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Environmental and Cost Analysis at Volvo Locistics Corporation Emballage

- A study of the flow of L-packaging between producers, terminals and users in Europe and an evaluation of direct transports.

Bachelor of Science Thesis (Economy and Manufacturing)

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Abstract

Sustainable development is getting more important than ever in today's industry. Transportation stands for a significant part of the green house gas emissions, and heavy-duty vehicles represent about a quarter of EU road transport CO2 emissions (EU commission, 2011). Traditionally, logistic research has been focusing on costs; however a green logistics area of research is emerging. This thesis is focusing on Volvo Logistic Emballage's supply chain, focusing on newly manufactured packaging from a green logistics and a lean perspective. The purpose of this thesis is to examine the environmental and economical performance of the current flow of wooden packaging material, focusing on wooden packaging in VLC's L-series.

VLC is using a closed loop system where the same pallets and frames are used several times. There is a constant need of new packaging as packaging material brakes and the user base increase. The new packaging is an input in the pool system. This thesis focuses on the four largest producers of L-packaging in Europe, all located in Sweden. The two main users of the packaging is also analyzed, one is located in Sweden and one in the Netherlands. Transport stands for one of the largest cost within VLC, which makes it a potential area of cost reductions. External carriers are performing the transports and the transport cost is based on pay agreements between VLC and the carriers.

Today, the produced packaging is being transported from the producers to the terminals, from where the packaging is being sent to the users together with other types of packaging. The large quantities ordered open up for direct transports between producer and user. The filling degree when sending pallets and frames separately is around 75 % for pallets and around 80 % for frames. A mixed load of pallets and frames shows a filling degree of up to 91 %. The transport distances of direct transport in Sweden are cut by up to 58 % when not passing the terminal in Gothenburg, and up to 70 % in the Netherlands, when not passing the terminal in Gent. Emission auditing of the transports shows significant decreases of emission caused by road transport by using direct transports, in some cases by up to 50 %. However, the decrease from mixed transport is slightly lower than the decrease when using full loads of separated packaging.

The costs for direct transport are significantly lower than transports via terminals, focusing on the transport cost and the handling cost at the terminal. The cost reductions are estimated to up to 55 percent, due to shorter and fewer transports and avoiding unloading at the terminal. Estimated numbers have been used, in order to calculate the cost if direct transports as no agreements for the distances are set up today. The change might also lead to increased costs due to administration and inventory costs. The cost savings due to direct deliveries need to be larger than the increased costs.

The change might also lead to changes for the organizations concerned. Depending on how the direct transports is implemented, administrative work and inventory holding might occur. However, it is important that the quality of the new packaging is controlled and that the packaging is registered in the system. Even though the work load might increase to some extent, direct transports comes with lower costs and significantly lower emissions and the thesis comes to the conclusion that direct transports are beneficial for VLC.

Keywords: returnable packaging, green logistics, Lean, direct transports, vehicle utilization, flow, emission auditing, cost analysis.

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Vanja and Sofie

Table of Content

1. Introduction

In this section, the background of the thesis is presented. The current literature review of scientific research as well as Volvo Logistics is described. Furthermore, the purpose of the thesis and the problem discussion follows.

1.1 Background

Sustainable development is getting more important than ever in today's industry. Transportation stands for a significant part of the green house gas emissions, and heavy-duty vehicles represent about a quarter of EU road transport CO_2 emissions (EU commission, 2011). The transport system needs to be changed if sustainable growth is to be achieved. Moreover, the human population is growing which leads to an increased demand of freight and public transport around the world. Thus, it is getting more important for society and businesses to have efficient transport systems to reduce emissions.

Traditionally, logistic research has been focusing on costs; however a green logistics area of research is emerging. Green logistics is an environmentally responsible logistics approach where the environmental aspect is taken into account within the supply chain. Thus, the environmental impact of the total system has to be evaluated. Moreover, sustainable logistics has three dimensions: the economic dimension, the environmental dimension and the dimension of the society (Green Logistics, 2010).

Furthermore, a Lean approach to logistics has been developed. Lean logistics has evolved from Lean Production that has dominated the manufacturing trends during the last decade. Lean attempts to find activities that do not create value and can therefore be eliminated from the system. Often, each of the elements of the supply chain optimizes its own performance and forgets about the rest of the supply chain. It is important to view the sequence of activities in the supply chain as a whole in order to find the lowest total cost solution (Jones at al, 1997).

This thesis is focusing on Volvo Logistics' (VLC's) supply chain, focusing on newly manufactured packaging from a green logistics and a lean perspective. VLC is one of the leading providers of logistics services to the global automotive-, transportation- and aerospace industries. Their task is to develop logistics solutions for the entire Volvo Group as well as for external companies (Volvo Group, 2012).

Transport stands for one of the largest cost within VLC, which makes it a potential area of cost reductions. VLC has worked on reducing climate impact of their transport activities by focusing on lower emissions, alternative fuels, energy efficiency and development of knowledge. The overall objective is to reduce carbon emissions per ton-km from transport in Europe by 50 % until 2020. Between 2006 and 2010, Volvo AB cut their CO_2emissions from transports by 22 %, measured in average number of grams of CO_2 per ton-kilometer (Motormagasinet, 2012). This achievement has been a reason for pride within the company and has created a desire to continue the sustainable development work. However, the achievements have to be continuous, and a more radical approach might be needed.

VLC is offering a range of standard packaging solutions and is using a closed loop system where the same pallets and packaging are used several times. The purchasing of new packaging material is important to understand the total supply chain, and is also of importance when it comes to the total flow of material within the system, hence this thesis focuses on the distribution of new packaging. The optimization today is performed from an economical point of view primarily, which makes it interesting to investigate possible environmental improvements.

Even though Volvo AB has been working on its environmental impact there is a lot of improvements left to do. One incentive to become a sustainable company is economic benefits such as cost reductions. It has been shown that making the supply chain green can lead to economic benefits such as lower transportation costs (Bearth, 2008). By using vehicle utilization and optimizing the supply chain the amount of transport can be reduced, leading to reduced CO2 emissions and cost reductions. Moreover, improvements that lead to benefits for the society as well as the economy and the environment are likely to become long term solutions.

The environmental impact is getting more enlightened than ever and for a company like Volvo AB it is important to continue the development of its environmental profile. The societies, customers as well as the employees are more demanding considering environmental issues and Volvo AB must not forget to take the environment into account to be prepared for future regulations and changes in demand. This also leads to economic benefit for the company. Moreover, the distribution of new packaging within Volvo Logistics is an important part of the total flow of material and improvements would affect the whole supply chain.

1.2 Purpose

The purpose of this thesis is to examine the environmental and economical performance of the current flow of wooden packaging material within the returnable packaging pool at Volvo Logistics, focusing on the distribution of newly manufactured packaging to users, as well as to analyze and discuss potential improvements.

1.3 Problem Definition

Sustainability is one of Volvo's core values, thus it is important to improve the environmental, economic and social impact within the distribution area.

The general problem formulation is: *How can the current supply chain be improved in order to minimize cost and environmental impact within Volvo Logistic, focusing on newly manufactured packaging to users?*

This general problem is broken down into the following research questions:

RQ1: How is the current flow of packaging material organized?
RQ1a: Which are the producers of the wooden packaging?
RQ1b: Who are the main users of the wooden packaging?
RQ1c: How is the flow of information organized?

RQ2: How can transport cost and environmental impact be reduced?

RQ3: What requirements does the redesign have on the organization of terminals?

1.4 Structure of the thesis

In order to clarify the disposition of this thesis, the structure of the report is presented below.

Chapter 1 – Introduction
The background, purpose and the problem definitions of the thesis are here described.

Chapter 2 – Volvo Corporation
This chapter describes the company which is the base for the thesis. Volvo Logistics Corporation (VLC) is a part of the Volvo Group and is divided into three divisions: Emballage, Inbound and Outbound. This thesis is focusing on the division Emballage.

Chapter 3 – Method
This chapter describes the system boundaries for the thesis and the different research strategies chosen. The data collection techniques used was literature, interviews and observations. Moreover, Mapping of Activities and Emission Auditing have been performed.

Chapter 4 – Theoretical framework
This chapter describes the theory that has been studied in order to perform the thesis study. The theoretical framework is generally based on the sustainability- and lean approach to logistics.

Chapter 5 – Empirical findings
This chapter gives a detailed description of VLC and what the thesis is focusing on. The current situation is presented in order to understand the possible improvements.

Chapter 6 – Analysis
This chapter presents the analysis of this thesis and the relationship between the methods, the theoretical framework and the empirical findings.

Chapter 7 – Discussion and Conclusion
This chapter gives a further discussion about the analysis and different aspects that are important to take into account. A research question check point is presented in order to know where in the thesis the answers are to be found. Moreover, the chapter summarizes the conclusions of the thesis which are based on the research questions. Finally, the chapter ends with recommendations to Volvo Logistics Corporation.

1.5 List of definitions

IPCC- Intergovernmental Panel on Climate Change, part of UN's general assembly.
VLC- Volvo Logistics Corporation, part of Volvo Group.
PMR- Packaging Material Receipt, part of Volvo Logistics' business system.
TPS – Toyota production system, developed by Toyota.
V-EMB – Volvo Emballage.
L-packaging – The most commonly used type of wood packaging within Volvo.
L-series- Same as L-packaging
Pallets - Flat transport structure that supports goods, one part of the L-packaging.
Frames – Supporting material on pallets, part of the L-packaging.

Emissions focused on in the environmental analysis:
PM – Particular Matter
HC – Hydrocarbon
NOx – Nitrogen Oxide
SOx – Sulfur Oxide
CH4 – Methane
CO2 - Carbon Dioxide

2. Volvo Corporation

In this chapter, a brief description of Volvo Group and Volvo Logistics is presented. Furthermore, the Emballage, Inbound and Outbound divisions at Volvo Logistics will be presented.

2.1 Volvo Group

The Volvo Group offers commercial transport solutions and is one of the world´s leading providers of products such as trucks, buses, construction equipment, engines and drive systems for boats and industrial applications, as well as aircraft engine components. The Volvo Group also provides its customers with financial solutions and other services. Volvo Group has about 100 000 employees with production in 19 countries and sales in about 180 markets (Volvo Group, 2012).

In 1915, Volvo was a part of AB SKF. The founders, Assar Gabrielsson and Gustaf Larson decided to start the construction of a Swedish car that was aimed to become one of the world´s leading manufacturers of transport solutions. The first car was made in Hisingen, Gothenburg and rolled out in April 14, 1927, which is the official date of the founding of Volvo. However, in 1999 the passenger coach division Volvo Cars was bought by Ford Motor Company. Since 2011 Olof Persson is CEO of the Volvo Group and president of Volvo AB.

The Volvo Groups vision is to be seen as the world´s leading provider of commercial transport solutions. Its corporate culture is seen as a unique asset and by taking advantage of the culture and the expertise provided; the Volvo Group can reach their vision. Quality, safety and environmental care are Volvo Groups mutual values that make an important part of its corporate culture. The values permeate the organization and influence their products and their work.

The Volvo Group has an established and strong position in Europe, North America and South America. The position has been strengthened in many markets in Asia since UD Trucks and Lingong became a part of the Volvo Group as well as the cooperation within trucks and buses with Indian Eicher Motors. As a result from this the Volvo Group established a global industrial structure within manufacturing, sales- and distribution channels in all continents.

2.2 Volvo Logistics Corporation

As a part of the Volvo Group, Volvo Logistics Corporation (VLC) provides logistic solutions within the automotive and aviation industry. VLC has more than 50 years in the business and serves a global market with a series of logistics services across the supply chain. VLC serves the companies within the Volvo Group as well as external customers like Volvo Cars Corporation, GM, Aston Martin, Ford and suppliers of the automotive industry. VLC has more than 30 offices throughout the world and 1914 employees (VLC, 2010).

VLC´s mission is to develop and deliver complete supply chain solutions that add value to its customers worldwide. Moreover, VLC's vision is to be recognized as the leading logistics partner within the automotive, commercial transport and aviation industries. As a part of the Volvo Group, VLC also share its core values; quality, safety and environmental care. The core values are common for all the companies within the Volvo Group and in a logistic context they imply focusing on quality regarding customers' expectations, safety issues such as punctual deliveries and undamaged products as well as working conditions for the people handling the goods and environmental care, mainly concerning decreases of carbon emissions.

Furthermore, VLC is certified with the quality standard ISO 9001 as well as the environmental standard ISO 14001.

VLC is divided into three divisions: Emballage, Inbound and Outbound. Emballage is responsible for the packaging and protection of goods, whereas inbound and outbound are responsible for the goods transported from suppliers to factories and from factories to customers. The areas that belong to Emballage and Inbound are seen in figure 1.

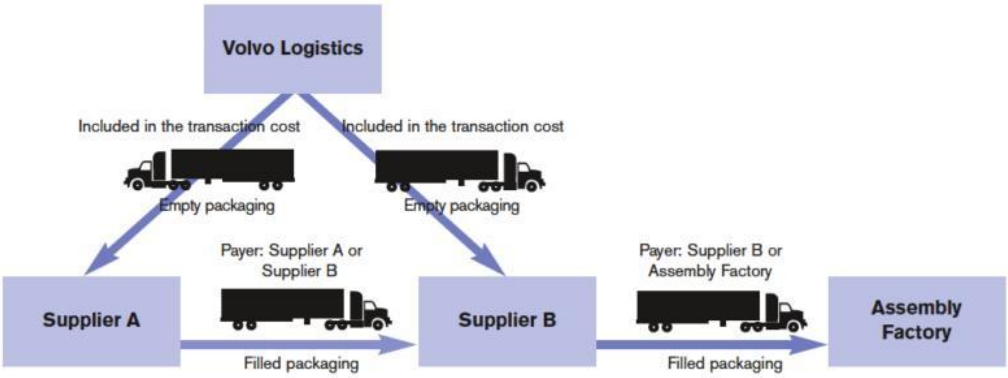

Figure 1. VLC Emballage and VLC Inbound (Volvo Group, 2012).

2.2.1 VLC Emballage

The Emballage division is responsible for the packaging of goods. The users can choose from standard packaging systems or an individually tailored solution for their goods. VLC Emballage makes sure that the right packaging is developed and transported to the user. The standard packaging is owned by VLC through its whole life cycle whereas the customers own the tailored solutions. The packaging material is made out of plastic or wood and VLC Emballage offers a range of standard models.

VLC has around 30 terminals and depots throughout the world, where they store different types of empty packaging. The main terminals are placed in Gothenburg and in Gent. The standard packaging is organized in a closed loop system where the packaging material is being washed, repaired and reused. Some of the warehouses have washing stations and repairing stations which normally allow the plastic pallets to be reused for up to seven years, whereas wooden pallets last for about three years.

This thesis focuses on the production of wooden packaging and the flow of material from the producers to warehouses and users. In order to organize and control the flow of material, VLC Emballage uses a PMR system (Packaging Material Receipt Note) to locate its packaging material. The users of the packaging register PMR:s as the material is being sent or collected which allow VLC Emballage to control the flow of material between the producers, inventories, suppliers and factories. Almost all of the newly manufactured packaging is today being sent to the main terminals in Gothenburg and Gent, thus the focus in the thesis is on these terminals.

The wooden packaging is divided into different families depending on size and type. This thesis focuses on the L-family which is the most commonly used pallets, carriers, shim and top covers at VLC. The quantities used and produced are large and growing and the flow of material from the producers affects the loop system and positioning of packaging. Thus, an improvement of the current flow of material would affect the amount of transports in the system as a whole.

This thesis concentrates on VLC Emballage, and in the empirical findings the Emballage division is presented in further detail. Moreover, the flow of newly manufactured L-family packaging is analyzed in order to find improvements on the amount of transport used today.

2.2.2 Inbound

VLC Inbound is responsible for the supply of material between users and factories. They offer transport solutions as well as development of inbound material flows. VLC Inbound makes analyses of the production system to make sure that the offered logistics solution suits and become an integrated part of the system.
Inbound is responsible for the transportation of goods from supplier to factories. As VLC inbound is not the focus of this thesis this division will not be further discussed.

2.2.3 Outbound

VLC Outbound is responsible for the transportation and distribution of vehicles from the factories to the customers. As VLC Outbound is not the focus of this thesis this division will not be further discussed.

3. Method

In this chapter, the methodology of the thesis is described. First, the scope of the thesis was chosen, which is described in the system boundaries section below. Moreover, the data collection was an ongoing process for the first half of the project, and different types of methods used follows. Furthermore, the empirical study is based on interviews and observations that has been collected in a mapping of the activities and used in emission auditing calculations. The mapping of the activities in the system boundaries helped to make a clear picture of how the situation looks like today and the emission auditing was used to show what result an improved system would have regarding CO2 emission.

3.1 System Boundaries

In order to answer the objective of this thesis, system boundaries have been defined. The thesis focuses on the distribution of newly manufactured packaging to the warehouses and users, thus the empirical study focuses on VLC Emballage and the distribution from the producer of L-family wooden packaging to VLC's two main warehouses in Gothenburg and Gent. Moreover, the analysis discusses an improved flow of packaging, which includes sending packaging directly to the user.

The distribution system of packaging is complex and, as seen in figure 2, all of the divisions at VLC are taking part in the distribution lane. VLC uses a closed loop system, where packaging is used over and over again. As packaging material brake and the demand increases, new packaging is needed. This leads to a flow of newly manufactured packaging, which also takes part in the distribution system. Furthermore, as the packaging material has been used, the user sends it back to the warehouse closest to them. Because of the complexity of the system, this thesis only focuses on the distribution of newly made packaging, as seen in figure 2.

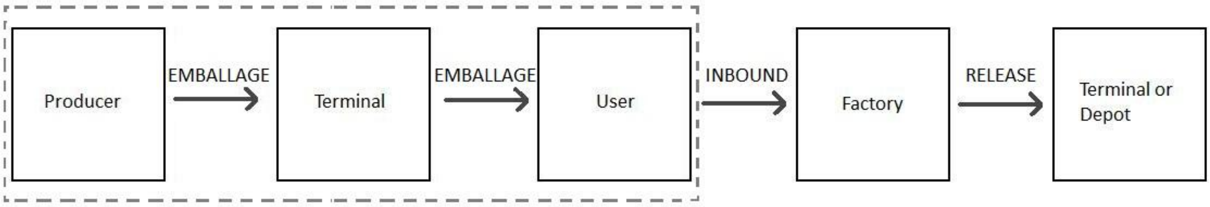

Figure 2. System boundary used in this thesis, based on the distribution system of packaging that is performed by VLC Emballage.

3.2 Data Collection

The different data for the entire thesis was collected during January and April in 2012. The data requested in order to perform the Mapping of Activities and estimation of costs and CO2 emissions, were for January to June in 2011. Only the first half of year 2011 is taken into account when calculating since the summer is not representative, because of the vacations. A description of the data collection techniques used in this thesis is presented below in order to explain how these techniques have been approached.

3.2.1 Literature

The theoretical framework in the thesis is based on literature in the areas of environmental logistics, Lean Production and sustainability.

Before starting the literature search it is good to decide what type of material that is needed. The subject boundaries of the search need to be carefully chosen. To make the thesis relevant, full account of what has gone before and what is going on in the environment around should be taken. Therefore, fully awareness of all the relevant literature on the subject needs to be ensured (Moore, 2000).

Furthermore, awareness of the main issues and policies are needed in order to understand the topic and to be able to collect the correct and relevant data. The main point of the literature study is to prepare for the empirical study. Contacts with other researchers working in the field may also be of interest. The knowledge that is finally brought to the project needs to be complete and up to date. Thus, literature searching is necessary (Moore, 2000).

3.2.2 Interviews

Most of the empirical study is based on semi-structured interviews. The interviews have been performed during February to April 2012 and the interviewees have been employees from concerned parts of the VLC organization as well as employees at the producers of packaging material. The interviewees and the dates of the interviews are presented in Appendix A.

Semi-structured interviews are partly planned in advanced and the conversation is focused on certain subjects and areas that have been chosen in advance. In order to do so, an interview guide is needed, where the structure and questions are planned (Dalén, 2007). The guide includes central subjects that should cover the scope of the study. One way to compose the interview is to start at areas around the subject, in order to get a softer bridge to the central subject that may be emotional for the interviewee. It is of importance to ask questions in a way that make the interviewee comfortable and that let them speak freely.

3.2.3 Observations

Observations have been made in order to learn and understand more about the organization. Observations have been performed to create a more detailed understanding as well as a more holistic overview.

The observations have foremost been performed at two chosen producers of wooden packaging materials. The purpose of the observations was to see the production and the distribution of the packaging materials from the producers' perspective. This could then be taken into account when a direct delivery between producer and user was evaluated and suggested. Furthermore, this considers whether a change of the flow is even possible for the producer.

3.3 Mapping of Activities

The packaging material has numerous activities during a single loop from the producer to the end customer before it is finally reused. During the loop between producers, terminals and users it is possible to find activities that are more unnecessary than others. Value Stream Mapping is used in this study to visualize a holistic view of the flow of packaging materials as well as the information flow between these activities. The tool Value Stream Mapping gives a visual and detailed approach that helps identify specific activities that could be improved or activities that certainly are affected by any change performed in the flow of packaging materials.

From a Lean perspective, the transportation of packaging materials adds no real value to the user or customer but is still a necessary activity, which can be improved from an environmental perspective. As there are many different users of packaging materials and since every user is located differently and have differing demand, it would be inaccurate to create one detailed map that fits all users. Therefore, specific flows between producers, terminals and users have been chosen and detailed mapping of activities are only performed on these.

Due to the currently high amount of users, their unpredictable demand of packaging materials and the fact that new packaging materials are continuously entering the flow in order to cover user's demand, the average lead time for a packaging material to complete a single loop would be difficult to estimate. It is for this reason that the Value Stream Mapping is used in this study to visually understand the flow of materials rather than to estimate the lead-time and the estimated future state for every user. Nevertheless, it is possible to suggest a future state that might fit the specific producers and users chosen in the empirical study.

3.4 Emission Auditing

Emission auditing is the process of calculating the amount of greenhouse gases and air pollutants that are emitted into the atmosphere due to transport. When estimating the emission from vehicles many factors need to be taken into account. The amount of emissions is depending on the vehicle age, engine size, driving style and the types of road being used (Piecyk, 2010). Speed is a major factor when it comes to emissions, and a shorter route is not always the most efficient one. Moreover, the relationship between distance and emission is not linear and a more detailed approach is needed. In this thesis the emission auditing is based on a model from NTM, a Swedish non-profit association representing major logistics companies (Bäckström , 2008). The aim of the model is to help transport companies and their customers to evaluate the environmental performance of their transport activities. The model takes type of vehicle, euro class, type of road, distance and filling degree into account, in order to calculate emissions. The NTM-model shows the amount of emission per vehicle, which has been used in order to get the amount of emission per kit of packaging. The calculations are presented in Appendix B.

3.5 Cost Calculation

In order to understand the costs of the current flow of packaging and compare it with an improved flow of packaging, a cost calculation has been performed. Employees concerned have provided the costs of the current transports. Also, estimations of the costs of an improved flow have been done in corporation with employees concerned. The calculations are presented in Appendix C.

4. Theoretical Framework

In this section, the theoretical framework of the thesis is presented. First, substantial logistics definitions will be presented. The sustainability research is of importance as it is connected with the problem definition. The sustainability approach to logistics will be described, as will the lean approach to logistics. A description of different types of costs and a total cost perspective will follow.

4.1 Logistics Definitions

The thesis is based on logistics theory, which is why some important logistics definitions are described. The definitions of terminals, warehouses and the performers of the transportation system will be presented and put in its context. Furthermore, single and multiple sourcing, design of delivery and packaging theory will be presented. As Volvo Logistics is divided into Emballage, Inbound and Outbound a brief description of the inbound and outbound system will follow.

4.1.1 Terminals

A terminal is a facility to which the goods are being shipped, put together or broken down into new parties. The goods might be added value through other activities and are thereafter being transported to the customer. Some storage may be necessary in the terminal since it can be difficult synchronizing all incoming and outgoing shipments (Jonsson and Mattsson, 2011).

Unloading and loading is usually a bottleneck in the terminal's operations. This is particularly the case for truck terminals where it often occur congestion in the mornings and evenings. Because of this imbalance, terminals have to be greatly oversized. To deal with this problem, loading and unloading times should be shared out more evenly throughout the day even if it is not always optimal from a transportation planning point of view (Jonsson and Mattsson, 2011).

4.1.2 Warehouse

A warehouses is a facility that exists to contribute to manufacturing and distribution efficiency. The traditional role of warehouses has been to stock inventory. Contemporary warehouses have a broader value in terms of economic and service benefits. Economic benefits include consolidation, seasonal storage and reverse logistics (Bowersox at. al, 2007).

It is not always enough with one warehouse between the producer and the customer if the distribution system shall be able to fulfill its role. In many instances it is necessary to use a hierarchy of storage. For example, it may be necessary to have a central warehouse close to the production and some smaller warehouses closer to the customers. The number of levels and number of warehouses in such warehouse hierarchies is a measure of the degree of centralization in the distribution channel. The fewer warehouses and levels of hierarchies, the higher is the degree of centralization (Jonsson and Mattsson, 2011).

4.1.3 Performers of a transportation system

The operators of a transport system are responsible for transportation coordination, the physical movement and infrastructure in order to create a transport service. Transportation coordinators do not own their movement resources. Their role is to take responsibility of the structure and implementation of transportation by planning and buying the necessary resources of movement. They also take care of other activities along the logistics chain, such as storage and terminal activities. The transport coordinators do not normally perform the physical transport themselves, but buy services from carriers that are targeted to different modes of transport (Jonsson and Mattsson, 2011).

4.1.4 Single and multiple sourcing

Single sourcing means that the company only uses one supplier for a particular article, although there are several alternative suppliers available in the market. Single sourcing is usually used in volatile markets, when the complexity and strategic importance of the product is high. Single sourcing incorporates a collaborative exchange between the supplier and the company and should lead to a close relationship with shared operational linkages and shared information linkages. Single sourcing is also used when appropriate alternatives are difficult to find or are situated too far away (Hutt and Speh, 2010).

Multiple sourcing means that the company uses several alternative suppliers for the same article. Customers are likely to prefer multiple sourcing when the supply market is stable and features many alternatives (Hutt and Speh, 2010). The main objective, when using multiple sourcing, is to be able to play suppliers against each other, in order to improve the bargaining position when prices and delivery terms are to be determined. Furthermore, multiple suppliers reduce the risk of late deliveries and availability. However, in the purchasing of non-complex products in small volumes, multiple sourcing gets administratively costly. Multiple sourcing most often result in a transactional exchange and are less likely to involve operational linkages and adaptations between the two companies (Hutt and Speh, 2010).

4.1.5 Design of delivery

The flow of material from supplier to customer can differ a lot. Some different patterns that are commonly used in the industry are; delivery to the warehouse, delivery via a logistics center and direct delivery to customer (Jonsson and Mattsson, 2011).

The *delivery to a customer's warehouse* is made for the costumer’s later on usage. An alternative to this is a *delivery via a logistics center*. A logistics center can be used to make sure that complete sets of material can be delivered directly to the production site of a company when needed. Finally, *direct delivery to the customer* means that the goods are being transported from the manufacturer to the user. The user can be either the customer or the customer’s customer. Thus, direct delivery of goods can be transported to the customer without ever passing the customer company. However, a prerequisite for this to work is that the quantity that the supplier delivers corresponds to what the user company has ordered (Jonsson and Mattsson, 2011).

4.1.6 Packaging

It is not only the product itself that is being transported between companies in the flow of material. To enable efficient handling and storage, provide protection to the material and the environment during handling and for identifying the material, the goods is usually enclosed in a package or loaded on a carrier (Jonsson and Mattsson, 2011).

The packaging that is handled in the material flow can be a so-called unit load carriers, which is greater and standardized packaging that can be handled as individual units. A pallet is a unit load carrier. Using standardized unit load carriers, which has the same size and shape, is important in order to facilitate handling. In Europe there is a standard pallet system, called

EUR pallet. Far from all companies use the EUR- pallet standard, but have developed their own pallets and other unit load carriers instead. Volvo, for example, has their own pallet standard and small plastic boxes as unit load carriers (Jonsson and Mattsson, 2011).

In many situations, the packaging is expensive or specialized, which means that it has to be returned to the sender for economic reasons, thus a return flow of packaging is created. When using EUR-pallets or other international standard unit load carriers, it is not necessary to build an own return flow system for the units. Instead, the pallets are being exchanged or sold after use and instead of bringing empty pallets back, the users are switching them between each other in so-called pallet pools (Jonsson and Mattsson, 2011).

4.1.7 Inbound and Outbound

Inbound logistics handles goods between a supplier and a user, which is usually the transportation of raw material, parts and components. Outbound logistics, on the other hand, handles goods that are considered finished products. It is easy to understand that the outbound logistics handle goods with higher product value and often have stricter requirements regarding safety and delivery time (Wu and Dunn, 1995).

4.2 Sustainable Logistics

The most popular definition of sustainability is to "meet present needs without compromising the ability of future generations to meet their needs" stated at an UN conference in 1987. Moreover, sustainability has three dimensions (Green Logistics, 2010): the economic dimension, the environmental dimension and the dimension of the society, which are shown in figure 3. To keep the economic growth at the same time as being more environmentally friendly is a current topic for many countries. Unemployment, efficiency and competitiveness are part of the economic situation and the sustainable supply chain has to take these aspects as well as society issues as safety and health into account. Moreover, climate change, air quality, noise, land use, biodiversity and waste are environmental effects.

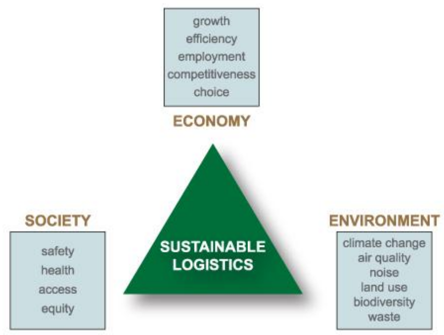

Figure 3. The three dimensions of sustainability. (Greenlogistics, 2012).

Transport systems are an important part of our society, but they are not sustainable (Doll and Wietschel, 2008). An efficient transport system is important to reach other markets and gives all people access to health care and education. Furthermore, it is crucial in order to serve the supply chain of producing companies.

4.2.1 Unsustainable Impacts of Freight Transport

The climate change impact from vehicles is substantial. Climate change is an ongoing problem and a lot of focus is concentrated on reductions of greenhouse gases. UN’s

Intergovernmental Panel on Climate Change, IPCC, listed 27 greenhouse gases, which were combined into six categories in the Kyoto Protocol in 1997. The categories are as follows: CO2, methane, nitrous dioxides, hyrdroflourocarbons, perflourocarbons and sulphur hexafluoride. Transportation stands for a significant part of the green house gas emissions, and heavy-duty vehicles represent about a quarter of EU road transport CO2 emissions (EU commission, 2011). To cope with the climate change, International organizations and national governments have been setting greenhouse gas emission reduction targets for the next 10-40 years. EU aims for a reduction of 20 % by 2020. The emissions from transport have increased by 36 % since 1990. Even though the vehicle efficiency has been improved, the amount of transports, both personal and freight, have increased (EU Commission, 2011).

The European Union has worked internationally to handle the climate change and the global warming. As the transport sector is the second biggest cause to emission that affect the climate change (EU Commission, 2011) the importance of decreasing these emissions is crucial.

In June 2000 the European Commission launched a European Climate Change Program (ECCP) in order to implement an EU strategy to identify and develop ways of meeting the goals of the Kyoto Protocol set up in 1997. As a part of the program, each EU member state has to place national actions to reach the goals. It is clear that the actions need to be made stronger than today in order to cut greenhouse gas emissions levels required by the Kyoto protocol. In 2005 a second program was launched where member states, industry and environmental groups as well as different departments of the European Commission worked together to find ways of finding a better solution.

The European Commission has already made regulatory measures that have been approved that ensure that emissions from passenger cars is reduced (EU Commission, 2011). They plan to introduce similar CO2 targets for new light goods vehicles. As the emissions from heavy duty vehicles stand for a significant part of the road emissions similar measures might be appropriate on this sector. However, as the freight transport in many ways is linked to the economic development this is a challenging problem. As a part of the EU's future strategy regarding heavy duty vehicles fuel consumption and CO2 emissions, the goal is to improve engines, materials and design as well as cleaner energy use through new fuels and better use of networks and a more efficient fleet operation.

Transport is not only contributing to global warming, it also causes air pollution, noise, vibrations, accidents and congestions. Some of the most harmful air pollutants are carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), and particulate matter (PM). PM is probably the most health affecting substance from transport (Blinge, 2010) and is dependent on the conditions of the fuel and engine. The noise emission is restricted to time and the effect depends on in what area and at what time of the day the noise occurs (Doll and Wietschel, 2008). Moreover, a constantly high noise level can lead to physical deceases, such as high blood pressure and heart attacks. The congestions in cities and in the transport systems can lead to additional CO2 emissions and air pollution as well as time losses that results in large costs, which accounts for approximately 1% of EU's gross domestic product, GDP (EU Commission, 2007). These congestion costs are projected to increase by about 15 per % by 2050 (EU Commission, 2011).

Besides the impact on nature, transports affect the individual's physical, mental and social well-being. Emissions such as NOx and PM can provide a variety of health problems. They can cause asthma symptoms, lung function to be defamatory and give respiratory diseases. PM can also cause cancer (Jonsson and Mattsson, 2011).

The emissions' impact on the environment is local, regional or global. The local impact includes emissions that affect the environment relatively quickly and close to the source of emissions, which makes them easy to identify and reduce. Emissions with regional impacts travel further distances and affect the environment in the longer term, which makes them harder to identify and reduce. CO2 is an example of an emission that has a global impact. They spread rapidly around the world, regardless of the emission source and cause longer effects than the regional (Jonsson and Mattsson, 2011).

Moreover, companies need to be prepared for future government policies and need to manage and understand their emissions and how to improve their logistics from a sustainable point of view to cope with upcoming regulations and to be competitive in a long term perspective.

4.2.2 Environmental Approach

An environmentally responsible logistics approach extends the scope of logistics by adding another objective: the environmental impact (Wu and Dunn, 1995). Thus, the environmental impact of the total system has to be evaluated.

In order to make the supply chain greener, the view on supply chains has to extend (Beamon, 1999). The extended supply chain allows consideration of the environmental effects of all products and processes in a supply chain. Thus, considering reversed logistics and transport is a part of the extended supply chain as they have a potential environmental impact (Wu and Dunn, 1995). Reversed logistics includes shipments of packaging waste, recyclable packages and customer returns in the logistics system (Wu and Dunn, 1995).

When introducing environmental management the performance is usually separated from the operational performance (Beamon, 1999). As the environmental performance become a part of the general operational objectives advantages such as reduced product life cycle costs, reduced environmental risk, reduced health risk and safer and cleaner factories, can be seen.

Green logistics traditionally focuses on the effects of logistic activities on the environment. However, it is also of importance to consider how logistics is affected by climate change (McKinnon andKreie, 2010). The effects on logistics can either be direct or indirect as shown in figure 4. The direct effects concerns modifications of the logistic system whereas indirect effects concern the demand of logistic services. Businesses, governments and individuals also affect the logistic system as they cut the emissions of greenhouse gases.

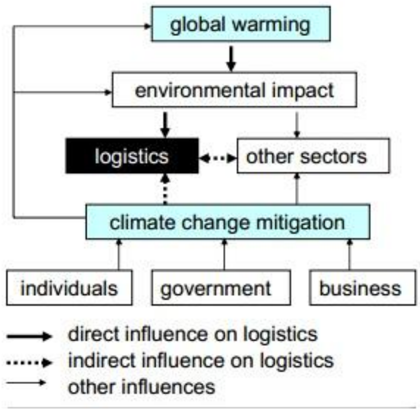

Figure 4. Logistics affects due to climate change (McKinnon and Kreie, 2010).

It tends to be more environmentally friendly to use fewer shipments, less handling, shorter movements, more direct routes and better space utilization within the supply chain. However, a trend is to use a reduced number of warehouses which makes it possible to keep inventory levels down, cutting costs as well as keep, or sometimes increase the customer service. The environmental impact is often neglected, and a consolidation of warehouses often increase the numbers of fright movements, which has a negative impact on the environment (Wu and Dunn, 1995).

Making the supply chain green can also lead to economic benefits such as lower transportation costs. By using vehicle utilization and optimizing the supply chain, the amount of transport can be reduced, leading to increased carbon dioxide and cut costs. Moreover, focusing on transport patterns rather than hauling equipment is sometimes more efficient in the reduction of environmental impact and transportation cost (Bearth, 2008).

4.3 Lean logistics

According to Jones at al. (1997) as much as 60 % of the activities in a factory add no value to the customer, 35 % are necessary none-value adding activities and only 5 % of the activities truly add value. It is more difficult to identify the activities, which do not add value, that exist around the activities than noticing the activities that actually add value. Often each of the elements of the supply chain optimizes its own performance and forgets about the rest of the supply chain. It is important to view the whole sequence of activities in the supply chain in order to find the lowest cost solution. When introducing Lean, it is most reasonable to start to analyze a specific product or product family in order to find possible wastes that can be eliminated. Lean logistics has evolved from Lean Production and is a part of the Lean theory.

4.3.1 Lean production

Lean Production is based on the Toyota Production System, TPS, which is Toyota's unique way of relating to production. Lean Production has dominated the manufacturing trends during the last decade. Lean is a holistic system that needs to go through the entire organization, thus it needs to be implemented in all areas of the business. The leaders need to be fully committed in the daily operations as well as to continuous improvements. Lean is a philosophy, an approach where the tools and methods are only a part of the philosophy as a whole (Liker, 2009).

A Lean business has five cornerstones: an identified costumer value, a mapped value stream, a smooth flow, a pull system based on the customer demand and at last it is constantly trying to achieve perfection (Womack and Jones, 2003).

A brief summary of the fourteen principles that make "The Toyota Way" is described below. The principles are divided into four larger sections; philosophy, processes, people and problem solving (Liker, 2009).

Philosophy

Principle 1: Base management decisions on long-term philosophy, even at the expense of short-term financial goals.

Processes

Principle 2: Create continuous process flow that brings problems to surface.

Principle 3: Let demand control to avoid overproduction.

Principle 4: Level out the workload (Heijunka).

Principle 5: Build a culture that stops the process for solving problems to get quality right the first time.

Principle 6: Use standardized work as a base for continuous improvements and staff participation.

Principle 7: Use visual control so that no problems remain hidden.

Principle 8: Use only reliable, well tested technologies that support staff and processes.

People

Principle 9: Develop leaders who understand the work, lives the philosophy and tech it to others.

Principle 10: Develop exceptional people and teams who follow your company´s philosophy.

Principle 11: Respect the extended network of partners and suppliers by challenging them and helping them improve.

Problem Solving

Principle 12: Go and see for yourself to really understand the situation (Genchi Genbutsu).

Principle 13: Make decisions by consensus, consider carefully all options, implement decisions rapidly.

Principle 14: Become a learning organization through relentless reflection (Hansei) and continuous improvement (Kaizen.)

4.3.2 Value stream mapping

Value stream mapping is one of the most important and most common tools in lean production. Value stream mapping is a way of showing processes, flows of material and flow of information for certain products and lead to identification of wastes in the systems (Liker, 2009).

The value stream includes all activities in a process, the ones which create value as well as those which do not. A mapping of the present state of the value stream provides a common ground for discussions regarding possibilities of eliminating waste and thus improving the efficiency of the flow. There are seven types of wastes that are all symptoms of root causes which need to be found. The wastes that add costs but no value are: overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary movements and defects (Jones at al., 1997). The value stream mapping result in a suggestion of a future state and enables a comparison with the present state. Thus, the value stream mapping shows opportunities to reduce wastes.

4.3.2.1 Process activity mapping

Process activity mapping is one of the tools for value stream mapping and has its origin in traditional industrial engineering. It applies five principles (Jones at al., 1997):

1. The study of the flow of processes;

2. The identification of waste;

3. A consideration of whether the process can be rearranged into a more efficient sequence;

4. A consideration of a better flow pattern involving different flow layout or transportation routing;

5. A consideration of whether everything that is being done is really necessary.

First, a careful analysis of the activities is performed, as well as an identification of the distance moved, time taken and the number of people involved. When problems has been identified the "5 Why?" method can be used. By asking "Why?" five times, aiming for the perquisite answer, a root cause of a problem can be identified. The purpose of this technique is to try to eliminate unnecessary activities, simplify or combine others and to find sequence changes in order to reduce waste (Jones at al., 1997).

4.3.3 Just-in-time and transshipment terminals

Just-in-time is a set of principles, tools and techniques that enables a company to produce and deliver products in small quantities with short lead times to satisfy specific needs. Without the "pull-system", which reflects customers' needs by simply loading the components that are consumed at the next operation, just-in-time would never have emerged. Simply put, you can say that just-in-time delivers the right products at the right time and in the right amounts. The power of just-in-time is that it is adjustable to changes in customer demand (Liker, 2009).

To accomplish just-in-time deliveries of components, several times a day when the suppliers are spread globally, a partial solution is to use transshipment terminals. The components are being sorted out in different product mixes and transported by trucks as mixed loads with the correct number of components for a few hours of production. Transshipment terminals enable efficient retrieval of supplier components, and just-in-time delivery to the assembly plant. From Toyota's perspective, transshipment terminal is an extension of the assembly line and thus part of a critical flow. The transshipment terminals enables the components to be delivered just-in-time from the supplier to the vehicle and then to the customer (Liker, 2009).

Furthermore, the purpose of transshipment terminals is to bring in deliveries from distant suppliers a few times a day, temporarily store the pallets of material and then load up and send away a truck with a mixed load to the assembly plant about twelve times a day. Assembly plants then get regular just-in-time deliveries and the trucks are loaded to capacity between suppliers and terminal, and between the terminal and plant (Liker, 2009).

It is easier to organize delivery systems such as distribution chains and milk round with known quantities if dealing with a limited numbers of suppliers. This type of distribution system results in higher transport utilization. However, the benefits of a small lot just-in-time delivery are large as emergency shipments and costs of holding inventory are removed (Jones at al., 1997).

The system of transshipment terminals decreases the transportation costs significantly. Without them, the trucks are forced to run small, half-filled and thus expensive deliveries from suppliers at great distances from each other. With transshipment terminals, trucks are almost always filled in each direction (Liker, 2009).

Toyotas transshipment terminal has been designed according to all principles of the Toyota Production System. It is built for a thoroughgoing flow, the employees are participating in continuous improvement, and there are visual signs and devices for failsafing everywhere, which ensures high quality and reliability. Truck drivers have well-defined roles when collecting and returning, within tight deadlines and they also conduct quality inspections. Noting is left to chance (Liker, 2009).

However, the JIT-system has its opponents. According to Wu and Dunn (1995), the JIT-system result in more transports and affects the environment negatively. Just-in-time deliveries are frequent and generate additional traffic. Wu and Dunn claim that in most management models the trade-offs used are inventory-carrying costs and transport costs. In the case of high value products, the JIT-system is chosen, as the reduction in inventories outweighs the increase in transport costs quickly.

4.4 Cost Theory

In this section, a brief introduction to cost theory is presented. Common costs within the logistics area are described and a total perspective on costs is discussed.

4.4.1 Logistics costs

Logistics costs are costs due to the logistics activities (Jonsson and Mattsson, 2011). There are direct costs for physical handling, transfer, storage, administration and costs of capital investment. Capacity- and shortage costs are indirect costs that also are included in the logistic costs. The total logistics costs can be broken down into the following cost categories:

- Transport- and handling costs
- Packaging material costs
- Storage costs
- Administrative costs
- Order costs
- Capacity related costs
- Shortage- and delay costs

4.4.1.1 Transport- and handling costs

The main activities are transfer, transshipment, loading and unloading of goods for carriage between the company's own facilities and between suppliers and customers. The shipped material ties capital during transport. The cost of capital investment is thus also part of the total transport cost (Jonsson and Mattsson, 2011).

Transportation is the largest factor of the logistics costs and its operations have a critical impact on logistics performance. It is hard to perform transportation cheap when operational expectations become more precise and margins for error reduced near zero. Transportation has to be effective in order to meet expectations (Bowersox et.al, 2007).

4.4.1.2 Packaging material costs

Cost of packing material includes all costs associated with packaging materials, packaging and tagging of goods. When using reusable packaging, costs for administration, storage and reshipment of packaging is added, provided that these costs are not counted in any of the other logistics costs (Jonsson and Mattsson, 2011).

4.4.1.3 Storage costs

The costs of storing the goods depend on the quantity held in stock and consist of a financial part, a physical part and an unsure part. The financial part is represented by the company´s return requirements on the capital tied up in the stock. The cost of the physical storage consists of operating costs for the physical stock, and the uncertainty costs has to do with the risk associated with stocking material (Jonsson and Mattsson, 2011).

4.4.1.4 Administrative costs

Administrative costs include all costs associated with long-term planning and operational control of material flows. Primarily it is costs for administrative staff but it is also costs of acquisition and operation of computer- and communication systems for the logistics business (Jonsson and Mattsson, 2011).

4.4.1.5 Order costs

Order costs are those costs that are associated to the managing of purchasing- and producing orders. Order costs can often be attributed to the other identified cost types, but since it often is used in the dimensioning of the order quantities it is here reported as a separate cost of logistics (Jonsson and Mattsson, 2011).

4.4.1.6 Capacity related costs

The available facilities, vehicles, machines and staff represent the available capacity. Annual depreciation and, maintenance and operation of the facilities are capacity costs, which can be influenced by the degree to which the equipment is used (Jonsson and Mattsson, 2011).

4.4.1.7 Shortage- and delay costs

Shortage costs emerge when a delivery can´t be done by the customers’ desire. This cost has a direct connection to customer service commitments and the opportunities to create value and generate revenue (Jonsson and Mattsson, 2011).

4.4.2 Total Cost of Logistics system

Studying the logistic system's total cost means taking impact of a logistic decision on total logistics costs into account, rather than minimizing the cost of an individual logistic activity. The least expensive method of transportation may not result in the lowest total cost of logistics. Logistic systems should utilize transportation that minimizes total system cost (Bowersox et.al, 2007). It is therefore necessary to have an overall perspective of costs when making logistic decisions.

Different logistic costs also contribute to customer service performance and environmental impacts. However, these are very difficult to quantify and therefore it may be better to complete the total cost estimates with quality customer service- and environmental effect assessments that indicate the solutions' potential revenue impact (Jonsson and Mattsson, 2011).

5. Empirical findings

In this chapter, a description of the current situation of the flow of packaging between producer, terminal and user is presented. A description of the carriers and how their vehicles are being loaded is presented in order to understand the environmental impact as well as the filling degrees of the vehicles. In the end of the chapter the producers and users that the thesis focuses on are mentioned and data, necessary to understand the flow of material, is obtained.

5.1 Flow of Packaging

In this section, a description of the flow of packaging is described, starting with describing the terminals and depots, and the flow of material and information in the system. Moreover, the registration and control of the flow are presented, and the repositioning of packaging is explained.

5.1.1 Terminals and Depots

Volvo logistics has eight terminals and thirty depots spread over the world, as shown in figure 5. Their function is to perform storing, sorting, handling, washing and repairing. The main difference between a terminal and a depot in the system is that any user can release empty packaging material to a terminal after usage. However, a depot most often belongs to an assembly plant, from which the depot receives released packaging material. Moreover, the different services offered differ between terminals and depots; some have washing and repairing facilities whereas others have not.

Figure 5.VLC:s terminals and depots (Volvo Group 2012).

5.1.2 Flow of Material and Information

VLC's packaging is organized in a pool system where the packaging is being reused. There is a constant need of new packaging as packaging material brakes and the user base increase. The new packaging is an input in the pool system. Following is a description of the flow of information and the flow of material focusing on the order process of new packaging and the packaging transfers between producer, terminal and user, as shown in figure 6. The figure is simplified, as there are many different terminals and depots as well as many users. However, this thesis focuses on the flow of material from the producers of newly manufactured packaging and the simplified picture covers the important aspects needed in order to analyze the flow of material from the producer to the terminals and users.

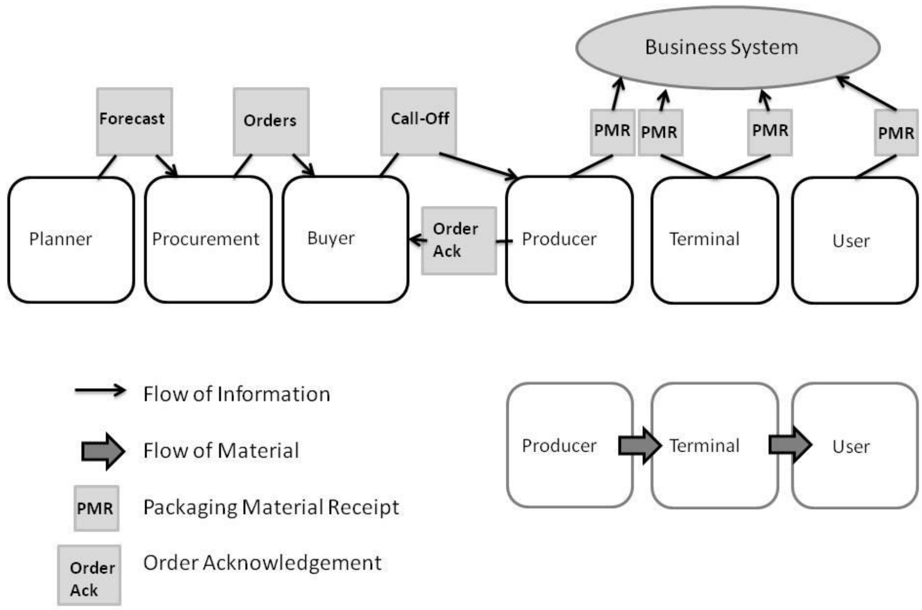

Figure 6. Flow of material and information.

5.1.2.1 Flow of Information

When ordering new packaging, the strategic planner at VLC Emballage makes a forecast of the need of new packaging. The forecast is based on historic data as well as on a forecast on the users coming need. The procurement department at VLC is receiving the forecast and makes a decision on what quantities to order and from what producer. The procurement department is also responsible for contracts and agreements between VLC and their producers as well as the supplier relationships with the producers. The procurement department split orders between producers in order to take care of all of their relationships. After receiving the forecast, the procurement department send the buyer an ordering plan and the buyer makes the call offs, as shown in figure 6. The buyer is contacting the producers by phone and email, and makes orders for four weeks at the time. After receiving the orders, the producer sends the buyer an order acknowledgement, stating lead times and delivery dates. Packaging Material Receipts, PMRs, are being registered in the business system when sending packaging, in order to control the flow of material. The PMR system is further discussed below.

5.1.2.2 Flow of Material

As the producer gets the call offs from the buyer at VLC Emballage, they start the production of the wanted quantities. Most producers keep an inventory of finished packaging, ready to send to VLC's terminals. They base their production on the same forecasts as the procurement department receives from the strategic planner at VLC Emballage. However, VLC has no legal obligation to buy anything else then the actual orders state. The finished packaging is being sent to VLC's terminals as shown in figure 6, most often in Gothenburg and Gent. The terminals are receiving and controlling the goods when it arrives. The packaging is then mixed up with the reusable packaging and is included in the packaging pool system. The packaging is then being sent to users.

5.1.3 Packaging Material Receipt

In order to control the flow of material VLC is using Packaging Material Receipt, PMRs. A PMR is registered in the business system when the packaging material is being transferred in the loop system. The producer registers a PMR in the database as they send new packaging to a terminal. The packaging is marked "on transport" in the system until the terminal receives it and register a new PMR. When the terminal is sending the packaging to the users they register a new PMR. The user and the factory in the system only register PMRs when they send packaging and not when they receive it, see figure 7 below.

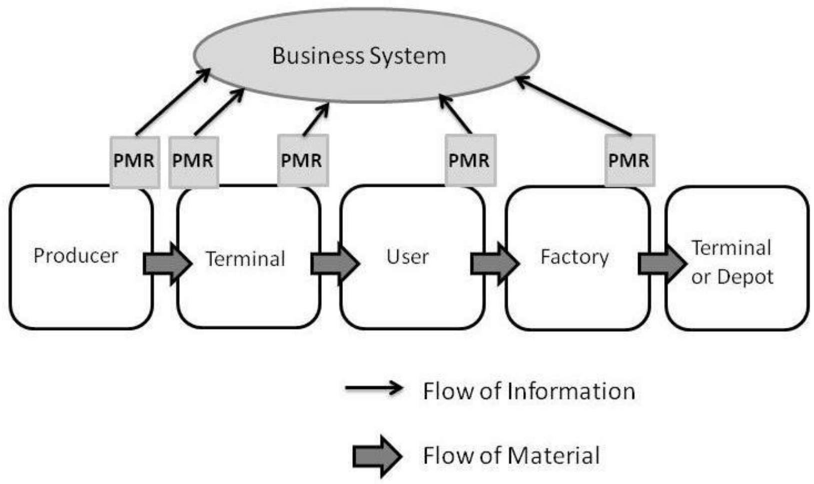

Figure 7. Packaging Material Receipt

The PMR system helps VLC to control the packaging material and is also a base for invoicing users and factories. Furthermore, it is of great importance to the user of the packaging that the PMR registration is made correctly as they have to pay rent for storing packaging too long. From VLC's point of view, it is important that the packaging material doesn't stay at the same location too long, as the loop system need the material to circulate.

5.1.4 Repositioning of the Packaging Material

Repositioning of material is one of the important stages in controlling the flow of material. The main reason for the need of repositioning is the imbalance in the access and demand of packaging. The factories release empty packaging from their sites, and the users (the factories' suppliers) need empty packaging. The factories and users are not always close geographically, which create an imbalance in the closed loop of returnable packaging, thus repositioning is necessary. Furthermore, the terminals and depots are positioned all over Europe and Volvo Logistics is proud to be able to serve the users quickly. On the other hand, as the warehouses are spread out geographically, and the users' need varies, there is a constant need of repositioning.

There are three types of repositioning: transport of packaging between terminals and depots, transport of released packaging to be washed and repaired and transports of newly manufactured packaging.

The transports between terminals and depots are primary due to imbalances in access and demand at different warehouses; both quantities and types of packaging. The factories are responsible for releasing the packaging after using it at their production site and send it to the closest VLC terminal. The factory has to carry the transport cost and it lays in their interest to keep the transport distance low. This has led to the founding of depots and terminals in connection with the factories, where the factories can release their packaging material, see figure 9. This result in lower transport costs for the factory, in contrast to increased repositioning costs for VLC, as it most often creates imbalances and cause additional transports. However, as the factory and VLC are most often part of Volvo Corporation, a total cost perspective shows that the transport savings made for the factories is worth having extra warehouses and additional repositioning costs for VLC.

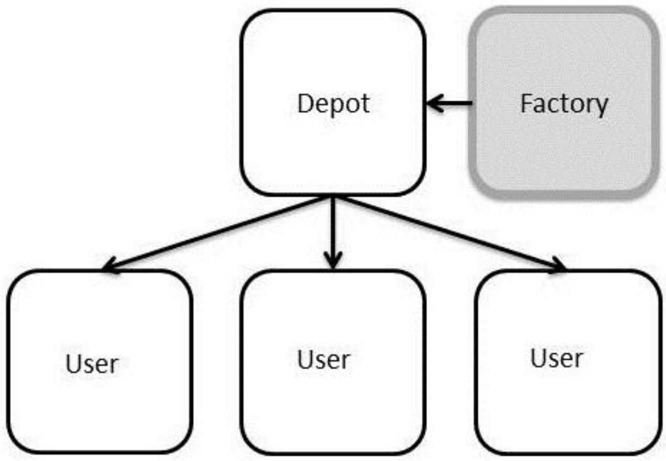

Figure 8. Repositioning of packaging from factory to closest depot, and from depot to other users.

Furthermore, as shown in figure 9 the packaging material from the depots is being sent to users in the same area to reduce transport costs. The imbalance is created when the access and demand at the depot differ. The users often need different types of packaging and it is not likely that the factory releases the needed quantity and type to the depot. This cause transports from other terminals and depots with the missing packaging.

Another problem is that some of the packaging that is released from the factories needs washing and to be repaired. Not all the terminals and depots have washing stations, thus extra transports are needed. The factories release the empty packaging to the closest terminal and VLC has to send them on to washing stations and repairing stations.

The third type of repositioning is the transports of newly manufactured packaging. As old packaging brakes and VLC increases its user base the need of new packaging is increasing. The producers are spread out geographically and different types of packaging are produced at different producers, thus transports from different producers to the terminals are needed.

In conclusion, the repositioning is the foundation of the closed loop system of returnable packaging. The repositioning of packaging is crucial in order to reduce transport costs as well as to serve customers efficiently. Furthermore, the repositioning is necessary to even up the unbalanced created from packaging released to depots and terminals where the demand is small as well as from newly manufactured packaging and packaging that need washing before reuse.

5.2 Costs for Packaging Material

Transports stand for 30 % of the costs for VLC, including both repositioning and distribution costs, thus improvements in this area has major affect on the total costs for the company. Except from the largest costs of keeping capital, other costs are administrative costs, sorting costs, handling costs, washing- and repairing costs and costs for IT, development and procurement.

External carriers are performing the transports and the transport cost is based on pay agreements between VLC and the carriers. The carriers have more transports in some directions than others and their transport balance situation is not always balanced. Thus, the pay agreement is primary based on the carrier's transport balance situation, that is, in what directions they need to fill their vehicles in order to optimize their organization of vehicles. This means that the same distance can be priced differently, depending on the direction of the transport. However, distance is also an important part of the price. VLC Emballage stands for the transportation costs between producer, terminal and user, as well as repositioning costs between terminals. The transportation cost, when releasing the packaging material from factory to terminal, is paid by the factory.

The largest part of the revenues for VLC comes from the transaction cost paid by the users and factories. A transaction cost is the cost that the using company pays for each packaging material used. The transaction costs are based on the PMR system that registers where the packaging material is and who has been using it. The main principle for deciding who pays for the use of packaging is that the user or factory that is sending the packaging pays for the transaction, as shown in figure 8. However, most often special pay agreements are set up. If the receiving factory is part of Volvo, they pay the transaction and if the receiving company is not part of Volvo, it is the user that has to pay for the transaction.

The reason for why the main principle of the payment for used packaging material is not possible to follow in most cases, is that if the sender should pay for the transaction and the sender is a third supplier, it leads to a cost for the supplier that they shouldn't be responsible for. Because of situations like this, certain pay agreements has been set up between users and VLC in order to make the paying situation logical. 85 % of the transactions today are based on special pay agreements.

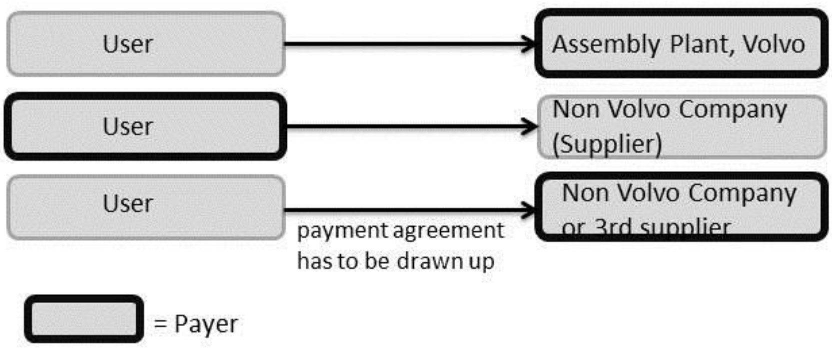

Figure 9. Costs for packaging material (Volvo Group, 2012).

Rent is also a part of VLC's revenues. The rent system is used in order to keep the loop system working. The user only pays rent for the packaging material that has been stored for more than three weeks. The rent is an incentive for the user to return packaging in time, which is important to the pool system and thus the transaction costs. As the rent stand for about 8 % of VLC Emballage's revenues the transaction costs are of more importance.

When VLC optimize orders, users do not have to pay rent for packaging that arrives earlier than they have asked for. VLC optimize the orders to get reduced transportation costs and letting the users keep packaging longer is the price they pay for this. The user has to keep a certain safety stock in order to ensure the availability and VLC has a problem with users that are keeping stock of packaging too long.

5.3 Loading of Packaging

In this section, a description of the vehicles and L-packaging is obtained, in order to understand how to load the vehicles, which is presented in packing charts in the end of the section.

5.3.1 Carriers

Volvo is using external carriers to perform their transports between producers, terminals, depots and users. The procurement department establishes contracts with the carriers which includes prices and other agreements. Volvo's external carriers are using four types of vehicles; Lorry/Truck + Trailer, Tractor + Semi-Trailer, Tractor + Mega-Tralier and Lorry/Truck + Semi-Trailer. However, the lorry/truck + semi-trailer is only allowed to be driven in Sweden. When VLC orders a transport, it is the carrier that decides which vehicle that is being used even if the order handler can optimize the order to influence the carrier. Table 1 below presents the load capacity and the inner dimensions for the different vehicles.

	Vehicles Type	**Load capacity**	**Inner Dimensions**		
		[tone]	Length [m]	Width [m]	Height [m]
	Lorry/Truck + Trailer	22	7.7 + 7.7	2.48	2.65 – 2.8
	Tractor + Semi-Trailer	26	13.6	2.48	2.8 – 2.96
	Tractor + Mega-Tralier	33	13.6	2.48	2.96 – 3.0
	Lorry/Truck + Semi-Trailer	40	7.7 + 13.6	2.48	2.8 – 3.0

Table 1. Load capacity of different vehicles (Volvo Group, 2012).

In table 2 below, the fuel consumption for the different vehicles is presented. How much fuel the vehicles consume depends on what kind of road the transportation is being performed. In this thesis, it is assumed that it is either motorway or rural road. When a vehicle is driving empty, its utilization is 0 % and when a vehicle is driving with maximal cargo capacity, its utilization is 100%. The vehicles have a weight limitation as well as a volume limitation.

Fuel Consumption [g/km]				
	Motorway Cargo capacity utilization by weight		Rural Road Cargo capacity utilization by weight	
Vehicle Type	0%	100%	0%	100%
Lorry/Truck + Trailer	0.226	0.360	0.230	0.396
Tractor + Semi-Trailer	0.226	0.360	0.230	0.396
Tractor + Mega-Tralier	0.246	0.445	0.251	0.495
Lorry/Truck + Semi-Trailer	0.282	0.540	0.334	0.608

Table 2. Fuel consumption (Bäckström, 2008).

All vehicles belong to a certain euro class. Which euro class a vehicle belongs to depends on when in time it is produced and what impact the vehicle has on the environment while it is being used. The vehicle that belongs to Euro class 5 is the newest kind and also the vehicle that has the lowest impact on the environment. In this thesis euro class 5 has been chosen in the calculations, since this is the most common used vehicle and in the future this will be the only euro class allowed. In table 3 below, is the emission data presented when using euro class 5. The emission data is stated in the unit g/liter fuel consumed for the emissions HC, NOx, PM, CO2, CH4 and SOx.

Emission data [g/l] for Euro Class 5	
HC	0.04
NOx	7.74
PM	0.06
CO2	2621
CH4	0.000768
SOx	0.00333

Table 3. Emission data Euro Class 5 (Bäckström, 2008).

5.3.2 L-packaging

This thesis focuses on L-packaging, since it is the most commonly used type of wooden packaging within VLC. The two most basic and important components in the L-series are the pallet and the frame. The total quantity of pallets circulating in the pool system were 2 082 855 units in April 2011. The quantity of frames circulating in the system was 4 218 285 units during the same time. The pallet is the base for the packaging. The frames can be combined in different heights in order to create high flexibility. Using wooden packaging enables both reuse and recycling and generates less environmental impact than plastic packaging.

The pallets in the L-series are stackable and are packed alternate up and down, except from the one on the top. When the packaging is transported empty the pallets are packaged in bunches of ten, as shown in figure 10. The bunch is strapped with a belt drawn around it. In table 4 below, are the dimensions of the L-type wooden pallet, both as a unit and as a packaging kit.

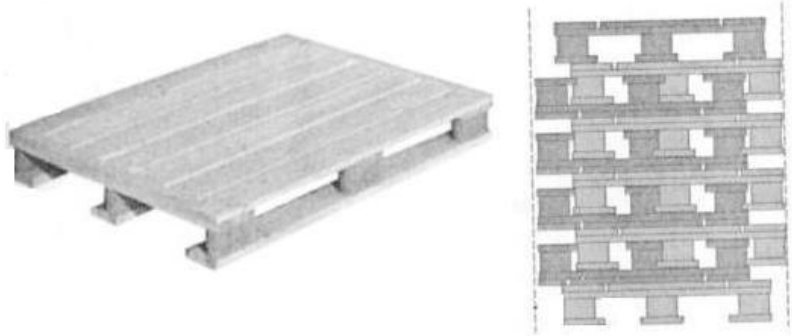

Figure 10. Pallets of L-packaging (Volvo Group, 2012).

Dimension	One Unit	Packaging kit
Length [mm]	1225	1225
Width [mm]	820	920
Height [mm]	151	1150
Volume [m^3]	0,152	1,300
Weight [kg]	25	250

Table 4. Dimensions of pallets (Volvo Group, 2012).

The frames in the L-series are foldable. When transporting empty packaging the frames are therefore possible to be packed in bunches of fifty. A bunch contains frames packed in ten layers on height and five in width, as shown in figure 11. The bunch is placed on two pallets in order to be able to transport them. These fifty frames, resting on two pallets, are strapped with two belts across the bunch. Below are the different dimensions for the L-type wooden frame and its transportation dimensions while packed in a bunch of fifty, see table 5.

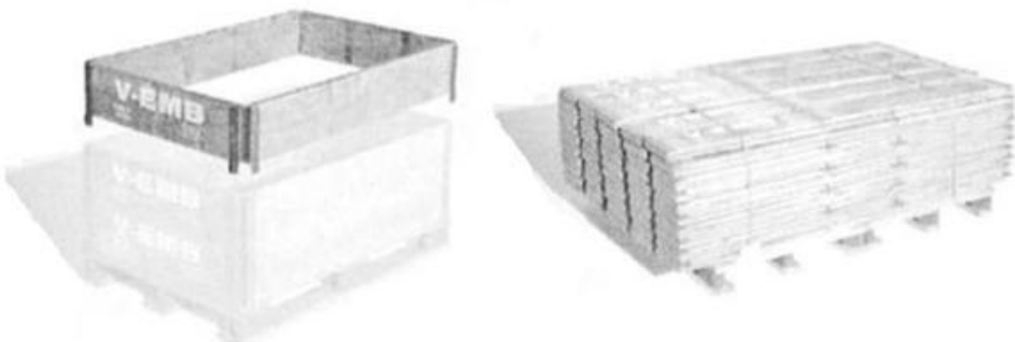

Figure 11. Frames of L-packaging (Volvo Group, 2012).

Dimension	One Unit	Packaging kit
Length [mm]	1220	2000
Width [mm]	815	1225
Height [mm]	195	700
Volume [m^3]	0,190	1,720
Weight [kg]	10	550

Table 5. Dimensions of frames (Volvo Group, 2012).

Since the pallets and the frames are made out of wood, they can be stored outside. Both the pallet and the frame are marked with the initials V-EMB, which stand for Volvo Emballage. It is hard to keep wooden packaging in a good condition because it is exposed to several harsh movements during handling. VLC repairs the packaging and therefore it can maintain an average of 7 years.

5.3.3 Packing Chart for Vehicles

An assumption that the pallets and frames are being sent separately from the producer has been made. Other alternatives will be discussed in the analysis. As the objective of this thesis is to calculate the emissions of the transports, this assumption helps to see the difference in emissions between different vehicles. In the figure below, a packing chart is presented in order to see how many packaging kits that fits onto the different types of vehicles.

First, a packing chart for the pallets onto the four types of vehicles that VLC uses, is presented (figure 12). The first vehicle is a lorry/truck + trailer, the second is a tractor + semi-trailer, the third a tractor + mega-trailer and the fourth is a lorry/truck + semi-trailer. The pallet kit is 1.15 meters high and the vehicles only allow for two kits to be stacked on top of each other.

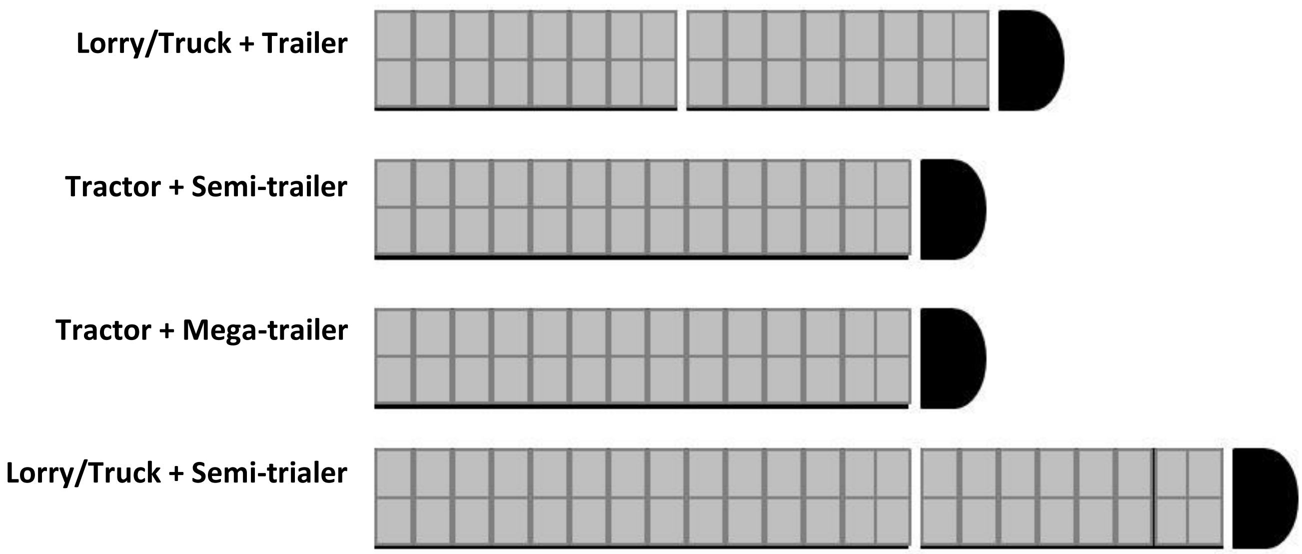

Figure 12. Packing chart of pallets

Second, a packing chart for the frames onto the four types of vehicles that VLC uses, is presented (figure 13). The frame kit is 0.7 meters high and the vehicles allow for four kits to be stacked on top of each other. According to the volume, the first two vehicles allow for more frames to be stacked on each other as seen in figure 13. However, these vehicles load capacity do not allow it, since a frame kit is rather heavy and it reaches its weight limit.

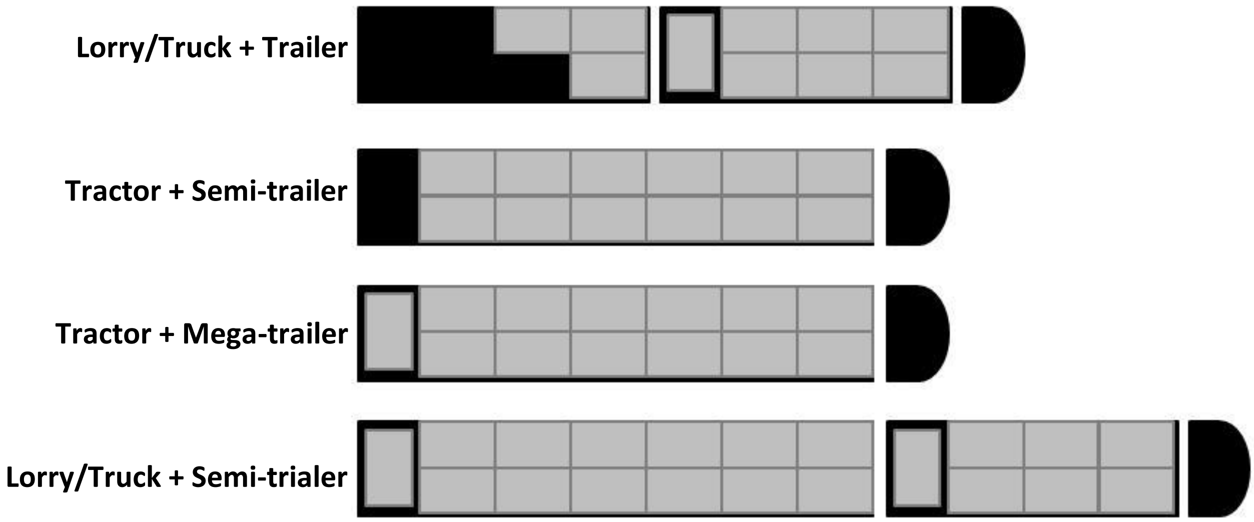

Figure 13. Packing chart of frames

According to the packing charts the amount of packaging kits that fit onto a vehicle varies, depending on type of packaging and type of vehicle. As seen in table 6, the frames can be sent more efficiently, by three vehicles, than the pallets, as the size of the pallet kit does not fit the vehicle, thus the filling degree is low. It is sometimes possible to send mixed transports, which is discussed in the analysis.

	Amount of Pallet Kits	Filling Degree (volume), Pallets	Amount of Frame Kits	Filling Degree (volume), Frames
Lorry/Truck + Trailer	64 pcs	80 %	40 pcs	66 %
Tractor + Semi-trailer	56 pcs	74 %	47 pcs	82 %
Tractor + Mega-trailer	56 pcs	72 %	52 pcs	88 %
Lorry/Truck + Semi-trailer	88 pcs	76 %	80 pcs	91 %

Table 6. Amount and filling degree of pallets and frames based on volume.

5.4 Stakeholders

In this section, the most important stakeholders of the packaging material are presented. Four producers and two users have been chosen, in order to describe the current situation.

5.4.1 Producer

VLC is using different producers for packaging. This thesis focuses on the largest producers of L-pallets and frames in Europe. Four producers have been chosen in order to analyze the current flow of packaging between producer and user (Producer 1, Producer 2, Producer 3 and Producer 4). The largest suppliers are all located in the south of Sweden and the packaging material is being sent from the producers to VLC's main terminals in Gothenburg and Gent. Data of the packaging that has been sent between January to June 2011 is presented in table 7 below.

Producer	Type of packaging	Quantity Jan-June 2011 to Gothenburg [pcs]	Quantity Jan-June 2011 to Gent [pcs]	Total Quantity Jan-June2011 [pcs]
Producer 1	Frames	79200	31500	110700
Producer 2	Frames	204595	232950	437545
Producer 3	Frames	39600	96750	136350
Producer 4	Pallets	324375	245760	570135

Table 7. Packaging quantities sent between producers and terminals

The producers get forecasts on what quantities that are ordered and are keeping an inventory of finished packaging that are being produced in order to cover the forecast, using a push system. The distance between producer and terminal varies according to table 8 below. Moreover, it is assumed that 90 % of the route is motorway and 10 % is rural road.

Distance Between Producer and Termnial [km]	Distance to Terminal in Gothenburg	Distance to Terminal in Gent
Producer 1	143	1206
Producer 2	156	1163
Producer 3	127	1213
Producer 4		1134

Table 8. Distance between producer and terminal

5.4.2 User

Users of L-pallets and frames have to be chosen in order to find improved transport solutions within the distribution of newly manufactured packaging. This thesis is focusing on the two largest users, as they order large quantities. As they are big clients of packaging, an improved transport solution would make them most affected by the outcome, and a change of their orders would have a significant effect on the whole system. The users are also selected because they are well positioned geographically in order to be able to make improvements in the distribution design.

User 1 is located in Sweden and order large quantities of frames. User 2 is located in the Netherlands and is the biggest client of frames. User 2 is also a user of pallets and order quite large quantities of those as well. In table 9 below, the order quantities of L-Packaging for both users are presented. Six month of consumption, between January and June 2011, is summed up.

Ordered Quantities for 6 months of L-Packaging [pcs]		
	Pallets	**Frames**
User 1, SE		82 000
User 2, ND	62 000	250 000

Table 9. Order quantities of L-packaging for users

User 1 mainly receives packaging from the terminal in Gothenburg and User 2 receives packaging from the terminal in Gent. In this thesis, an assumption is made that the routes of the vehicles are performed on either motorway or rural road. Based on map observations, assumptions have been made that 10 % of the distance is performed on rural road and 90 % of the distance is performed on motorway. In table 10 below is the distance between users and terminals presented.

Distance between User and Terminal [km]	
User 1 to terminal in Gothenburg	144
User 2 to terminal in Gent	247

Table 10. Distance between users and terminals

6. Analysis

This chapter analyzes direct transports between producer and user. Furthermore, filling degrees of transports with pallets and frames is analyzed. An environmental analysis will be presented which shows the environmental effects of the transports today compared to direct transports between the different producers and users. Moreover, a cost analysis is presented in order to capture the economic impact of direct transports. Last, the impacts direct transports would have on VLC and its different units as it is organized today are discussed.

6.1 Filling Degrees of Direct Transports

In this section, the distances of direct transports are described. Filling degrees of shipments are discussed and mixed loads of pallets and frames are analyzed.

6.1.1 Direct Transports

Today, the produced packaging is being transported from the producers to the terminals, from where the packaging is being sent to the users together with other types of packaging. As the quantities of packaging being transported between producer and terminal is rather large, it is interesting to analyze what environmental as well as economic benefits to expect from direct transports between producer and user instead of transports via terminals.

The transport distances of direct transport between the producers and the user in Sweden are cut by up to 58 % by using direct transports instead of passing the terminal in Gothenburg, as seen in table 11. The distances between the user in the Netherlands and the producers in Sweden are cut by up to 70 % by using direct transports. The distances between the chosen producers and users are clearly cut by using direct transports instead of passing the terminals in Gothenburg and Gent. However, it is also important to understand how the filling degree is affected by using direct transports.

Transport Distance	**User 1, SE**			**User 2, ND**		
[km]	Via terminal in Gothenburg	Direct	**%**	Via terminal In Gent	Direct	**%**
Producer 1	287	130	**45**	1453	1013	**68**
Producer 2	300	175	**58**	1410	970	**67**
Producer 3	271	120	**44**	1460	1020	**70**
Producer 4				1381	941	**68**

Table 11. Direct transport distances between producers and users.

Having said this, direct transports might not always be a shorter alternative. The users that have been chosen in this thesis are close to the largest producers, which is the reason to why the distances are shorter. However, it has been observed that many users are interesting to be further investigated, as direct transports might lead to less transport. The amount of transport that is needed does not only depend on the distance; the filling degrees and the quantities of packaging are also of importance. This is discussed further on in the analysis. It is important to see how direct transport affects the whole system, the repositioning and the deliveries from terminals might be affected to some extent and producers and users might also be affected. The main focus of the thesis is to investigate how direct transports affect the environment, that is, if they lead to fewer transports and less emission, and to economic benefits for the company. The cut distances are a positive result for sure, but it is also important to look at the other aspect of direct transports. This analysis discusses this further.

Some producers might be better than others in an environmental and a cost perspective and it might be tempting to only have one supplier of packaging material. However, this might not be the best option for Volvo in the long run and VLC needs to maintain the partnership with all its producers to secure availability. Even if it would be possible to use only one supplier for a period, VLC might need more packaging material than one producer manages to produce for another period. This thesis focuses on producer 1 and producer 4, when making emission auditing and cost calculations, because of limitation of cost information regarding the other producers. These producers are interesting to focus on since one of them produces pallets and the other produces frames.

Moreover, at the distance between the producers and User 2, one part of the distance is on ferry. However, as the situation between direct transports and transports via terminals do not differ in this concern, this effect on the environment is neglected, in order to focus on the differences between direct transports and transports via terminals.

6.1.2 Filling degrees of shipments

The filling degree of the shipments is important to investigate to see if direct transports are a better alternative than transports via terminals. Even though the distances are shorter, it is of importance what filling degrees the actual transports between producer and user has. As large users have been chosen, the quantities needed shouldn't be a major problem. The shipment needs to be big enough to fill a significant share of the cargo capacity of the truck, which should be covered. However, the filling degree when sending pallets and frames separately is around 75 % for pallets and around 80 % for frames. A consolidation with other goods would probably make the filling degree higher.

Moreover, when sending the packaging to the terminals, it becomes easier to make consolidated loads to users. A consolidation with other goods would raise the filling degree, but it would also lead to longer distances, as the vehicles have to pass the terminal instead of going straight to the user. The consolidation is only possible if the user needs different types of packaging or if different users are located close to each other and need different types of packaging. This thesis focuses on pallets and frames within the L-family wooden packaging. A consolidation of pallets and frames is discussed in the section below.

Moreover, as VLC is using external carriers it is not known if other goods are transported together with the pallets and frames. The optimization of the transports is out of VLC's responsibility and they can't control it. In this thesis, the filling degrees used in calculations is based on shipments of pallets and frames and the carriers' optimization with other goods is neglected.

Also, when empty packaging is being transported to a user, the user often has filled packaging that should be delivered to the factory, which is VLC Inbound's responsibility. VLC Emballage, who are responsible for the empty packaging, and VLC Inbound have no cooperation when it comes to booking transports, which might lead to extra transports.

6.1.3 Packing charts of mixed shipments

Sometimes, it is possible for the producer to send mixed transports with both pallets and frames. In figure 14 below, a packing chart is presented in order to see how the packaging kits can be mixed efficiently onto the different types of vehicles.

First, an example of a packing chart with two layers of frames in the bottom and one layer of pallets on the top is presented, as seen in figure 14. The first vehicle is a lorry/truck + trailer, the second is a tractor + semi-trailer, the third a tractor + mega-trailer and the fourth is a lorry/truck + semi-trailer. The pallets weigh less than the frames, which is why the pallets are placed on top of the frames in the vehicle.

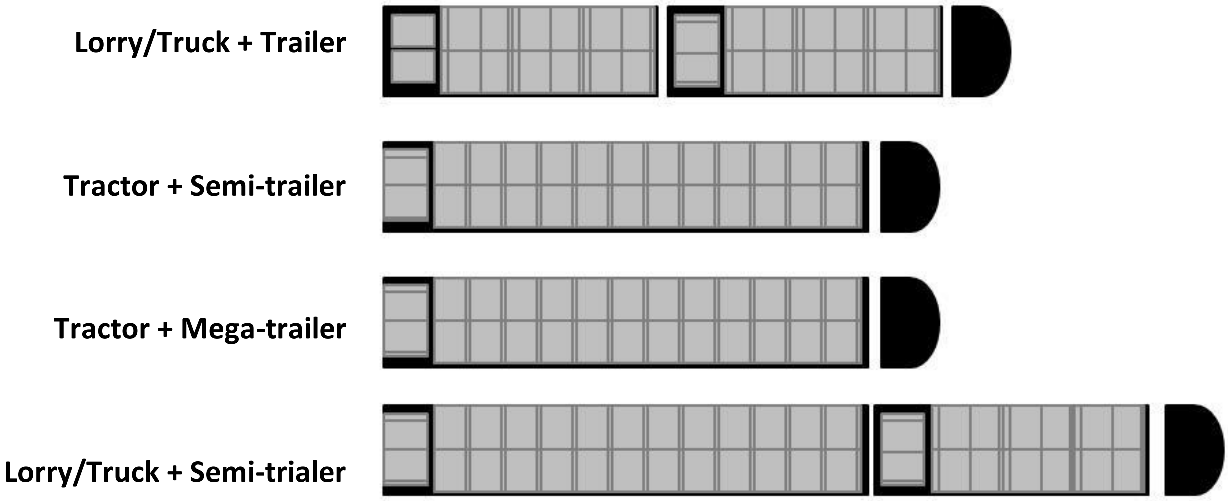

Figure 14. Packaging chart of mixed shipments for different types of vehicles.

In table 12 below, the amount of pallet kits and frame kits on each vehicle, is presented. The filling degree for each vehicle with the optimized mix of pallets and frames is also shown.

2 layers of frames 1 layer of pallets	Amount of Pallet Kits	Amount of Frame Kits	Filling Degree (Volume)
Lorry/Truck + Trailer	28 pcs	27 pcs	81 %
Tractor + Semi-trailer	26 pcs	26 pcs	78 %
Tractor + Mega-trailer	26 pcs	26 pcs	78 %
Lorry/Truck + Semi-trailer	40 pcs	40 pcs	80 %

Table 12. Amount of pallet kits and filling degrees for each vehicle based on volume.

Another suggestion is to place one layer of frames in the bottom and two layers of pallets on top, as seen in the packing chart in figure 15. The first vehicle is a lorry/truck + trailer, the second is a tractor + semi-trailer, the third a tractor + mega-trailer and the fourth is a lorry/truck + semi-trailer. The pallets are placed on top of the frames, as they weigh less.

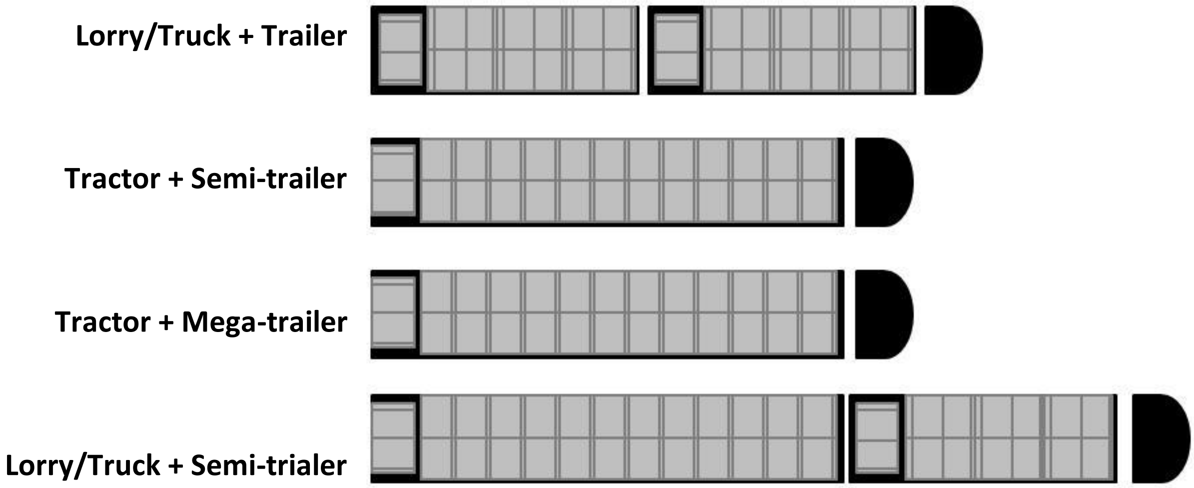

Figure 15. Packaging chart of mixed shipments for different vehicles.

In table 13 below, the amount of pallet kits and frame kits on each vehicle is presented for the mix suggested above. The filling degree for each vehicle with the suggested mix is also presented. This mix gives a significantly improvement of filling degree comparing to pack the pallets and frames separately. However, the mix chosen needs to be adapted to the users demand. The two suggestions of mixes of pallets and frames above are therefore only suggestions of how possible mixes could be designed.

1 layer of frames 2 layers of pallets	Amount of Pallet Kits	Amount of Frame Kits	Filling Degree (Volume)
Lorry/Truck + Trailer	56 pcs	14 pcs	93 %
Tractor + Semi-trailer	52 pcs	13 pcs	91 %
Tractor + Mega-trailer	52 pcs	13 pcs	91 %
Lorry/Truck + Semi-trailer	80 pcs	20 pcs	92 %

Table 13. Amount of pallet kits and filling degrees for each vehicle based on volume.

6.2 Environmental Analysis

In this section, the environmental effects of direct transports are analyzed and different types of vehicles are compared from an environmental aspect. In the end of the section, a sensitivity analysis is presented, in order to show the robustness of the calculations.

6.2.1 Environmental effects of direct transports

In order to see the environmental effects of direct transports, emission auditing of the transports has been performed. The emission auditing is based on a model from NTM, a Swedish non-profit association representing major logistics companies. The model takes type of vehicle, euro class, distance, filling degree and type of road into account, in order to calculate emissions. Also, in order to include the empty transport on the way back from the delivery, an estimation of 30 % of the distance driven is added, assuming that the filling degree is zero %. This is based on statistics on how much empty heavy-duty vehicles that is in use today. The calculation approach is presented in Appendix B.

Below is the different emissions caused by transports between the producers and users, for the four types of vehicles stated earlier in the thesis. The emissions that are taken into account are HC, NOx, PM, CO2, CH4 and SOx. CO2 emissions have a global impact while HC, NOx and SOx have a regional impact. PM, HC, SOx and NOx have a local impact. The amount of emission presented in the tables below is presented in grams per vehicle.

Table 14 shows how much emission that is produced by transporting the packaging material via terminal and also the emissions produced when transporting the packaging material direct from Producer 1 to User 1. The different filling degrees for the four types of vehicles and when transporting frames are used in the calculations. The filling degrees for transports of frames are based on the packing chart in the empirical study. By observing this first example, with Producer 1 and User 1, the option of delivering the packaging material direct instead of via terminal seems to be better. All the emissions are reduced significantly and the result is notably improved.

User 1 Producer 1 Frames							
[gram/vehicle]		HC	NOx	PM	CO2	CH4	SOx
Lorry/Truck + Trailer	Via terminal in Gothenburg	4	855	7	290000	0,08	0,4
	Direct	2	387	3	131000	0,04	0,2
Tractor + Semi-trailer	Via terminal in Gothenburg	5	904	7	306000	0,09	0,4
	Direct	2	409	3	139000	0,04	0,2
Tractor + Mega-trailer	Via terminal in Gothenburg	6	1110	9	376000	0,11	0,5
	Direct	3	503	4	170000	0,05	0,2
Lorry/Truck + Semi-trailer	Via terminal in Gothenburg	7	1354	10	459000	0,13	0,6
		3	613	5	208000	0,06	0,3

Table 14. Emissions produced from transports via terminal and direct transports between producer 1 and user 1.

In table 15, the emissions produced between Producer 1 and User 2, is presented. This example also shows that direct transports are beneficial. Moreover, CO2 has a global impact and is spread rapidly around the world, regardless of the emission source and causes long-effects. Nevertheless, the CO2 emissions appear to show a clear improvement of amounts in this analysis. HC, NOx and SOx have a regional impact which means that these emissions travel further distances and effect the environment in the longer term. Because of this, it is important to note the reduced results of CO2, HC, NOx and SOx, as they are usually hard to reduce and identify. PM, HC, NOx and SOx affect the environment relatively quickly and close to the source of emissions, which is the reason why the emissions also have a local impact which is reduced.

User 2 Producer 1 Frames							
[gram/vehicle]		HC	NOx	PM	CO2	CH4	SOx
Lorry/Truck + Trailer	Via terminal in Gent	22	4328	34	1466000	0,43	1,9
	Direct	16	3018	23	1022000	0,30	1,3
Tractor + Semi-trailer	Via terminal in Gent	24	4575	35	1549000	0,45	2,0
	Direct	16	3190	25	1080000	0,32	1,4
Tractor + Mega-trailer	Via terminal in Gent	29	5618	44	1902000	0,56	2,4
	Direct	20	3917	30	1326000	0,39	1,7

Table 15. Emissions produced from transports via terminal and direct transports between producer 2 and user 1.

Table 16 shows the emissions produced from the distance between Producer 4 and User 1. This example confirms that a direct delivery, instead of a delivery via terminal, is causing lower amount of emission. Similar for the three examples above is that the amount of emissions is steadily and consistently reduced to about half of the amount that is emitted today, when introducing direct transports. However, it is of importance to remember that these producers and users are carefully chosen based on their geographically location, which enables a much shorter distance when choosing a direct delivery. The distance between producer and user is thus much shorter than the distance between producer, terminal and user.

User 2 Producer 4 Pallets							
[gram/vehicle]		HC	NOx	PM	CO2	CH4	SOx
Lorry/Truck + Trailer	Via terminal in Gent	22	4319	33	1463000	0,43	1,9
	Direct	15	2943	23	997000	0,29	1,3
Tractor + Semi-trailer	Via terminal in Gent	22	4231	33	1433000	0,42	1,8
	Direct	15	2883	22	976000	0,29	1,2
Tractor + Mega-trailer	Via terminal in Gent	26	4991	39	1690000	0,50	2,1
	Direct	18	3401	26	1152000	0,34	1,5

Table 16. Emissions produced from transports via terminal and direct transports between producer 2 and user 4.

It is not only one type of emission that has improved results, but all emissions show much better values, when using direct transports. Also, as NOx and PM can provide a variety of health problems the heavily reduced amount of these is a positive result.

A comparison of the different vehicles at this stage is not possible, since the vehicles are of different sizes and has different capacity of transporting packaging material. A comparison of the different vehicles when transporting pallets and frames is presented further on in the analysis.

As discussed earlier, some transports consist of a mix of pallets and frames. The environmental effects of these transports are rather complicated, as the consolidation of the pallets and frames is done at the producer or at the terminal. As shown in the left part of figure 16, the direct transports of mixed packaging consist of a transport between the producers, in order to mix frames and pallets before a mixed load is sent to the user. In the other case, when the transport passes the terminal, a consolidation of pallets and frames will be performed at the terminal, and a mixed load will be sent to the user from there, as shown in the right part of figure 16.

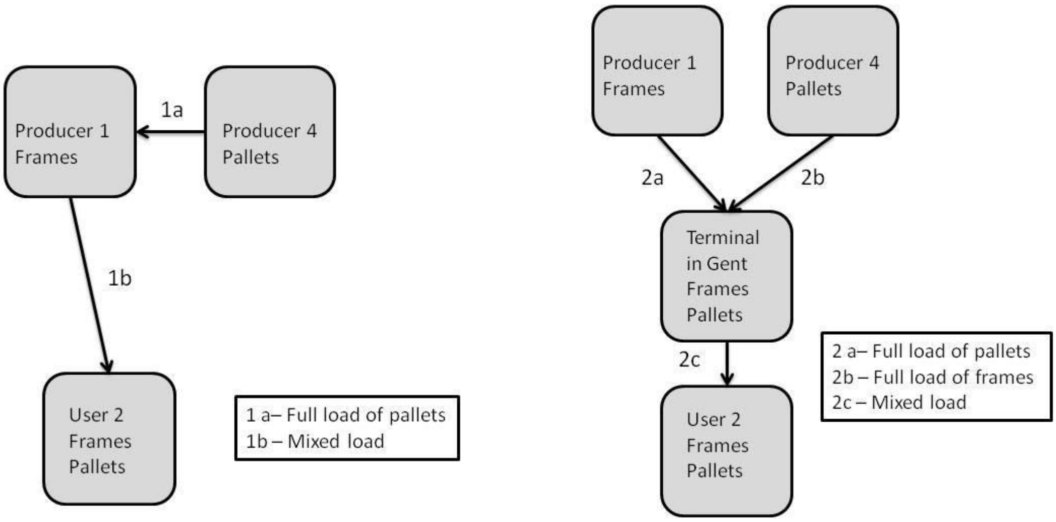

Figure 16.Mixed transports using consolidation at producer or terminal.

To be able to compare the different environmental effects from the different types of transports, assumptions have been made. It is assumed that a full load of pallets is sent to Producer 1, who is making frames. The pallets that are not used in the mixed transport are assumed to stay at Producer 1, and wait for the next mixed transport. When the transports are consolidated at the terminal, it is assumed that one full load of pallets and one full load of frames are being sent to the terminal from the producers. The pallets and frames that are not used in the mixed transport are assumed to stay at the terminal. Moreover, as just some of the packaging is being sent in the mixed transport, only that part of the separated transports that cover the mixed transports are being used in the calculations. This means that if only one third of the mixed transport is pallets, only one third of the distance with a full load of only pallets affects the environmental analysis, and two thirds of this transport is neglected in the calculations. As the vehicles differ when it comes to filling degrees, different calculations have been performed for each type of vehicle, as seen in table 17. The filling degrees are the same as the mixed packing chart presented earlier. The distance between Producer 1 and Producer 4 is not presented earlier in the thesis, and is required when making calculations on mixed packaging. This distance is 142 km.

User 2 Producer 1 & 4 Mixed Packaging							
[gram/vehicle]		HC	NOx	PM	CO2	CH4	SOx
Lorry/Truck + Trailer	Via terminal in Gent	28	5425	42	1837000	0,54	2,3
	Direct	19	3734	29	1264000	0,37	1,6
Tractor + Semi-trailer	Via terminal in Gent	27	5300	41	1795000	0,53	2,3
	Direct	19	3673	28	1244000	0,37	1,6
Tractor + Mega-trailer	Via terminal in Gent	32	6268	49	2122000	0,62	2,7
	Direct	23	4506	35	1526000	0,45	1,9

Table 17. Emissions produced from transports via terminal and direct transports between producer 1 and user 4 when transporting mixed packaging.

It is clear that the direct transport lead to significantly lower amount of the different types of emission. The CO2 emission for a truck + trailer and the tractor + semi-trailer is decreased by 31 % when using direct transport, compared to the tractor + mega-trailer, where the CO2 emission is decreased by 28 %, which is a significant decrease. However, the decrease from mixed transport is slightly lower than the decrease when using full loads of separated packaging. The reason for this is that a transport between the producers causes an extra transport.

Moreover, a further calculation shows that sending two vehicles, one with frames and one with pallets, gives less CO2 emissions compared with sending one vehicle with mixed packaging. However, this once again depends on the users need. Sending two vehicles could cause more need of storage at the users place and thus cause less flexibility for the user. The values for this calculation are based on the approach analyzed above. Table 18 shows the CO2 improvements of driving two separate loads instead of one mixed load.

Tractor + Mega-trailer	CO2 [gram/vehicle]
Direct transport Mixed load	1526000
Direct transport Separated load	1401000

Table 18. CO2 for transports with mixed and separated loads.

6.2.2 Type of Vehicle

As shown in the section above, the emissions caused by the different types of vehicles differ. However, the different vehicles also differ in size of shipment. To understand what type of vehicle that is most beneficial from an environmental point of view, when delivering packaging, the amount of emission per kit of packaging has been calculated as well as the amount of emission per ton. When calculating the amount of emission per ton, the maximum weight capacity for each vehicle is being used, thus the filling degree is assumed to be 100 %. As shown in the empirical study, the filling degree differs between pallets and frames, which had been taken into account, when calculating emission per kit of packaging.

As shown in the last column in table 19, the larger vehicles cause less emission per ton, then the smaller ones. However, the vehicles have to be loaded with its maximum weight for this to be true. In the case of transporting frames according to the packing chart in the empirical findings, this appears to be incorrect, as the filling degrees are not high enough.

Producer 1 to User 2					
Direct transport	CO_2 per vehicle	CO_2 per kit of frames		CO_2 per ton, maximum weight used.	
[gram]					
Lorry/Truck + Trailer	1161000	29000	**2**	53000	**3**
Tractor + Semi-Trailer	1228000	26000	**1**	47000	**2**
Tractor + Mega-Tralier	1507000	29000	**2**	46000	**1**

Table 19. CO2 emission per kit of frames and per ton.

Using the filling degrees for pallets and frames, while transported separately, certain types of vehicles has shown to be appropriate, from an environmental point of view. As shown in table 20, the lorry/truck + trailer is most suitable when transporting pallets between Producer 4 and User 2, followed by the the tractor + semi-trailer and the tractor + mega-trailer. However, the vehicles have to be loaded with its maximum weight for this to be true.

Other producers and users could have been chosen, as t he result is linear with the distance. Moreover, table 20 only shows the relationships with CO_2, but the same results are given with the different types of emissions.

Producer 4 to User 2					
Direct transport	CO_2 per vehicle	CO_2 per kit of pallets		CO_2 per ton, maximum weight used.	
[gram]					
Lorry/Truck + Trailer	997000	16000	**1**	45000	**3**
Tractor + Semi-Trailer	976000	17000	**2**	38000	**2**
Tractor + Mega-Tralier	1152000	21000	**3**	35000	**1**

Table 20. CO2 emission per kit of pallets and per ton.

6.2.3 Sensitivity Analysis

When calculating the environmental impacts, several assumptions have been made. For instance, the euro class and the capacity utilization have been assumed. Moreover, the part of the distances that is motorway and the part that is rural road have been assumed. Since these assumptions have been made the results of this analysis are uncertain. A sensitivity analysis has been performed in order to find out the robustness of the calculations.

In a sensitivity analysis the value of an input is changed. The impact of this change can then be analyzed and two results are possible. The first one is that a change of an input parameter has a significant impact on the result. The affect would be that the previous best option performs now worse than the alternative. In this case further investigation to increase the certainty of the parameter is necessary since the robustness of the calculations is low. The second result that can occur is that a change of an input parameter has a comparable low impact on the result. The affect would be that the previously best option is still better than the alternative. In this case the calculations are rather robust to this parameter.

In figure 17, a sensitivity analysis is presented, where the parameter that is changed is distribution of motorway and rural road from Producer 1 to User 1, with the vehicle Lorry/Truck + Trailer. The assumed values were 90 % motorway and 10 % rural road. The analysis based on the assumed values shows that a direct delivery is the preferable option. Changing the input parameters to 100 % motorway and 0 % rural road, shows that these calculations are quite robust since the previously preferable option still is the better alternative. This is also confirmed when the input parameters are changed to 75 % motorway and 25 % rural road or 50 % motorway and 50 % rural road. In figure 17, the sensitivity analysis described above for the emissions SOx, CH4, PM and HC is presented.

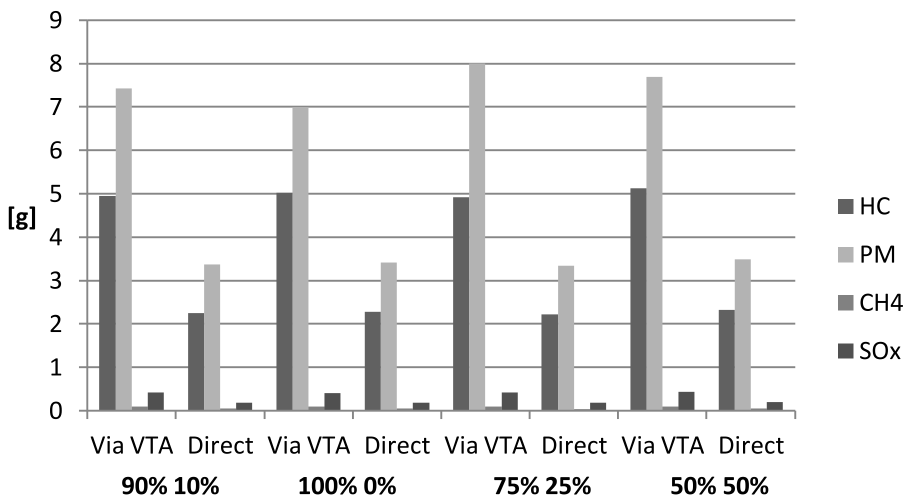

Figure 17. Sensitivity analysis where the parameter that is changed is distribution of motorway and rural road from producer 1 to user 1 for each Lorry/Truck + Trailer.

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In figure 18, the sensitivity analysis above is further demonstrated for the emissions NOx and CO2. The results are still convincing and reliable.

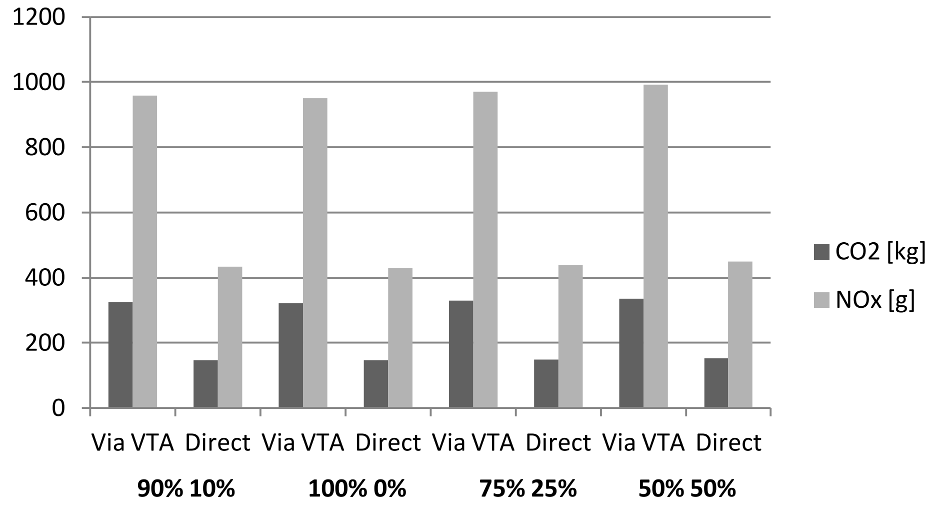

Figure 18. Sensitivity analysis where the parameter that is changed is distribution of motorway and rural road from producer 1 to user 1 presented in grams per Lorry/Truck + Trailer.

A sensitivity analysis has been performed on the transports between Producer 1 and User 1, were the parameter that is changes is capacity utilization. This change of input parameter indicates a reliable calculation. The previously best option is still the better alternative and a change of the input parameter has a comparable low impact on the result, se figure 19. The assumed value of capacity utilization was based on the packing chart when packing pallets and frames separately. However, the capacity utilization can differ depending on how the packaging material is packed. Still, a direct delivery shows less CO2 emissions compared to a delivery via the terminal, which correspond to the results in the analysis.

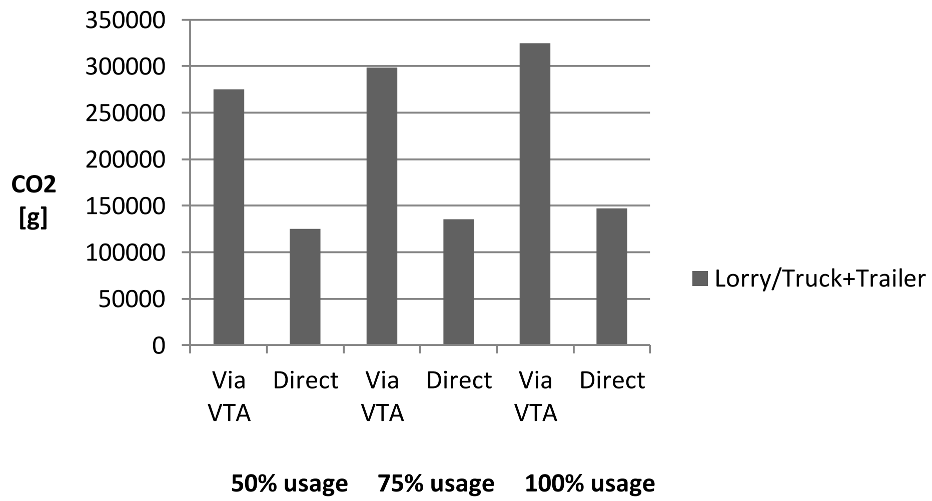

Figure 19. Sensitivity analysis where the parameter that is capacity utilization from producer 1 to user 1 and the table shows grams of CO2 per vehicle.

6.3 Transportation Cost Analysis

The cost aspect of direct transports is of importance to create a sustainable solution for VLC. The distance of direct transport has shown to be shorter, but the carriers do not only base their cost on distance. To be able to use direct transports, transport agreements have to be set up. In order to calculate how much it is possible to cut costs by using direct transports, estimated numbers for the carrier cost of the direct transports have been used. The estimation is made together with staff in the area concerned. Moreover, by using direct transports, the inventory handling at the terminals is not necessary, thus further cost reductions are made possible. Also, the carriers add a fuel cost based on the distance driven. The distance of direct transports is shown to be significantly shorter than a transport via terminal, which also allow for cost reductions. However, this reduction is not included in the calculations, as numbers are hard to estimate.

User 1 mainly needs frames, which makes it convenient to send shipments of only frames from the producers to User 1. Figure 20 shows the direct transports of frames and the transport via the terminal in Gothenburg.

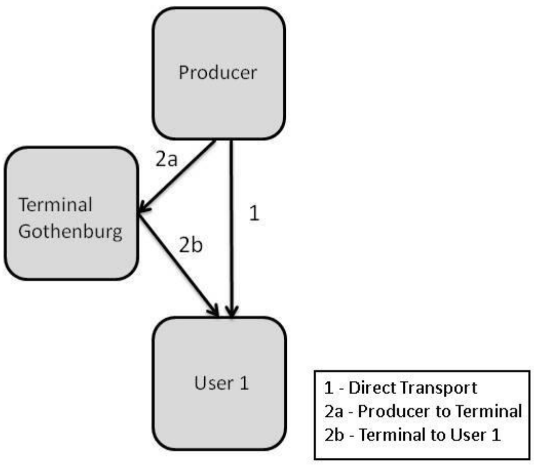

Figure 20. The direct transports of frames and the transport via terminal in Gothenburg.

The cost calculation approach is presented in Appendix C. Cost calculations of the shipments from Producer 1 to User 1 shows that direct transports allow for cost reductions of 55 %, which can be seen in figure 21. The cost calculations are based on the cost for a truck + semi-trailer, which is most commonly used at this distance. The reduction consists of reduced handling costs at the Gothenburg terminal and one transport instead of two ones.

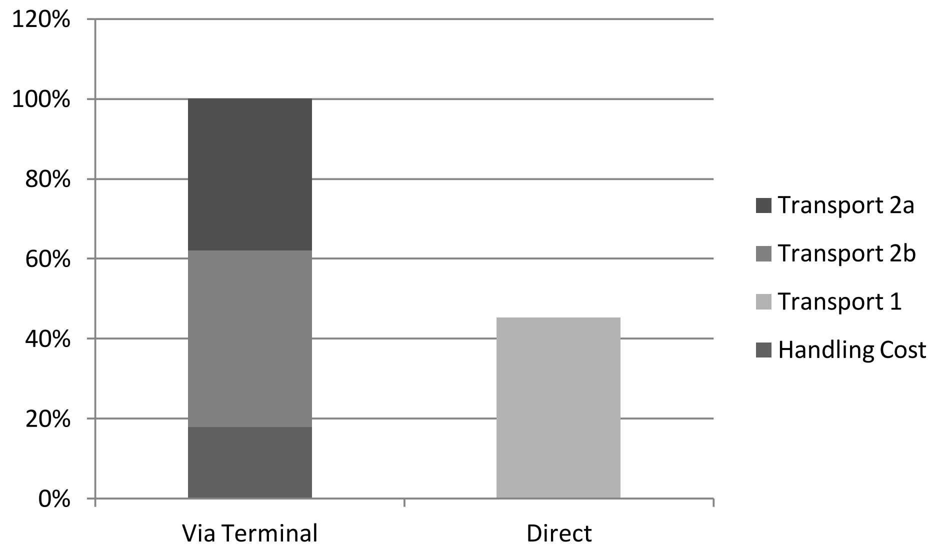

Figure 21. Costs of shipments from producer 1 to user 1.

User 2 needs both pallets and frames. When the shipments are made separately, the shipment of frames is sent from a producer of frames and the shipment of pallets is sent from a producer of pallets. Cost calculations of the shipment of pallets between Producer 1 and User 2 shows that a direct transport allows for cost reductions of 14 %. The shipment of frames between Producer 4 and User 2 allows for cost reductions of 13 %. The calculations are based on the cost for a tractor + mega-trailer, which is most commonly used at this distance. The reductions consist of reduced handling costs at the Gent terminal and one transport from each producer instead of two transports for each, which can be seen in figure 22 (transport 1, 2a and 2b are explained in figure 20).

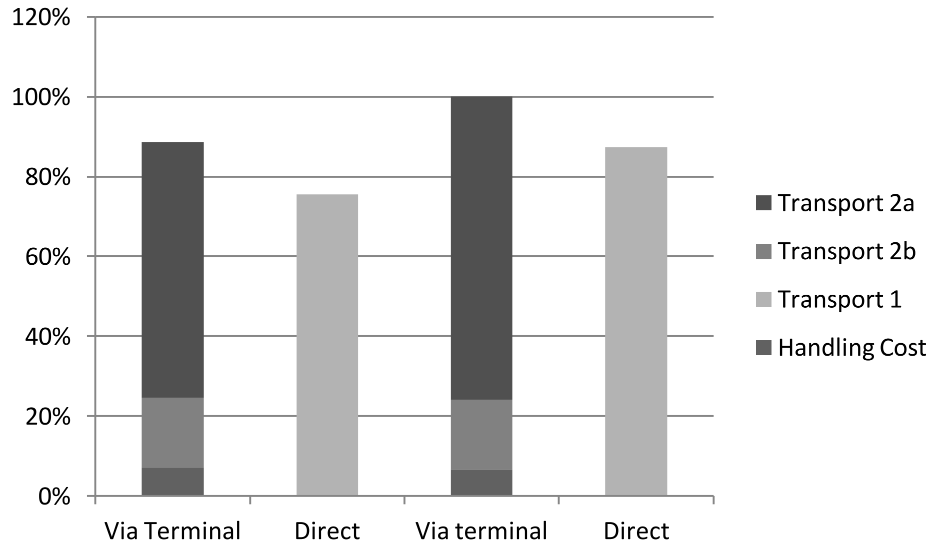

Figure 22. Costs of mixed shipments from producer 1 and 4 to user 1.

When shipments of pallets and frames are being shipped from the producer to the user, the situation is somewhat complicated. Frames need to be shipped to Producer 1, who are the main producer of pallets in order to coordinate the different packaging material, as shown in the left part of figure 23.

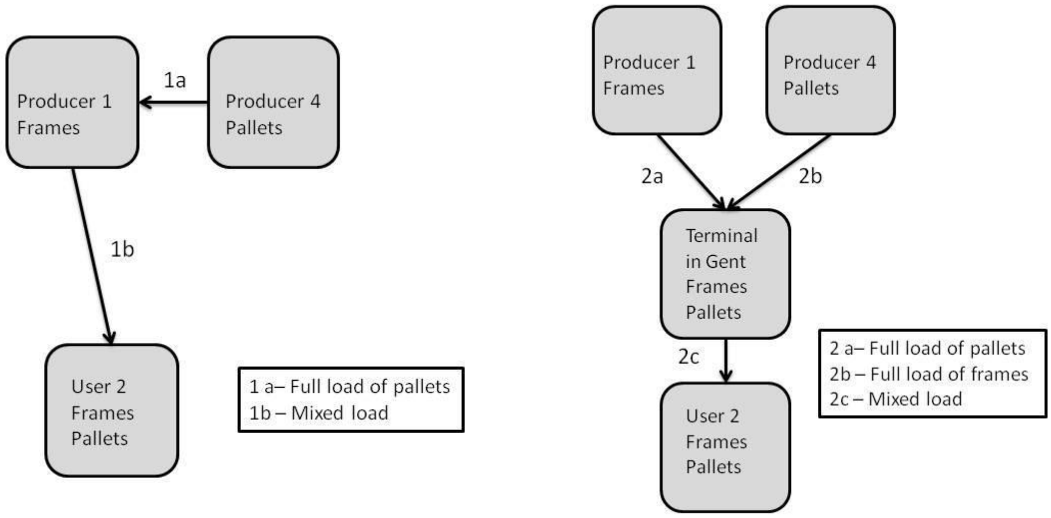

Figure 23. Mixed transports with a consolidation at the producers or the terminal.

The mixed shipment is then being sent to User 2. This is compared with sending one shipment of pallets and one shipment of frames to the terminal in Gent, where a new shipping of mixed packaging is shipped to User 2, as was shown in figure 23. The direct transport of mixed packaging allows for cost reductions of 12 %. The calculations are based on the cost for a tractor + mega-trailer, which is most commonly used at this distance. The cost reductions consist of reduced handling costs at the terminal and one short and one long transport, instead of two long and one short transport, as shown in figure 24.

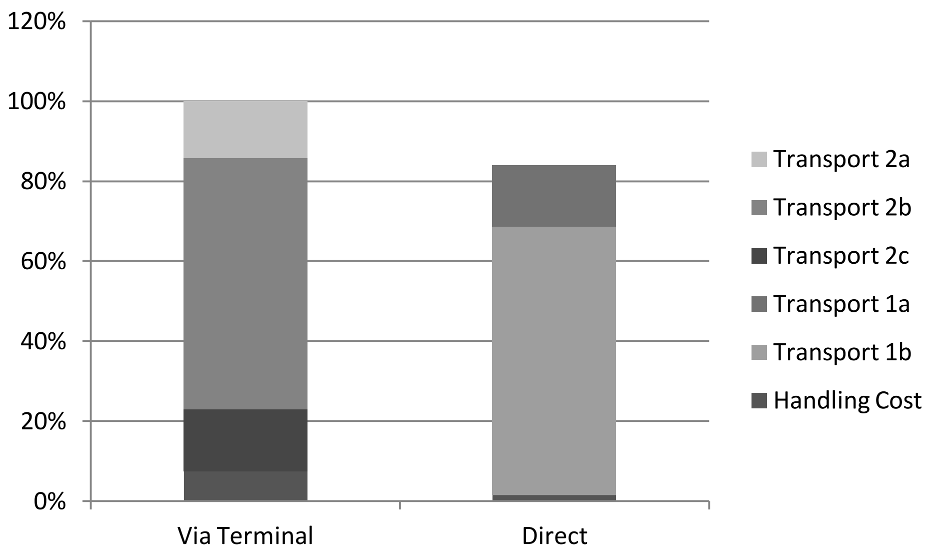

Figure 24. Costs of consolidated shipments from producer 1 and 4 to user 1.

6.4 Impact on the units at VLC

Direct delivery of newly manufactured packaging to the users from the producers instead of delivering via a terminal causes changes for the involved organizations. Even if a change to direct deliveries results in reduced environmental impacts as well as reduced transportation costs, it is also of interest to analyze how it affects VLC's working methods. Increased work due to administration, inventory, handling or loading is also important costs. The cost saving due to direct deliveries needs to be larger than the costs caused by the extra administration, inventory and handling.

It is difficult to predict how a change to direct deliveries would affect the units' daily work and what adjustments that would be necessary. What adjustments are necessary is also depending on which producer and user are chosen. To start with, this change could be implemented for one producer and one user, in order to come up with a sustainable process.

Unlike how it is today, the producer needs to register that the packaging material has left their storage, is loaded and is on its way to the user, in the PMR system, as shown in figure 25.

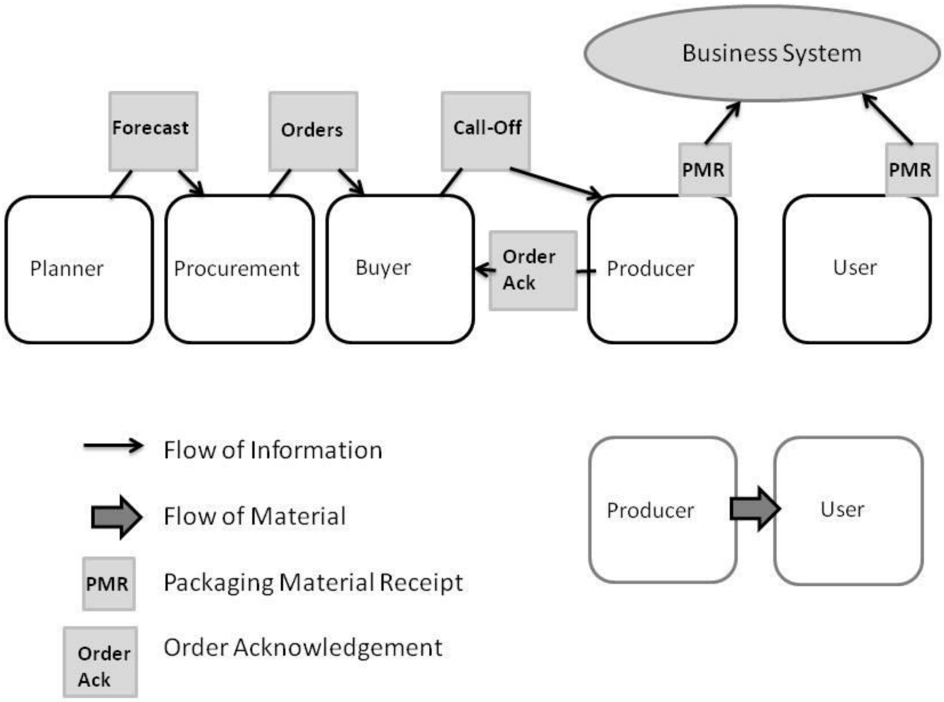

Figure 25. Material and information flow of a direct delivery.

Moreover, since the packaging material is transported directly from the producer to the user, the employees at Volvo's terminals can no longer perform quality controls. This becomes a disadvantage for the users who then gets packaging material directly from the producer without any quality control. The direct delivery, without passing Volvo's terminal, can also create questions about when the ownership turns to Volvo. The direct transport also has to be possible to implement in the business system and the PMR system. As the packaging is sent straight from the producers the quantity at the producer need to be known, in order to make transport orders.

One idea is that the producer could have two inventories located at their area, and that they could perform the quality controls instead. They could have one ordinarily inventory for the producer's own stock and one inventory owned by Volvo. The inventory owned by Volvo is called a consignment inventory and is positioned at the producer but legally still belongs to Volvo. The advantage is that the user gets newly manufactured packaging directly from the producer, but the disadvantage is that Volvo must keep capital in inventory at the extra inventory. Volvo would be the one who controls and regulates the levels of this stock. PMR would then be registered by the producer when packaging material is moved from the producer's ordinarily inventory to Volvo's consignment inventory. It is also a disadvantage that the producer now needs to perform the quality control themselves, which might lead to a question of trustworthiness.

Furthermore, contracts dealing with legal matters need to be arranged with the producers. In this type of contracts agreements about insurance, robbery and bankruptcy need to be stated, in order to be in agreement with producers when questions of responsibility occur.

If the consignment stock would be hosted by the users, they could perform the quality controls by themselves. This would be a good solution since they would certainly inspect the packaging material critically. However, keeping a second storage at the users place can also be adverse. When the user is not in need of new packaging material, it may well be a redundant storage. This costs money for Volvo but not for the user, since the consignment stock is owned by Volvo. However, the producer can continuously distribute packaging material to different users and thus avoid unnecessary costs for Volvo.

A great advantage for the users is that a direct delivery from the producer gives them brand new packaging material. Since the packaging material is newly produced, it has never been used and is thus possible to use for components which is particularly sensitive. The user might consider the advantage of getting new and unused packaging material greater than the disadvantage of not getting the packaging material quality controlled by Volvo.

The loading, unloading and storing at the main inventories would decrease by using direct transport, as some of the packaging does not pass the terminals, which will lead to reduced inventory costs. On the other hand, there will be unloading and loading costs at the producer when performing mixed transports from the producer to the user.

In conclusion the producers and users need to be educated about the changes in the system and possible redesigns. Contracts with carriers need to be rearranged since the routing is different and legal matters must be agreed. This change causes a different work method for some involved, but still, the benefits seem greater than the disadvantages. However, this area has not been the main purpose of this thesis and therefore further researches are needed in order to be sure of how the units are affected due to direct deliveries.

7. Discussion and Conclusion

In this chapter a discussion based on the analysis is presented. Important points and aspects are discussed. Furthermore, a check-point for the research questions that describes where to find the answers to the research questions in the thesis is presented. Moreover, the conclusion based on the research question will be obtained. Finally, recommendations for Volvo Logistics Corporation will be presented.

7.1 Discussion

In the end it is always the user's need that decides what amount of pallets and frames that are loaded on a vehicle. Even if an optimal filling degree is found, the favorable combination of packaging will not be possible to use every time since the users' need might differ. The total quantity of pallets circulating in the pool system were 2 082 855 units in April 2011 and the quantity of frames circulating in the system was 4 218 285 units during the same time. The relation between pallets and frames in the system is not necessarily the same when it comes to the produced packaging. Users' needs might vary and the time of reuse differs between different types of packaging as some brake more easily, thus the amount of pallets and frames are hard to predict in advance.

The suggestions of mixed packing charts with pallets and frames are only suggestions of how possible mixes could be designed. It is important to remember that the filling degrees used is assumptions as this thesis only focuses on pallets and frames in the L-family of wooden packaging. It might be possible to send shipments mixed with other types of packaging and it is also possible that the carriers are optimizing their loads and mix it with other goods.

The mixed direct transports are somewhat complicated and assumptions have been made, in order to make calculations on costs and emission. It is assumed that pallets from Producer 2 are transported to Producer 1, where the shipment is mixed with frames. The producers are part of the same corporation, which is why collaboration is made easier. Moreover, Producer 1 has large areas of storing, which would allow for letting non-used pallets be stored until next mixed transport occurs. If the mixed shipments would be organized differently, the distances used in the calculation might differ. However, most of the producers are located in the south of Sweden, thus the results are not be notably changed.

It is important to notice that the geographical position of the users was a parameter when choosing users for the calculations. Other users and producers might not give the same results. Nevertheless, it is likely that many users get similar results, but it is important that their order quantities are relatively large and that the distance between a producer and them is shorter than the distance from the producer, via terminal, to them.

Direct transports would decrease VLC's amount of transports and their environmental impact. Environmental consciousness is getting more important than ever in today's industry and reductions of transport are significant. VLC would not only get positive promotion by cutting their environmental impact; a more consciousness might also reach new, greener segments of the market. VLC also needs to be prepared for future regulations concerning the environment and a more environmentally responsibility-taking mindset might be required in the future.

The solution of using a consignment inventory might not be the optimal solution in order to control the level of storage at the producer. This would cause increased costs due to the inventory, which is owned by Volvo. It could also increase administration costs due to new system and routines. However, some units might be affected differently and get less administration and handling which once again results in reduced costs. It is of importance that the cost reduction due to reduced transportation costs and handling cover the increased costs for inventory and administration. However, this is not the main focus of this thesis and therefore not further investigated.

Moreover, sustainability has three dimensions; the economy, the environment and the society. The introduction of direct transports at VLC would not only allow for environmental improvements, but also be economically beneficial. Environmental solutions that are also financially favorable are also more sustainable, as companies get incitements to improve themselves in order to become more cost efficient.

7.2 Research Questions Check Point

RQ1: How is the current flow of packaging material organized?
General answers of this question are presented in section 5.1 and 5.3 in the empirical study.

RQ1a: Which are the producers of the wooden packaging?
The producers are described in section 5.4 in the empirical study.

RQ1b: Who are the main users of the wooden packaging?
The users are described in section 5.4 in the empirical study.

RQ1c: How is the flow of information organized?
The flow of information is described in section 5.1 in the empirical study.

RQ2: How can transport cost and environmental impact be reduced?
The current types of cost of transports are presented in the empirical study in section 5.2. A potential cost reduction is analyzed in section 6.3 in the analysis and further discussed in section 7.1. The environmental impact of the current flow is calculated in section 6.2 in the analysis. The environmental impact reduction of direct transports is analyzed in section 6.1 and 6.2 in the analysis and further discussed in section 7.1.

RQ3: What requirements does the redesign have on the organization of terminals?
The organization is presented in the description of VLC in Chapter 2. The impact of direct transports on the different units at VLC is further discussed in section 6.4 in the analysis.

7.3 Conclusion

This thesis shows that direct transports of pallets and frames from chosen producers to chosen users are significantly shorter than transports via terminals, and that the environmental impact from the transports are notably lower, based on filling degrees of pallets and frames on the vehicles most commonly used by the carriers. This is true for shipments where pallets and frames are sent separately as well as shipments when they are sent in mixed loads. However, the user's orders have to be rather large, in order to secure full shipments from the producer. Also, the user has to be located in a position where the distance from the producer is shorter than the distance from the producer, via a terminal, to the user, for this to be true.

Some vehicles are more environmentally efficient when transporting pallets and frames than others. Calculations show that the lorry/truck and trailer is favorable when transporting pallets and that the tractor + semi-trailer is favorable when transporting frames. However, the calculations also show that if the weight limit of the vehicle is reached, the tractor + mega-trailer is preferable. In conclusion, the choice of vehicle depends on how the shipment looks like and what filling degree that is reachable. The suggestions above are based on the packing charts presented in the empirical study. However, it is not always possible to influence what vehicle the carrier uses, and most pay agreements between VLC and the carriers are based on the usage of a certain vehicle.

Direct deliveries from producers to users, without passing the terminal, result in significantly decreased transportation costs and handling cost, when sending pallets and frames separately. The cost reduction includes fewer amounts of transports and less handling costs at the terminals. Moreover, sending mixed transports also results in cost reduction. However, there might be extra handling costs at the consolidation point and the packaging that do not fit on the mixed shipment has to be stored at the producer which also is a cost. It is therefore of importance that these extra costs that occurs due to direct deliveries, are exceeded by the reduced costs.

7.4 Recommendation to Volvo Logistics Corporation

It is recommended to implement direct transports between the producers and users focused in this thesis, in order to reduce the environmental impact. When choosing producers and users it is of importance to take the geographical locations into account in order to reduce the distances. It is also of importance that the quantities of deliveries are large in order to perform effective transports. The environmental impact has shown to be reduced with about 45-70 % when sending packaging direct from producer to user.

It is recommended to adjust the way of packing the vehicles according to the users need, in order to accomplish best filling degree possible. However, the results in this thesis show a better filling degree for mixed shipments of pallets and frames compared to transports with separate loading. When possible it is recommended to pack one layer of frames in the bottom and two layers of pallets on top, which gives a filling degree of 93 %. A better filling degree contributes to reduced environmental impact as well as reduced transportation costs.

It is recommended to implement direct transports between the producers and users focused on in this thesis, in order to reduce transport costs. The cost reduction includes fewer transports and less handling costs at the terminals. However, administration costs and costs for storing might emerge, which have to be exceeded by the transport cost reductions in order to get a total cost reduction. Transport cost reductions have shown to be up to 55 % when sending packaging to the user in Sweden and up to 14 % when sending packaging to the user in the Netherlands.

It is recommended to use a lorry/truck and trailer when transporting pallets and a tractor and semi-trailer when transporting frames in order to reduce the environmental impact from transports and make the usage of transports more efficient. Moreover, if the filling degree reached 100 %, the lorry/truck + semi-trailer is recommended when possible and a tractor + mega-tralier when not.

7.5 Future Research

An implementation of direct transports would need further investigation. The costs of holding a consignment inventory would need to be analyzed. Also, a breakpoint could be found for when it is appropriate to use direct transport, concerning inventory costs and amount of transports. Furthermore, it would be interesting to analyze the different carriers from an environmental point of view, in order to prioritize, when contracts with carriers are formed.

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Appendix A. Interviews

Date	Name	Responsibility
Regular Meetings	Sönke Behrends	Examiner, PhD, Chalmers
Regular Meetings	Ferdrik Mällo	Tutor, Manager Order DistributionVLC
120126	Johan Torgersson	Process Developer, VLC
120202	Eva Kristofferssen	Area Manager, VLC
120203	Johan Lagerström	Core Values Coordinator, VLC
120209	Emir Dzudzevic	Planner, VLC
120216	Niklas Jirden	Business Process Manager, VLC
120222	Birgit Martens	Planner, VLC
120223	Christian Finnsgård	PhD Candidate, Chalmers
120315	Fredrik Stensson	Packaging Engineer
120229	Lars Bertil Lindblom	Quality Coordinator Procurement, VLC
120403	Claes Arvidsson	VD, Producer 1 and 4
120403	Anders Adolfsson	VD, Producer 3

Appendix B. Emission Auditing

Emission for packing pallets and frames separately

First select relevant vehicle type.

A; Emission, g

B ; Fuel Consumption (FC) on Motorway depends on the cargo capacity utilization (CCU) by weight, FC = FC, empty + (FC, full – FC, empty) × CCU % utilization for separate packaging

C; Motorway, X % of total distance

D; Fuel Consumption (FC) on Rural road depends on the cargo capacity utilization (CCU) by weight, FC = FC, empty + (FC, full – FC, empty) × CCU % utilization for separate packaging

E; Rural road, X % of total distance

F; Emission, when using Euro Class 5, g/l

G; Distance, km

H; Estimated value in order to include the empty transport on the way back from the delivery, an estimation of X % of the distance driven is added, assuming that the filling degree is zero %.

I; Fuel Consumption on Motorway, 0 % utilization

J; Fuel Consumption on Rural road, 0 % utilization

$$\boldsymbol{A} = (\boldsymbol{B} \times \boldsymbol{C} + \boldsymbol{D} \times \boldsymbol{E}) \times \boldsymbol{F} \times \boldsymbol{G} + \big(\boldsymbol{H} \times \boldsymbol{F} \times \boldsymbol{G} \times (\boldsymbol{I} \times +\boldsymbol{J} \times \boldsymbol{E})\big)$$

Emission for mixed packaging

First select relevant vehicle type.

A; Emission, g

B; Fuel Consumption (FC) on Motorway depends on the cargo capacity utilization (CCU) by weight, FC = FC, empty + (FC, full – FC, empty) × CCU % utilization for mixed packaging

C; Motorway, X % of total distance

D; Fuel Consumption (FC) on Rural road depends on the cargo capacity utilization (CCU) by weight, FC = FC, empty + (FC, full – FC, empty) × CCU % utilization for mixed packaging

E; Rural road, X % of total distance

F; Emission, when using Euro Class 5, g/l

G; Distance driven with vehicle having mixed packaging; total distance, km

Distance driven with vehicle having separate packaging;

distance, km = total distance $\times$ $\left(\frac{\text{amount of kit on vehicle according to mixed packaging chart}}{\text{amount of kit on vehicle according to seprate loading}}\right)$

The distances for driving packaging separate and mixed are thereafter summarized.

H; Estimated value in order to include the empty transport on the way back from the delivery, an estimation of X % of the distance driven is added, assuming that the filling degree is zero %.

I; Fuel Consumption on Motorway, 0 % utilization

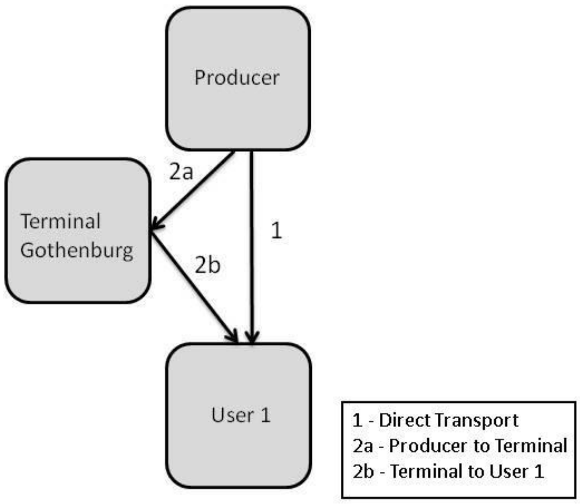
J; Fuel Consumption on Rural road, 0 % utilization

$$\boldsymbol{A} = (\boldsymbol{B} \times \boldsymbol{C} + \boldsymbol{D} \times \boldsymbol{E}) \times \boldsymbol{F} \times \boldsymbol{G} + \big(\boldsymbol{H} \times \boldsymbol{F} \times \boldsymbol{G} \times (\boldsymbol{I} \times +\boldsymbol{J} \times \boldsymbol{E})\big)$$

Appendix C. Cost Analysis

Transport Costs, User 1

The costs of direct transports have been compared with the costs of transports via terminals. The different transports for User 1 are presented in the figure below.

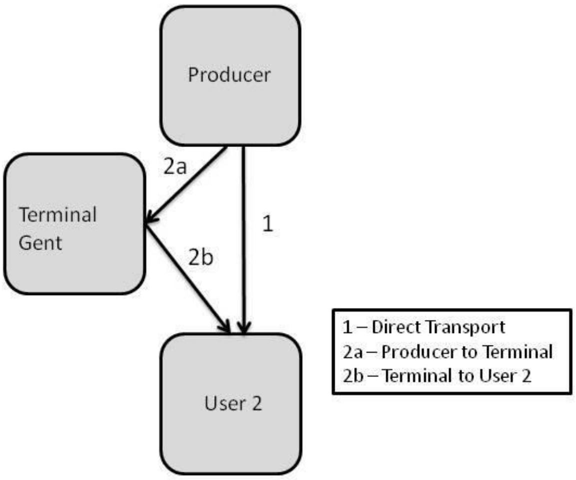


$$\frac{1-\dfrac{Transport\ Cost\ 1}{Transport\ Cost\ 2a + Transport\ cost\ 2b + Handling\ Cost * 40}}{100} = \%\ Cost\ Reduction$$

- The costs for transport 2a and 2b were given.
- The cost for transports 1 is assumed together with employees concerned.
- The exchange rate for Euro is set to 8.9 SEK.
- The transport cost is based on the cost for a truck + trailer, as this is the vehicle most commonly used at this distance.
- The truck + trailer fits 40 frames.
- A standard handling cost is added per packaging kit that is loaded and unloaded at the terminal in Gothenburg.

Transport Costs, User 2

The costs of direct transports have been compared to the costs of transports via terminals. The different transports for User 2 when sending **pallets and frames separately** are presented in the figure below.

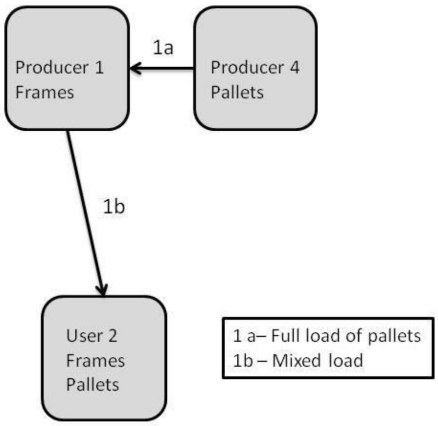


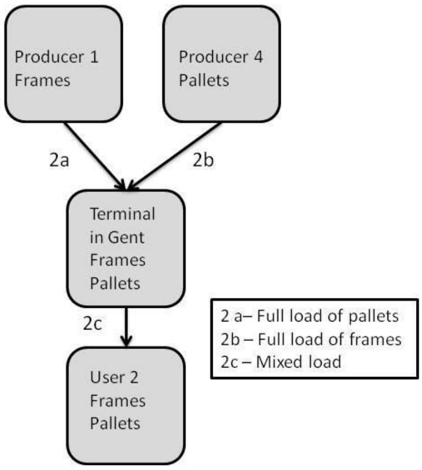
$$\frac{1 - \frac{Transport\ Cost\ 1}{Transport\ Cost\ 2a +\ Transport\ Cost\ 2b + Handling\ Cost * X}}{100} = \%\ Cost\ Reduction$$

X=amount of pallets/frames on the tractor + mega-trailer

- The costs for transport 2a and 2b were given.
- The cost for transport 1 is assumed together with employees concerned.
- Freight cost for the ferry is added.
- The exchange rate for Euro is set to 8.9 SEK.
- The transport cost is based on the cost for a tractor + mega-trailer, as this is the vehicle most commonly used at this distance.
- The tractor + mega-trailer fits 56 pallets or 52 frames.
- A standard handling cost is added per packaging kit that is loaded and unloaded at the terminal in Gent.

The transport costs for User 2 when sending **mixed loads** of packaging is explained in the figure below. The direct transports costs for 1a and 1b are compared with the costs for transports via terminals (2a, 2b and 2c).





$$\left(\frac{52}{56}\right) * Transport\ Cost\ 2a + \left(\frac{13}{52}\right) * Transport\ Cost\ 2b + \ Transport\ Cost\ 2c + Handling\ Cost * (52 + 13) = Total\ Cost\ via\ Terminal$$

$$\left(\frac{52}{56}\right) * Transport\ Cost\ 1a + Transport\ Cost\ 1b = Total\ Cost\ Direct\ Transport$$

$$\frac{1 - \frac{Total\ Cost\ Direct\ Transport}{Total\ Cost\ via\ Terminal}}{100} = \%\ Cost\ Reduction$$

- The cost for transport 1a, 2b and 2c were given.
- The cost for transport 1a and 1b are based on assumptions made together with employees concerned.
- Freight cost for the ferry is added.
- The exchange rate for Euro is set to 8.9 SEK.
- The transport cost is based on the cost for a tractor + mega-trailer, as this is the vehicle most commonly used at this distance.
- The tractor + mega-trailer fits 52 pallet kits and 13 frame kits
- The tractor + mega-trailer fits 56 pallet kits or 52 frame kits.
- The coefficient 52/56 is obtained by dividing the number of pallet kits on the mixed transport by the number of pallet kits on a transport with only pallets.
- The coefficient 13/52 is obtained by dividing the number of frame kits on the mixed transport by the number of frame kits on a transport with only frames.
- A standard handling cost is added per packaging kit that is loaded and unloaded at the terminal in Gent.