be found in table 4.1. In this case, the cost of pallets is not included in the new additional cost for packaging since it already exists today.

No. of modular boxes	Cost of modular boxes SEK	Packaging time (h)	Material handling cost SEK	Total cost for packaging SEK
9218	4 109 412	1086,5	1 436 608,74	5 546 020,74

Table 6. 2: Estimated packaging costs

6.2 Effects on fill rate

As (Garcia-Arca., 2006) mentions, implementing tertiary packaging in supply chains can have a significant effect on transportation efficiency and the total transport costs. Higher efficiency as a result of packaging is mainly reflected in the volume utilization of vehicles, since it can enable for stackability and standardization of cube dimensions (Kye et al., 2013; McKinnon et al., 2003; Abdou & Yang, 1994). As mentioned before, Machine Corp. has a tertiary packaging strategy for deliveries outside the EU which includes the same type of modular boxes as presented in this study. By conducting observations at Machine Corp. on the loading process for shipments outside the EU, it was made visible that a large amount of other components and products was able to be stacked on top of the modular boxes.

Together with the company, estimations on how much extra volume that could be added on each type of modular box were conducted. As McKinnon & Edwards (2010) explains, the volume-based fill rate includes the total dimensions of unitized goods, where the height restriction is the most important aspect to consider in order to provide an accurate percentage of the fill rate. With the height restrictions in mind, it was estimated that approximately 75% of the volume for cardboard boxes was unutilized, and approximately 33% for the plywood boxes. I.e. adding 75% respectively 33% more based on the current volume on top of a modular box was possible before reaching the height restrictions. The average fill rate increase for all modular boxes would account for approximately 54%. By stacking the additional volume (other products and components) on top of the modular boxes, this will also reduce the total amount of LDM shipped per year, as the LDM only considers the utilized deck area and not the utilized height and total volume of the trailer (Santén & Rogerson, 2018). Without the modular boxes, these products and components would have been placed on the floor of the trailer accounting for additional LDM, which now will be removed as they are stacked on the modular boxes.

If the products for the European market would be transported in modular boxes - the total LDM would be 4854,60 based on the number of units shipped 2019. However, when applying the estimated volume-based fill rate increase, the total amount of LDM would reduce significantly, as displayed in table 6.3. The following calculations have been carried out for every modular box shipped to determine the new LDM based on fill rate increase:

$$\textit{LDM based on fill rate increase} = \textit{LDM per plywood modular box type} \cdot (1 \div 1.33)$$
$$\textit{LDM based on fill rate increase} = \textit{LDM per cardboard modular box type} \cdot (1 \div 1.75)$$

The LDM per modular box type is found in table 4.1. As a result of packaging the products, instead of mounting them naked onto pallets, the average fill rate for truck transportations is estimated to increase with around 54%.

Modular box type	**Total LDM**	**Estimated fill rate increase per LDM**	**Total LDM based on fill rate increase**
Plywood	2478,20	33%	1863,31
Cardboard	2376,40	75%	1438,46
Modular box type	**Total LDM**	**Average fill rate**	**Total LDM based on fill rate increase**
Plywood + Cardboard	4854,60	54%	3301,77

Table 6. 3: Total LDM estimation based on fill rate increase

The above calculations would in turn mean that less transports would be required to ship the total amount of products. Based on the new LDM figures, the amount of transport required to ship the total amount of goods would mean a reduction by 114 trucks/year (displayed in table 6.4) - assuming that each trailer fully utilizes the maximum amount of LDM (13,6).

$$\textit{Trucks required} = \textit{Total LDM} \div 13{,}6$$

As the same amount of goods would still be transported, it would as well result in a higher average weight/per truck, as displayed in table 6.4. The average weight of a modular box is approximately 4 kg, thus the total weight of the goods would increase by around 6,63 tonnes. To determine the average weight for each truck, the following equation is used:

$$\textit{Average truck load weight} = \textit{Total weight} \div \textit{Trucks required}$$

	Total weight (tonnes)	Total LDM	Trucks required	Average truck load weight (tonnes)
Modular boxes + pallets	5818,18	3301,77	243	23,94
Only pallets	5811,55	4854,60	357	16,27
Difference	+6,63	-1552,83	-114	+7,67

Table 6. 4: Trucks required and weight-based fill rate estimations

Table 6.4 displays that the average truck load weight with packaged products would increase by 7,67 tonnes. As shown in figure 3.2 by Lumsden (2012), the maximum load weight that a standard EU-trailer can carry is 26 tonnes. Thus, the weight-based fill rate as explained by Ülkü (2012) would measure **92%** (23,94÷26 tonnes) which can be opposed to a estimated weight-based fill rate of **62,6%** (16,27÷26 tonnes) if the product were to be shipped naked on pallets. This calculation also assumes that every truck fully utilizes the maximum LDM capacity (13,6).

6.3 Effects on transportation costs

The decrease in total LDM and amount of trucks required to, would also have an effect on the total transportation costs. In order to calculate the reduction in transportation costs, the chargeable weight has to be considered at first. As explained by Lumsden (2012) and Sudalaimuthu & Anthony Raj (2009) the chargeable weight is calculated with the following formula:

$$\textit{Chargeable weight} = \textit{LDM per unit} \cdot 1850\ \textit{kg}$$

To then determine the total transportation costs, the calculation for chargeable weight per kg is applied:

$$\textit{Total cost} = \textit{Total chargeable weight} \cdot \textit{Price/kg}$$

In the case of Machine Corp., the price/kg varies depending on the consignee country and whether the products are shipped from SE or CE. The average price/kg for the SE and CE outbound deliveries can be found in appendix 2. To carry out the calculations for the new estimated total transport costs, each shipping location (SE & CE) have been calculated separately. And from the shipping location, the deliveries to each country have also been calculated separately, due to the individual prices/kg for every country.

Load carrier	Total chargeable weight (kg)	Total transport cost (SEK)
Modular boxes + pallets	6 108 271	19 805 425
Only pallets	8 981 010	29 129 407
Difference	-2 872 739	-9 323 982

Table 6. 5: Total estimated transport costs

As a result of the total LDM reduction with modular boxes mounted on the products - the total chargeable weight would decrease, as visualized in table 6.5. Naturally, a reduction of the total chargeable weight results in lower transportation costs, and in this case it accounts for a reduction of 9 323 982 SEK.

6.4 Environmental benefits

The total reduction of LDM means that Machine Corp. would be able to decrease the total amount of vehicles ordered from the haulier and thus, the total distance for their shipments will reduce as well. Since the shipments of Machine Corp. are spread all over Europe to a wide range of different countries, it was decided to only investigate the travelled distance between the SW terminal and the CE terminal. However, this route is the most trafficked in regards to Machine Corp's transport operations and accounted for 2181,6 LDM out of a total 4854,60 LDM as displayed in table 4.3 and 4.5. Thus, the volume on the route from SW to CE accounted for about 45% out of the total volume for the five products in the project scope.

To determine the number of trucks required, the same formula as for table 6.4 is used. To calculate the total distance, the distance between SW and CE (1476 km) is multiplied with the number of trucks required to ship the total volume. The number of trucks required indicates in this case how many travels that are needed. Then, to determine the total tonnes-km, the weight of the total transported goods in tons is multiplied with the total transport distance in kms (McKinnon & Edwards, 2010). The addition of modular boxes means that the total weight for the shipped products will increase to some extent. The average weight of a modular box is 4kg, which has been multiplied by the shipped quantity to calculate the new total weight. This gives the following calculation for total tonnes-km in this case:

2581,6 (total weight) · 162360 (total distance) = 419 183 159 tonnes-km

	Distance (km)	Total LDM	No. of trucks	Total distance (km)	Total weight (tonnes)	Average weight/truck	Total tonnes-km
Modular boxes + pallets	1476	1490,7	110	162360	2581,8	23,47	419 183 159
Only pallets	1476	2181,6	161	237636	2553,0	15,86	606 685 896
Difference	0	-690,9	-51	-75276	+28,8	+7,61	-187 502 738

Table 6. 6: Total tonnes-kms with the new packaging strategy

However, this calculation does not consider empty running for the return trip, which is the proportion of vehicle-kms than run empty (McKinnon & Edwards, 2010) and is an inevitable consequence of one-way freight transport. However, the aspect of empty running is out of control for Machine Corp. in this case, since the responsibility lies in the hands of the haulier. Although, the results of the measure with new modular boxes and the fill rate increase taken into consideration, shows that the total tonnes-km will reduce by 187 502 739 or approximately 31% per year on the SW to CE route. A less amount of vehicle travels needed and less tonnes-km transported indicates that Machine Corp. can reduce their environmental impact with a fair amount, as this means less carbon emissions, fuel consumption and infrastructure wear and tear for the transportation activities. This measure has only been applied on one specific route, and the outcome indicates that Machine Corp. can achieve further environmental savings for the other routes as well - as a result of the new packaging strategy.

6.5 Summary of the cost estimation model

The results of the cost estimation model shows that the cost implications of adopting a new packaging strategy would account for a total of 6 982 629 SEK in terms of material and material handling costs. However, the potential saving as a factor of improved vehicle fill rate and lower transportation costs would account for 9 323 982 SEK. This would give Machine Corp. a total saving of 2 341 353 SEK per year, as displayed in table 6.7.

	Costs with the new packaging system (SEK)	Current total costs (SEK)	Total outcome difference (SEK)
Packaging	6 982 629	0	+6 982 629
Transportation	19 805 425	29 129 407	-9 323 982
Packaging + Transport			**-2 341 353**

Table 6. 7: Total costs and savings

In terms of the evaluation regarding fill rate and environmental impact, the measures conducted also indicate significant benefits if the new packaging strategy was to be implemented. As mentioned earlier, Machine Corp. could not provide any current data on fill rates, since it is not measured at the company today. However, the estimations in this case are only theoretical and the calculations assume that all transports are fully utilized in terms of LDM. In order to achieve hundred percent accurate metrics for fill rates, measures must be done continuously in reality for physical shipments. Nevertheless, the estimations provided still indicates that a new packaging strategy would benefit stackability and fill rate in line with the suggestions of McKinnon et al. (2003). In terms of the volume-based fill rate, it was estimated during observations with company employees that the cardboard box was able to utilize 75% more of its volume by stacking other goods on top and the same case was made for the plywood boxes, but with an estimation that a further 33% of its total volume could be utilized. As a result of the increased volume for shipments, the weight-based fill rate would also naturally increase. Based on our estimations this metric would increase to 92% from 62,6%. However, the weight-based fill rate measure only takes the weight of the five products into consideration and would deviate to some extent if other products were to be considered.

Furthermore, a result of the increased fill rate would be that less vehicles and less shipments would be required. Considering the reduced LDM, the total trucks required would decrease by 114 per year. Considering the decrease in trucks necessary to ship the yearly volume and the improved weight-based fill rate, the total tonnes-km per year would also be reduced by a large margin. The measures applied on the route between SW and CE suggest a total tonnes-km reduction of around 31%, which would significantly decrease the environmental impact of Machine Corp's transportation operations.

Metrics	New measurement	Current measurement	Outcome difference
Volume-based fill rate: Plywood boxes	33%		+33%
Volume-based fill rate: Cardboard boxes	75%		+75%
Weight-based fill rate	92%	62,6%	+29,4%
Total vehicles / shipments required	243	357	-114
Total tonnes-km	419 183 159	606 685 896	-187 502 738 (-31%)

Table 6. 8: Evaluation of measurements for fill rate and environmental impact

7 Discussion

This section includes a discussion about the findings of the study with connection to the theoretical framework. The section concerns the main areas of the study; packaging, fill rate, transportation and environmental impact, followed by a discussion about the generalizability of the cost estimation model and opportunities for further research.

7.1 Logistics driven packaging

The packaging logistics concept and the interaction between logistics and the packaging system has the potential to add value to the entire supply chain. Packaging constitutes an important part of logistics operations that is aimed at minimizing costs of delivery and protecting the products to remain profitable (Chan et al., 2006; Paine, 1981). Tertiary packaging refers to a specific packaging method that relates to transportation and logistics where the main purpose is to standardize packaging for transport, enhance cube and volume utilization and to protect the products (Hellström & Nilsson, 2011). The lack of tertiary packaging at Machine Corp. for the European market is the main issue in their logistics operations, which made this particular case study to emerge. Standardized packaging is a fundamental aspect in improving transportation operations in order to shape the dimensions and allow for stackability. The overall cube utilization of the goods is what enables for increased fill rates and in the end, lower transportation costs (Garcia-Arca., 2006). The cost estimation model in this report proved the above statement. The results indicate increased fill rates by 33% respectively 75% depending on tertiary packaging type, and the transportation cost was estimated to reduce by approximately 32% per year (9 323 982 SEK). Ultimately, the decreased transport costs were able to finance the additional cost of introducing the new packaging strategy (material and material handling costs) and generate a total saving of 2 341 353 SEK.

Improved packaging also has direct consequence on environmental aspects as it is linked to the load utilization of shipments (Strömberg et al., 2003) and this was also reflected in the case study. The metrics regarding environmental impact displayed a reduction in required vehicles, leading to lower tonnes-kilometres and consequently lower carbon emissions. In conclusion, the implementation of tertiary packaging provides substantial benefits both economically and environmentally.

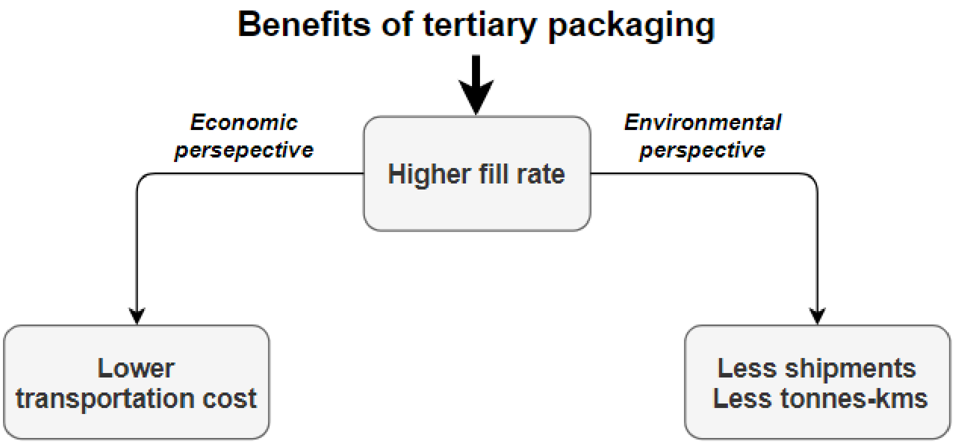

Figure 7. 1: Benefits of tertiary packaging. Own illustration.

The main limitation of the study considering the packaging strategy, is that the results presented are only based on five product types. If the total collection of products would have been included, the results of the cost estimation model would have differed. However, the products in the project scope have the highest shipment quantities and account for approximately 50% of the total volume shipped per year. Thus, the company considered them suitable to be representative for all the measures and estimations provided in the report. Another noticeable aspect considering the packaging of the products, is that the additional time needed for material handling might require Machine Corp to employ an additional packaging operator which would limit the total saving to an extent. However, the increased volumes of packaging material needed to be purchased can strengthen the bargaining position of Machine Corp. against their suppliers, and it is very likely that they can negotiate better prices, which could further increase the total saving.

7.2 Fill rate

As mentioned above, improving the packaging process has the potential to improve the vehicle fill rate of transports. As proven in this case, if vehicle fill rate can be improved through better packaging, then the same amount of goods can be shipped, but with less vehicles and less travelled kilometres (EEA, 2010). The cost estimation model shows that both the volume-based and weight-based fill rate would increase, leading to a less number of vehicles and shipments required. Furthermore, according to McKinnon & Edwards (2010) this would lead to a higher freight efficiency and ultimately lower transportation costs, which was also proven in the case as the transportation costs saw a significant decrease. The improved fill rate measures also assists in reducing total freight vehicle traffic, thus leading to less congestion, emissions and other environmental impacts caused by the road freight transports (EEA, 2010).

In terms of vehicle loading, Jordan (2011) suggested to load the vehicles starting with the largest and heaviest goods, to then fill up with the smaller units to increase the amount of weight and volume carried. This will be an important aspect for Machine Corp. to consider to fully utilize the packaging of the five products in the project scope, since the ambition is to exploit the benefits of the modular boxes by stacking other goods on top. This would further validate the estimations made on fill rates in the study. To keep in mind however, is that the fill rates are purely based on estimations. Although the company used worst case scenarios when the volume-based fill rate estimations were made, this might not reflect the reality if the new packaging strategy were to be implemented. It is also assumed that all vehicles would utilize the total LDM (13,6) which might not always be the case in reality. However, the estimations would still indicate a significant improvement, which is also strengthened by literature.

7.3 Transportation

As mentioned by Lumsden (2012) transport buyers should strive towards a FTL when ordering transports from the hauliers. The purpose is to enable a more cost efficient relation toward the haulier's pricing methods and thereby establishing cost effective transportations. Findings from this study indicated that Machine Corp, by implementing the new packaging strategy, would improve their ability to utilize more of each vehicle load for shipments on the European market. The increased vehicle utilization reduced the total chargeable weight, thus leading to a lower total price paid for the shipped quantity based on the volumes of 2019. This also corresponds to the chargeable weight multiplied with cost per/kg pricing method explained by Sudalaimuthu & Anthony Raj (2009). The increased vehicle utilization will also enable Machine Corp. to have a higher rate of FTL orders from their haulier (Lumsden, 2012). Machine Corp's current packaging strategy which consists of products that are directly mounted on pallets without tertiary packaging, does not allow for stackability which is a crucial step in achieving a cost efficient transportation for both transport buyer and haulier.

The limitations in the findings related to transport costs are that the calculations are applied on the volumes based on 2019 and only considers the five products in the project scope. Since the new implementation of packaging for the European market will result in a new lowered required vehicle capacity based on 2019 years shipped volume, the prices for the transports set by the hauliers could differ from the prices used in this study. However, the reductions in transportation costs presented still indicate that a new packaging strategy would have a positive effect on transport operations.

7.4 Environmental impact

The environmental metrics conducted in the study showed a significant decrease in environmental impact for the transport operations of Machine Corp. This due to an optimization of packaging which enabled for better cube utilization that reduced the empty space creation between transported units (Hellström & Nilsson, 2011). The results of the model showed that the total tonnes-km would reduce by 31% per year and the total amount of vehicles needed to distribute goods would decrease by 114 per year. Thus, the findings of this study does not only provide incitament for reduced transportation cost as a main driver, but the implementation can also be justifiable by reductions of negative environmental impact, which increases Machine Corp's standing in terms of corporate social responsibility.

A limitation for the estimations on environmental impact could be that the increased demand for packaging material will result in a higher consumption of natural resources to produce the modular boxes. An interesting aspect to consider to mitigate this issue, would be for Machine Corp. to investigate a potential return flow of packaging material once it has arrived at customers. This would enable the company to potentially reuse packaging material and reduce natural resource consumptions in the production of new packaging material.

7.5 Generalizability of the findings

As the findings in this thesis are based on a single case study, the findings may not be applicable for all manufacturing companies that distribute their products without tertiary packaging. However, according to Björklund & Paulsson (2014), case studies can to some extent be generalizable if placed in a similar context and if thick descriptions about the case are provided. As Machine Corp's transportation system and freight pricing methods are similar to the ones described in literature, the transportation operations of Machine Corp. could be considered as representative for other companies that distribute a large volume of goods per year with varying dimensions and weights.

Furthermore, the cost estimation model is based on activities and statistics identified from Machine Corp's packaging and transport operations and could therefore not be used to draw any specific statistical conclusions. Although, if the cost estimation model would be applied to a similar company in a similar situation as Machine Corp. the level of generalizability is increased. The model's generalizability is further increased due to that all costs and numerical data can be changed for the metrics and adapted to a specific company. The assumptions made in the model can also be subject for change and some of the metrics can be removed without any consequences. Even though the cost estimation model could be considered to be applicable for a company with the same type of product and packaging characteristics and with the same type of transport operations, the generalizability should be considered relatively low as it is based on single case study.

7.6 Opportunities for further research

Due to the limitation in time and the scope of this study, a total holistic approach of investigating a new packaging strategy for the whole collection of products on the European market could not be taken. This would have provided a more accurate picture in terms of the impacts in costs and potential savings. However, the main opportunity for future research would be to include practical test runs when implementing a new packaging strategy, to compare the results of the cost estimation model with real time transport operations. This would provide the study with accurate measures that have the potential to strengthen the current outcome results. Another interesting aspect would be to investigate the impact of the new packaging strategy on damaged goods. This was not possible in this study as there were no available statistics regarding the matter. For future research, this aspect could be included if current statistics are available - to then be compared against the reality after implementing a new packaging strategy. If a decrease in damaged goods can be achieved, this could lead to higher service levels and improved customer satisfaction.

8 Conclusion

This section presents the concluding remarks of the study and answers the research questions that have been evaluated in this study.

The purpose of this study was to create a cost estimation model that would illustrate what effects a new packaging strategy will have on transportation costs, fill rate and environmental aspects. The purpose was divided into a main research question and two sub-research questions. The main question was what the cost implications and potential savings would be by adopting a new packaging strategy. The sub questions were what impact the new packaging strategy would have on vehicle fill rate and environmental aspects. To answer these questions, a cost estimation model was created containing metrics collected through literature and empirical data. Thereafter, the metrics were calculated and analysed and the results were presented.

RQ: What are the cost implications and potential savings of adopting a new packaging strategy?

The results of the cost estimation model showed that investing in a new packaging strategy would increase the total packaging cost by 6 982 629 SEK. However, an implementation of a new strategy was proven to reduce the total transportation costs by 32 %, from 29 129 407 SEK to 19 805 425 SEK. Thus, the data analysis confirmed that that the adoption of a new packing strategy would come with great monetary benefits and the reduction in transportation costs would cover the cost for packaging with a wide margin, ultimately generating a substantial saving of 2 341 353 SEK per year.

SRQ1: How does the new packaging strategy affect vehicle fill rate?

Further data analysis showed a clear connection between improved packaging and fill rate. The new packaging strategy involved the adoption of modular boxes, which enables stackability of transported goods, leading to better volume utilization in vehicles. The findings of the case study showed that the volume-based fill rates would increase with 33% for products packaged in plywood boxes and 75% for the products packaged in cardboard boxes. In terms of the weight-based fill rate, it was estimated to increase by 29,4%. Therefore, conclusions can be drawn that the new packaging strategy would have a positive impact on fill rate and Machine Corp. would efficiently optimize their loads during transportation.

SRQ2: How does the new packaging strategy affect environmental aspects?

As mentioned previously, fill rate has a direct impact on the optimization of transport operations. The choice of packaging is a critical aspect in logistics, as empty spaces arising from low fill rates leads to more overall shipments than necessary, which ultimately leads to negative effects on the environment. The findings of this research reveals that an adoption of a new packaging strategy will have a positive effect on the environment. The increase in fill rates is estimated to reduce the total truck shipments required by 114 per year. Less required transportations per year would also lead to a significant reduction in travelled tonnes-kms. The total tonnes-kms were estimated to decrease by 31% on the SW to CE route, consequently leading to a significant carbon emission reductions.

To conclude, the cost estimation model indicates that the benefits of implementing a new packaging strategy would exceed the total costs required, thus leading to both monetary savings and more efficient and sustainable road freight operations.

9 References

Abdou, G., Yang, M. (1994). A systematic approach for the three-dimensional palletization problem, *International Journal of Production Research*, Vol. 32 No. 10, pp. 2381-2394.

Ahrne, G., Svensson, P. (2015). *Handbok i kvalitativa metoder.* Stockholm: Liber.

Arvis, J.F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., Raj, A. (2014). Connecting to Compete 2014 - Trade Logistics in the Global Economy. *The Logistics Performance Index and its Indicators*. [Online] Available at: http://hdl.handle.net/10986/20399 [Accessed 2020-04-17].

Blais, P. (2011). *Business Analysis: Best Practices for Success. The definitive guide on the roles and responsibilities of the business analyst.*

Björklund, M. & Paulsson, U. (2014). *Academic papers and theses – to write and present and to act as an opponent*. Lund: Studentlitteratur.

Bryman, A. (2018). *Samhällsvetenskapliga metoder*. 3rd ed. Stockholm: Liber.

Bryman, A., Bell, E. (2017). Företagsekonomiska forskningsmetoder. 3rd ed. Stockholm: Liber

Cao, G. (2007). The Pattern-matching Role of Systems Thinking in Improving Research Trustworthiness. *Systemic Practice Action Research* Vol. 20 pp. 441–453.

Chan, F.T.S., Chan, H.K., Choy, K.L. (2006). A systematic approach to manufacturing packaging logistics, *International Advanced Manufacturing Technology*. Vol. 29, pp. 1088-1101.

Collis, J., Hussey, R. (2014). *Business Research: A Practical Guide for Undergraduate and Postgraduate Students*. eng. 4th edition. Palgrave Higher Ed M.U.A.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th ed. Sage Publications, Inc.

Creswell, J.W., Plano Clark, V.L. (2007). *Designing and Conducting Mixed Methods Research*. Sage Publications, Inc.

Denscombe, M. (2010). *The Good Research Guide: for small-scale social research projects*. 3rd ed. Maidenhead: Open University Press

Doherty, S., Hoyle, S. (2009). Supply Chain Decarbonization : The Role of Logistics and Transport in Reducing Supply Chain Carbon Emissions. *World economic forum*. Geneva.

Easterby-Smith, M., Thorpe, R., Jackson, P. R., Jaspersen, L. J. (2018). Management & Business Research. 6th ed. London: SAGE Publications Ltd.

ECR Europe (1997). The Efficient Unit Loads Report, *ECR Europe*. Brussels.

Edwards, J., Mckinnon, A., Cullinane, S. (2010). Comparative analysis of the carbon footprints of conventional and online retailing: A “last mile” perspective. *International Journal of Physical Distribution & Logistics Management.*

Ejvegård, R. (2009). *Vetenskaplig metod*. 4th ed. Lund: Studentlitteratur AB.

European Commission. (2015). Directive (EU) 2015/719 of the European Parliament and of the Council. Strasbourg: European Union. [Online] Available at: http://data.europa.eu/eli/dir/2015/719/oj [Accessed 2020-04-28].

European Environment Agency. (2010). Load factors for freight transport. [Online] Available at: http://www.eea.europa.eu/data-and-maps/indicators/load-factors-for-freight-transport [Accessed 2020-04-16].

European Environment Agency, (2005). [Online] Available at: https://www.eea.europa.eu/data-and-maps/indicators/ load factors for freight transport [Accessed 2020-05-12].

Fawcett, S.E., Cooper, MB. (1998). Logistics Performance Measurement and Customer Success. *Industrial Marketing Management*. Vol. 27(4), pp. 341-357.

Garcia-Arca, J., Prado-Prado, J.C. and Lorenzo, A.G. (2006). Logistics improvement through packaging rationalization: a practical experience. *Packaging Technology and Science*. Vol. 19, pp. 303-308.

Gourdin, K. (2001). *Global logistics management: a competitive advantage for the new millennium.* Oxford UK: Blackwell Publishers Ltd.

Gustafsson, K, Jönson, G, Smith, D & Sparks, L (2005). Packaging logistics and retailers´ profitability: an IKEA case study Paper presented at 13th *Research Conference of the European Association for Education and Research in Commercial Distribution*. Lund: Sweden, 2005/06/29 - 2005/07/01.

Gustavo, J.U., Pereira, G.M., Bond, A.J., Viegas, C.V., Borchardta, M. (2017). Drivers, Opportunities and Barriers for a Retailer in the Pursuit of More Sustainable Packaging Redesign. *Journal of Cleaner Production*. Vol. 187, pp. 18-28.

Hellström D., Olsson A. (2017). Managing Packaging Design for Sustainable Development: A Compass for Strategic Directions. 1. No. Oxford, UK. *John Wiley & Sons*

Hellström, D., Nilsson, F. (2011). Logistics-driven packaging innovation: a case study at IKEA. *International Journal of Retail & Distribution Management*, Vol. 39(9), pp. 638-657.

Hernon, P., Schwartz, C., (2009) Reliability and validity. *Library & Information Science Research* Volume 31(2), pp, 73-74.

Hänel, G. (2018). *Calculate Loading Meter (LDM)*. [Online] Available at: https://impargo.de/en/blog/calculate-ldm#truck [Accessed 2020-04-25].

ITF (2010). Reducing transport greenhouse gas emissions : Trends and data 2010, *international transport forum*, OECD report.

Johnson, R.B., Onwuegbuzie, A.J., Turner, L.A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*. Vol. 1(2), pp. 112-133.

Jonsson, P., Mattsson, S-A (2016) *Logistik, läran om effektiva materialflöden.* 3rd ed. Lund: Studentlitteratur.

Jordan, T. (2011). How to Increase Gross Weight or Load Factor. [Online] Available at: http://www.ehow.com/how_5767255_increase-gross-weight-load-factor.html [Accessed 2020-04-26].

Jönson, G. (2000). Packaging Technology for the Logistician, Second Edn, *Department of Design Sciences, Division of Packaging Logistics*, Lund University, Lund.

Kasilingam, R. (1996). Air Cargo Revenue Management: Characteristics and Complexities. *European Journal of Operational Research*. Vol. 96, pp. 36-44.

Kulinska, E. (2014). Importance of Costs of Risks in Material Management. *Foundations of Management*. Vol. 6 (1), pp. 7-19.

Kye, D., Lee, J. and Lee, K. (2013). The perceived impact of packaging logistics on the efficiency of freight transportation (EOT). *International Journal of Physical Distribution & Logistics Management*. Vol. 43(8), pp. 707-720.

Lai, K-H., Ngai, E.W.T., Cheng, T.C.E. (2004). An Empirical Study of Supply Chain Performance in Transport Logistics. *International. Journal. Production Economics*. Vol. 87, pp. 321-331.

Laia, J., Harjatib, A., McGinnisc L., Zhouc, C., Guldberg, T. (2008). An economic and environmental framework for analyzing globally sourced auto parts packaging system, *Journal of Cleaner Production.*

Lama, B., Schofer, J.L. (2019). Freight Performance Measurement in FAST Act-Mandated State Freight Plans. *Transportation Research Record*. Vol. 2673(4), pp. 458-472.

Lambert, D.M., Stock, J.R. and Ellram, L.M. (1998). Fundamentals of Logistics Management, *International ed*., McGraw-Hill/Irwin, Boston, MA.

Lee SG, Lye SW (2003). Design for manual packaging. *International Journal Physical Distribution Logistics Management* Vol. 33 (2) pp,163–189

Lumsden, K. (2012). *Logistikens Grunder* 3rd ed. Lund: Studentlitteratur.

Mariano, E.B., Gobbo, J.A., Camioto, F.C., Rebelatto, D.A.N. (2016). CO2 Emissions and Logistics Performance: A Composite Index Proposal. *Journal of Cleaner Production*. Vol. 163, pp. 166-178.

Merriam, S.B. (2002). *Qualitative research in practice: examples for discussion and analysis.* Jossey-Bass: San Francisco, USA

Merriam, S.B. (1998). *Qualitative research and case study application in education*. Jossey Bass:San Francisco, USA

Merriam, S.B. (2009). *Qualitative Research: a guide to do design implementation.* John Wiley & Sons: USA

McKinnon, A. C. (1999). Vehicle Utilisation and Energy Efficiency in the Food Supply Chain: Full Report of the Key Performance Indicator Survey. *Logistics Research Centre*. Heriot-Watt University.

McKinnon, A., Ge, Y., Leuchars, D. (2003). Analysis of Transport Efficiency in the UK Food Supply Chain: Full Report of the 2002 Key Performance Indicator Survey. *Logistics Research Center*. Heriot-Watt University.

McKinnon, A., Ge, Y. (2004). Use of a synchronised vehicle audit to determine opportunities for improving transport efficiency in a supply chain. *International Journal of Logistics Research and Applications*. Vol. 7(3), pp. 219-238.

McKinnon, A., Ge, Y. (2006). The Potential for Reducing Empty Running by Trucks: A Retrospective Analysis. *International Journal of Physical Distribution & Logistics Management*. Vol. 36(5), pp. 391-410.

McKinnon, A., Leonardi, J. (2008). The Collection of Long Distance Road Freight Data in Europe. *8th International Conference on Survey Methods in Transport*.

McKinnon, A., Edwards, J. (2010). Opportunities for improving vehicle utilization. In: McKinnon, A., Browne M., Piecyk, M., Whiteing, A. *Green logistics: improving the environmental sustainability of logistics*. Kogan Page Limited: Great Britain, United States. pp. 195-213.

Mentzer, J.T., Konrad, B.P. (1991). An Efficiency/Effectiveness Approach to Logistics Performance Analysis. *Journal of Business Logistics*. Vol. 12(1), pp. 33-61.

Nilsson, L. J., Khan, J., Andersson, F. N. G., Klintman, M., Hildingsson, R., Kronsell, A., ... Smedby, N. (2013). *I ljuset av framtiden: Styrning mot nollutsläpp 2050*. Lund University.

Nilsson, F. Pålsson H. (2006). Demand-driven logistics from a packaging perspective. *Logistics Research Network* pp. 288-293

Paine, F.A. (1981). Fundamentals of Packaging, 1st revised ed., *Brookside Press*, Leicester.

Pennington, R.A. and Tanchoco, J.M.A. (1988). Robotic palletization of multiple box sizes, *International Journal of Production Research,* Vol. 26(1), pp. 95-105.

Penman, I, & Stock, J, R (1994). *Environmental issues in logistics: The logistics handbook*. Robeson JF, Copacino WC (eds).The free press: New York: 840–857.

Piecyk, M., (2010). Analysis of Long-term Freight Transport, Logistics and Related CO2 Trends on a Business-as-Usual Basis. PhD Thesis. *Heriot-Watt University*.

Powell R.R., Connaway L.S. (2004) *Basic research methods for librarians*. Libraries Unlimited: Westport, CT. pp, 170-173.

Pålsson, H (2018). *Packaging Logistics: Understanding and managing the economic and environmental impacts of packaging in supply chains*. 1st ed. Kogan Page: London.

Pålsson, H., Finnsgård, C. and Wänström, C. (2013). Selection of packaging systems in supply chains from a sustainability perspective: the case of Volvo. *Packaging Technology and Science*. Vol. 26(5), pp. 289-310.

Santén, V., Rogerson, S. (2018). Shippers' Transport Efficiency: An Approach for Measuring Load Factor. *Logistics Research*. Vol. 11(3), pp. 1-15.

Santén, V. (2017). Towards More Efficient Logistics: Increasing Load Factor in a Shipper's Road Transport. *International Journal of Logistics Management*. Vol. 28(2), pp. 228-250.

Saunders, M., Lewis, P. & Thornhill, A., (2016). *Research Methods for Business Students*. Harlow: Pearson Education Limited.

Sjöström, K. (2000). Building towards theory in packaging logistics, *Packaging Logistics Review*. Econpap. Finland, pp, 101-106.

Sudalaimuthu, S., Anthony Raj, S. (2009). *Logistics Management for International Business - Text and Cases*. PHI Learning Private Limited, New Delhi.

Swedish Transport Agency; Trafikverket; Trafikanalys, (2011). *Regeringsuppdrag att analysera och föreslå åtgärder för minskad tomdragning och ökad fyllnadsgrad*. Sweden.

Tompkins, J.A., White, J.A ., Bozer, Y.A, Tanchoco, J.M.A. (2010). *Facilities planning*. 4th ed. Wiley: New Jersey.

Ülkü, M.A. (2012). Dare to care: Shipment consolidation reduces not only costs, but also environmental damage. *International Journal of Production Economics*. Vol. 139(2), pp. 438-446.

Williamson, K., (2002). *Research Methods for Students, Academics and Professionals*. Wagga: Woodhead Publishing Ltd.

Wills G (1990). Packaging as a source of profit , *International Journal of Physical Distribution & Logistics Management* Vol. 20(8), pp, 5–20.

Yin, R. K. (2009). *Case study research: design and methods*. 4th Edition, SAGE publication: London, UK.

Yin, R. K. (2003). *Case study research*. 3rd ed. Vanderbilt University: Washington DC, USA.

Zheng G. X., Bu, A-Y. (2009). Interpretation of conceptual picture languages in packaging, *2009 IEEE 10th International Conference on Computer-Aided Industrial Design Conceptual Design*. pp. 1593-1596.

Åkerman, I., Jonsson, R. (2007). European Modular System for Road Freight Transport – Experiences and Possibilities. *Transport Research Institute Report 2007:2 E*. [Online] Available at: http://www.modularsystem.eu/download/facts_and_figures/20080522att01.pdf [Accessed 2020-04-05].

Linnæus University
Sweden

10 Appendices

10.1 Appendix 1

Calculations for transport cost

Product	Quantity	Consignee country	Modular box	LDM	Current chargeb. weight	% increase fill rate	New LDM	New chargeable weight	Price per/kg	Total cost (SEK)
1	1	SE	001 Plywood	0,7	1295	33%	0,53	973,68	0,72	701,05
1	1	SE	001 Plywood	0,7	1295	33%	0,53	973,68	0,72	701,05
1	1	SE	001 Plywood	0,7	1295	33%	0,53	973,68	0,72	701,05
3	1	LT	012 Cardboard	0,4	740	75%	0,23	422,86	0,80	338,29
3	1	LT	012 Cardboard	0,4	740	75%	0,23	422,86	0,80	338,29
3	1	LT	012 Cardboard	0,4	740	75%	0,23	422,86	0,80	338,29

Calculations for packaging cost

Product	Quantity	Modular box	LDM	Modular box price	Labour cost (h)	Packaging time (h)	Material handling cost	Total packaging cost
1	1	001 Plywood	0,7	1003,08	862,52	0,25	215,63	1218,71
1	1	001 Plywood	0,7	1003,08	862,52	0,25	215,63	1218,71
1	1	001 Plywood	0,7	1003,08	862,52	0,25	215,63	1218,71
3	1	012 Cardboard	0,4	299,12	862,52	0,13	115,00	414,12
3	1	012 Cardboard	0,4	299,12	862,52	0,13	115,00	414,12
3	1	012 Cardboard	0,4	299,12	862,52	0,13	115,00	414,12

10.2 Appendix 2

Price lists for SW and CE

Sweden Outbound, including domestic Sweden		
Shipper Country	Consignee Country	SEK Cost/kg
SE	SE	0,72
SE	FR	1,02
SE	NO	2,04
SE	RU	2,03
SE	PL	1,97
SE	IT	2,07
SE	DK	2,52
SE	FI	2,57
SE	GB	2,97
SE	DE	1,40
SE	EE	0,95
SE	TR	2,57
SE	ES	3,26
SE	GR	2,31
SE	NL	1,97
SE	LT	0,80
SE	BE	1,62
SE	IE	3,02
SE	PT	3,05
SE	AT	1,67
SE	UA	4,67
SE	LV	1,05
SE	BG	3,75
SE	HR	2,25
SE	CH	2,36
SE	RS	3,26
SE	CZ	1,47
SE	HU	1,53
SE	XS	5,06
SE	SI	3,90
SE	RO	2,61
SE	CH	2,66
SE	PL	1,65
SE	SK	3,15
SE	LU	3,09

Central Europe Outbound		
Shipper Country	Consignee Country	SEK Cost/kg
CE	FR	5,70
CE	GB	6,75
CE	IT	4,05
CE	DE	3,75
CE	SE	18,00
CE	ES	8,55
CE	NL	4,35
CE	BE	3,90
CE	FR	3,75
CE	HU	6,30
CE	IE	8,40
CE	AT	7,20
CE	CZ	3,90
CE	RO	8,10
CE	PT	10,35
CE	LU	4,65
CE	FI	12,30
CE	PL	10,50
CE	DK	13,80
CE	EE	15,00
CE	LV	6,90
CE	CH	7,20
CE	LU	4,65