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Returnable plastic packaging flow in the automotive industry

An evaluation of the washing from a green logistics' perspective

Master of Science Thesis

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Gothenburg, Sweden, 2011
Report No. E 2011:061

MASTER'S THESIS E 2011:061

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Chalmers Reproservice
Göteborg, Sweden 2011

Abstract

In this thesis, companies using returnable plastic packaging are investigated from a green logistics' perspective, focusing on the washing process performed after they are used. Returnable plastic boxes used to carry components are, in some cases, washed systematically to secure customer requirements.

The purpose of this master thesis is to describe existing flows of returnable plastic boxes by investigating customer requirements on cleanliness of the boxes and to evaluate the activities within their supply chain as well to assess the environmental impact related to the washing.

A case company in the automotive industry was involved in this thesis, and their supply chain of returnable boxes was the main source of information. The research methodology utilised in this study consisted of semi-structure interviews with different actors related to the supply chain of the boxes. Other companies using returnable boxes were also investigated as point of reference.

The empirical findings was analysed by using a Lean approach, performing a Material Flow Mapping (MFM) at one washing terminal in Sweden and a Life Cycle Assessment (LCA) at four washing terminals in Europe. The MFM result showed that the lead-time inside the washing terminal for one box was approximately 12 days and that only 4 min was dedicated to the washing or the relative "value added time". The LCA showed that the washing of one box contributes on average to 50 g of CO_2 emissions and consumes 0,24 kWh of electricity and 0,7 litres of water. The results revealed that the washing stands for high environmental impact during the life cycle of a box.

The main reasons for companies to perform systematic washing were identified and were evaluated to some extent i.e. some of the attached identification labels are difficult to remove by hand. Sorting has been identified as the only way to avoid systematic washing. Potential set-ups of supply chain have been identified, if deciding to sort clean/dirty boxes and specific guidelines are needed for the different set-ups.

The principal conclusion was that by eliminating the unnecessary washing of returnable plastic boxes, related activities to the washing process itself could be reduced but new activities like manual sorting may occur. Other conclusions are that the design parameters of the boxes are key factors that determine the relative definition of the level of cleanliness, the logistic terminals are not just useful for the washing but important consolidating points and to offer the same type of services to different customers does not guaranty customer's satisfaction.

Recommendations to the case company are to look further into sorting set-ups of their supply chains, standardize the labels' specifications, and try to differentiate the solutions regarding customer requirements by looking into different alternatives i.e. disposable boxes.

Keywords: returnable packaging, plastic box, washing, reverse logistics, life cycle assessment, material flow mapping, Lean.

Acknowledgments

This Master thesis has been conducted in cooperation with Volvo Logistics Corporation and the Division of Logistics and Transport at Chalmers University of Technology.

We would firstly like to thank our supervisors Christian Finnsgård from Chalmers and Jimi Österholm from Volvo Logistics. The advice and support that you have given throughout the thesis period has been extremely helpful. Despite even the busiest moments, your positive attitude and helpfulness has kept our motivation very high.

We also owe equally great gratitude to everybody that contributed in somehow to the realization of this master thesis.

Thank you!

Aarón and Fredrik

Table of Contents

1. Introduction

This chapter describes the problem background of the current situation, the problem description and the purpose of the thesis, the research questions that will be the main guideline for the structure of this report and the scope of the thesis.

1.1. Problem Background

The development of logistics has taken many actions the last decades to solve sustainability issues and the complexity in the globalised business world. There are many examples in how to handle the issues such as the focus of environmental performance or some times called "green" solutions by for example extending the supply chains and by a greater responsibility in waste management (Wu and Dunn 1995). Another focus has been to increase the efficiency in logistics by for example with the concept of Lean by identifying waste or no value adding activities in flows such as in the automotive industry (Liker 2004).

Green logistics can be seen as a more environmentally responsible logistics system by including more steps or closed-loops in the system or supply chain then traditionally made in logistics. To explain the major steps in a green logistics system the following steps can be included: raw material acquisition, inbound logistics, transformation, outbound logistics, marketing, after-sales service and reverse logistics (Wu and Dunn 1995).

In the key step, reverse logistics, the use of returnable packaging is an example of how environmental and economical performance can be improved, since it can be both cheaper to use returnable packaging then single use packaging and result in a reduction of generated waste from packaging (Wu and Dunn 1995).

In the automotive industry a large number of parts needs to be in place to assemble the final product, returnable packaging then gives many benefits when organizing the complexity of an assembly plant, for example the possibility to standardize many of the operations such as deliver parts in a consistent way and the ability to stack or collect the packaging when transported without goods (Liker 2004).

There are some disadvantages with returnable packaging such as it requires a system of reverse logistics that imply a more complex network for transport planning and a need of extra space for storing returnable packaging (Wu and Dunn 1995). Another important disadvantage in the reverse logistics of returnable packaging is to maintain their cleanliness to meet quality requirements from customers, which means some kind of washing of the returnable packaging before being re-used in the supply chain (Kroon and Vrijens 1995).

In the research area of reverse logistics and returnable packaging there are some areas covered for example the use of tracking by RFID to reduce shrinkage and the cost related to it, (Johansson and Hellström 2007) but mainly the focus have been on the benefits of returnable packaging for example when scoring compared to one-way packaging (Faruk et. al. 2002) although according to Pålsson et al., (2011) in one case presents: when comparing one-way with a returnable packaging system from an environmental and economic perspective, the one-way packaging was favourable and thereby contradicting some earlier research. The activities related to the washing of returnable packaging has been discussed by Pålsson et al., (2011) and just mentioned by other authors, but the washing of returnable packaging has not been described in more depth or very detailed, for example how the activities such as the washing process and the activities that can be related to the washing such as storage, sorting, handling or transportation of returnable packaging are performed.

There is a possibility of reducing the amount of washed packaging by for example sorting out clean packaging from dirty, which could be feasible in the automotive industry since no hygienically aspects needs to be considered from the customers perspective. The handling and other activities related to the sorting can be costly since many persons needs to be trained and it can be a very time consuming activity. From a Lean perspective, the unnecessary washing of packaging can be seen as waste, as there is no value adding to the existing supply chain (Liker 2004).

1.2. Problem Description and Purpose

Companies using returnable plastic boxes require being more efficient when handling these types of items. The unnecessary activities that can be identified at any supply chain are not justifiable unless they create value to the organization and their customers. Unnecessary washing of returnable plastic boxes is not justifiable in the modern societies that are aiming to be more sustainable.

The quality requirements of cleanliness for a returnable plastic box, is met when the returnable plastic boxes are clean from impurities such as oil, dust and other undesired residuals, both on the inside and the outside. A large quantity of the boxes that arrives to the washing terminals are meeting the quality requirements, but the lack of sorting criteria has created the need of systematic washing of all the boxes to achieve this quality demand. The trade-off between to guarantee quality (cleanliness) and to eliminate unnecessary processes (washing, transportation etc.) of packaging is a possible conflict when it comes to customer requirement.

From a environmental point of view, a reduction of washing leads to savings in energy and water consumption, use of less chemicals that might be harmful to the environment and a potential reduction in the required transportation leading to less CO_2 emissions. By changing from systematic washing and by adding sorting guidelines there are possible economical and environmental earnings for companies using returnable packaging.

The purpose of this thesis is to describe an existing flow of returnable plastic boxes by investigating the customer requirements on cleanliness of the boxes and to evaluate the activities within their supply chain as well to assess the environmental impact related to the washing of these returnable plastic boxes.

Finally, recommendations of potential improvements will be described in order to reduce non-value adding activities related to the unnecessary washing of returnable plastic boxes.

1.3. Research questions

To support the thesis work and set a focus of the research, five main research questions have been stated. The questions are divided in the categories: the current state of the box flow, the customer requirements, how other companies are working, the possible future state of the box flow and an environmental analysis.

RQ1:

"How is the current supply chain of the returnable plastic boxes designed?"

To describe the current situation is of importance to be able to analyze the supply chain and to come with recommendations on what can be re-designed. Examples that will be of importance are why certain activities exist, what value it gives to the customer, what the case company require and what there actions are to deliver the service of packaging. Other questions are which activities need to be performed in the current supply chain and the problems that can relate to these activities?

RQ2:

"What are the different customer's requirements for the boxes?"

The customer's requirement on the level of cleanliness of the boxes is one of the main reasons to wash the boxes in the current situation. Since there are many suppliers and customers using the boxes it is possible that the requirements of cleanliness are different. How the requirements differ is then of interest to study in the investigation. The boxes pass to a large number of places and can then be contaminated from various sources; to describe what causes the contamination will also be investigated. A common customer is a company requiring the components carried by the returnable boxes.

RQ3:

"How is the flow of returnable plastic boxes designed in other companies?"

There exist other supply chains and to describe them can give information on how are other companies dealing with the issue of washing and what can be learnt from them and also what is possible to implement in the current supply chain?

RQ4:

"How can the current supply chain be re-designed to reduce washing of the boxes?"

After investigating the current situation both at the case company and at the customers side, the information will give options on how the flow of plastic boxes in the perspective of reducing the washing can be re-designed and improved. An example of re-designing the supply chain can be by sorting, but important issues to investigate are where and by who the sorting should be made and how much the cost will be by changing the activities in the supply chain. A key question is under what quality requirements can the boxes be sorted to meet different customer demands.

RQ5:

"What is the environmental impact related to the washing of one plastic box?"

The washing has an environmental impact and including it in the investigation will give information about the environmental performance of washing the boxes. The use of energy and its related CO_2 emissions, water and chemical use will be investigated to be able to describe the current situation. What potential reductions of CO_2 emissions can be achieved by changing the current system in the case company will also be investigated.

1.4. Scope

The thesis will be based on a literature study in the main areas: green logistics, lean and returnable packaging.

The thesis will focus the study in the case company Volvo Logistics Corporation.

A number of interviews with the personnel of the case company and related customers will be performed according to their availability and willingness to take part in the study. Other companies dealing with returnable plastic boxes will be investigated as well.

The data collection of the returnable plastic box will be made mainly at the logistics terminal in Gothenburg, Sweden, by videotaping and observations.

Visits at the case companies customers will also be performed for interviews and observations of the usage of returnable plastic boxes.

1.5. Thesis Outline

Chapter 1 (Introduction) outlines the use of returnable packaging in reverse logistics and the background, purpose with research questions, scope and outline for the thesis.

Chapter 2 (Theoretical framework) presents a review of literature concentrated to the issues and aspects of the field that relates to the questions of the work.

Chapter 3 (Methodology) presents the methods used in the study and the justifications of the choice of method. Methods described are interviews, data collection, Material Flow Mapping, Life Cycle Assessment etc.

Chapter 4 (Case Study) gives a detailed description of the case company VLC.

Chapter 5 (Empirical Findings) shows the main results from the MFM and LCA of the activities involved with the case study.

Chapter 6 (Analysis) presents an analysis of the case and the relationship to the theoretical framework.

Chapter 7 (Discussion and Conclusion) summarizes the conclusions of the thesis.

Chapter 8 (Recommendations to the company) gives suggestions on future research and development to the company.

To make it easier for the reader to find information related to each research question, the chapters considered most relevant to each research questions is presented in the table 1.1.

Table 1.1. Research questions with specific chapters.

Research Questions	Specific Chapters
RQ1	1.1 2.4 4.1.1, 4.2 5.2
RQ2	2.1 4.3 6.1, 6.4
RQ3	2.4 6.2, 6.5.1
RQ4	5.5, 5.6 6.2, 6.3, 6.5, 6.6.1-4, 6.7
RQ5	5.1, 5.3, 5.5

2. Theoretical Framework

This chapter describes the main concepts used in the analysis of the study. It gives the theoretical basis to illustrate and support ideas related to the improvement of the flow of returnable plastic boxes.

The following concepts describes from a logistics and environmental approach, the required knowledge that could be needed for the reader to follow up the future environmental and customer-oriented analysis.

2.1. Customers and Quality

According to Bergman and Klesjö (2010), the customer is the people or organization for whom the company wants to create a value to, through their product or service. The customer is the main reason for the company's activities to exist.

From a customer's perspective, quality could be defined as the ability of a product or service to satisfy, and preferably exceed, the needs and expectations of the customer. These expectations might be in some cases, elements that the customers do not really need and some times, these needs might be even difficult to realize as a need (Bergman and Klefsjö 2010).

To identify the customer it might be in some cases an easy task as it might be easy to notice who is the person or organization that the company would like to create value to. Once identified the customer, it is easier to focus in their specific needs and expectations, then trying to satisfy every single demand. In the case when multiple customers of the same product or service exist, to focus on the same quality level in an established customer group would be inappropriate, as there are several customer categories, the various needs and expectations do not always coincide (Bergman and Klefsjö 2010).

Customers differ in the type of final product, available resources, locations, socio-cultural characteristics and other aspects that determine their needs and expectations when using the boxes. The cleanliness of the returnable boxes carrying food, pharmaceuticals or any component will definitely vary in levels of cleanliness exigency. For example, according to the Food and Drug Administration (FDA), there are different specifications for the type of plastics with food-contact and non-food-contact. The FDA even presents in its website, specific requirements when recycling this type of plastics for reuse in the same purpose.

Every product, article or service must meet its own special set of customer requirements. The specific needs and expectations should be thoroughly investigated and should have a major impact on the planning of the future work activities. As quality is a relative term, it must be the customer who is able to perceive the value of it when meeting the "moment of truth", which is the moment when the product reaches the customer (Bergman and Klefsjö 2010).

The selection of a strategy for a specific product or service depends on the customers' definition of value, meaning that if the company strategy is based on the customers' value standards and perceptions, the channel of resources can be directed more effectively and will meet customers' expectations better than if the strategy is based only on the standards of the company creating the value for the customer (Zeithaml 1988). The decisions made to create real value to customers, must be supported by facts and it demands that the company providing value acquire systematic information about the needs, requirements, reactions and opinions from their customers (Bergman and Klefsjö 2010).

The different customer requirements will play a key roll in the further analysis, so is important for the reader to have in mind how can customer's requirement be easily affected by different decision taken.

2.2. The Cost of Poor Quality

In former years, the term "cost of quality" has been used to define the related costs connected to quality issues (Juran 1951). These costs consist in the following four parts:

- Internal failure costs: Costs caused by internally detected materials or product that deviate from set requirements.
- External failure costs: Costs due to defective products detected after delivering to the external customer.
- Appraisal costs: Costs for inspection of products and materials
- Prevention costs: Costs for the quality simulating activities like implementing quality management systems, education in quality and cost for audit suppliers.

The term "cost of quality" suggests that high quality costs, but what really costs is the lack of quality and it has been recommended to use the term "costs of poor quality" instead (Bergman and Klefsjö 2010). The cost of poor quality could be assigned to costs incurred by defect units, imperfect processes or lost of sales revenue. The costs of poor quality in industry are often estimated at 10-30% of the sales.

The following up of the costs of quality does not mean that the quality problems have been solved, but it gives the starting point where to look for problems in the organization.

The reader will be able to further notice in this thesis, different situations where the cost of poor quality might have an impact on the different actor's revenue.

2.3. Trade-Offs

Trade-offs is a concept that mainly refers to the different aspects of performance at different points in time, where in order to excel in some particular aspects, would imply to some extent to sacrifice the performance of other aspects (Slack and Lewis 2008).

Making the decisions of which aspect is more important can deliver two main conclusions. The first one is that all measure of performance will not have equal importance for an individual operation so certain aspects of performance will prevail over others. The second conclusion is that certain aspects of performance will to some extent trade off against each other. For example, the trade-off relationship between competitive objectives (cost, quality, delivery, variety, inventory, capital investments, etc.) means that the excellence in one objective usually implicates a poor performance in some or all the others (Slack and Lewis 2008).

In further analysis, trade-offs will be identified and discussed in order to highlight the different performances that might be affected when dealing with different situations.

2.4. Returnable Transport Items

Returnable Transport Items (RTI) can be considered as items of equipment used for the transportation, handling, storing and protection of products within supply chains, which are returned for further usage when emptied. RTI comes in the form of pallets, containers, cages, trolleys, trays, crates, boxes, etc (IC-RTI 2001).

According to Stam (2003), there are two ways to use RTI, the first one is called direct exchange and implies that the RTI is used internally in an organization or bilaterally between two organizations. The other one is called pool organization management and it implies that a RTI pool organiser makes RTI, acquired from a RTI supplier, available to a supply chain of users that will fill up the empty RTI and send it to the next user to acquire the content of it. At the end of the loop, the RTI must return to be filled up once again, not necessarily by the exact same users.

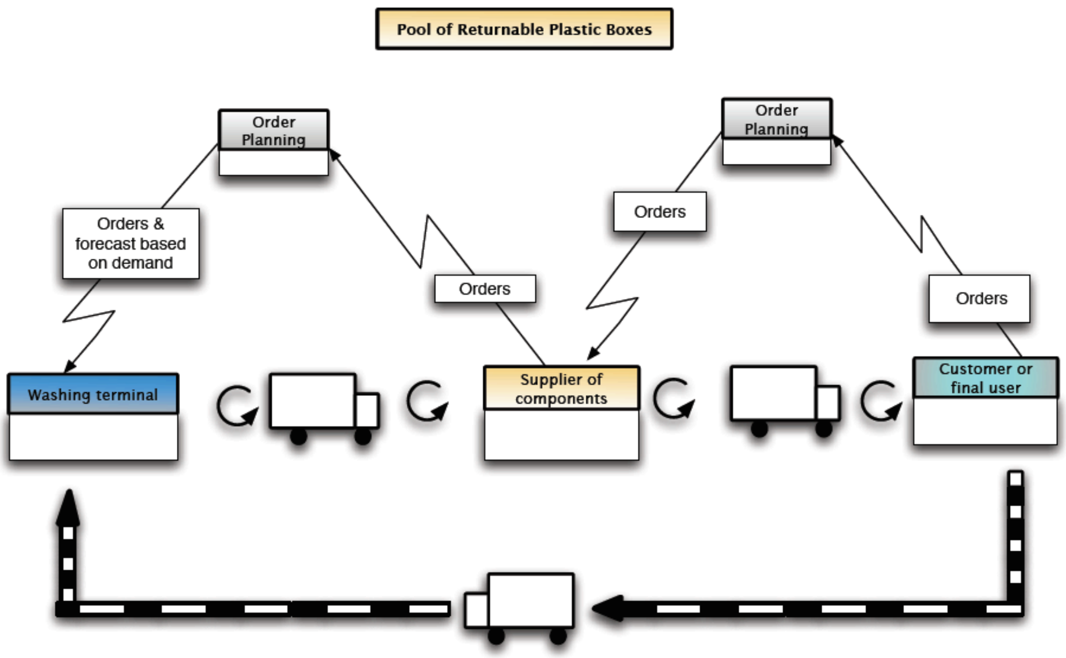


Figure 2.1. Pool system of RTI illustrating a pool organization management system.

RTI are known as well as secondary packaging, which is returnable. Secondary packaging is the material used for packaging items during transportation from sender to recipient (Stock 1992). Traditionally, card boxes have been used as secondary packaging material, with the main difference of being know as one-way package, as they are used only once (Kroon and Vrijens 1995)

In addition of transporting the returnable packaging, the return logistic system involves also the cleaning and maintenance, as well as their storage and their administration (Kroon and Vrijens 1995).

According Lutzebauer (1993), there are three types of pool systems related to returnable items:

Switch Pool Systems: In this system, every participant in the pool has its own allotment of returnable packaging. Thus cleaning, control, maintenance and storage of the returnable packaging is responsibility of each participant.

System With Return Logistics: In such a system, the returnable packaging is owned by a central agency. The main prerequisite is that the recipient bundles the used empty packaging and stores them until a sufficient number has accumulated for cost-effective collection. In this type of set-up, exists the possibility to transfer the package to another user or to send it back to a storing depot where it is possible to do maintenance and cleaning if needed, besides the fact of making them available for further users.

System Without Return Logistics: In this type of system, the returnable package is still owned by a central agency but a user rents the packaging from the agency and as soon as the user no longer needs the returnable packaging, then they are returned to the agency. The user renting the package is responsible for all the related activities to the package, such as return logistics, cleaning, control, maintenance and storage. By using this system, the user renting the returnable package can decrease his fixed cost by renting varying number of packaging as required.

The initial focus of this thesis work will be in the previous described pool organization management system and system with return logistics due to the similarities to the study case, but the remaining described systems will be considered when analysing the different types of possible set-ups.

2.5. Logistic Centres

Logistic centre is a term found in industries that aims to describe a specific location performing different activities related to a supply chain. The core business of a logistic centre is to provide handling and warehouse services to suppliers and final users (Volvo 2011), being one of the main intentions to diminish the lead-time between long distanced suppliers and the final user of the goods.

Logistic centres may include activities related to warehousing services, cross docking, container handling, packaging terminal, packaging sorting and general cargo distribution.

The combination of services provided by a logistic centre allows a wide flexibility of activities to be performed. For example, warehouse and distribution centres have been identified as crucial components in modern supply chains (Abbasi 2011), as they perform key activities like material handling, distribution of goods between facilities in various echelons and levels, keeping the required inventory to guarantee availability of goods.

Cross docking could be considered as a warehousing strategy that has great potential for controlling the logistics and distribution costs while simultaneously maintaining the customer service (Apte and Viswanathan 2000). This strategy mainly consists in moving materials directly from the receiving dock to the shipping dock with a minimum dwell time in between, allowing the different supplier's cargos to be consolidated into multi-product shipments that are send to the final user. By using cross-docks, economies of transportation could be achieved due to the possibility of using full truckloads by consolidating cargos. Another benefits is that the cost of holding inventory can be reduced as well as the order cycle time, helping the flexibility of responsiveness of the distribution network. Nevertheless, for a cross-dock to work properly, the items that come into the warehouse must be demanded or pulled out by the final user quickly. Also, the decided location for the cross-dock should be carefully studied as the distances from the warehouse to the other points in the distribution channel, the services required and the density of business will determine the justification to use a cross-dock.

Logistic centres will be further suggested as possible solutions in how to deal with specific situations and the main problem described in this thesis.

2.6. Packaging Cost

When offering services related to a pool organization management, there are different costs involved to the packaging itself that the pool organizer will charge to the users of returnable plastic boxes. Among the related costs, we can find the following (Volvo 2011):

- Usage or transaction cost
- Stock or hiring cost
- Replacement cost
- Disposal cost

According to Hobbs (1996), the mentioned transaction cost could be seen as the cost of carrying out any exchange between firms in a market place. This transaction cost arises wherever there is any form of economic organization.

In some cases, the so called transaction cost is a fixed price, for each packaging type, set by the owner of the returnable plastic boxes that mainly include costs of operational fees, cost of capital, handling and transportation costs. Within the handling cost, the cost for washing may be included.

This transaction cost is charged to the users of the plastic boxes in a specific point within the supply chain and it depends on contractual agreements which of the users pay each part of the cost.

It is important to quote that the mentioned transaction cost is not seen in this thesis as from the economic concept related to transaction cost theory, instead it is described as a common terminology used by different actors when intending to describe certain type of costs.

Within this transaction cost, lies one of the main problems of companies paying for different unwanted services and it has been one of the main motivators, from a cost saving perspective, to impulse in this thesis work.

The stock or hiring cost is the cost for the capital binding of the plastic boxes. The replacement cost is charged when a box is missing in an inventory count, to cover the cost for a new box. The disposal cost is the cost for scrapping a box.

2.7. Identification Labels

The tagging of items has been in the industry since the 1950's (Bose and Pal 2005) and identification systems have become a commonplace in industries with a need of tracking and identifying items at any point of service within the supply chain (Agarwal 2001). Identification systems can be found in the form of a barcode, RFID tags, optical character recognition and many more.

One of the existing debates when discussing identification systems is the one between barcode labels and RFID tags, both systems being advantageous and disadvantageous in certain aspects when compared to each other. Stam de Jonge (2003) presents the following comparison between barcodes and RFID tags:

Barcodes	RFID tags
Can only be read individually	Faster reading, as they can be read simultaneously.
Must be visible to be read	No line of sight required.
Cannot be read if they are dirty or damaged	Can deal with rough and dirty environments better, because tags can be integrated into the packaging materials.
Are usually read manually and thus incur labour costs. Automated scanning demands standardisation of barcode location.	Are read automatically so no labour costs.
Information cannot be changed (new label required) Limited quantity of information	Information can be changed, if desired, for example temperature fluctuations. Quantity of information depends on application.

Figure 2.2. Comparison of barcodes and RFID tags (Stam de Jonge, 2003)

RFID tags have been proven to help with the asset's management of pools of returnable transport items and also with the traceability of goods at any point of the supply chain, but at the expense of a number of implementation issues (Stam de Jonge 2003).

The barcode technology was successfully introduced in the 1970's in the grocery retail business and it is essential part of our daily activities (Parlikad, et al. 2009). The barcodes have an optical nature and they encode identification data into light and dark regions either directly into a part or in a label.

The identification of the returnable plastic boxes and their content is greatly done with barcode labels, where data gathered in the barcode gives unique information about the components inside the box, the company producing the component, the series number of production and many other information characteristic for each component.

One of the main differences between the RFID tags and barcode labels is that the first one can be reused and new information can be reassigned to the same label, while the barcode can be codified only ones. Due to the returnable characteristic of the evaluated packaging, it has been opportune to consider these different types of identification methods.

2.8. Adhesive Labels

Adhesive identification labels may be composed by a first paper, which has been printed out with information on one surface, coated with adhesive glue on its other surface, and a second paper attached to the glued surface of the first paper. In use, the first paper is affixed to an item after being released from the second paper (Kazumasa 1988).

Labels may use different type of adhesive chemicals in order to be able to stick to the item to be identified. Some of the common chemicals we can find are urethane resins (Kazumasa 1988), acrylics resins and combinations of other adhesives formulas made in-house by different suppliers of adhesive solutions (3M Company 2000).

The specific adhesive composites used by the different suppliers of adhesive labels will determine the level of strength to which the label will stick to the identified item and at the same time, it will determine the level of easiness to remove the label, ones it has been used for its purpose, having a direct impact in the cleanliness of the used package.

2.9. Life Cycle Assessment

Probably the most established and developed method for assessing environmental impact is the life cycle assessment (LCA) and defined in ISO 14040 as: "LCA is a method used to assess environmental aspects and potential impacts associated with a product" (ISO 2006). A LCA can be divided in four interdependent phases, (figure 2.3) (Baumann and Tillman 2003):

1. Goal and scope definition: The intentions of the LCA and in which context it will be used are stated, for example the direct applications such as product development etc.
2. Life cycle inventory analysis: The life cycle inventory (LCI) deals purely with the physical inputs and emissions, and cannot evaluate qualitative effects such as human health or aesthetic quality. It does, however, provide us with sufficient information for educated estimations of the damage caused to the environment by products and processes, and indeed all types of commercial activity (Lee, O'Callaghan and Allen 1995).
3. Life cycle impact assessment (LCIA): Selection of impact categories is made and the aim is to describe the environmental consequences of the environmental loads quantified in the inventory analysis. The general categories used are resource use, human health and ecological consequences.
4. Life cycle interpretation: A presentation of the results typically made in diagrams to reach conclusions and recommendations.

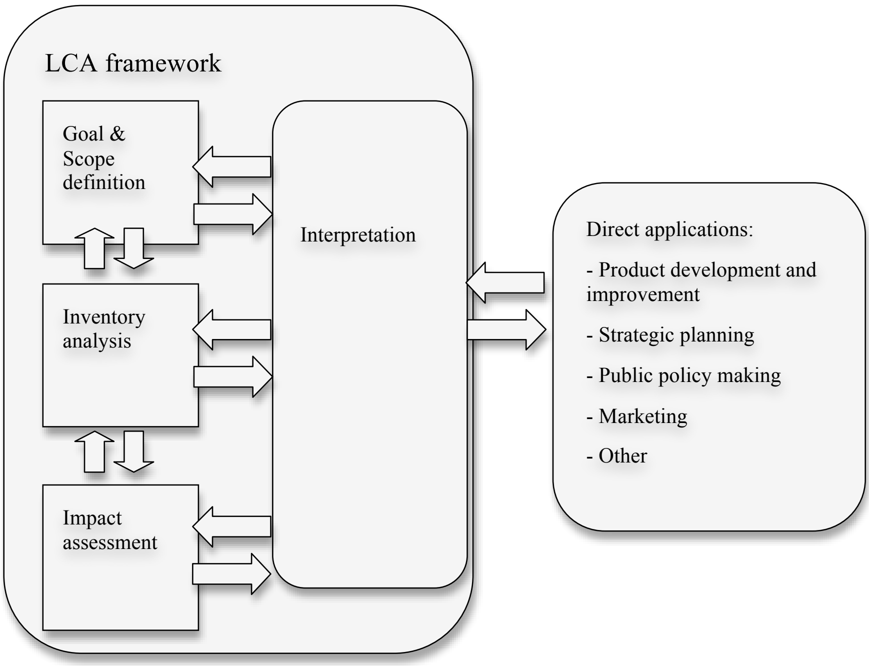


Figure 2.3. LCA framework (ISO14041, 1998)

Important decisions when performing a LCA are to choose functional unit, system boundary: what should be included respectively excluded from the system for the assessed product. Making a LCA on a product is a complex method and have many practically problems for example by being very time consuming, the data available etc (Lee, O'Callaghan and Allen 1995, Ayres 1995, Udo de Haes 1993). To reduce the resources used in time etc. there is for example streamlined LCA, a method that can be viewed as "What can be eliminated from a full-scale LCA design and still meet the study goals? (SETAC 1999).

There are at least three distinguished types of quantitative LCA studies (Baumann and Tillman 2003):

- Accounting type and change oriented: both used for different types of comparison and to have fairness it puts requirements on methodology for example when selecting functional unit.
- Stand-alone LCA: used to describe a single product and to identify where the greatest environmental impact in the life cycle.

LCA is a common approach to study systems from an environmental perspective and is in this thesis used to present the environmental performance of the system studied. In the methodology the system and the approach is presented further.

2.10. Green Logistics

Green logistics means environmentally responsible logistics and is sometimes called green supply chain (Beamon 1999). Wu and Dunn (1995) describe green logistics as "being environmentally responsible means improving operational efficiency by conserving resources and reusing them as much as possible". The issues that are developed in green logistics compared to the traditional logistics thinking is to extend the supply chain with reverse logistics and to improve transportation in order to decrease pollutants and the negative environmental impact (see figure 2.4). An example of reverse logistics is returnable packaging or RTI (see also section 2.3), a type of secondary packaging that can be used several times in the same form (Kroon and Vrijens 1995).

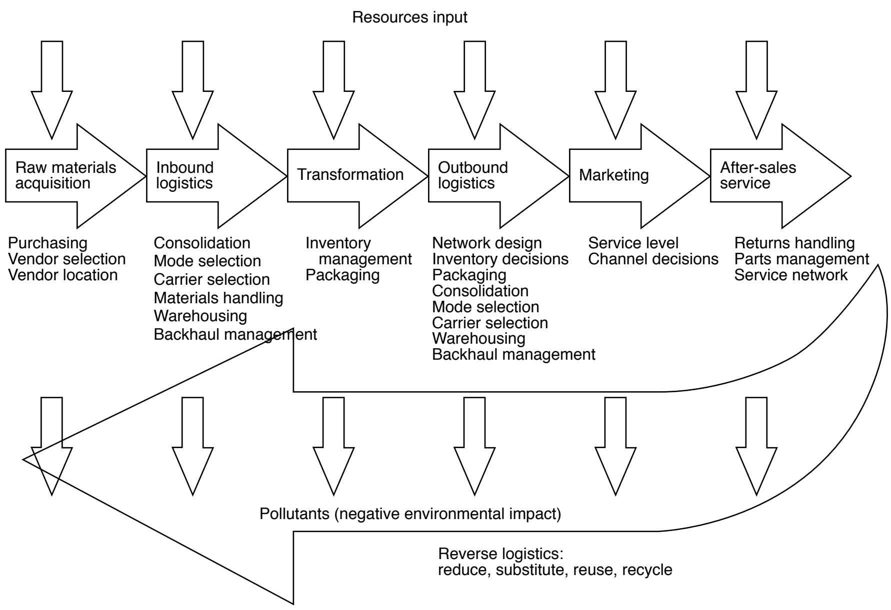


Figure 2.4. Reverse logistics in the logistics system (Wu & Dunn, 1995)

In reverse logistics it is very important the understanding of the trade-offs between environmental impact and optimal supply chain efficiency when managing these issues (Wu and Dunn 1995). Reverse logistics includes shipments of packaging waste, recyclable packages, and customer returns in the logistics system and as described in the following figure with the main four principles of reverse logistics: reduce, substitute, reuse and recycle.

A drawback with reverse logistic is the shipments to disposal sites, since it creates demands for logistical capacity and adds no value to the goods. For example returnable plastic boxes requires extra space, more handling and more planning to cover a two-way system instead of a one-way system. Reductions of sources or by substituting to more environmentally materials in the reverse logistics flow are more preferable then reuse or recycle, since for example recycling needs some chemical or physical process for a new life (Wu and Dunn 1995).

The negative environmental impact from transportation can be reduced, like for example, using a more efficient and environmentally friendly means of transporting and the use of freight consolidation that generates fewer trips (Wu and Dunn 1995).

In this thesis green logistics can be seen as the “big picture” of the supply chain and the returnable packaging system as a subsystem of this “big picture”. If the resources used in the returnable packaging system could be diminished, it is expected that this reduction might carry more important and wider benefits when seen from a wider point of view.

2.11. Lean Production and Lean Logistics

Lean production is a practice invented by the Toyota Company, which has created a global transformation over many different supply chain’s philosophies and methods (Liker 2004). Lean could be considered as a five step process that consists in identifying customer’s value, the mapping of the value stream of activities within the supply chain, the creation of a smooth flow towards the customer, creation of a pull system based on customer’s demand and finally repeating all the steps until the perfect value is created without waste (Womack and Jones 1996).

Figure 2.5: Lean process (Lean Enterprise Institute).

According to Jones et al. in their *article Lean Logistics (1997),* this logical thinking has identified that less than 5% of the activities in a regular supply chain actually add value, 35% are necessary non-value-adding activities and 60% of the activities add no value at all to the customer. In order to eliminate these non-value-adding activities, to focus in the whole supply chain is the first step, as by optimizing each piece of the supply chain in isolation does not lead to a lowest cost solutions. The second step is to focus on the product and finally focus on the flow of value creation. This sequence has been named “value stream” and is conceived as a very useful unit of analysis.

The following statements are the key elements that describe the Lean Logistics and are part of the Taiichi Ohno's toolbox when implementing Lean (Jones, Hines and Rich 1997):

- Level out the workload and the flow of product's orders, eliminating the causes of demand distortion and amplification (Heijunka).
- Organize the activities so the product flows with no interruptions.
- Produce or deliver what is pulled from the upstream step in order to replace what the customer has taken – sell one, order one.
- Work throughout the system to the same pace as customer's demand.
- Use the best work cycle for each task as a standard to ensure consistent performance.
- Use the minimum necessary safety stock between operations.
- Build a culture of stopping an operation whenever an error has been detected (Jidoka).
- Use visual control devices to detect problems.
- Report irregularities and create priorities when conducting root cause elimination in order to prevent recurrences and finally remove waste from the flow.

Lean thinking is usually mistaken as a group of tools that help to eliminate waste instead of being seen as a cultural transformation that pushes forward the improvement of a company and their stakeholders together (Liker 2004).

2.12. The Lean Principles

Liker (2004) mentions in his book *The Toyota Way* that in order to become Lean, companies require doing more than just eliminating waste. The real transformation occurs when the workers in the company live the Lean philosophy, bringing the system to life by working, communicating, resolving issues and growing together.

The widely known 14 principles that constitute the Toyota Way are mentioned below and they have direct relation with the previous mentioned Taiichi Ohno's toolbox:

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

Principle 2: Create continues process flow to bring problems to surface.

Principle 3: Use "pull" systems to avoid overproduction.

Principle 4: Level out the workload (Heijunka).

Principle 5: Build a culture of stopping to fix problems, to get quality right the first time.

- *Poka-Yoke Devices:* This term is used to relate to those creative devices that make it nearly impossible for an operator to make an error due to its design.

Principle 6: Standardized tasks are the foundation for continuous improvement and employee empowerment.

Principle 7: Use visual control so no problems are hidden.

Principle 8: Use only reliable, thoroughly tested technology that serves your people and processes.

Principle 9: Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.

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

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

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

Principle 13: Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.

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

- *Five-why Analysis:* In order to identify the root-cause of a problem, one must find the answer of why the problem occurred. Asking "Why?" five times, requires taking the answer to the first why and then asking why that occurs. This method suggests that for each answer, countermeasures could be taken depending on the level of understanding of the problem.

According to Liker (2004), in order to become Lean, the full set of the Toyota principles must be followed. If only a few selected principles are implemented, the results will be short-term jumps on the performance measures, which will not be sustainable.

In this thesis, Lean has been identified as a potential practice that could reveal some key elements, which might have important relevance when dealing with the further confronting issues.

2.13. Value Stream Mapping

Value Stream Mapping (VSM) is a method used in Lean manufacturing developed to capture processes, material flows and information flows of a given product family, helping to identify waste within a system (Liker 2004).

There are seven VSM tools described by Hines and Rich (1997) that are intended for researchers and practitioners to identify the seven common wastes found in a supply chain, and find an appropriate route to remove or at least reduce them. The seven main identifiable wastes in a VSM are known as overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion and defects.

The VSM tools have been designed from a variety of origins and they have different level of usefulness related to the type of waste willing to identify by the researcher (Hines and Rich 1997).

It is expected that by applying VSM in this thesis, a better comprehension of what the problem is and its measurable magnitude will give at least a point of reference when intending to discuss how activities affect the studied supply chain.

2.14. Process Activity Mapping

It is one of the VSM tools that has its origin in industrial engineering and is very useful to identify any of the seven wastes, especially the ones known as waiting, transport, inappropriate processing and unnecessary motion (Hines and Rich 1997). This tool, most commonly known as process analysis, has a five stages approach:

1. The study of the flow of the processes.
2. Identification of the seven common wastes.
3. The consideration of a better arrangement of the process into a more efficient sequence.
4. The consideration of a better pattern of the flow. A different transport routing or flow layout.
5. The consideration of everything that is being done at each stage is really necessary and what would happen if not required tasks are removed.

Process activity mapping consist basically in the analysis of the processes, followed by a detailed recording of all the items required by each process. The result is a map where it is easy to identify the activities, distance moved, time taken and number of people involved in different processes within the supply chain (Hines and Rich 1997). By asking why, how, where and when an activity occur, who does it and on which machine, it is possible to perform a deep analysis and identify further improvements of the current flow.

2.15. Sustainable Value Stream Mapping and Ecological Supply Chain Analysis

There are some tools that have been developed from LCA and VSM related to environmental impacts for logistics for example Sustainable Value Stream Mapping (SVSM) (Mason, Nieuwenhuis and Simons 2008) or Ecological Supply Chain Analysis (EcoSCAn) (Faruk, Lamming and Cousins 2002).

The objective of SVSM is to simultaneously maximize value added and minimize CO_2 emissions, in other words both improve economical and ecological performance of the supply chain. Adding an environmental perspective allows a broader interpretation of “end-to-end” integrated chain management, for example by considering in how much of the CO_2 emissions actually gave benefits to the customer? The difference to for example process activity mapping is that the identification of processes, transports and the analysis of the steps include CO_2 emissions combined with time data such as value added time. In figure 2.6 an example of how this can be presented in a process step (Mason, Nieuwenhuis and Simons 2008).

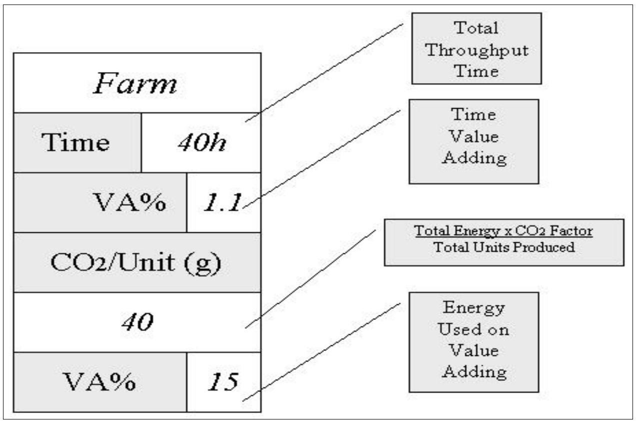


Figure 2.6. An example how the CO_2 emissions can be presented in a VSM process step (Mason, Nieuwenhuis and Simons 2008)**.**

The EcoSCAn is a management tool for an assessment of environmental impacts along extended supply chains and is meant to reduce the costs and time involved compared with for example traditional LCA studies (Faruk, Lamming and Cousins 2002).

Since CO_2 emissions and the use of other resources is a result from the LCA study, the SVSM is a method that shows how the LCA information can be combined with VSM in a presentable way and thereby useful for the thesis. Nevertheless, the EcoSCAn will not be actually used in this thesis work because a limited numbers of studies have been found using this approach. The EcoSCAn could be an alternative method to assess the CO_2 emissions but the SVSM is considered to be more relevant to this thesis approach.

2.16. Material Flow Mapping

Material Flow Mapping (MFM) is a tool developed at Chalmers University of Technology by the department of Logistics and Transportation, which is aimed to describe and assess the performance of material flows in supply chains (Finnsgård, Medbo and Johansson 2011). The tool is largely beneficial to describe and assess activities related to handling, administration, storage, transportation and throughput-time within supply chains.

VSM is a method that has to be adapted in order to be really effective in the analysis of material supply systems, which has generated as consequence the need of new tools like MFM that intend to cover the details that might be difficult to achieve with a regular VSM. In the supply of materials it is difficult to categorize any activity as value adding, as they do not really add value to the customer's product but they are necessary in order to be able to assemble or to produce the final product (Finnsgård, Medbo and Johansson 2011).

The procedure to perform a MFM follows the subsequent methodology:

Select the study object, scope and requirements: The scope of the study sets the length of the studied flow and the requirements of the end user, affecting the design of the material's flow.

Data collection: The tool suggests videotaping and following one single item during the entire chain of processes. Acquire as much information as possible and identify every single activity and steps related to the selected flowing item. Interview operators and managers to understand different requirements. The main data collection will be through observation.

Data compilation: The data compilation should aim to visualise the flow in a schematic picture and continue then to a data analysis.

Analysis of video: The aim of the videotaping is to structure the MFM in the exact order as every activity occurred, including the time taken.

Compilation of the MFM: Gather all the data collected including requirements and processes' descriptions.

HATS Analysis: Perform an analysis of the MFM and denominate the activities as handling, administrative, storage and transportation. Summarise the number of activities, total timing for the categories and the averages.

Re-iterate: Confirm with the actors within the MFM if there is any missing step or the collected data is correct.

Collecting data from a single item that is following a downstream flow could be time consuming for certain cases, taken days, weeks or even months, so the collection of data from discontinuous flows is acceptable (Finnsgård, Medbo and Johansson 2011).

3. Methodology

In this chapter, descriptions of the performed activities for data collection and for better comprehension of the problem are presented. Different data collection techniques and analysis tools were applied in order to obtain a better understanding of the present situation of companies using returnable plastic boxes. The main activities for this study are presented and the level of detail will hopefully be interesting enough for the reader.

3.1. Data Collection

The activities for data collection have as main goal to describe why are some activities related to the returnable plastic boxes considered to be an issue. How, why, when and who is being affected by this issues, are questions that will always be present during the entire study.

From a general perspective, the data collection techniques used, could be described as interviewing, observing and using the existing available information (Karlsson 2010). A more detailed description is listed below in order to explain how these techniques have been approached.

The starting point, for the following data collection activities, has been the unnecessary washing of returnable plastic boxes as the main problem.

3.1.1. Interviews

Semi-structured interviews are a very common type of data collection technique used when doing this kind of study so it is considered to be suitable for the understanding of the activities related to the returnable plastic boxes. This type of interview is performed in order to guarantee that the initial topic is covered but still gives enough flexibility to vary the dynamic of the discussion during the entire interview (Karlsson 2010).

As the personnel to be interviewed varies considerably in their responsibilities related to the returnable plastic boxes, the same preliminary questions are used only as a guideline from where to start approaching a more detailed and unstructured questions that will be more connected to the interviewee's tasks. In this manner it is expected to acquire a more worthwhile feedback than when using structured interviews.

When formulating the original questions for the interviews, the sequence of the questions intent to create a "funnel", starting with very general questions and continuously increasing the level of detail as the interview proceeds. Initially asking questions related to facts and moving forward to questions requiring reflection and evaluation according to the interviewee's expertise (Karlsson 2010).

With the intention to create coherent and relevant questions that could reveal the uncovered problems related to the unnecessary washing of returnable plastic boxes, the Lean method known as five why (Liker 2004) is used to formulate the questions for the interviews. The actual method will not be used directly with the interviewees in order to avoid certain criticisms that have arisen in the past due to the lack of practical training required to apply the correct whys (Minoura 2003). Instead, the method has been used to elaborate the particular questions that will guide the interview and are considered to be very relevant for this thesis. By asking five times why an activity occur, is also possible to create other relevant and simple questions aimed to acquire a deep level of detail related to an activity. The questions are intended to be open-ended, easy to understand, neutral and minimize the demand on memory in order to obtain satisfactory results (Karlsson 2010).

As the activities related to the returnable plastic boxes differ among the different users, two different templates of guideline questions have been created in order to cover specific topics that only apply to specific users. The main difference among this two templates is that one is directed to the user of plastic boxes from an administrative point of view or office user perspective and the second one is intended to cover the site or work-shop where the actual user handles the plastic returnable boxes directly.

One of the most important expected findings intended with the structure of the interview is to acknowledge the present situation with the flow of returnable plastic boxes through the particular explanation, assessment and reflection of each interviewee, as well as the desired future state that they would like to work with. The questions for the interviews intent also to obtain a holistic view of the activities related to the reuse of the plastic boxes, as any possible suggested solution or change of the present situation could definitely impact more than one user within the supply chain.

Appendix D shows more in detail the general questions used as the guideline for the interviews. In most of the cases, there were many other specific questions that were only relevant to the position of the employee but do not appear in the template.

The persons that were interviewed in the study are considered to be main stakeholders in the company, selected with the help of the supervisor at the case company. Most of them have long experience in the case company and some are in positions were they also could affect decisions for future solutions. For example the key account managers (KAM) for the main customers have been included in the study and they have a position that besides giving information from the case company also have unique information about the customer such as their requirements.

3.1.2. Mapping of Activities

The returnable plastic boxes have a numerous activities during a single loop for reuse, where it is possible to find the key factors that determine the customer's requirement for a clean box. Inside the reuse loop between the customers, suppliers and logistic terminals, it is possible to find the main reasons for a plastic box to lose its cleanliness and where in the supply chain is actually required a clean box as well as its required level of cleanliness.

Value Stream Mapping and Material Flow Mapping are used in this study to visualize, among other things, a holistic view of the flow of the plastic boxes and how are different users interconnected, identify the main activities where a box is being handled, stored, transported, added value to and the administrative activities included in their flow.

The tools VSM and MFM gives a very visual and detailed approach that helps to identify specific activities that could be improved or activities that will be certainly affected by any change performed in the flow of returnable plastic boxes. The combination of the tools pretend to identify the real value adding activities that might be difficult to achieve only by using VSM. From a Lean perspective, the supply of returnable boxes add no real value to the customer's product but they are still necessary activities, that in the case of the automotive industry, are required to properly assemble the final good as they carry the components that put together the final product.

As there are many different users of these plastic boxes and every user has a different storage time and quantity under their management, it would be inaccurate to create one detailed map that fits all the users. Detailed mapping of activities will be performed where possible and wherever access to different facilities is allowed, as well as access to the required information to complete the mapping.

Due to the current high amount of users, its unpredictable demand of plastic boxes (Jonasson 2011) and the fact that there are continuously new plastic boxes entering the flow due to new incoming boxes that are being purchased to cover user's demand (Balov 2011), the average lead time for a box to complete a single loop would be difficult to estimate with a high level of precision. It is for this reason that the VSM 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 will be possible to suggest a future state that might fit some specific users in the Volvo Logistics' case study.

When making reference to VSM it is important to state that the specific tool used will be the known as Process Activity Mapping, which is the most appropriate among the seven different VSM tools (Hines and Rich 1997) according to the desired kind of wastes that could be interesting to identify in the present thesis.

The suggested procedure of videotaping when applying MFM might be not easy to implement in every activity within the flow of material, especially due to confidentiality policies within the different users. Nevertheless, the videotaping of activities will be performed certainly at the Volvo Terminal Arendal (VTA) in Gothenburg, as it has been the place granted complete access and authorization to perform this activity.

3.1.3. Available Information

Previous data in different related topics has already been collected and documented by different contributors. Universities and different companies continue to evaluate different issues within their range of interests, which could be useful to include in this study in order to support evolving ideas and the consequences of applying them.

The easiest information to access will be the existing thesis works, articles and other bibliographies given by different universities. Especial efforts will be oriented in the available information at Chalmers University of Technology, as the university has already granted access to information from the very beginning of this study.

There are already existing reports within companies that where intended to clarify uncertainties of any specific topic. These reports might help to give key information that will be used to guide the research activities in a proper direction and avoid wasting energy and time in answering questions that has been already answered. Due to the especial interest of Volvo Logistics in the present study, reports within the company are expected to be easy to acquire and use in order to evaluate different scenarios.

Even though many companies publish in magazines and their websites some of their activities and way to deal with problems, some activities are kept confidential. Different companies handling plastic returnable boxes will be contacted, mainly in the automotive industry, and it will depend on their level of interest and willingness of participating in this study that related information will be acquired from them.

3.2. LCA Method

In this part, the methodology used for the investigation of environmental impact with LCA is explained and which system is studied, what is included and excluded, and the justification of the study.

3.2.1. Goal and Scope

The returnable plastic boxes are studied from the perspective of the washing and with the type of accounting LCA. The study will not be a complete LCA, more closely to a life cycle inventory (LCI): the physical inputs and emissions related to the box. The environmental impacts will not be calculated, but the term will be used to explain the physical flows that affect the environmental impact. The washing is done on four different locations in Europe and comparing the different facilities will give information of the environmental impact of washing associated to the box. The environmental impact will be presented in emissions of carbon dioxide (CO_2) per box, use of water per box and use of chemicals per box depending on location. The information will give estimations on how much the environmental savings can be made if the washing is reduced or if the uses of washing facilities are changed.

The study has a gate-to-gate approach and is not looking on the whole life cycle of the product like a cradle-to-grave approach. Thereby the information where the greatest environmental impact in the whole life cycle will not be investigated, although the production of the plastics will be used to estimate the implication with the box. In the figure 3.1 is a simplified flowchart over the life cycle of a plastic box from production to use and to disposal.

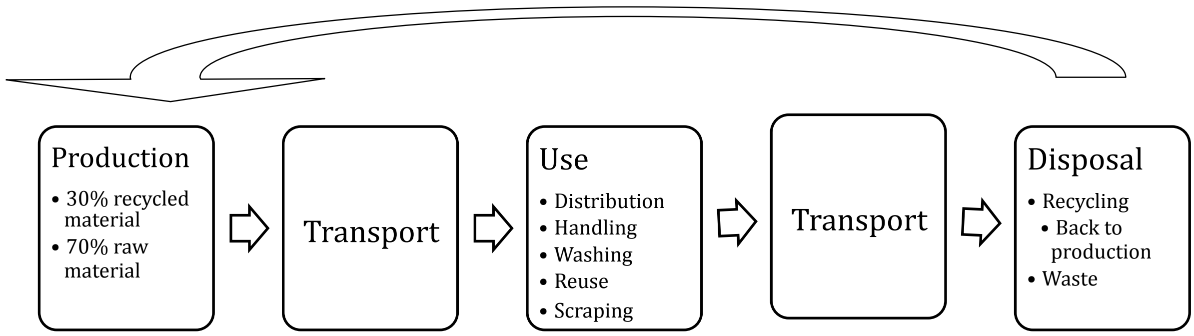


Figure 3.1. The life cycle of one plastic box.

3.2.2. System Boundaries

The following system has been chosen based on the research question stated in the introduction, since the main focus is to investigate what environmental impact from the washing perspective. The foreground system is the washing process. The background system is the production (including recycling), handling and distribution (transportation). The production will although be taken in account to compare the washing in relation to the production of the plastics. The distribution is complicated to calculate related emissions since there are a large number of possible locations or distances and the boxes are normally transported with other goods and an estimation of contribution needs sophisticated allocation methods (Baumann and Tillman 2003). Therefore the distribution is not included in the analysis.

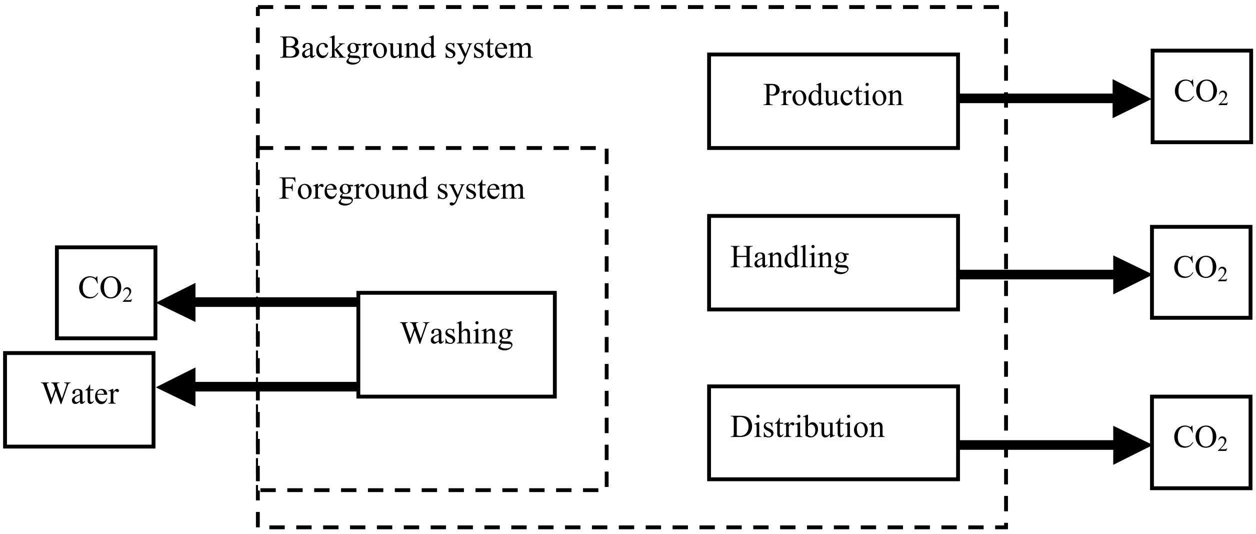


Figure 3.2. System boundaries: Background and foreground system with emissions.

3.2.3. Functional Unit

The functional unit is one returnable plastic box of the type V-EMB 780. In the study a normalised value will be used to be able to make a fair comparison by using the total of V-EMB 780 and discard the other boxes washed at each facility.

3.2.4. Data Collection

The data was collected during March and April in 2011 with a question-based method by sending e-mails with a questionnaire to the washing managers of each washing facility. A limited number of questions were asked and the questions were closed to make them easy to answer since some investigation may be required for the person filling the answer. The data requested were for the latest year 2010 (see Appendix A).

4. Case Study

In this chapter, the case company will be presented with a focus on the returnable plastic boxes and some related activities. The evaluated boxes are one of the most used among the packaging solutions offered by Volvo Logistic Corporation (VLC). Some current supply chain set-ups within the Volvo Group will be described and analysed in order to address different issues related to the returnable packaging. By evaluating this case study it is expected to acquire relevant information as well as to be able to provide VLC with further recommendations on how to deal with their case.

4.1. The Company: Volvo Group AB

The Volvo Group is one of the largest manufacturers of heavy commercial vehicles and diesel engines. The Volvo group have about 90,000 employees and production facilities in 19 countries, and sales activities in some 180 countries. The group is divided in six business segments trucks, buses, marine and industrial applications, construction equipment, aerospace industry, financial services. To support the different segments the Volvo group has a number of business units: Volvo 3P, Volvo Powertrain, Volvo Parts, Volvo Logistics, Volvo Business Services, Volvo Information Technology, Volvo Group Real Estate, Volvo Technology, Volvo Technology Transfer, Volvo Group NAP. See figure 4.1 for a schematic organisational picture.

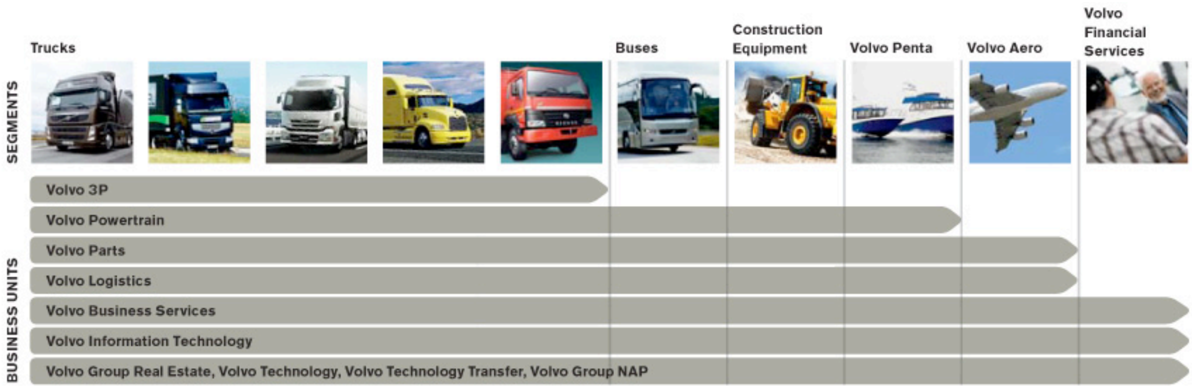


Figure 4.1. The Volvo Group organisation (Volvo Group Annual Report 2010).

The Volvo group corporate values are quality, safety and environmental care, which are shared throughout the companies in the group and their focus when developing products, how customer and employees are approached. (Volvo Group Annual Report 2010)

4.1.1. Volvo Logistics Corporation

Volvo Logistics Corporation (VLC) is a business unit within the Volvo Group that provides logistics solution both in the Volvo group and externally mainly to automotive industry, which consists of cars, trucks and buses.

VLC´s mission is to develop and deliver complete supply chain solutions that add value to our customers worldwide and they are represented in Europe, North and South America, and Asia. VLC main customers in the Volvo Group are Volvo Trucks, Renault Trucks, Volvo Powertrain and Volvo Construction Equipment. Outside the Volvo Group the biggest customer is Volvo Car Corporation that also belonged to the Volvo Group.

The company is organised in three operational areas: inbound (material supply), outbound (distribution) and emballage (packaging materials). Inbound is working with the transport system for packaging materials from VLC terminals to around 1500 suppliers around the world. Outbound is the distribution to customers from suppliers, mainly to large assembly plants in Europe. Emballage have over 100 standard packaging both single use packaging such as cardboard boxes and a pool of returnable packaging for example pallets of wood and plastic boxes of various sizes. Emballage design the packaging system for the customers and can also make individual packaging solutions (Volvo Logistics Corporation 2011).

VLC provides a system of returnable packaging for transport of goods from suppliers to customer plants, as well as for the use within the plants. There are a number of terminals where packaging is collected. In Europe the terminals for washing are located in Sweden, Belgium, France and the UK. The terminal in Sweden is owned by VLC and the others are outsourced operations. In the terminals is where the packaging has a starting point of usage and where they end up when released from customers. At the terminals most of the packaging types are handled and stored. Activities that are done are for example loading and unloading of trailers, sorting out broken packaging, washing and inventory control.

4.2. Packaging Cost

The so called transaction cost for the use of a plastic box is automatically generated as soon as filled packages are booked as dispatched from a supplier's site (see figure 4.2).

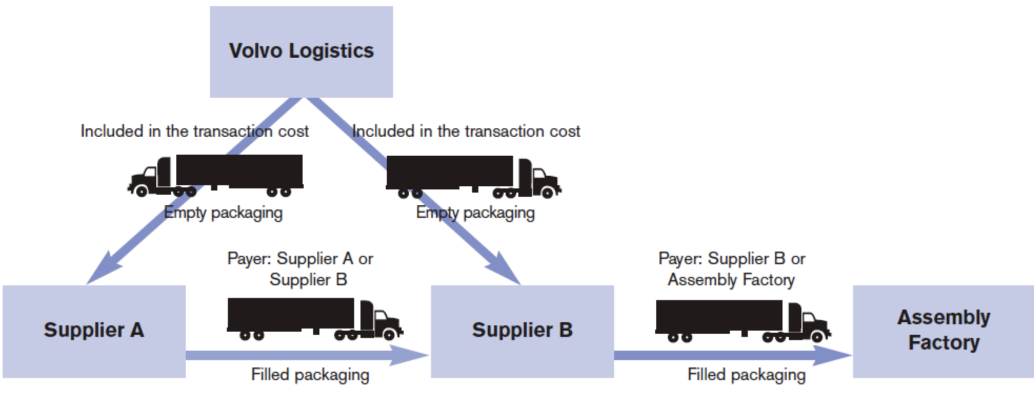


Figure 4.2. The VLC logistics model (Volvo Logistics Corporation 2011).

Debited costs are based on the registered transactions of filled packages from and to the customer's packaging account. The invoice of the so called transaction cost is made in a monthly base system and is charged to the customer within the Volvo Group by default whenever there is a filled packaging coming from a non Volvo company (suppliers) and whenever filled packaging is sent to another Volvo Group company or external company (VLC 2010).

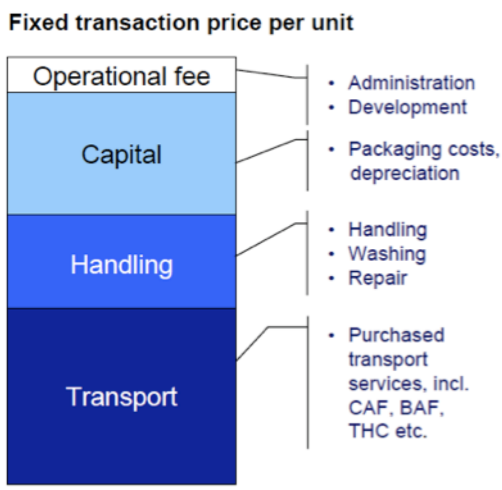


Figure 4.3. VLC transaction price broken down in parts.

When breaking down the handling cost included in this transaction cost (figure 4.3), we can find the cost of the washing of the packages, which in the present case study implies an important part of the total usage cost (Österholm 2011).

In the present case study the customers will be initially identified as any user within the Volvo Group, buying the services of returnable plastic boxes from Volvo Logistics Corporation i.e. companies within the Volvo Group.

4.3. The Labels

Every time a plastic box is refilled with components and is sent to a customer's location, a new label is attached to it in order to identify the part and its location when stored, meaning that in most cases, the plastic boxes end up with more than one label attached to it when the box have been finally emptied from components.

The labels on the boxes are ripped off by hand or during the washing process. The responsibility to rip off of the labels depends on the contractual agreements between the customer and the owner of the plastic boxes, where extra charges can be made to the customer if they require that the owner of the boxes do this work for them. The washing process is not initially intended to remove the labels but it actually occurs, during the washing, if some of the labels were not ripped off before entering the washing facility (Hellberg 2011).

According to interviewed personnel, in the case of non-adhesive labels that need to be added to the boxes i.e. add extra information in a sheet of paper, a common way to stick them to the plastic boxes is by using staples, which represent a risk of injury for the personnel handling them, as well as affects the relative perception of cleanliness.

5. Empirical Findings

In this section the data collected and empirical findings from the washing is presented. A cost estimation for sorting of the plastic boxes is also presented, evaluating different scenarios where the sorting of plastic boxes is included in order to reduce the unnecessary washing. The main results from the MFM and LCA are described and shown as part of the empirical findings that are intended to visualize the actual activities and the environmental impact related to the washing.

5.1. The Washing of Plastic Boxes

There are three types of plastic boxes that are washed (see table 5.1). The V-EMB 780 is the most used and washed box (see figure 5.1), where the total amount of washed plastic boxes at each VLC washing facility is shown. All data are from year 2010.

Table 5.1. The boxes washed in the Volvo Logistics pool.

Plastic box (V-EMB no.)	Bundled	Cycle time	Comment
840	20 boxes, 20 lids	12 s per box	Double size to 780
780	40 boxes, 40 lids	6 s per box	64% of total washed
750	80 boxes, 80 lids	3 s per box	Half size to 780

The washing facilities in France, Belgium and Sweden are located close to the customers. For example the washing facility in Sweden is located few kilometres from two large customers' plants which gives a short transportation distance for the customer to release the boxes back to the pool.

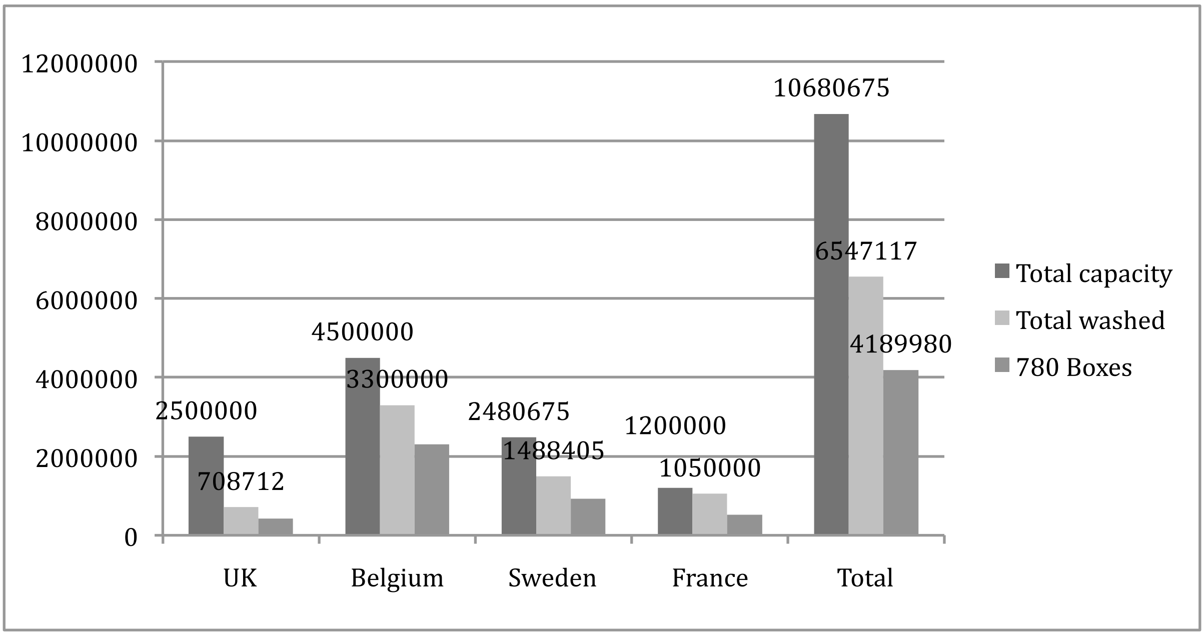


Figure 5.1. Total washing capacity, total of washed boxes and number of V-EMB 780 washed per year and by location.

5.2. The Washing in Sweden

As result from the specific MFM performed at the Volvo washing facility at the terminal in Gothenburg (VTA), the following detailed description was able to be remarked due to the videotaping, interviews and following of one piece flow suggested previously by this tool. In combination with the compiled MFM shown in Appendix E, these are the detailed description of activities:

Table 5.2. Activities related to the washing process at the terminal.

Summary of steps	Comment
Unload truck	Forklift unloads pallets
Storage on storage yard	Normal storage 4 days supply, ~1000 pallets (780 V-EMB)
Transport to conveyor belt	Forklift
Storage before washing	2 lines, 3 pallets in height, 25-32 pallets in line on conveyer belts
Lifting down one pallet from storage	Automated lift
Removal of plastic straps on pallets	By hand with a nipper
Removal of wood lid	Here the operator changes the set-up if changing type of box washed. Changeover time around 16 min.
Take plastic lids into washing machine from pallet	By hand for small boxes (since small lids are not washed). By machine for the other type of boxes
Take boxes into washing machine	Cycle time 12 second/box (840)
Washing & Drying	240 s for 20 boxes (840) & 225 s for 20 lids (840)
Stacking boxes back on pallet	Automatically by machine
Stacking lids on top of the boxes	Automatically by machine or by the operator depending on the size of the lids
Wood or plastic top lid placed	Automatically by machine or by the operator depending on the size of the lids
Plastic straps attached	By machine with assistance from the operator
Stapling of pallets	Automatically by machine
Storage after washing	4 days supply, ~1000 pallets (780) 200m and 400m from washing machine

Deliveries of empty packages arrive to the terminal, which is unloaded by a forklift and then the boxes are stored outdoors on a yard around 50-100 m from the washing machine. The forklift driver transport stapled pallets of boxes and puts them on one of the two conveyer belts that go into the washing machine. The two conveyer belts have a capacity of three stapled pallets (vertically) and 25-32 pallets in waiting line. With the V-EMB 780 stapled, the inventory on the conveyer would be 6000-7680 boxes.

The operator decides which of the conveyer belts that will be used, depending of which boxes have the highest demand in the planning. An automated lift takes down the pallet to a single conveyer that leads to the washing machine; the plastic straps that keep each bundle together are cut off by hand with a nipper. After the straps are removed, the wood lid over the pallet is taken off and the machine takes the plastic lids and boxes when arriving to the end of the queue.

In the first section inside the machine, heated water mixed with a degreaser is flushed towards the sides where the labels should be placed, initially intended to remove remaining glue from the labels and any other residual, but it also removes un-ripped off labels that should have been eliminated previous this step. The removed labels and other residuals are collected in filters, which are cleaned by an operator when required. In the second section, the boxes are dried up in a warmer section that mainly removes the remaining water and when leaving the washing machine the boxes and lids are stapled in bundles back together. The process ends with a wood lid placed on top and two plastic straps are being put on with a strapping machine and then delivered outside to a conveyer belt under roof, where the forklift driver can pick up the pallets to store them under shelter and make them available for a new usage loop.

When changing the type of box washed, the operator empty the line of the current type boxes, this changeover time is around 16 minutes for any type of box. One operator per shift handles the washing machine, being his main tasks to remove the plastic straps, remove broken boxes to be scraped, clean the filters, set-up the machine (i.e. the box type) and control that the machine works without stopping.

The following figure shows the number of HATS activities identified within the Volvo washing terminal, the average time spent in total for each type of activity, the actual time for washing or relative value added time for a pallet of plastic boxes, and the actual lead-time for a pallet to go through the washing terminal.

	No. Activities	Average Time
Handling	2	2130 s
Administration	2	60 s
Transportation	4	480 s
Storage	2	1.036.800 s

¨Value Added Time¨= 240 s
Lead-Time= 1.063.470 s

Figure 5.2. Results from MFM and VSM.

The lead-time might as well be perceived as 12 days, 7 hours, 24 minutes and 30 seconds, which compared to the 4 minutes that takes to wash a complete pallet, is quite a large amount of time that should be considered when sending this boxes to the washing facilities, as it is expected to affect the availability of these items within the supply chain.

It could be said that the terminal lacks of a continuous flow of the packaging, as they remain waiting for the different activities to occur. From a Lean perspective, it would be required to create this flow in order to bring problems to surface. It was not the initial intention when performing the VSM and MFM to propose a future state of the terminal but it is recommended that for future decisions related to the lay out of the terminal, this continuous flow creation should be considered.

5.3. Water and Energy Consumption

When performing the LCA in the different VLC washing facilities in Europe, the CO_2 emission factors in table 5.3 were used to convert the usage of the different sources to CO_2 emissions.

Table 5.3. CO_2 emission factors used for calculations.

	Energy source for Operations	Emission factor	Energy source for water heating	Emission factor
UK	Electricity	587 g CO_2/kWh	Liquefied Petroleum Gases (LPG)	1495 g CO_2/l
Belgium	Electricity	381 g CO_2/kWh	Natural gas	286 g CO_2/m^3
Sweden	Electricity	107 g CO_2/kWh	District heat	24 g CO_2/kWh
France	Electricity	134 g CO_2/kWh	Natural gas	870 g CO_2/m^3

The emission factor for electricity comes from the EU database: ELCD core database version II. The other emission factors are in general collected from various sources. See Appendix B for more details.

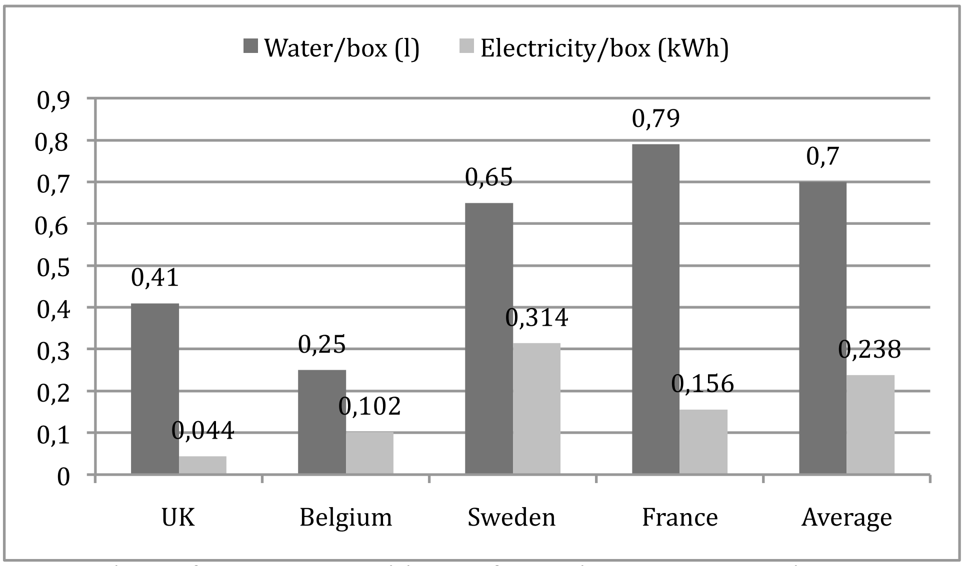


Figure 5.3. Water and electricity used for washing one box per location.

The water and electricity consumption per box differ quite a lot as seen in figure 5.3, the source for heating has not been added in this figure and can be viewed with more detailed data in the Appendix C that presents the LCA results from washing. In the CO_2 emissions (figure 5.5), the heating is named other source since it is different depending on location.

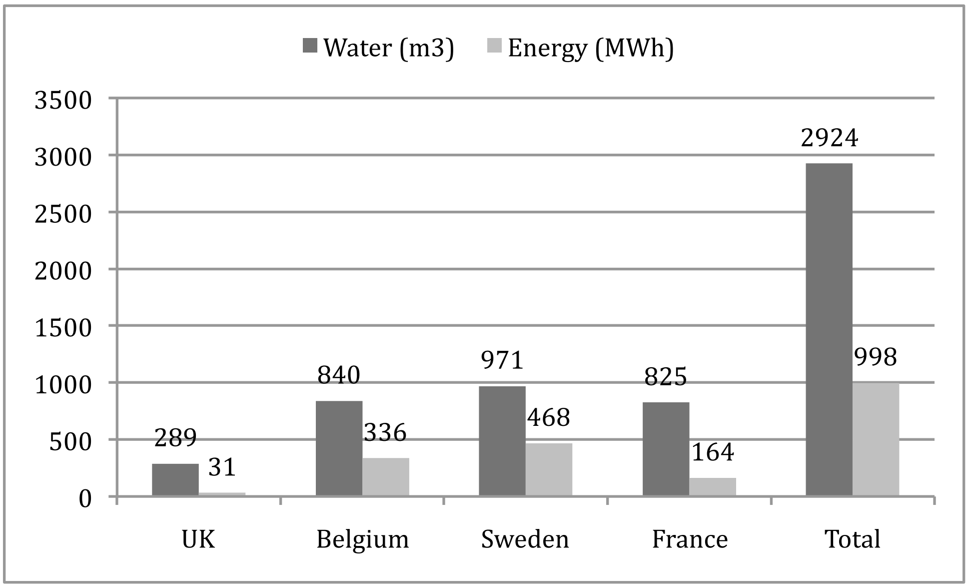


Figure 5.4. The total water use and energy use in electricity for the V-EMB 780 boxes.

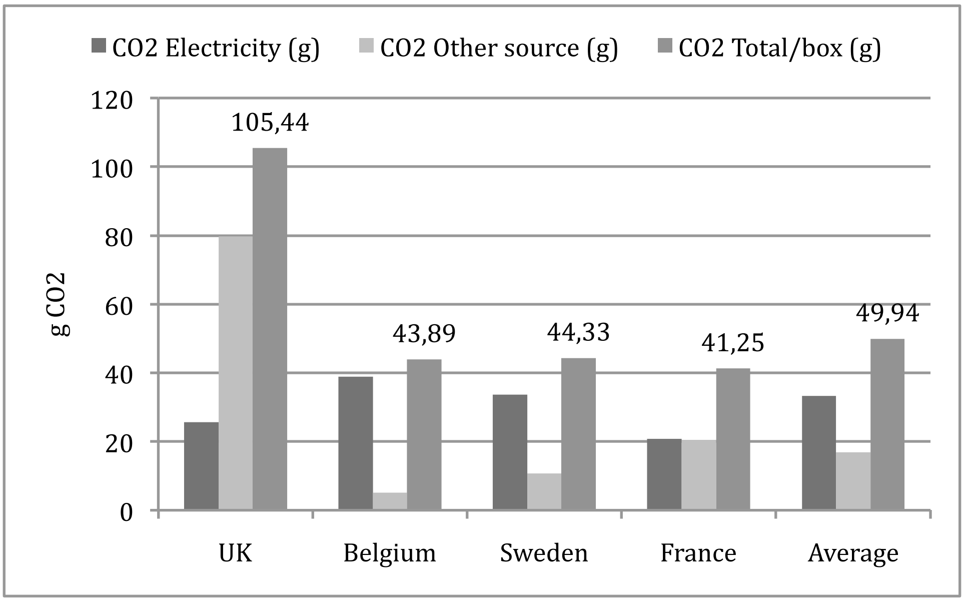
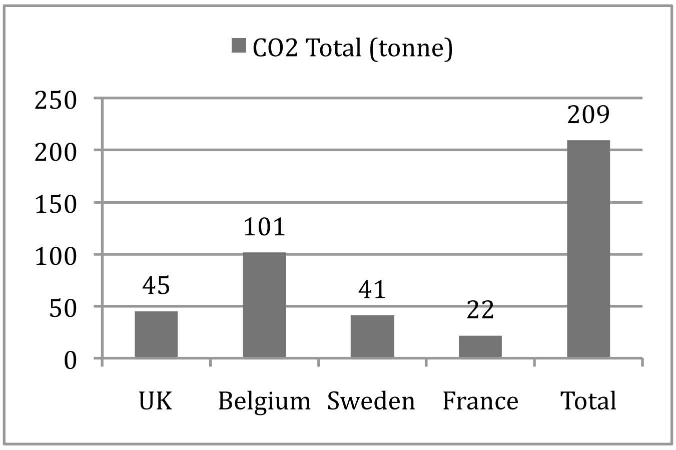


Figure 5.5. The CO_2 emissions for washing one box per location.

The average of CO_2 emissions is almost 50 g CO_2/box, the highest emissions per box is from the UK washing facility and the lowest emissions per box is in France, closely followed by Belgium and Sweden. The use LPG for the heating of water in UK is one of the reasons why the CO_2 emissions is more then double here then other locations, interesting to notice is that the CO_2 emissions related to electricity in UK is the second lowest after France. A reduction of washing especially at the UK facility would probably make the biggest impact on the average since the other three is below the average.

Summarizing the washing findings, almost 1 GWh/year of electricity and 3000 m^3 or 3 million litres a year of water are used for the washing of the V-EMB 780 boxes annually (see figure 5.4), resulting in 209 tonnes of CO_2 emissions every year, see figure 5.6 for the contribution from each location.



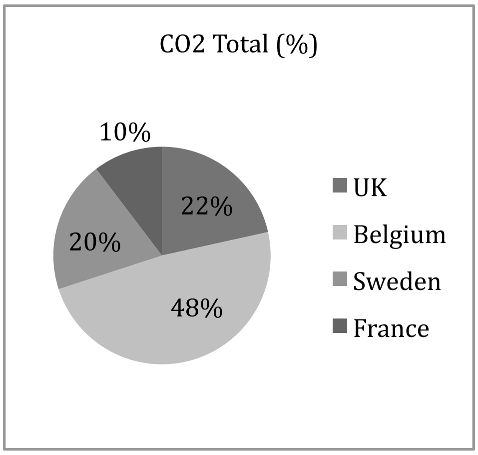


Figure 5.6. Total CO_2-emissions in tonnes and in percent from the washing of boxes V-EMB 780.

5.4. CO_2 Emissions From Plastic Production

The CO_2 emissions related to the production of the plastics used in one plastic box and lid (virgin material). The data is from I Boustead (2005). The recycle rate has not been considered. During the product life cycle (PLC) it is considered to be 50 washing loops, the transportation is not considered. In figure 5.7 CO_2 emissions related to the production and to washing can be viewed, which shows that the washing stands for an important contribution in the product life cycle.

Table 5.4. CO2 emissions related to the production for the plastic box and lid.

V-EMB780	Lid	Box
Weight	0.84 kg	2.05 kg
Material	PP	HD-PE
Emission factor (kg CO_2/kg material) Source: (I Boustead 2005)	1.67	1.57
CO_2emissions	1.4	3.22
Total CO_2 emission (Lid and box)	4.62	

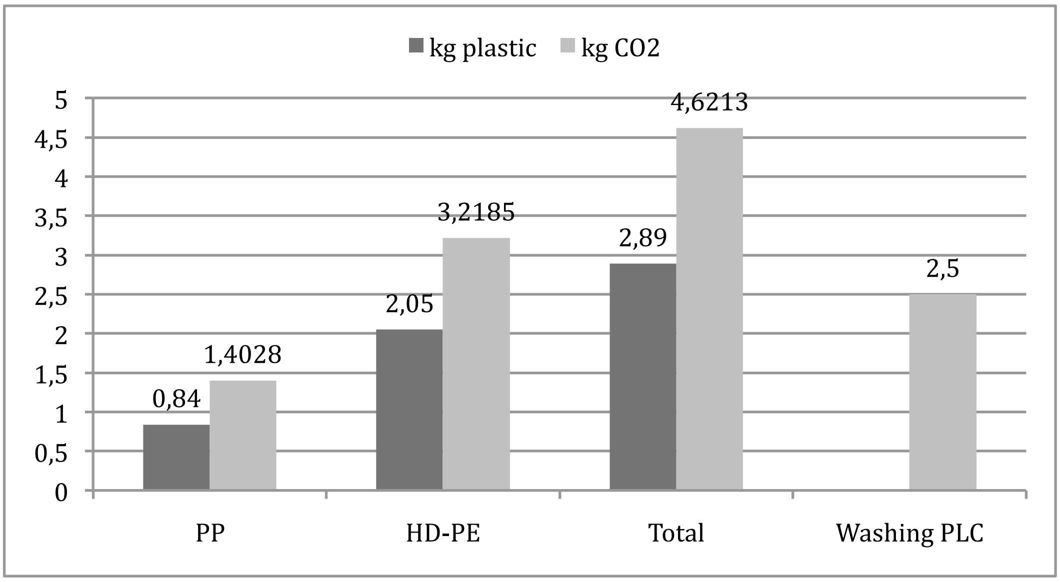


Figure 5.7. CO_2 emissions related to production of plastics used in one plastic box and the estimated emissions from washing during the PLC.

5.5. Potential Reduction of Washing

The main idea with the LCA was to estimate the environmental impact of the physical inputs and emissions of CO_2, use of chemicals and water consumption related to the washing. If the system boundary is to be extended outside the present scope, the transportation by forklifts and trucks could be interesting to include. If some specific transportation cases would have been studied, it could have also required the application of sophisticated allocation methods since many different goods are transported together (Baumann and Tillman 2003).

To put the washing in the a comparable context, the assessment of the environmental impact of the production of the plastics gave a indication of the impacts of maintaining the boxes clean compared to just produce the amount of plastics in the boxes. The comparison gave the result that the washing has a large impact on the product life cycle and a reduction of number times washed would give striking environmental savings also based on the perspective of the whole product life cycle.

A potential reduction of washing can be as much as around 60-70% (according to persons interviewed) with a parallel reduction of the environmental impact, but a bigger effect could occur if the boxes are sent between shorter distances and with a possible drawback of not achieving a high rate of cargo consolidation, which is a benefit when dispatching packages from the terminals or the logistics centres.

With the perspective of environmental savings a reduction of energy and water usage is preferable since for example the case company have an environmental policy to reduce the emissions of for example green house gases such as CO_2. A reduction of 25% washing would mean at least as much as one million fewer washes per year of the boxes (V-EMB780) and around 50 000 kg CO_2 less emissions.

The data collection gave quantitative from all the locations and only qualitative data from VTA. More qualitative data from the other locations such as a description of the washing process would have given more information for the analysis, for example the washing machine in Sweden is automated while the others have more manual handling, which can reflect the energy used for the operations. The CO_2 emission factors selected were primarily used to make a fair comparison between the locations, another emission factor could have been more appropriate if the study were a stand-alone approach. A number of different CO_2 emission factors were taken into account but especially on the electricity the same data source was used (see list in Appendix B).

5.6. Cost Analysis

In this section a cost analysis will be presented and the reason for the section is to present how different scenarios can affect the total cost of the boxes, especially to give a hint of their potential impact. Most important is to introduce the sorting activity at different locations. The scenarios are summarized in the last paragraph.

5.6.1. Cost for Returnable Packaging at VLC

The average cost for packaging in the case company is shown in figure 5.8, where transportation cost (39%) and investment cost (26%) stands for the majority. The washing (9%) stands for a fairly low number, since some packaging not is washed with water, such as wood pallets. On the other hand for the returnable plastic boxes, the washing stands for as much as 35-50% of the cost. The returnable plastic boxes are not repaired, that is possible for pallets and other packaging, and the plastic boxes are instead recycled when broken. The exact cost for the boxes will be not presented completely because of confidentiality from the case company; the data will be presented in percent relations instead.

The scenarios in this chapter are based on discussions with employees at the case company and the intention is to confirm ideas and suggestions from them and also to see what possible economical effects a change of unnecessary washing potentially can lead to. The sorting activity is of main interest since it has been suggested as a solution: but with economical drawbacks if made at VTA and to continue washing 100% of the boxes would be more beneficial then sorting.

Shortly described the scenarios are: reusing a certain number boxes at the customer, sorting at the customer, sorting at washing terminals and sorting at VTA.

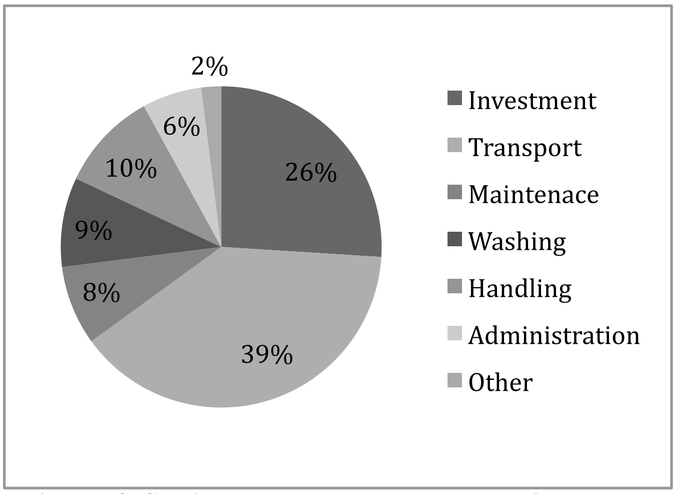


Figure 5.8. Cost in percent related to total packaging cost.

5.6.2. Scenario 1: More Reuse of Boxes at Customer

Explanation of the case of closed loop or internal use loops:

The customer has 25 000 boxes in stock on average and decides to use more boxes in a kind of closed loop. It is assumed that the customer uses 200 000 boxes a year, the same number of the so called transactions cost thereby. In case 2 they decides to use 5000 boxes in closed loops, which circulates 10 loops a year and these boxes will stand for 50 000 usage loops. A cost reduction related to this change will be around 19%. Since the closed loop will give some additional cost, a fee for the closed loop is taken out to cover for example the extra control of supplier and customer by pool owner VLC. How large this extra cost is in need of further discussion. The number used is the double stock hire cost, which can be considered low. See the figure below where:

Case 1: Business-as-usual, without reusing in loops.

Case 2: 5 000 boxes reused in loop at customer.

Case 3: 7 500 boxes reused in loop at customer.

Case 4: 10 000 boxes reused in loop at customer.

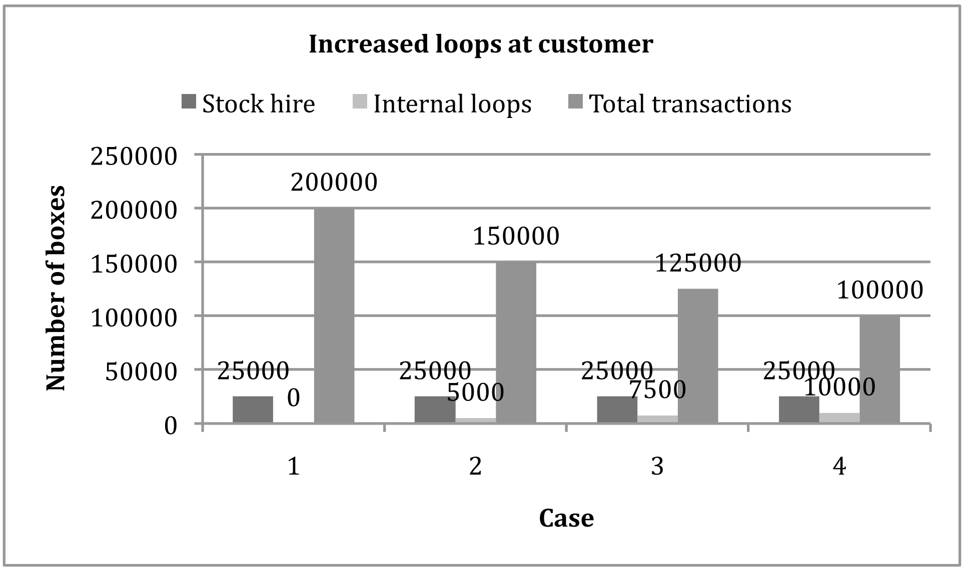


Figure 5.9. The use of boxes for different cases: stock hire, internal use and total usage/transactions.

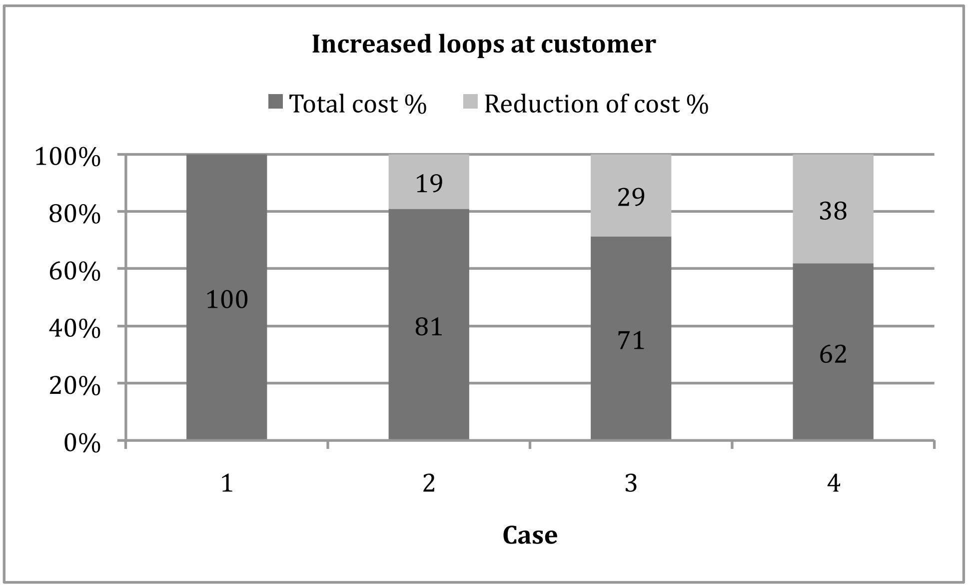


Figure 5.10. Potential cost reduction of total cost in %.

5.6.3. Scenario 2: Sorting at the Customer

The same usage as the scenario above is used for the calculation. The boxes is sorted out by the customer and 30-50% can be considered in need of washing, the figure 5.11 shows the potential cost reductions including only the reduced washing cost. The numbers are potential numbers, excluding many factors and the potential of only 30% washed case should be considered with restrictions to give a more fair value. The factors that need to be looked into more is especially making all of the thousands of users to do the right sorting, without comprising on the quality and to implement this fully can be time consuming and especially require more space for the sorting at the customers location i.e. double pallets at many locations in the factory if not made in designated area, which could mean double handling.

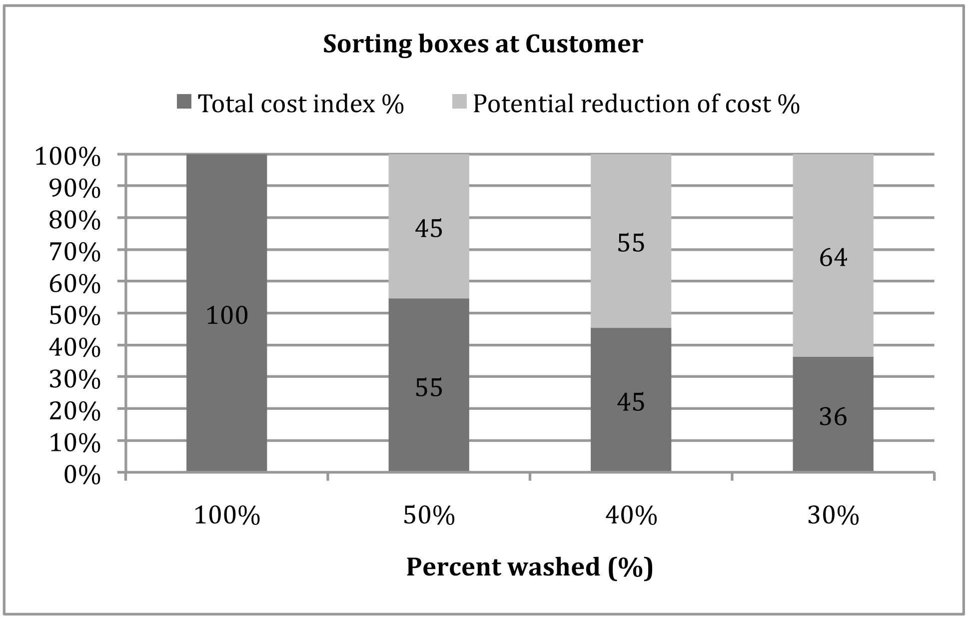


Figure 5.11. Potential cost reduction of total cost in percent when just considering a reduced washing cost.

5.6.4. Scenario 3: Sorting at the Terminals

Figure 5.12 shows a potential reduction compared to a reference, business-as-usual: all boxes are washed. In the examples the sorting activity and a cost associated with it is added. The reason for doing the sorting in the terminals is to be able to control the quality of the sorting, but this double handling is not recommended. If just taken in account the reduced cost of washing and an increase in sorting cost including labour cost (in Sweden). It shows a potential reduction in cost if the washing is reduced by at least 37% otherwise it will increase the total cost.

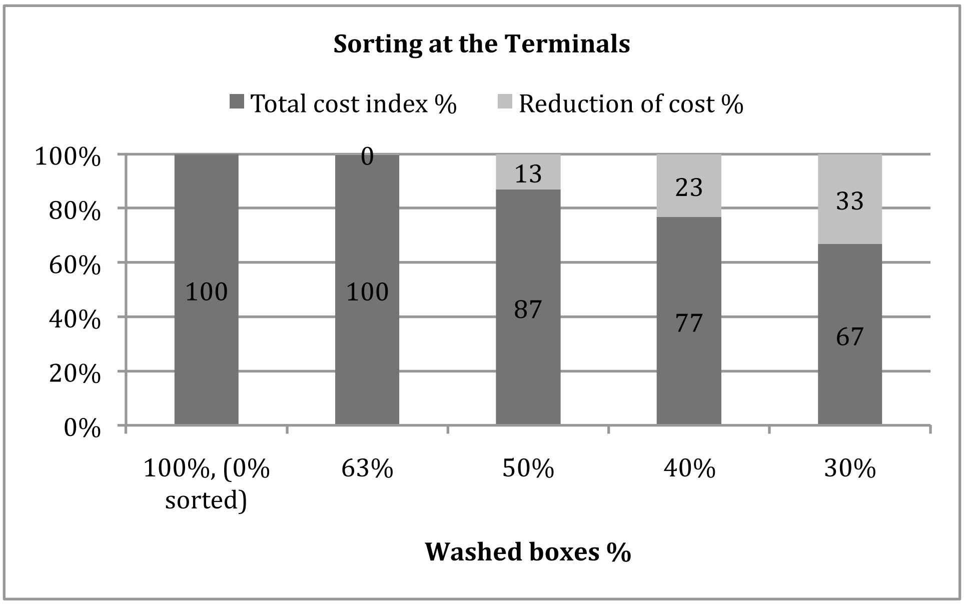


Figure 5.12. Potential reductions of total cost in % based on total of washed boxes.

5.6.5. Scenario 4: Sorting at Terminal in Sweden

At VTA the volume of washed boxes can be viewed in figure 5.13. A tendency before the financial crisis in 2008-2009 was an increased demand of washed boxes. VLC is expecting a further increase of the use of boxes at their customer since the Volvo Production System (VPS) is in favour of standardizing activities and the last quarter of 2010 also shows some increase.

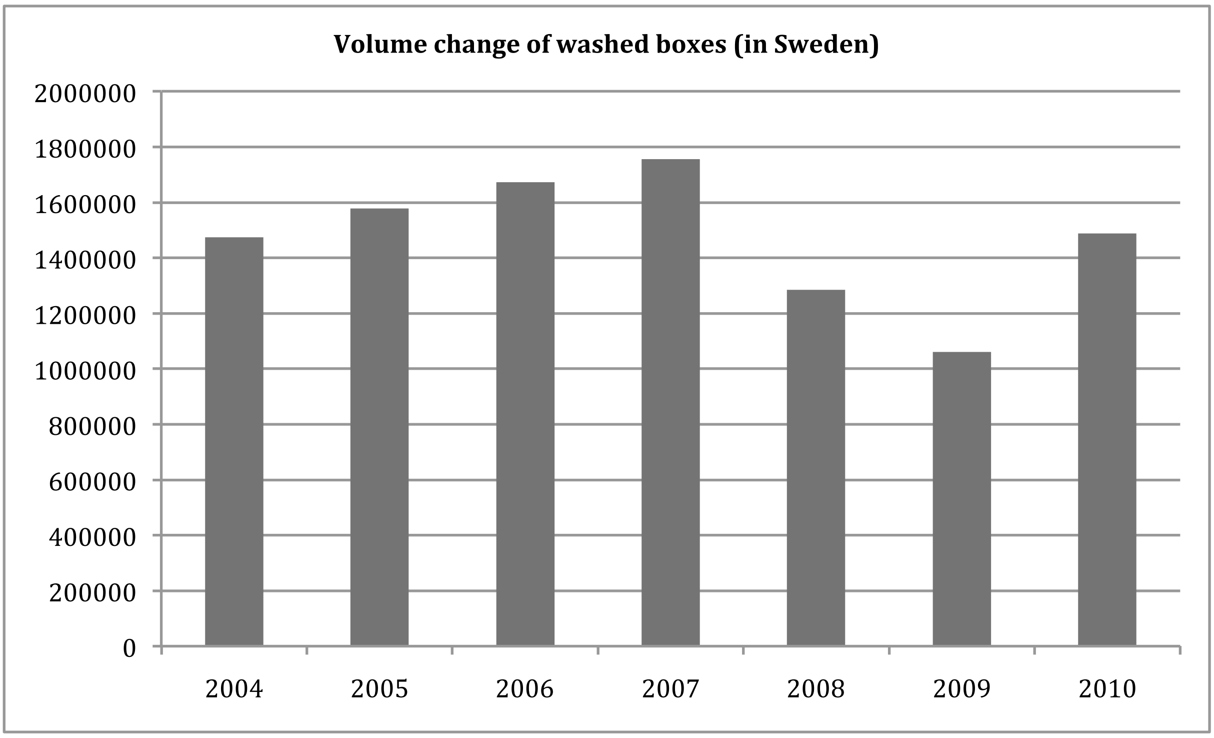


Figure 5.13. Volume change of washed boxes at VTA.

In this scenario more detailed data have been used: estimated by the performed calculations and input from case company. See table 5.5.

Table 5.5. Input data used for calculations for the terminal in Sweden.

Input data for sorting		
Sorting time/box	s/box	18
Sorted boxes per hour and person,	Boxes/h	150-200
Labour cost per person	SEK/h, (10SEK~1€)	230
Working hours (2 persons)	h	80
Sorting		
Sort cost	SEK/box	1,55
Sorting need per hour	Boxes/h	300
Boxes per week average	Boxes/week	24000
Space		
Warehouse space cost per year	SEK/m^2 year	1170
Space for the sorting	m^2	400
Washing		
Cost per box	SEK/box	4,20

If both labour cost and space cost is included a larger amount of the washed boxes is needed to be sorted to make it feasible to do the sorting in the terminal and almost 45% of the boxes must at least be clean. This number is without the investment cost to build the warehouse space, which can be costly since a sheltered space is required in Sweden due to many cold months. The space cost is based on an area of 400 m^2, where at least two days of incoming and two days of sorted boxes can fit stapled: three pallets in height, nine pallets in width and depth and room to handle the pallets with a forklift. The capacity usage of the washing machine will probably be lower and an overcapacity can be seen as waste or as an opportunity to close another washing machine. In table 5.5 the data input for the VTA is presented and in the figure 5.14 the scenario is plotted.

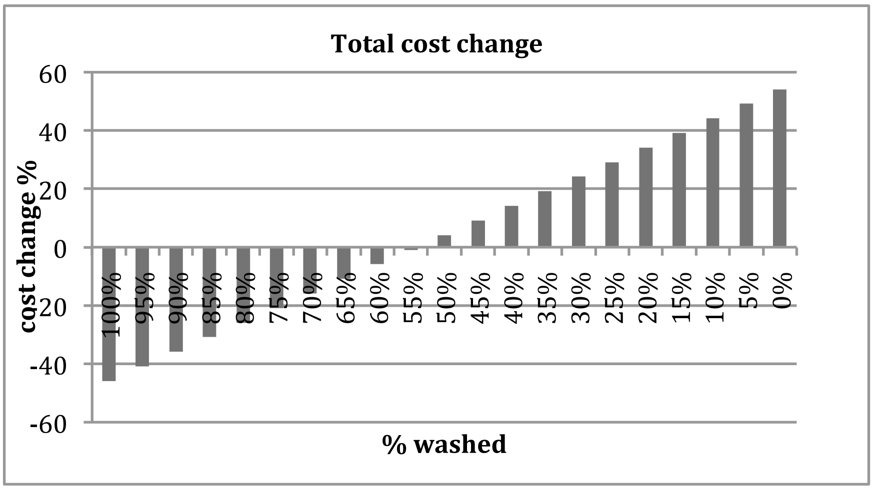


Figure 5.14. Potential reductions of total cost in % based on washed boxes at VTA.

5.6.6. Summary of Cost Analysis

To start sorting out the boxes could give a high impact on the reduction of cost for the customer. The highest impact is by introducing the sorting activity at the customer and thereby creating a reduction of the washing at an early stage in the supply chain. But there are some more important values that can have negative effects, such as the cost of poor quality (Bergman and Klefsjö 2010) since the responsibility of the quality could be in some extent on the customer, meaning that if a non-clean box arrives to another customer, the pool organiser might receive complains. Sorting the boxes at the customer means in these scenarios that they stand for the labour and space cost, thereby getting some economical benefits because of the reduced washing cost. Sorting out the boxes at VTA by VLC will be costly and will depend much on the ability to reduce the number of washing loops. The capacity usage of the washing machine and the increased sorting cost (space and labour cost) are two important factors when reducing the washing and need to be considered if changing the business-as-usual scenario.

A mix of the scenarios with both sorting at customers and at the terminal can also be possibility. In the scenarios it is assumed that all boxes are sorted, but sorting a lower fraction of boxes can be a possibility to better fit the current situation.

The scenarios have confirmed earlier statements such as sorting at VTA can be more costly then just continue washing 100% of the boxes. Sorting at the customer would probably reduce the cost, but how much this exactly would be need further research and collaboration with customers that have a interest in cost reduction.

6. Analysis

This chapter presents the analysis of the present situation that many companies using returnable plastic boxes are facing in the working field. The presented arguments are based on existing facts and some opinions based on the experiences of different actors in the flow of these boxes.

The different user's experiences were acknowledged due to the flexibility that the performed semi-structured interviews allowed. Every person related to the use of the plastic boxes had a different perspective directly connected to their specific functions. By being able to reformulate and create new questions during the interviews, it gave a different level of discussion in different subjects more related to each interviewee's position. In Appendix D a summary of the interviews can be found.

Even though different companies were contacted to evaluate their particular situation, the main analysis is focused on Volvo Logistics Corporation (VLC), their customers and suppliers.

6.1. Unnecessary Washing

The starting point and main purpose of this study has been to evaluate and try to minimise, if not able to completely eliminate, the unnecessary washing of returnable plastic boxes.

According to Taiichi Ohno, overproduction is considered a fundamental waste since it causes most of the other wastes analysed in Lean production (Liker 2004). If we consider the washing of non-dirty boxes as overproduction and over-processing of considerably clean boxes, we will easily identify most of the other unwanted Lean wastes within the supply chain of returnable plastic boxes.

Based on the first of the Toyota principles, manager decisions must be made on a long-term philosophy, meaning that this unnecessary washing of boxes should be considered in current decisions when planning the future state of existing and upcoming companies. It is expected that the use of returnable plastic boxes will increase due to expanding markets so the future set up of different supply chains is being currently analysed (Österholm 2011).

A cause-and-effect diagram can describe the type of causes that can possibly produce the observed quality problem (Bergman and Klefsjö 2010). In figure 6.1, the main reasons for a plastic box to be washed systematically is presented in a fishbone diagram, which main causes were able to identify with the help of the five-why analysis described before. In this case, the main question to answer and first why was *¨Why are the plastic boxes washed systematically? ¨:*

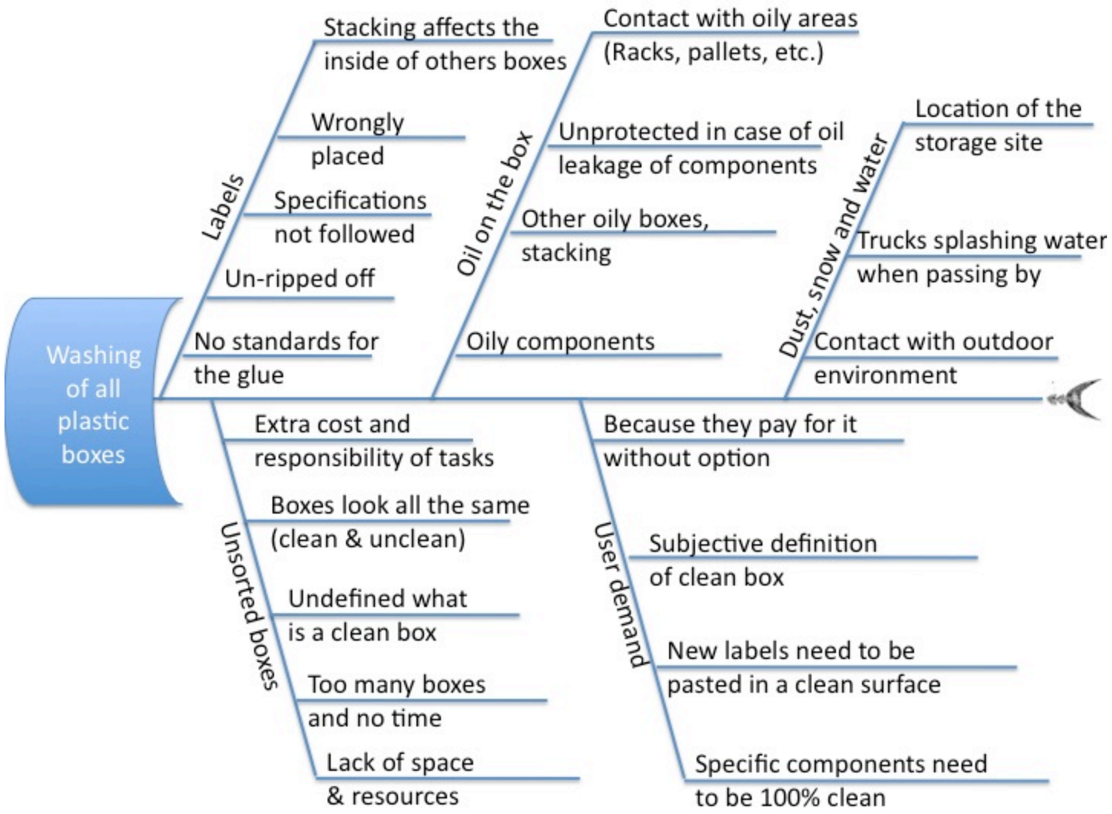


Figure 6.1. Causes for systematic washing.

The required countermeasures suggested in the five-why analysis, are the main reasons for the further discussions and main justification of the structure of this report. Nevertheless, the details further described are based on the reached level of comprehension of the problem.

6.1.1. The Company Case

In the particular case of VLC, there are four washing machines in Europe aimed for the washing of the blue plastic boxes, in other parts of the world VLC may use manual washing that requires personnel to wash the boxes with the help of a water hose and then allowing the boxes to dry in the sun on a backyard (Lindblom 2011). VLC current supply chain set-up of returnable plastic boxes requires that every empty used box needs to be transported systematically from the customer's location to one of these washing locations before they can be sent to be refilled again. Therefore this implies additional transportation to the washing facility, waiting time in the queue to be washed, additional movements to complete the washing process, excess of inventory and defects caused by additional handling. In other words, the main Lean wastes have been identified when washing systematically.

Even though that the washing of the returnable boxes does not add any value to the final customer and their product, it could be said that the washing adds value to the boxes only when they are considered to be dirty, which leads to the prerequisite of a definition of a clean box. The relative and undefined concept of a clean plastic box may vary from user to user and seems to be the main reason for VLC to justify systematic washing in order to satisfy the need for a clean box (Österholm 2011). Nevertheless, some VLC customers have presented special interest in reducing the washing cost, as they might be willing to deal with different levels of cleanliness (Wising 2011).

In the case when the identification labels have not been ripped off manually from the used plastic boxes before they are sent to the washing facility, the washing process is expected to remove them. This could be seen as a useful activity to guarantee the ripping off the labels, but has been more considered as a misuse of resources as the labels are supposed to be ripped off before the plastic boxes are washed.

6.2. The Returnable Plastic Box

The use of returnable plastic boxes can be seen in many industries, like for example the automotive, grocery and pharmaceutical industry. One may find several designs with different dimensions, shapes and colours that try to fit practical requirements of their users. The different designs may consider ergonomic factors according to the handling, storing, identification, transportation, filling rate and other general aspects related to their usage.

Figure 6.2. VLC Plastic Box V-EMB 750.

The particular returnable plastic blue boxes used by VLC is made of high-density polyethylene (HDPE) and have been designed in different sizes and dimensions in order to fulfil most of customer's requirements. Nevertheless, new designs are still being evaluated in order to cover existing demands, like for example better fill rates and different sizes that fit better in the production lines (Backman 2011). Future designs might find useful some of the further presented considerations.

6.2.1. The Colour

From a Lean perspective, to add visual control so no problems are hidden is considered to be appropriate (Liker 2004). Based on this principle, one could say that it is worthy that every type of box has specific designs and visual characteristics that can easily allow identifying the proper way to use them, like for example which type of items have to be filled in each type of box.

One of the issues that might occur when deciding a colour for visual control is what would you like to control, as it has been found that the colour of the returnable plastic boxes used in the automotive industry, pretend mainly to identify its owner. In this case it has been assumed that the cleanliness of the boxes plays a minor roll when deciding their colour, as otherwise it could be expected that all the boxes should be white or even transparent if we assume that these colours are the easiest for identifying non-clean items.

The particular blue colour of VLC plastic box is a peculiar aspect that helps, among other characteristics of the box, to identify VLC as the owner of these boxes. This blue colour might vary in intensity due to the lifetime of a particular box, including handling and outdoor storage that degrades the blue colour, and also due to new boxes, which are produced in some cases with approximately 70% new material and 30% with recycled material from scrapped boxes. The lifetime of a blue box is expected to be from 10 to 15 years but it entirely varies with the particular usage, the conditions in which the box seems like after some time (Balov 2011).

VLC currently offers a similar plastic black box made of antistatic material that is used for special electrostatic discharge (ESD) sensitive components and implies an extra cost compared to the blue box. The suppliers of components are responsible, when making a request of empty packaging to VLC, to demand for the correct type of package according to customer's specifications. It has been found that sometimes the packaging has been wrongly made and ESD-sensitive components have been found in blue boxes as the boxes have the same designs but different colour (Hellberg 2011). Based on assumptions, the misuse of the boxes has been due to the existing availability of the type of boxes or the actual cost for each different type of box, though this fact was not confirmed.

It has been discussed for this study that by including a new box colour to differentiate the boxes that requires washing, meaning to wash or not wash boxes according to their colour, it would not be guaranteed the proper use of it, as it would be expected that boxes with different colour could still be stacked together, requiring the extra non-value adding activity of sorting them back again by colour.

In this matter, the Lean principle related to using visual control should be combined with the term Poka-Yoke device, as the box would require a better design in order to avoid the discussed mishandling i.e. The design of the boxes with different colours should avoid to stack them together, eliminating the possibility of mixing them.

To add a different box colour would require, from an administrative point of view, to add a different packaging number into the existing packaging solutions, which all the users would have to start getting use to in order to use the package properly (Österholm 2011), involving as well to calculate and administrate a different type of cost for the new type of package.

6.2.2. The Lid

Among the different characteristics of the plastic boxes, in some cases they include a plastic lid (see figure 6.3), which could also need to be washed and stacked together with the empty plastic boxes before and after the washing. In this manner, the unnecessary washing of plastic boxes carry with them the Lean waste of over processing also the additional components that comes with them. At the VLC terminal in Gothenburg, the lids are being washed at the same time as the boxes. The breakdown of a pallet is done entirely one at a time, lid-by-lid and box-by-box, requiring being stacked back together after the washing. The VLC plastic lids for the V-EMB 780 boxes are made of polypropylene (PP).

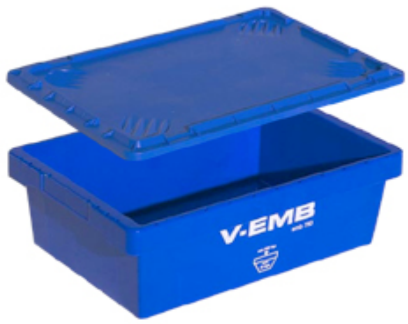


Figure 6.3. Plastic Box and Lid, V-EMB 780.

Some VLC customers would prefer to avoid the use of the plastic lids in specific locations, as when the boxes are being used in the assembly line, they do not require the lid. In the meanwhile, the lids need to wait until empty boxes comes back in order to return them together to the terminals (Backman 2011).

6.2.3. The Surface

The surfaces of the returnable plastic boxes are mostly designed flat, except in some cases for the designated area to allocate the identification labels, which has been intentionally raspy surface to make it easy to rip off the labels after they are used. It has been found that for some returnable plastic boxes used in the grocery industry, this raspy surface is on the entire external lateral sides of the boxes, meaning that the inside area and bottom of the boxes are the only flat areas.

In many VLC boxes, the raspy surface area may be found in two external lateral sides of the box, but newly designs include the four external lateral sides due to requirements of allocation of the identification label and its legibility when the box is located in the production line of a VLC customer, these raspy areas covers great part of the lateral sides but not entirely it.

When the adhesive labels are located wrongly outside these designated areas, it can be quite difficult to rip them off the box. It have been found evidence of labels attached to the correct area of the box, which are still quite difficult to rip off due to the type of adhesive on the label. The adhesive of the label is discussed in more detail further in this chapter.

It has been discussed that it could be convenient to design the entire box with this raspy surface in order to reduce the problems related to the wrong allocation of the labels. Following the Poka-Yoke term (Liker 2004), to create the entire surface of the box mistake proofing against miss allocation of the labels could be considered appropriate, even though is also expected that if the box is washed having this surface increased, the required time to dry them up might enlarge due to this special surface (Balov 2011) and also is easier for dust to stick into the raspy surface, making the box even more difficult to clean. For this case it would have to be further analysed with the box designers, which areas of the box would be worth to include this surface type.

6.3. Identification Labels

In most cases when a returnable plastic box is filled up, an adhesive label is attached to it for indicating many different information related to its content. In the case of VLC packaging, some RFID tags are being used for very special components but in the extensive majority of the transported items, the identification label is a barcode kind (Österholm 2011).

Using a RFID tags to identify a returnable plastic box would be expected to be beneficial to record a number of different information like the following:

- Identification of washed and unwashed boxes.
- Identification of the user of a specific box.
- Create controlled closed loops between customers and suppliers.
- Create a record of usage for each box.

If RFID were used to identify all the VLC plastic boxes, it could be easier to invoice the washing cost to the user of a specific box, as well as the cost for damages. The responsible for a specific cost could be easier to identify as well as to manage the available boxes globally, reducing the systematic washing that some customers are willing to eliminate from the present VLC usage cost for the packaging.

To change from an existing barcode system to a RFID system would imply that all the users of returnable plastic boxes, including all the suppliers and customers, have to acquire not only the tags but also the tag’s reader and the software that integrates the information to the existing software at each user's location. The cost involved for the tags would not be as big as it would be for the tag readers and the software itself (Stam de Jonge 2003).

The implementation of a new type of identification system would have to consider the learning curve of the new system (Slack and Lewis 2008) and be economically justified as it could be expected that the usage of the existing barcode system would still be paying its initial investment. Nevertheless, it has been proven that for certain cases, RFID systems are easy to use, quick to learn and they might leverage existing infrastructure and smooth implementation (Stefansson and Holmqvist 2006).

It has been discussed with many participants in the present study that it might be more reasonable to justify the investment of RFID systems from the components perspective than from a relatively low valued plastic box. By identifying the components with RFID tags, there could be a better quality control and availability of components, among other worthy benefits.

6.3.1. Adhesive Labels

It can be found that the different suppliers of labels use particular chemicals in order to create the adhesive characteristic in an identification label. Some of these glue's specifications can be found in existing patents and some others might be kept as a trade secret. In other words, the chemicals used for these glues are not totally standardized and it depends entirely on the supplier of labels which final formula of glue to use.

Figure 6.4. Plastic box with label difficult to remove.

The packaging guide that VLC supplies to the users, textually indicates that they should use a semi-permanent label, allowing a wide range of different type of adhesive labels to fit this requirement as there is no further details in which specific chemicals are allowed or prohibited.

The different type of labels found attached to the plastic boxes (see figure 6.4) are in some cases impossible to rip off by hand, due to the glue, requiring a specific service performed directly by manpower where the plastic box is taken a side from the others to remove the labels and other undesired attachments. The customer is charged extra for this service and in the case when VLC personnel considers that the box too difficult to clean or too damaged, the plastic box is scrapped and the customer has to pay for it.

Following Lean, to standardised is the foundation for continuous improvement (Liker 2004), so it would be necessary to standardized the adhesive of the labels with detailed information of the specific chemicals that have been proven to give positive results as well as identify the chemicals that would not be allowed due to their negative effect on the plastic boxes or even to the environment.

It has been found for some cases that after the labels are used, they are scraped together with other scraped materials and sold as material to be used for combustion. The further environmental consequences of scraping or burning these labels have not been longer investigated but it could be expected to vary depending on their composites. It has been found label solutions that are considered to be ¨recycling compatible¨, as their film and adhesive system have no detrimental effects on the reuse of different materials, the resulting recycled material of these labels is considered to be a virgin (See www.3m.com).

In the case of VLC, it has been discussed that in order to identify the appropriate label composites that should be standardised, further evaluations of the labels should be performed with the help of Volvo Technology or similar entities (Lindblom 2011).

6.4. Customer Requirements

As discussed before, according to Bergman and Klesjö (2010), there are two types of customers who will determine the level of satisfaction of a product or a service. In order to be successful when improving quality, requirements from both types of customers must be considered. Some of the requirements for each type of customer of the plastic boxes have been identified and further described.

6.4.1. Internal Customers

The owner of the returnable plastic boxes may have its own demands in order to guarantee a good quality of their services and perform a proper work to the external customers. It can be found that certain conditions must be followed in order to allow a stakeholder to use the returnable plastic boxes. VLC for example, has given to their users the following prerequisites when using the plastic boxes:

- Labels must be affixed to the designated areas only.
- Adhesive on the labels should be non-permanent and the labels should be removable.
- Glue left from the labels is allowed.
- When returning the box, flags or labels must be removed.
- Plastic document holders, staples and wire tags are strictly not allowed.
- No scratches, cracks or holes are allowed.
- The boxes can only be sent to an authorised user.
- Assure proper handling and storage of the packaging.
- Return empty packaging to designated VLC terminal.
- Secure your insurance cover for the packaging at your locations.

These conditions are the minimum identified requirements to guarantee a suitable washing of the box and avoid injuries when handling them. If the users fail to deliver the boxes in these conditions, they are charged additional costs for the sorting and extra cleaning.

From an administrative point of view, the owner of the plastic boxes requires to control the availability and location of each box. It is required to control the inbound and outbound of boxes at each site so the operation planer of the packaging logistics can balance availability for the users by relocating them in different terminals (Dzudevic 2011). This control, additionally allows assigning responsibilities of missing or scrapped boxes, as well as the amount of time that a user is in possession of a box, which in the case of VLC implies a disposal or rental cost that is charged to the users.

The pool organizer needs to guarantee the quality of their service to all their customers. Some users of VLC boxes would prefer to send the boxes directly back to their own suppliers, speeding up the flow of components and reducing the related costs of washing them, at the expense of using a less clean box. The problem with this last mentioned set-up arises when washed and unwashed boxes are mixed up within the global pool and the pool organizer is no longer able to guarantee a clean box to the customer with the highest demands for cleanliness.

The administration of two type of costs due to washed or not washed items when is the same class of package, would require a peculiar set-up if implemented both type of charges at one particular site, this set-up is currently unknown by companies like VLC (Holmgren 2011). It is important to remember that VLC charges the usage cost to a customer's account once filled boxes are dispatched from the supplier's site and it could be a problem for VLC if external customers paying for a washed box receive by mistake an unwashed one, as the supplier would be managing both types of boxes.

6.4.2. External Customers

The direct user of the plastic box or purchaser of the service has its own specific requirements for a clean box due to handling issues and to guarantee the quality of the components delivered inside.

Focusing on external customer demands, some quality requirements should be reached before being able to deliver a plastic box to a user. In the specific case of the analysed automotive industry, VLC has identified that the plastic box should be (Blomgren 2011):

- Free from splits or damages that could cause injury to users or damage to the components.
- Free from any type of scratch that represents a risk of damaging the components.
- The surfaces that will be in contact with the components must be free of dust or dirt. However, ingrained dirt in scratches that do not transfer to the hand when touched is acceptable.
- Dust particles in the exterior of the boxes, caused by transportation and storing are acceptable.
- Free from grease, oil or similar residues.
- Free from soap or rinse aid residues.
- Free from staples, wires or any sharp object.
- Free from label holders, although some residues may remain.
- Free from tape residues that may come into contact with the components. Partial residues may remain in the outside of the boxes.
- Free from any label on any side of the box, lid or spacer. Partial residues are acceptable.

Among the VLC customers visited during this study, one of them had very strict demands for a clean plastic box, as some of the components delivered to the assembly line were extremely sensitive to pollution and rust (Gustafsson 2011). For these types of components, the suppliers must place the special components inside a plastic bag and then inside the plastic box, meaning that the component never gets in contact with the washed plastic box.

As for many companies, the need to reduce costs where possible is a daily task. Some VLC customers have presented special interest in reducing the so called transaction cost when using the plastic boxes and therefore they demand for solutions in reducing the unnecessary washing (Wising 2011). This customer requirement could be also justified by the willingness of many companies practicing Lean, eliminating waste that does not add value to their product and at the same time, companies becoming more environmentally aware of the consequences of their actions and the services they buy (Björklund and Martinsen 2010).

6.4.3. Definition of a Clean Box

As simple as it initially may appear the definition of clean box, it only takes a few interviews to realise the relative perception of what is clean, especially when the cleaning involves an extra cost. VLC has standardised the requests of a clean box based on the highest demands of cleanliness necessary to satisfy their toughest customer (Franksen 2011). It has been considered that what is good for the most demanding customer would be enough for the rest of the customers. This assumption might be acceptable if the washing did not imply any of the extra costs already involved in it, as it could be difficult to imagine that customers would complain of a too clean box that does not require extra cost from them. In any case, the unnecessary washing would still be considered a waste, as from a Lean perspective this could be considered an overproduction and over-processing of clean boxes.

As described before, to treat different customers as a group of people or organizations with the same requirements is considered inappropriate. Every customer is to have a unique treatment and unique offers (Bergman and Klefsjö 2010). Some customers might be willing to pay for the washing in order to guarantee cleanliness and some other do not perceive the value of it as their definition of clean box might already be reached without the washing. In this matter, different levels of cleanliness should be accepted and the related cost must be customized to each user if the pool organizer is willing to satisfy every particular customer.

In the case of VLC, one of the customers with the highest demand for a clean box has given as reference of cleanliness that the boxes should strictly follow the requirements previously mentioned when describing the external customer (Gustafsson 2011).

6.5. Sorting of Plastic Boxes

One of the possible solutions to stop systematic washing of plastic boxes, is by using manpower to classify boxes that are considered to be not clean, sorting them out from the group of clean boxes. From a Lean perspective, this could be considered as a necessary non-value adding activity, as there is no real value added to the customer, even though the purpose of the sorting could be justified to avoid the unnecessary washing.

The companies considered in the present study have identified that sorting the boxes is one of the most viable ways to avoid unnecessary washing. According to the Lean principle of becoming a learning organization through relentless reflection and continuous improvement (Principle 14), companies should standardized the best practice, rather than reinventing the wheel (Liker 2004), meaning that the sorting should be performed by any company using returnable items as this is the suggested best way to deal with the clean issue. In this manner, the main concern would be in how much cost can be reduced by implementing the manual sorting instead of systematic washing, leading to the main questions of who and where should this sorting be performed?

The suggested sorting of returnable plastic boxes involves mainly the manual work performed by operators, where a box must be judged as clean or not clean, additional to the physical space to locate the classified boxes, in other words, a different approach in the use of resources than the way they are used nowadays when washing systematically. It is assumed in this description that the typical activities of removing the labels and other elements that are not part of the box would still have to be done.

By sorting, it is expected to reduce mainly the cost of transportation and washing, even though the cost of poor quality would be a risk due to the relative definition of cleanliness between users. It has been found that the sorting of plastic boxes could sort out between 30% to 40% of non-clean-boxes (Leprince 2011), meaning that there is a potential 60-70% of the total boxes, which could not require washing.

The sorting of boxes would have different costs depending on the location where the sorting is to be performed and the manpower handling them. Salaries among operators performing similar tasks but in different locations will impact the final cost as for example, according to the United Nations Economic Commission for Europe (UNECE), the salary between an employee in United Kingdom would be considerably higher than one in Poland, up to almost six times more according to data from 2006. According to Eurostat data from the same year (2006), salaries between these last mentioned countries were four times different, even though this difference reduced in the data from the following year (2007), meaning that the difference was still considerably high but the tendency seems to aim to be less notable year after year. In order to evaluate an accurate cost of sorting, it is recommended to acquire the latest salaries for each case as they may vary according to the year and source. It has been found that salaries in some Asian, African and South American countries would be even lower than European countries, but no real reliable and updated source has been found to support this argument. In any case, the analysis on where would be worthy to implement the manual sorting would have to consider specific salaries and also the cost of the location to perform the sorting.

It has been argued that the quality of the sorting might depend on the working conditions; the different worker's unions have accomplished different exigencies in different countries and industries, and it could be very difficult to achieve the same level of quality due to the working benefits of the manpower sorting boxes in a developed country, as they differ from the benefits of an employee in a developing one (Åström and Hjelmström 2011). As mentioned before, the employees are considered to be internal customers and their demands must be fulfil in order to improve quality. It could be expected that discontent employees might perform poor quality sorting.

One of the general issues identified among the companies already sorting plastic boxes, is that the relative perspective of what is a clean box still represents a problem as it depends on the final judgement of the operator which box needs to be washed and which could be reused right away, requiring in some cases a better training of the worker in order to develop their criteria (Lundgren 2011).

If we interpret that every user will have a relative definition of what is clean, then by applying the Lean principle of using reliable, thoroughly tested technology that serves the employees and the processes (Principle 8) to support helping the operator to identify a non-clean box, there would be a demand for the design of identification systems of clean boxes, which the users could rely the responsibility of judging if a box should be washed.

If the cost of implementing sorting instead of systematic washing were justifiable, then the major trade-off would be the reduction of the related washing activities at the expense of the quality of a clean box.

6.5.1. Sorting Case: Svenska Retursystem (SRS)

Returnable plastic boxes are used in many other industries and SRS is an example similar to VLC, but with the main difference of the products transported. SRS's pool system is described here to show how another company is handling the sorting and other issues related to their returnable plastic boxes.

SRS is the packaging pool provider for the biggest grocery chains in Sweden and has almost 11 million returnable units in their system (Svenska Retursystem 2011). The returnable boxes are used for different types of groceries. In the study made by Jönsson (2006) ICA, Coop and Axfood, the improvement of the cycle time for the returnable boxes used in SRS packaging pool have been evaluated. The flow can be viewed in the figure 6.5: from the washing at SRS facility (1), to the producer (2), to the wholesaler (3), to the store (4), back to the wholesaler and from wholesaler to the washing process (5).

The sorting is an issue and should according to Jönsson be made at the food stores, to have the biggest impact in the supply chain, and not as today at the wholesaler. The sorting activity often requires many persons for example at Dagab (a wholesaler); four persons are sorting 160-190 pallets per day. A requirement from the wholesaler is that the stores sort by themselves. Many persons interviewed in the study do not know these requirements for sorting of the returnable boxes. Another issue related to sorting of the boxes is the lack of space usually in the smaller stores, but also at wholesalers that handle large amounts of boxes (Jönsson 2006).

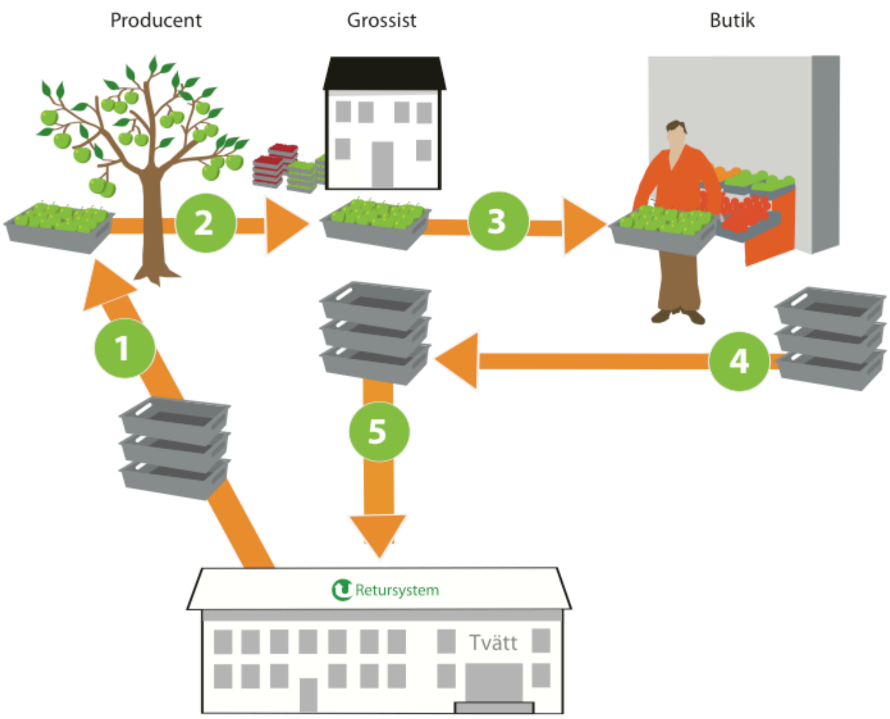


Figure 6.5. The flow of returnable boxes at SRS.

6.6. Customization of Services

One of the Lean principles says ¨*Respect your extended network of partners and suppliers by challenging them and helping them to improve*¨ (Liker 2004). This principle justifies giving more responsibilities to the stakeholders of the returnable plastic boxes, giving them the flexibility to manage these items in a more convenient way. It could be expected that it might occur a misuse of the boxes or even discordances between responsibilities that will carry on some costs, but companies that are willing to become more Lean, would have to encourage their stakeholders to improve together.

Following another Lean principle, the workload should be levelled out among processes, meaning that the existing overburden of washing facilities due to overproduction of clean boxes should be reorganised. It is expected that by giving more responsibilities to all the stakeholders, as well as increasing the flexibility of the services offered by the pool organizer, the workload would be redistributed and a smoother flow could be created.

If the judgement of cleanliness of returnable plastic boxes that are stackable is to be done when the box is empty and non-stacked, then there have been identified two main opportunities where it could be done without adding the non-value-adding activity of breaking them down just for checking the cleanliness level. The first opportunity is when the box has been just emptied and the second one is when the boxes are about to be filled up with new components.

There have been discussed situations where the cleanliness level could be identified and the unnecessary washing reduced if actions are made properly. The further described situations pretend to offer different set-up solutions within a pool of returnable plastic boxes, when pretending to diminish the unnecessary washing.

6.6.1. The Customer Clean Box

This situation assumes that box is still at the customer's site (see figure 6.6) and is here where the judgement of cleanliness must be done. The customer personnel or the subcontractor might perform some of the further described activities, but vary important considerations must be taken into account.

Following the principle of creating a culture of stopping to fix problems, the non-clean plastic box should be identified as soon as its purpose of carrying items has been completed, in other words, the identification of the problem should be when the box has just been emptied and is proximately to be stacked. In this case, as the customer's personnel is the one assumed to pick up the empty box, he would be the responsible for judging the level of cleanliness and proceed with further actions like cleaning the box to eliminate the problem with the proper tools i.e. with the use of a duster; or just classify the boxes as clean or not clean.

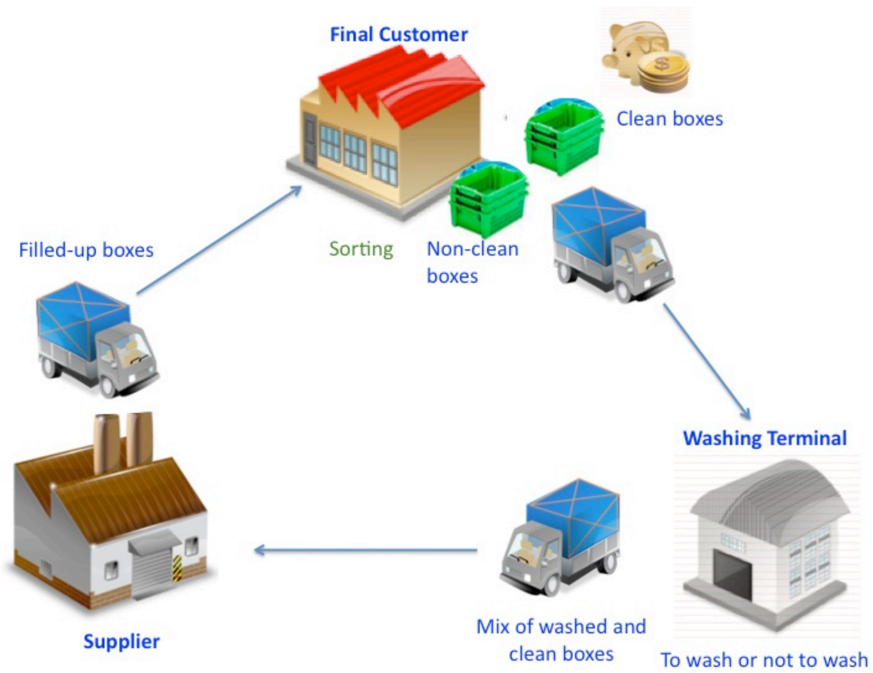


Figure 6.6. The Customer Clean Box Approach.

One of the main problems if the customer classifies the boxes is the relative judgement of cleanliness that other users might not agree with and further complains to the pool organizer might occur. Also, ones the boxes are stacked together, the cleanliness is really difficult to appreciate so it is not until the next breakdown of the boxes where it is possible to perceive its cleanliness.

In order to pass on the responsibility to the company renting out the plastic boxes, the pool organizer should perform the judgement of the clean boxes. In this manner, if there is a further complain of the cleanliness, the fault could still be assigned to one particular party. Nevertheless, it has not been concluded which would be the proper mean to involve the judgement performed by the pool organizer as the sorting could be performed directly by its personnel, supervised by an inspector, by using reliable technology or by properly educating the customer's personnel to judge the box.

If the boxes are classified, the cost for the amount of boxes requiring washing could be differentiated from the ones that will not require washing. It is expected that a different cost excluding the washing related activities could be properly estimated. This would require a different IT system approach than the currently existing in some companies, as now there would be a requirement to charge at least two different costs when before there was only one per type of box (Holmgren 2011).

It has been discussed that from the total amount of boxes that would not require washing after usage, the customer could receive a type of bonus or reposition of the paid cost for the washing, where costs related to the washing activities could be further excluded or simply returned back. In some way, this suggestion could be compared to the situation when recycling cans in supermarkets, where money is given back for each returned can.

6.6.2. The Logistic Centre

This suggestion is suitable for customers requiring the services provided by a logistic centre and the previously mentioned benefits that come by using one. As the logistic centre would perform some of the activities that the customer is willing to outsource or is not possible to perform in-house, it is assumed that the pool organizer would be running the logistic centre in order to maintain control of the boxes. It is uncertain the implications of allowing a third party to run the logistic centre due to responsibility issues over the boxes.

The logistic centre would be prepared to offer different type of services like re-packing, goods receiving, labelling, storing and delivering directly to the customer.

It is assumed that the filling up of the returnable plastic boxes will be mainly done in the logistic centre so it would be here the place to identify the non-clean plastic boxes. For the case of filled up plastic boxes that are delivered already in final size, meaning no repacking or even opening the box, it has been assumed that the supplier has received a previously washed or sorted as clean plastic box.

It is also assumed that there is a closed loop of returnable plastic boxes (see figure 6.7). Filled up boxes are delivered to the customer and coming back empty to the logistic centre, meaning that the customer can only deliver empty boxes back to the logistic centre. This approach is the so-called direct exchange mentioned before when describing RTI in the theoretical framework. It could be considered the case of the customer sending also empty non-clean-boxes directly to the washing terminal instead but it would have to be justified by the fill rate of the truck in order to avoid a waste of transportation (Jonasson 2011).

There would be a fixed amount of plastic boxes to be used in the closed loop, which is expected to pay the hiring cost for the use of the boxes. The cost for washing is expected to be included to the customer invoice when boxes are sorted out as non-clean and send for washing. The additional costs of the services included by the logistic centre like handling, storing and transportation would have to be separately adapted to each customer.

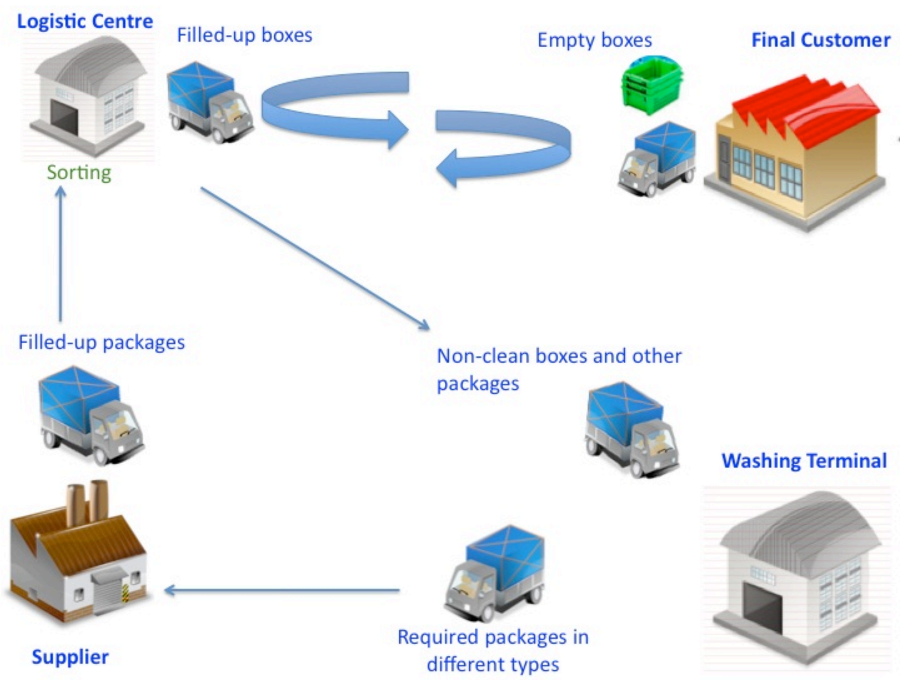


Figure 6.7. The Logistic Centre Approach.

It is suggested that the judgement of the clean box should be done at the logistic centre at the moment when the box is about to be filled up with components, relying the responsibility on the operator refilling. This responsibility of identifying non-clean-boxes could be shared at the customer's site as mentioned in the previous discussed case, but especial attention should be paid to not waste energy in repeating the same non-value-adding activity of judging the box.

If the logistic centre is to be used for different customers, it is expected a physical division of the hub and the activities for each customer in order to avoid mixing the boxes belonging to different loops.

This situation has been based on an specific set-up between a VLC terminal and one of their customers, where it is included that the suppliers should not be ever allowed to deliver direct to this customer as everything should be done through the logistic centre in order to have control of the packages (Franksen 2011).

Even though the described set-up assumes that the logistic centre is located outside the customer's location or boundaries, there is a possibility that customers are willing to perform all the services offered by a logistic centre in-house, for which the customer would only have to pay the hiring cost of the returnable boxes and deal with their own level of cleanliness while using them.

One of the expected improvements by implementing a logistic centre is to increase the fill rates of the trucks delivering to and from the centre. In order for this to work properly, the package used in each type of delivery might be different (Franksen 2011). The existing design of stackable plastic boxes allows, due to its lateral sides conic design, that much of the space of the truck is full with air when the boxes are carried full. This has been a trade-off between trying to pack the components in the proper box size from the beginning at the supplier's site, avoiding downsizing before the final location of the box, and maximizing the fill rate of the trucks. From this mentioned perspective and the requirement for sorting a used box, the downsizing activities seemed to be justifiable in this type of set-up.

6.6.3. The Sole-Vendor Supplier

This suggestion assumes that, for final customers willing to create a closed loop between them and their suppliers without proceeding with the systematic washing and accepting lower levels of clean boxes, it would be possible to hire a fixed amount of boxes designated for their use in a direct exchange manner. The customer would receive deliveries from different suppliers but only the ones fulfilling the further described requirements could be participating in the closed loop (see figure 6.8).

The main assumption for this case would be that, the suppliers that fill up the boxes would have to deliver these boxes to a specific customer and no other, meaning that they are still allowed to supply to other customers but in a totally different type of box that cannot be mixed with the one involved in the present closed loop.

Based on the previous description, the supplier could be seen as a sole-vendor of returnable plastic boxes, as other customers could not receive the components in this specific box. The main reason for this kind of prerequisite is that, even if other customers are interested in accepting a lower level of cleanliness and create a close loop as well, the accounts of boxes would be confused between different closed loops. It could happen that boxes that are being rented out by a specific customer might end up in another customer's site due to the supplier's mishandle, meaning that the rented box would be used by other customer. To avoid this problem, the supplier's site might even have to be physically separated to reduce the possibility to mix the boxes coming from one closed loop with the boxes from a different closed loop. If the supplier's site is not physically divided, then the approach of delivering to different customers would still be possible if accounts on the amount of boxes are shared by group of customers, even though this would not be recommended according to different interviewed personnel, unless all the parties have a considerably long-term and tight business relationship, which is quite difficult to achieve.

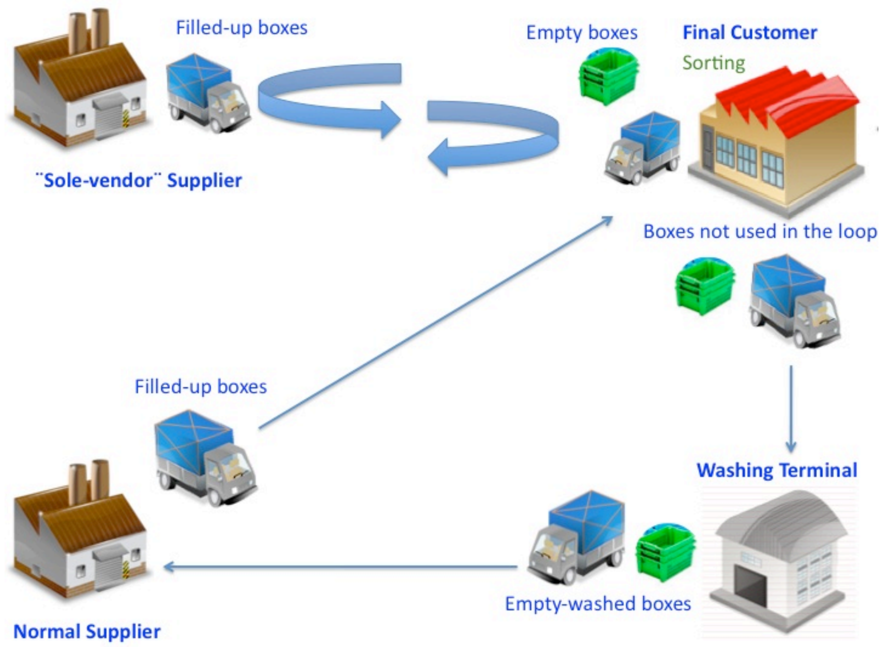


Figure 6.8. The Sole-Vendor Approach.

As the customer would still receive new washed boxes coming from the different suppliers that do not have a closed loop, the customer is able to sort out non-clean boxes from the closed-loop and change them for the considerably more clean boxes coming from these suppliers.

One of the major challenges in this case is to find suppliers that will only use this specific plastic box to send components to only one customer. It is expected that if many suppliers from one same customer implement the suggested set-up, a better logistic for the transportation could be achieved if milk runs, near the customer's site, are used for delivery and pick-up of boxes.

From the pool organizer's perspective, this set-up would not be as beneficial from a volume of sales point of view, as it limits its capacity to expand if the supplier would like additional plastic boxes to deliver to another customer.

As this type of boxes would still be used in a pool from a global perspective, it could be considered that the present situation is a direct exchange system into a pool organization management system of returnable items.

For the particular case of VLC, this approach would require a different administrative control as the cost for the usage of the boxes is charged as soon as the supplier dispatches filled-up boxes, so if the supplier requires new packages different from the ones used in the closed loop, it would be problematic to differentiate the packages that belong to the closed loop from the newly requested (Holmgren 2011). Nevertheless, it has been suggested that this cost for usage could be charged as soon as new package is delivered to the supplier site, where the customer would start paying the hiring cost for the new package as soon as the supplier receives it, instead of when the supplier dispatches it.

6.6.4. The Disposable Box

As mentioned before, some customers have specific quality requirements when it comes to cleanliness of the boxes due to the special components being carried. For these special components it could be suggested the use of a disposable box, guaranteeing a totally new box each time these special components needs to be delivered. Specific studies suggest that for some cases, this one-way package is favourable from an environmental and economic perspective, contradicting some existing literature that suggests that returnable packaging it is considered to be environmentally favourable (Pålsson, Finnsgård and Wänström 2011).

If the disposable boxes are used as an option for the special components, the returnable plastic boxes could reach a lower level of exigencies, meaning that they could be washed only when considered really necessary, even though this would still require a definition from each customer of when it is considered really necessary to wash the specific plastic boxes they are using.

It is expected that with less washing of the returnable items, the flexibility with which the boxes may be treated might vary depending on the user's requirements, and it will depend on the justified fill rate level on where in the pool system the boxes may go back to the supplier or to the owner's terminals.

6.7. The Terminal

One big concern if allowing closed loops between customers and their suppliers, without sending the boxes through the pool organiser's terminals, is the one related to the existing variable demand for different packages. In order to guarantee a high fill rate in the delivery trucks, it would required that the demand for specific types of packages would have to be stable, meaning that the suppliers will always require to receive back the same amount of boxes that were sent to the customer.

Currently the packaging solutions offered by the pool organizers vary in many different models in order to fit the different sizes and quantities of the components in them, the possibility for the supplier to ask for different packaging solutions would vary as the demand for components vary on the customer's site.

From a Lean point of view, to create a pull system to avoid overproduction seems to be very beneficial for a production line as described by Liker (2004), but when applied to a pool system of returnable items it might bring complications due to the varying demand for each type of item. If the principle of creating a pull system were applied directly from one station to the next station requesting the packages, the empty boxes at the customer's site should be transported to the next user requiring this specific type of package and if the required quantities do not match availability, this would carry some extra transportation from another location to cover the missing parts or in the other hand, extra inventory of the unrequested items.

For this last described situation, the terminals have been identified as an essential part of the supply chain in order balance the flow of the packages and obtain the highest possible fill rate in the trucks when delivering different types of requested packages (Holmgren 2011).

Some existing supply chains have a pull system from the customer's site, through the suppliers, and up to the terminals, but from the customer's site to the terminal it is perceived more as a push system, even though it has been found that in some cases the pool organizer can ask the customer to deliver empty boxes to different terminals in order to balance availability at each terminal (Dzudevic 2011).

Even if the unnecessary washing is eliminated, the amount of packages that could be send directly to a supplier from a customer's site, would have to be justified by a high fill rate level in order not to carry other Lean wastes including transportation, carrying as well environmental consequences (Blinge 2010).

6.8. The Lean Transformation

Some of the Lean principles are more related to the organization's philosophies and the way they grow their personnel inside the company, rather than the processes themselves. Liker (2004) describes how Toyota believes in growing and developing a personnel that believes in their culture, developing team works, putting the customer as the most important stakeholder, helping their network of partners to grow with them, continuously improving, making decisions slowly by consensus but implemented rapidly and many others discussed in his book, which are key elements to become a Lean company.

Following these last Lean descriptions, it has been identified that in order to eliminate the unnecessary washing of returnable boxes, there has to be a major transformation in some of the studied organizations. Thanks to the performed semi-structured interviews, was possible to acknowledge that the different interests among the employees differed one from another, meaning that depending on the personal advantages that a proposed solution was able to fulfil their interests, the solution was well perceived. When proposed solutions to avoid the unnecessary washing were colliding with some of the personnel's interests, directly related to their activities and responsibilities, the proposition was perceived with scepticism.

For the specific case of VLC, it appears that to solve the problem of unnecessary washing is of the interest to a few rather than for the entire chain of stakeholders. It has been perceived in certain interviews that some stakeholders of the plastic boxes rather wash systematically all the boxes instead of risking and jeopardizing the existing processes' performance and product quality, which would probably bring as consequence some further complications when implementing less unnecessary washing. The case company would have ahead the transformation process of achieving the required philosophy among the stakeholders to conveniently achieve reduction of unnecessary activities.

6.9. Research Questions Check Point

In order to verify that the previously presented research questions have been covered, summarised answers to each question are presented:

RQ1: "How is the current supply chain of the returnable plastic boxes designed?"

In chapter 2.4 a description of different types of supply chain systems for returnable boxes are presented. Supply chains identified with the names of pool organisation management, systems with return logistics and switch pool systems were considered convenient to be studied for the further analysis.

The existing supply chain of the case company is presented as an overview in chapters 4.1 and 4.2, where responsibilities and some related costs are highlighted. In chapter 5.2 a detailed description of the washing terminal is also presented, where specific activities are presented sequence wise from when the returnable plastic box enters the terminal until it leaves it.

RQ2: "What are the different customers' requirements for the boxes?"

A general perspective of customers' requirements based on quality is presented in chapter 2.1. Specific box related requirements are further presented in chapter 4.3, wherein requirements due to identification labels are emphasized. The requirements for the current systematic washing are presented in chapter 6.1.

The customers' requirements based on the case study are presented in chapter 6.4, where differentiations of different user's requirements are highlighted according to their needs. The focus of these requirements is based on the required level of cleanliness of the returnable box.

RQ3: "How is the flow of returnable plastic boxes designed in other companies?"

As mentioned before, chapter 2.4 describes different supply chain systems; some of them are similar to the case company's current set up and some other present a different approach, involving differentiation in the owner of the boxes, responsibilities or even the non-returnable characteristic.

In chapter 6.2, different external characteristics of the boxes used in the pharmaceutical and grocery chains are analysed in comparison to the case study.

Finally, in chapter 6.5 a general description of the company Svenska Retursystem's flow of returnable plastic boxes is presented, with the main difference being the extra activity of sorting out clean and dirty boxes, which the case company is not performing.

RQ4: "How can the current supply chain be re-designed to reduce washing of the boxes?"

In the chapter 6, the RQ4 is mainly answered. First with the focus on the returnable plastic box and its design features: colour, lid, surface and identification labels. Secondly different supply chains are analyzed for example to increase the sorting at different locations or by changing to more closed loops in the supply chain. In chapter 5.5 and 5.6, the environmental and the economical aspect are analyzed to highlight the potential impacts of a re-design of the current supply chain.

RQ5: "What is the environmental impact related to the washing of one plastic box?"

The environmental impact is presented in chapter 5.3 with data on water and energy consumption and the CO_2 emissions related to this consumption. Both the total and comparable measurements, in form of per washed box, from each washing location are presented. On an average, the CO_2 emission is 50 g CO_2/box and wash.

7. Discussion and Conclusion

In this chapter the final discussion and conclusion of this thesis work are presented. The discussion are mainly based on the different approaches that could be given to reduce the unnecessary washing of returnable plastic boxes and the conclusion are based on the consensus of ideas included in this thesis.

7.1. Discussion

Diminishing the unnecessary washing of returnable plastic boxes does not necessarily leads to costs reduction, but there is a potential possibility to reduce the amount of CO_2 emissions carried by the electricity generation and the water consumption.

The actual cost involved in the investment of a washing machine has to be justified by its utilization and amount of washed boxes in order to pay back the initial investment and further company earnings due to offering this service (Holmgren 2011). If the washing of boxes is reduced, the time to pay back the initial investment of the machine might be longer than estimated, unless the cost per box washed is increased, meaning that the customers would have to pay a higher price per box washed at the expense of not paying for the washing of all the boxes used. It is uncertain in this thesis, how much exactly would the washing cost increase if for example occurs a reduction of 60% of the current washing, which is a expected reduction if boxes are sorted out as clean and not clean (Leprince 2011). The main trade-off in this case would be between the reduction of unnecessary washing and the cost of those fewer boxes being washed.

As the terminals between users have been identified as consolidating points of the different packaging types, it is still expected that the returnable boxes would have to be transported to these terminals, meaning that the transportation would not be necessarily reduced. Even if the boxes will not be washed, they would probably still have to be transported to the terminals, as the dispatched shipments to suppliers would require different packaging solutions due to the varying demand for different packaging types (Jonasson 2011). The potential way to reduce transported distances would be through the suggested closed loops between suppliers or logistic centres and customers or final users of the box, but the fill rate of the shipments should be considerably high in order to reduce the shared CO_2 emission of the cargo (Blinge 2010).

The manual sorting activities has been only suggested as a manner to avoid systematic washing but is still not adding any value to the final user. The described set-ups in chapter 6 were considered beneficial to include the sorting, having a minor impact on the current activities. This suggested sorting will lead to two main costs, the personnel required to perform the sorting and the physical space to allocate separately clean and not clean boxes, probably increasing the demand for a greater space due to the differentiation when allocating each type of box. Depending on the specific location and the availability of these mentioned resources, the costs might justify to sort out or to wash systematically. The washing activity as well as the sorting do not add any value to the final product and should be both eliminated, so further analysis in how to carry components in a manner that satisfies customer demands and does not include or minimises the non-value adding or necessary but non-value adding activities would still be needed.

As showed previously, the cost for the usage of the returnable plastic boxes is sometimes a fixed cost and includes among other things the washing of the boxes. If the costs were to be differentiated, where the washing is included or excluded according to each case, then the administration system of the related costs would have to be able to notice this difference, meaning that when before there was only one cost related to the use of a box, now it would be expected that the system should distinguish at least two different costs, but for still the same used product.

Even if it is possible to reduce the CO_2 emissions of the electricity generated to be used by the washing machine by reducing the washing of boxes, meaning to reduce the use of the washing machine, is still unknown the CO_2 emissions that could be emitted due to the generation of new activities. For example, if the decision to sort the boxes as clean and non-clean is implemented, it might carry as consequence the requirement for a sheltered area where to sort them, possibly leading to the construction of the suitable infrastructure for the sorting. Also the sorting might require extra transportation if the layout of the terminals are not convenient or the sorting activities have to be located distanced from the terminals and other users.

The definition of a clean box still belongs to each user and is expected that even if some given definitions might be similar, some differences on the relative appreciations of what is clean will still be found. In this case, to satisfy each user by customizing the demanded requirements on a box would seem the most appropriate if companies want to satisfy each of its customers. The main trade off would be that customized services, intended to obtain high customer satisfaction, could very possibly end up in costly solutions for one part or another, possibly leading to further problems if suitable considerations are not taken into account for each set-up of activities.

If all the users within the pool of returnable plastic boxes implemented properly all of the Lean principles described before, it would be expected to create a culture of washing the boxes only when the non-cleanliness is irrefutable between users, as if every stakeholder followed a culture of identifying a non-clean box and eliminating this non-cleanliness immediately i.e. by using a cloth to eliminate residues on the box or ripping off residuals of a label, then the requiring for the washing would be expected to reduce considerably. As to clean the boxes seems to be a responsibility assigned to the pool organiser, as it is the entity charging for the washing, it would be expected that if every stakeholder carries part of this responsibility, then the need for washing would be reduced, as it would not be when sorting the boxes the place to identify clean and dirty boxes but in the entire supply chain of these items.

Further designs of the existing returnable plastic boxes would have to consider existing concerns related to convenient fill rates, recyclability, flexibility when occupying space, a convenient colour to easily identify cleanliness, a suitable surface that helps the cleanliness and avoid external components to stay attached to the box permanently, the identification of the box and their content as well as the specific characteristics of the content and its adequate conservation when stored or carried.

If the adhesive identification labels are to be standardised, in order to conveniently avoid cleanliness problems of the returnable plastic boxes, the proper composite on the adhesive side that will be in direct contact with the surface of the plastic box should be evaluated so the label remains attached to the box the required time but still would be able to be easily ripped off when needed. As companies are constantly evaluating the environmental effects of their products and services, to make the label and the adhesive with existing ¨recycling compatible¨ materials would be a convenient way to move forward to become a more environmentally friendly company.

7.2. Conclusion

- By eliminating the unnecessary washing of returnable plastic boxes, related activities to the washing process itself could be reduced, performing them only when really considered necessary instead of systematically. Nevertheless, there is a potential possibility that new activities like manual sorting of clean and dirty boxes might occur and the involved cost, quality and required time to perform each new activity will depend on the specific activity set-up and degree of implementation.

- In pool systems where different type of packages are used, terminals between some users have been identified as consolidating points from where to cover the varying demand of different packages, including the potential possibility of increasing the fill rate of the dispatch shipments from these terminals.

- The design parameters like the surface, the colour, the composite materials and the dimensions of the returnable plastic boxes, are key factors that determine the relative definition of the level of cleanliness that a user may assign to a plastic box, as the elements that may get attached to the boxes during its use and the components being carried, affect the external appearance of the boxes.

- To offer the same type of services to different customers does not guaranty customer's satisfaction. Even if the type of service has been intended to satisfy the customer with the highest exigencies, this level of quality might not be appreciated if it carries a major cost with it.

8. Case Study Recommendations

In this chapter specific recommendations and related comments to the case study are summarised and discussed from different perspectives that include different opinions of the participants in this thesis. Some of the further information describes in more detail, practical suggestions to be considered by the case company.

8.1. The Sorting

The only identified mode to avoid systematic washing, that companies in the automotive, grocery chains and pharmaceutical industry using returnable plastic boxes are using is by manual sorting, as boxes are sorted out and washed only when considered. In the analysis chapter, different set-ups of supply chains are suggested with potential possibilities to perform the sorting at different locations.

In the automotive industry, one of the investigated companies (different from the case study) is sorting out boxes for washing and has outsourced the sorting activities as well as the brake down of the pallets to an external company. The sorting is classified in two different piles, the ones sorted as clean are protected with a plastic bag for cleanliness concerns and the ones sorted out as non-clean are sent to the washing process. The same personnel classifying the boxes as clean takes away the labels and other attachments from the clean boxes, the washing personnel takes away the labels from the ones that have been sent to the washing process. The adding of the plastic bag could be useful but it would be important to reuse them as well, otherwise it just adds more wastes to the supply chain. It is important to remember that some users have considered the lid as problem so it could be expected that the plastic bag would be a burden as well. Even though this is not the case, is also important to have in mind that the bags should not be used immediately after the washing as it causes problem related to the existing humidity, as the boxes are still warm from the recently dry up process of the machine.

Another automotive company, having a customer roll, is currently sorting boxes at their site for some type of boxes and some other kinds are still being washed systematically. For this case, the customer is able to sort out the boxes that they wish to wash, and unwashed boxes are possible to be used in closed short loops with their particular suppliers. Even if it has been found that it was difficult to implement, the sorting has achieved a reduction of the transaction cost. A possible key factor in this case is the close relation between the customer, their suppliers and the pool organiser. It is expected that this solution will be implemented to all the type of packages used. One important issue in this case, is to assign responsibilities over the box, meaning that if the box is mishandled or lost, the related cost should still be easily allocated to a user without further long and profound discussions. When creating close loops due to customer's demand for it, then it should be the customer the responsible of the box at any time inside the closed loop.

One VLC customer was using other type of returnable boxes before 2003 and they were able to sort between 30% and 40% as ¨Dirty¨ boxes that were further washed. They had a washing machine at each plant. A current VLC customer is using the services of a VLC logistic centre, where savings for the customer have been achieved due to closed loops created between the customer and the logistic centre, including the savings due to the performed activities inside the logistic centre.

Some basic cost calculations, that mainly included the required manpower and the sheltered area to perform the sorting, suggested that the sorting would generate more costs if performed at the Volvo Terminal in Gothenburg, instead of washing systematically. It has been discussed that salaries in Eastern Europe are expected to be significantly lower than in other European countries, including Sweden, meaning that further cost calculations involving possibilities of sorting at VLC terminal in different global locations are suggested.

The sorting has been suggested as a way to avoid systematic washing, but it still adds no value to the final product and may carry the consequences discussed before in the discussion and conclusion chapter, but specific set-ups for specific customers may have potential possibilities of achieving savings.

If the sorting is implemented, it is expected that the current amount of boxes washed will be reduced, meaning that the initial investment in the washing machine might take longer to pay back the related expenses if the cost for washing is not incremented to the customers, or in the other hand the estimated earnings from offering this service might be less than originally estimated. In the case when VLC outsources the washing services, it has been discussed that VLC pays part of the initial capital cost for the washing machine and then pays a fix price for the exact amount of boxes washed, VLC is not committed by contract to wash a minimum amount of boxes a month at the outsource washing facility, but it is still unknown in this thesis the exact reaction that the companies offering this service will have if VLC decides to reduce the washing by for example 60%.

8.2. The Plastic Box Design

For further considerations in the new designs of packaging solutions, it should be included some of the following issues:

- If a colour is to be used in order to differentiate different type of boxes, then the external design of the box should not allow boxes with different colours to mix when stacked together as consequence of mishandling, requiring the extra activity of differentiate them again.

- The external raspy surfaces to allocate the adhesive labels are helpful when ripping labels off the boxes. Grocery chains use boxes with this raspy surface in almost the entire external surface of the box, the drawback is the extra time that the box could require to dry up in the washing machine or the additional dirt that could be attached to this type of surface.

- If labels are left on the boxes when stacked, they can easily be attached to the internal surface of the other box.

- Users have complained about the use of the lid, as they would rather not use it some times due to the extra space required to allocate them when the boxes are being used in the assembly line, requiring as well to put them back together to return them to the washing terminals.

8.3. The Adhesive Labels

VLC packaging instructions, indicating the proper use of their returnable plastic boxes, point out the requirement that the labels attached to the boxes should be non-permanent, but no further detailed information is given on the type of composites that should be used or prohibited on the label and the glue. It has been found that VLC customers indicate to their suppliers to use VLC package instructions so they seem to not give any further instructions on the specifications of the composites on the labels.

The wide range of different glue solutions found in this study, are mixes of glue formulas that might be included in existing patents as well as formulas treated as confidential information of companies offering adhesive solutions.

Some VLC customers are scrapping the used labels and selling them as material for combustion, it is unknown in this thesis the environmental impact of the burning of the different label composites. It has been found that a supplier of labels offers a type of label with ¨recycling compatible¨ materials, which could be a potential label solution if the labels are to be standardised.

It is suggested that further studies of the label composites should be performed by proper entities like Volvo Technology and further standards of allowed composites, as well as forbidden composites should be identified. The further implementation of this standardised label would be expected to be possible as in the past VLC has already identified and forbid labels that were too problematic, as it was very difficult to rip them off the boxes.

8.4. Alternative Solutions

It has been found companies where the owner of the box is the supplier, meaning that no pool organiser is actually required as it is a customer-supplier direct exchange of returnable transport items. In this case, it is believed that there might be a potential market for a type of package that could be sold to suppliers or customers and could be differentiated from the already known returnable plastic boxes, maybe a returnable box that has less expected live cycle and less cost. Still environmental considerations of recyclability and scrapping should be included in this suggested case.

For the customer with the highest demand for cleanliness, it could be offered as solution a disposable box that has not been used before, guaranteeing a high level of cleanliness. In this matter the returnable plastic boxes could be used only for the customers with lowest demand for a clean box, implicating to be able to reduce the transaction cost. For certain specific cases, these disposable boxes have been proven to have less environmental impact than when using returnable plastic boxes, so specific situations could be further analysed (Finnsgård, Medbo and Johansson 2011).

8.5. Customer Requirements

The summarized VLC customer requirements were previously presented in the analysis chapter where a combination of customer demands, based on inspector's reports and interview made to VLC customers, showed the compilation of requirements from different users of the plastic boxes.

One of the VLC customers assembling engines requires that the metallic components inside the boxes do not present signs of contamination or rust, meaning that no dust, oil, water or any other element external to the component can be attached to it as these components are very sensitive and the final quality of the assembled product depends on it. In order to be extra careful, suppliers have sometimes to cover the components in plastic bags to be able to deliver a good quality product when it arrives at the customer site, being the plastic bag a supplier's precaution rather than a customer's demand in most cases.

On the other hand, one of the VLC customers assembling the final vehicle, uses mostly plastic and other metallic, but not so sensitive, components in the plastic boxes, meaning that the risk for these components to get rusty or contaminated in some how is most likely minimum or could be eliminated by simple methods like using a cloth. In this case, the external elements that could get attached to the components seems to be less meaningful than for the customer assembling engines, meaning that water, oil and dust do not alter the main characteristics of the components inside the boxes.

It is suggested that a differentiation of the customers is required, meaning that the customer should be able to pay for what he is specifically requiring. One solution that fits all VLC customers was not possible to achieve due to the different supply chain set-ups and specific customer requirements.

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Appendix A. Questionnaire

The questionnaire used for data collection of the washing facilities.

Answer with the time interval you prefer for example per hour, day, week, month, year.

1. How big is the total washing capacity in number of boxes?
2. How many boxes are washed?
3. How many of the washed boxes are 780?
4. How much water is used in litres or m^3?
5. How much energy is used in kWh (or m^3 for gas)?
6. What energy source is used in the washing machine? (for example electricity, gas etc.)
7. What kinds of chemicals are used for the washing and how much? (for example at VTA they use a degreaser)

Appendix B. CO2 emission factors

CO_2-emission factors with sources:

	UK	Sweden	France	Belgium
Electricity[kg CO2/kWh]	0.543	0.023	0.056	0.285
Source	(SEAP, 2010)			
Electricity [kg CO2/kWh]	-	0,100	0,023	-
Source		(Naturvårdsverket/ Swedish EPA, 2010)	(ADEME, 2007)	
Electricity [kg CO2/kWh]	0.587	0.107	0.134	0.381
Source	ELCD core database version II (European Commission)			
Natural gas: [kg CO2/kg]	0.286 (for EU-27)	-	0.870	-
Source			(ADEME, 2007)	
District heat [kg CO2/kWh]	-	0.024	-	-
Source		(Göteborgs Energi, 2010)		
LPG	1.495	-	-	-
Source	(The Environment Agency UK, 2010)			

Appendix C. Washing data

Washing statistics from the terminals 2010, data is on annual basis.

Terminal	UK	Belgium	Sweden	France	Total
Capacity					
Total capacity	2500000	4500000	2480675	1200000	10680675
Total washed	708712	3300000	1488405	1050000	6547117
780 Boxes washed	427440	2310000	927540	525000	4189980
780 in percent of washed (%)	60,3%	70,0%	62,3%	50,0%	64,0%
Resource use total (780)					
Water (m3)	289	840	971	825	2924
Energy (MWh)	31	336	468	164	998
LPG (l)	37828	N/A	N/A	N/A	37828
Natural Gas (m3)	N/A	58800	N/A	24600	83400
District heat (kWh)	N/A	N/A	364381	N/A	364381
Resource use/box (780)	**UK**	**Belgium**	**Sweden**	**France**	**Average**
Water per box (l)	0,41	0,25	0,65	0,79	0,70
Electricity/box (kWh)	0,04	0,10	0,31	0,16	0,24
Other per box	0,053	0,018	0,000	0,023	
District heat (kWh)	0,000	0,000	0,446	0,000	
Chemical use	Prime cip vc93 (Johnson Diversy)	None	Techniclean S extra Castrol	None	
Total (kg)	N/A	0	3924	0	
Chemical per box (g)	N/A		4,23		
Emission factors					
Emission factor electricity (g CO2/kWh)	587	381	107	134	
Emission factor heating (g CO2/unit)	1495	286	24	870	
CO2 Emissions per box	**UK**	**Belgium**	**Sweden**	**France**	**Average**
CO2 Electricity	25,645	38,793	33,634	20,866	33,32
CO2 Other source	79,798	5,096	10,700	20,383	16,91
CO2 Total per box	105,44	43,89	44,33	41,25	49,94
CO2 Total (tonne)	45	101	41	22	209
CO2 Total (%)	22%	48%	20%	10%	100%
Total of washed (%)	11%	50%	23%	16%	100%

Appendix D. Interviews

Visits list:
Volvo Logistics Terminal Arendal (VTA), visits several times
Volvo Car Corporation, Torslanda assembly plant, 2011-03-08
Volvo Powertrain, Skövde assembly plant, 2011-04-11

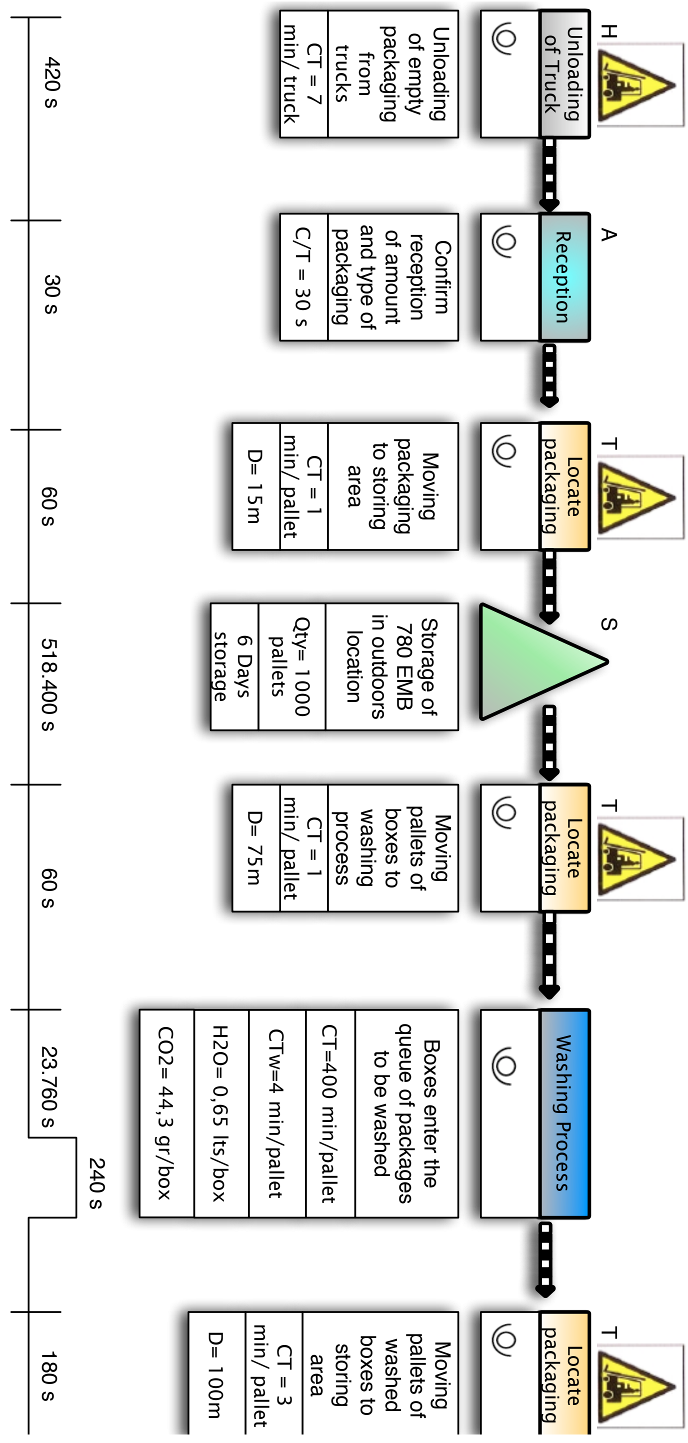
Interview list:

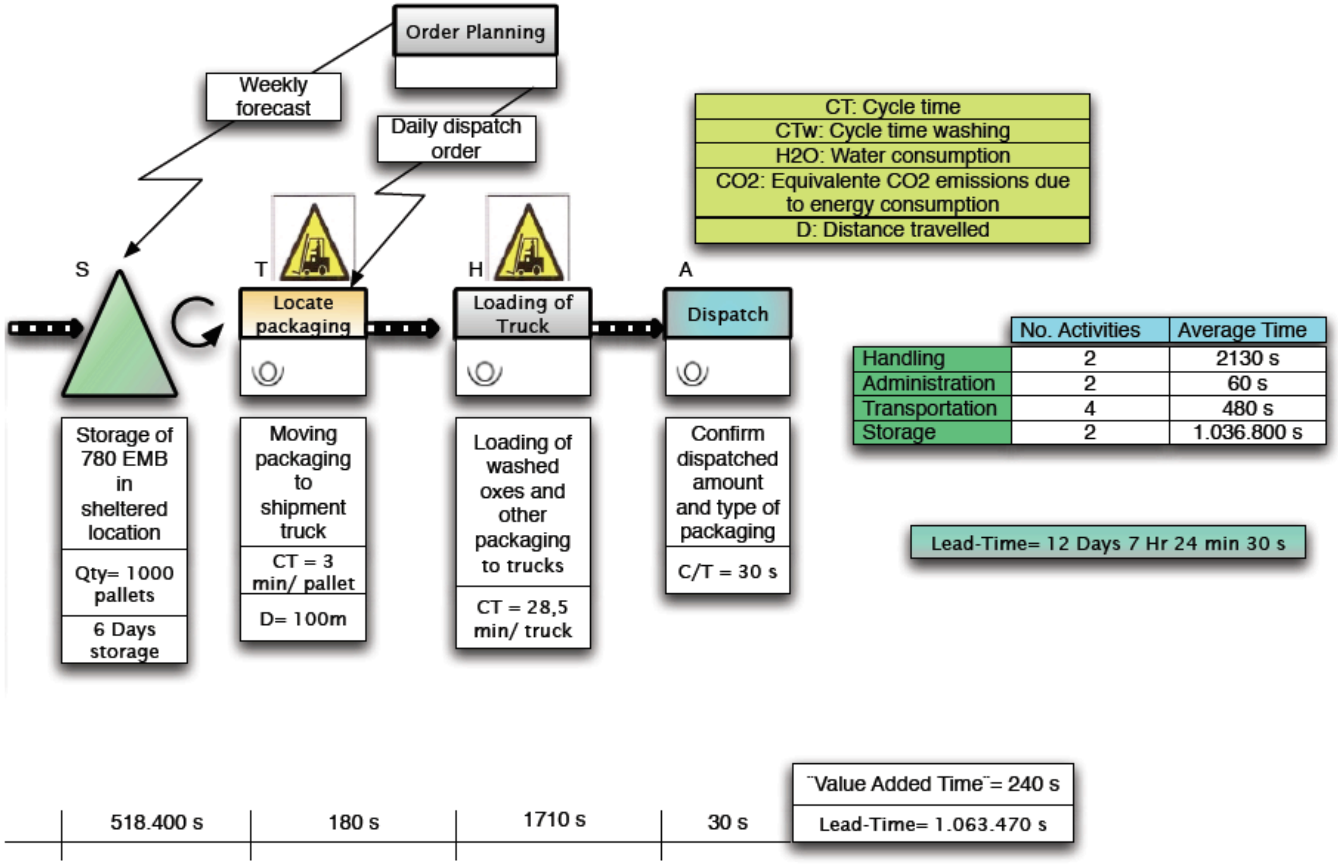
Semi-structured interviews		
Date	Name	Position
2011-02-01, 2011-03-17, 2011-04-20	Jimi Österholm	Global Logistics Development Manager
2011-02-22, 2011-05-03	Anders Holmgren	Logistics Developer/ Acting Manager Inbound Implementation
2011-03-04	Thomas Hellberg	Manager Sorting & Wash
2011-03-01	Susanne Jonasson	Transport & Logistics Developer
2011-03-02	Hristo Balov	Purchaser of Emballage & Washing Services
2011-03-08	Mats Backman	Key Account Manager
2011-03-09	Per Hjelmström, Anders Åström	Production Engineers
2011-03-15	Maria Franksen	Key Account Manager (VPT, VCE)
2011-03-16	Svante Wising	Key Account Manager (Renault Trucks)
2011-03-18	Emir Dzudzevic	Planner Operative
2011-03-29	Ann Jernbratt	Manager Planning and Inspection, Emballage
2011-04-11 (Visit VPT)	Jan Gustafsson	Manager of Packaging Group, Volvo Powertrain
2011-04-12	Lars-Bertil Lindblom	Supply Quality
2011-04-19	Thomas Holländer	Key Account Manager (Volvo Bus, EC, SKF, Atlet)
MFM interviews		
2011-03-08		Personal at VCC
2011-03-30		Washing operators Forklift drivers
E-mail contact		
Several times	Fredrik Blomgren	Inspector, VLC
2011-02-21	Lennart Lundgren	Scania
2011-04-13, additional times	Jean Marc Brieu, Nicolas Leprince	Manager Packaging Department, Renault Trucks
Questionnaire for LCA information		
2011-04-01	Wim Platteau,	Katoennatie, Belgium
2011-04-01	Simon Walliman,	Depot Manager, Norbert Dentressangle Logistics UK
2011-04-11	Philippe Schellekens	Katoennatie, France

A summary from the semi-structured interviews with the questions is presented in this section. The answers and comments are presented by bullet points and are from many perspectives. The information is used as a basis for the analysis in the thesis. 15 semi-structured interviews were performed in different workplaces during one to one and half hour.	
Questions	Answers and comments
How much time have you been in the company? What is your present position in the company?	– 6-43 years in company – Average 19 years in company – Key Account Managers, Managers, Planners, Logistics Developers etc.
Which are your activities and responsibilities related to the returnable containers?	– Customer relationships – Managing of the packaging – Quality inspection – Purchasing of packaging/washing/storage/transportation – Secure availability of clean boxes – Balance the pool: the amount of unwashed and washed boxes – Goods handling – Pricing and development issues – Cover customer's requirements – Solving problems with VLC services – Planning washing
What are your in-puts and out-puts? (What do you receive and what do you deliver?)	Inputs: – Input from the customers – Demand from customers – Quality problem – Need from users – Check available packages in all warehouses – Total amount of orders for next week Outputs, deliveries: – Create packaging instructions – Manage space in the line – Extend business – Convince the customer to use more services – Planning function – Full stock check – Good quality in the pool – Delivers a balance between warehouses to guarantee availability of packaging – Request for cost reduction – Deliver possible solutions as recommendations. – Price, solution, projects, delivery information – Solve customer problems – The request of a new packaging and deliver a recommendation of packaging – Procurement of carrier contracts according to the

	logistics and future demands of Volvo – Purchase of boxes
Which of your activities would you consider to be more difficult and why? (Including decision making)	– Defining customer requirements: many customers – Administration and communication: company divided in three units – Decision making in company: long process – Forecasting demand: only based on historical data
Which do you think it is the biggest issue with the returnable containers?	Boxes: – Labels with bad glue – Staples – Unwillingness to change box design – Storage – Washing: o Machine problems (capacity, drift) o Cost for washing
What do you think it could be changed, eliminated or added in order to make your job easier?	– Separate lid and box – Sorting – Listen more to the customer – Eliminate unnecessary washing
How would affect in your activities if there are changes in the supply chain of returnable containers?	– Will not affect Positive effects: – Stock reduction – Making boxes available faster Negative effects: – Quality issues – Complains from customers and suppliers – Sorting requires space
Other comments and suggestions	– Create a limit of the longest distance that you can a box to be cleaned, justify with environmental impact – Create a standard for labels – The customers don't want to sort the boxes – The sorting should be done by VLC in house or out house. – Wood free packaging solutions – Close loops with (big) suppliers – Plastic packages are being more demanded every day

Appendix E. MFM




Order Planning
Weekly forecast
Daily dispatch order
CT: Cycle time
CTw: Cycle time washing
H2O: Water consumption
CO2: Equivalente CO2 emissions due to energy consumption
D: Distance travelled
S
T
H
A
Locate packaging
Loading of Truck
Dispatch
Storage of 780 EMB in sheltered location
Qty= 1000 pallets
6 Days storage
Moving packaging to shipment truck
CT = 3 min/ pallet
D= 100m
Loading of washed oxes and other packaging to trucks
CT = 28,5 min/ truck
Confirm dispatched amount and type of packaging
C/T = 30 s
No. Activities
Average Time
Handling
2
2130 s
Administration
2
60 s
Transportation
4
480 s
Storage
2
1.036.800 s
Lead-Time= 12 Days 7 Hr 24 min 30 s
518.400 s
180 s
1710 s
30 s
"Value Added Time"= 240 s
Lead-Time= 1.063.470 s