Preface

The report *Sustainable Supply Chain Solutions* is the outcome of the master thesis of Sara Gertsson and Tanja Ling. The thesis has been produced during the fall of 2008 as the final step of the authors' Master of Science in Industrial Engineering and Management at Lund Institute of Technology in Sweden. The project was conducted in cooperation with the companies Syncron and Lantmännen Maskin and supported by the research center NGIL. Focus has been on the connection between logistics and environmental performance, in accordance with the interests of the involved parties.

The authors would like to express their gratitude towards those who have supported the project and provided it with input material. Especially, many thanks to Nils Oppelstrup at Syncron and Klas Merkel at Lantmännen Maskin who willingly have been engaged in the continuous work. We would also like to thank our supervisors Johan Marklund and Olle Stenius at the Department of Industrial Management and Logistics at Lund Institute of Technology, who have followed the procedure with great interest and frequently supported the evolvement of the project by discussing ideas and difficulties.

Lund, January 2009

Tanja Ling Sara Gertsson

Abstract

Title: Sustainable Supply Chain Solutions – *A Case Study Regarding Modifications of an Existing Spare Part Distribution System*

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Supervisors: Nils Opplestrup representing Syncron and Johan Marklund and Olle Stenius at the Department of Industrial Management and Logistics, Lund Institute of Technology

Purpose: The main purpose of the thesis is to provide Syncron with guidelines regarding how to modify their software for logistic planning in order to meet future customer needs. Furthermore, the thesis serves as input to the research project supported by NGIL, named *Design and Control of Sustainable Supply Chains*.

Problem Formulation: Transport costs have not been a significant cost driver in the past, which is why little effort has been spent on optimizing this area. With the predictions regarding new conditions within the transport industry, this will most likely change. To stay competitive, companies might have to focus a lot more on creating sustainable and cost efficient supply chains; sustainable in the sense that logistics are performed in an environmental and competitive way and are well adjusted to the optimal design of the inventory structure. With this in mind, the problem formulation has converged into:

- What upcoming legislations and other transport related obstacles will have impact on the design of the supply chain?
- How can Lantmännen Maskin's supply chain be adapted to the changes in transport related regulations in the sense that it is optimized with respect to environmental as well as economical aspects?
- With respect to Lantmännen Maskin, what additional costs are associated to new legislations and how much can these costs be reduced, by modifying the supply chain?

Methodology:

Both quantitative and qualitative data were used in the thesis. Data was collected from primary sources such as, email correspondence with authorities, interviews and a questionnaire, while secondary data was mainly gathered from government publications and other literature. Initially, a comprehensive theoretical framework, *Part 1*, was built using an analytical approach. Subsequently, a case study, presented in *Part 2*, was performed with a systems approach in order to obtain material on which to conduct an analysis. The analysis ends in conclusions and recommendations to concerned parties.

Theoretical Framework:

Part 1 consists of an extensive theoretical base where present and future environmental regulations, such as taxes and fees, have been investigated and discussed. The theoretical framework is completed by a short theory section in the beginning of *Part 2*. This section

includes general knowledge used in the analysis.

Empirics: A case study was conducted at Lantmännen Maskin in order to build an empirical framework, used for the analysis. The empirics present the current structure of the supply chain and the actors connected to it, but also some basic facts about the company.

Conclusions: In a near future, environmental costs will to a greater extent be transferred to the source and transport modes with large negative environmental impact will become more expensive. A kilometer tax is likely to be introduced and in 2012 the aviation sector will be included in the EU ETS. To meet these new conditions, companies have to modify their present supply chain structure by making it more efficient and by shifting to more environmentally friendly transport modes. It is important to bear in mind that solely optimizing the transport structure might result in sub-optimization, therefore the connection between transport routines, inventory structure and material handling must be taken into consideration. For Lantmännen Maskin this could be achieved by reducing the delivery frequency and by expanding their virtual supply solution to enable better coordination. Improving the environmental performance would both reduce the transportation costs and make a contribution to the establishment of a sustainable supply chain without having a negative effect on the service level, lead time and tied-up capital.

Keywords: sustainability, logistics, supply chain, emission, taxes, environmental regulations, transportation cost

Sammanfattning

Titel: Hållbar utformning av försörjningskedjor – *En fallstudie rörande anpassning av en befintlig reservdelsdistribution*

Författare: Sara Gertsson och Tanja Ling

Handledare: Nils Opplestrup från Syncron samt Johan Marklund och Olle Stenius vid Instutitionen för teknisk ekonomi och logistik, vid Lunds Tekniska Högskola

Syfte: Huvudsyftet med examensarbetet har varit att förse Syncron med riktlinjer för hur deras logistikmjukvara kan modifieras så att den bättre kan möta kundernas framtida krav. Utöver detta har examensarbetet även fungerat som en förstudie till forskningsprojektet *Design and Control of Sustainable Supply Chains*, som stöds av NGIL.

Problemformulering: Transportkostnaden har tidigare inte varit en betydande kostnadsdrivare, varför liten vikt har lagts vid optimering av detta område. Med nya och förändrade förutsättningar inom transportindustrin förmodas detta komma att ändras. Företag kan komma att behöva fokusera mer på att skapa hållbara och kostnadseffektiva försörjningskedjor för att fortsätta vara konkurrenskraftiga. Med hållbar åsyftas att logistikaktiviteterna utförs på ett miljö- och konkurrensmässigt sätt och att de är väl anpassade till en optimal lagerstruktur. Med detta i åtanke konvergerade problemformuleringen till:

- Vilka kommande lagstiftningar och andra transportrelaterade hinder kommer att påverka designing av en försörjningskedja?
- Hur kan Lantmännen Maskins försörjningskedja anpassas till ändringar i transportrelaterade styrmedel, i den meningen att kedjan optimeras med avseende på både miljö- och ekonomiaspekter?
- Med avseende på Lantmännen Maskin, vilka ytterligare kostnader kan kopplas samman med nya regleringar och hur mycket kan dessa kostnader reduceras genom att förändringar av försörjningskedjan görs?

Metod:

Både kvalitativ och kvantitativ data har använts i examensarbetet. Primärdata samlades in genom e-post korrespondens med myndigheter, intervjuer och ett frågeformulär, medan sekundärdata huvudsakligen inhämtades från statliga publikationer och annan litteratur. Initialt användes ett analytisk angreppsätt, då det omfattande teoretiska ramverket i *Part 1* skapades. Den därefter följande fallstudien i *Part 2* genomfördes med ett systemangreppsätt, för samla material att basera analysen på. Analysen leder till slutsatser och rekommendationer till berörda parter.

Teoretiskt ramverk:

Part 1 består av en omfattande teoretisk bas där nuvarande och framtida miljöregleringar, såsom skatter och avgifter, undersöks och diskuteras. Det teoretiska ramverket

kompletteras med ett kort teoriavsnitt i början på *Part 2*. Detta avsnitt inkluderar generell kunskap som används i analysen.

Empiri: För att skapa en empirisk bas, som underlag för analysen, genomfördes en fallstudie på Lantmännen Maskin. I empirin presenteras försörjningskedjans nuvarande struktur och dess aktörer. Även allmän fakta om företaget introduceras.

Slutsatser: I framtiden kommer miljökostnader att successivt hänföras mer och mer till uppkomstkällan, varför transportmedel med stor negativ miljöpåverkan kommer att bli dyrare. En kilometerskatt kommer troligen att introduceras och 2012 kommer flygbranschen att inkluderas i EU ETS. För att möta dessa nya förutsättningar krävs det att företagen anpassar den nuvarande strukturen av sina försörjningskedjor, genom att göra dem mer effektiva och genom att byta till miljövänligare transportmedel. Vid optimering av endast transportrutinerna uppstår risken för suboptimering, därför är det viktigt att ta hänsyn till kopplingen mellan transportrutiner, lagerstruktur och materialhantering då försörjningskedjan optimeras. För Lantmännen Maskins del skulle detta kunna uppnås genom en reducering av leveransfrekvensen samt genom en utökad användning av deras virtuella lagersystem, vilket resulterar i bättre koordinering. En minskad miljöpåverkan resulterar i lägre transportkostnader och bidrar samtidigt till upprättandet av hållbara försörjningskedjor utan att påverka

servicenivån, ledtiden och det bundna kapitalet negativt.

Nyckelord: hållbarhet, logistik, försörjningskedja, utsläpp, skatter, miljöregleringar, transportkostnad

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1 Introduction

This chapter will give an introduction to the thesis, including background, problem discussion and purpose. The scope and target group are defined. The disposition of the report is also presented.

1.1 Background

It is commonly accepted by scientists and politicians that the greenhouse effect can be held responsible for the increase of the global average temperature. Results of global heating are drought, floods, melting of glaciers and increased death rate due to intensified exposure to deadly diseases. All of these consequences, combined or alone, give rise to serious danger to life on earth, thus preventive actions are vital. As a result of the hazards related to the increased emission of greenhouse gases, such as carbon dioxide and nitrogen oxides, countries around the globe have come together in a united endeavor, where efforts preventing the negative environmental consequences are made.

Emission of greenhouse gases mainly originates from energy supply and transports, while a smaller amount originates from industry processes, agriculture and waste. CO_2 is the greenhouse gas that contributes the most to the greenhouse effect and its emission comes from the exploitation of the fossil fuels carbon, oil and natural gas. By reducing the usage of these fuels or by switching to renewable fuels the CO_2 emission could be decreased. Today China tops the list of countries' emission of CO_2 originating from fossil fuel usage, followed by USA, Russia and India.[1]

Because of the increased environmental concern and the identification of the transport industry as an important cause of the greenhouse effect, numerous political goals and regulations have been set for this industry on both international and national levels. Even if the effects of those goals and regulations are not yet clearly visualized, the concern and the related actions will most likely have an impact on transport costs and supply chain design in the future. To increase the awareness among companies performing transports or having an extensive supply chain, an idea about the size of the cost consequences would be helpful.

[1] Skogkär (2008): Het höst för klimatpolitiken, p A5.

1.2 Problem Discussion

Syncron International AB is a software company providing its customers with supply chain planning tools. Syncron believes that their customers sooner or later will require their software product to take transport costs, partly influenced by environmentally related fees and taxes, into account when optimizing the supply chain. To determine the validity in this belief, Syncron initiated this master thesis. Syncron is also taking part in a larger research project called *Design and Control of Sustainable Supply Chains*, which is performed within NGIL - Next Generation Innovative Logistics, and this thesis is their first contribution to the project. One of Syncron's customers, Lantmännen Maskin, will be studied more closely in the thesis in order to understand how new conditions within the transport industry will affect the costs of their single supply chain.

The assessment is based on analysis of transport costs, environmental effects, service level, lead times, tied-up capital and total cost, all of which are important components when establishing a sustainable supply chain.

Being competitive and efficient is vital for companies to survive the tough competition on today's worldwide market. Efficiency must be achieved in all areas of the company, including transport structure, environmental performance, inventory design and material handling, when developing a sustainable supply chain. Transport costs have not been a significant cost driver in the past, which is why limited resources have been spent on optimizing this area. If the predictions regarding new conditions within the transport industry would come true, this will have to change. To stay competitive, companies will have to focus a lot more on creating sustainable and cost efficient supply chains; sustainable in the sense that logistics are performed in an environmental and competitive way. The discussion above has, in cooperation with Syncron and Lantmännen Maskin, converged into the following problem formulation.

- What upcoming legislations and other transport related obstacles will have impact on the design of the supply chain?
- How can Lantmännen Maskin’s supply chain be adapted to the changes in transport related regulations in the sense that it is

optimized with respect to environmental as well as economical aspects?

- With respect to Lantmännen Maskin, what additional costs are associated with new environmental legislations and how much can these costs be reduced, by modifying the supply chain?

1.3 Purpose and Objectives

The main purpose of the thesis is to provide Syncron with input and guidelines regarding how to modify their software for logistic planning in order to meet future customer needs. The case study performed at Lantmännen Maskin will hopefully highlight new aspects of potential distribution channel modification. Furthermore, the thesis serves as input to the research project supported by NGIL, named *Design and Control of Sustainable Supply Chains*.

More in detail, the thesis will investigate whether or not it is possible to create gains, both environmentally and economically, when modifying the supply chain to make it more efficient. Ideas regarding how possible future legislation and other obstacles, such as lack of infrastructure capacity, may increase the costs associated to the usage of environmentally damaging modes of transport are presented and discussed.

A specification of the project on different levels can be found in Figure 1-1. The figure shows how the scope of the thesis is narrowed, leading to a definition of a specific system for this study.

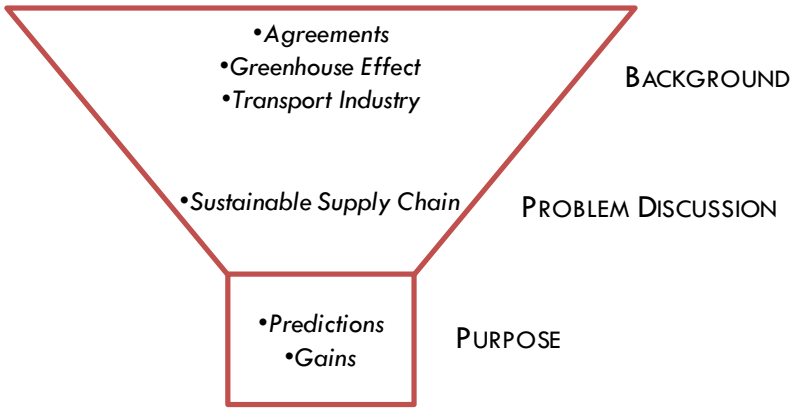

Figure 1-1. *Specification of the project.*

1.4 Focus and Delimitations

The sustainability concept is very comprehensive when discussed in supply chain contexts. When used in this report, it merely considers cost efficiency and environmental performance within the logistic network, since those are the areas comprised by the problem formulation.

In order to recognize the effects that future changes in the transport industry will have on companies and their supply chains, the overall focus of the thesis is placed on environmental regulations and costs related to them. In more detail, the focus lies on regulations and costs connected to emission of CO_2, given that this is the foremost greenhouse gas. Since road transports are the most commonly used mode of transport today, this transportation mode has been given more space than the other transport modes. This is also the area where most environmental related regulations exist and future regulations are to be expected. The Emission Trading System is also emphasized since the aviation sector is about to be included in the system, which will affect the entire transport industry. Geographically the report comprises Sweden with some relevant elements from the European Union.

In order to enable a deeper understanding of the areas in focus, some delimitations of the thesis' scope are made. Limitations are also necessary in order to get a lucid and quantifiable case study, on which a relevant analysis can be performed.

The case study performed at Lantmännen Maskin is restricted in several aspects. First of all, only outbound logistics of the spare parts, from the central warehouse to the retailers, is included in the study. This means that the replenishment of the central warehouse is not taken into consideration. Secondly, only one of Lantmännen Maskin’s seven sales regions is studied in detail. The chosen region comprises eleven different retailers, but only the ones using Syncron’s software for stock replenishment are included in the study. Those retailers count to eight and are located in the midst of Sweden. Since the central warehouse is located in Malmö, the logistics in focus is thus transports between the central warehouse in the south of Sweden and the retailers in the midst of

Sweden. Physical establishments in the supply chain, such as inventory points, are assumed to be fixed and not movable.

Placed orders are of different types, mainly depending on how urgent the order is. Since the most common are the so called refill, emergency and supplement orders, primarily these types are treated. At Lantmännen Maskin the choice of transportation mode depends on the order type. The choice is between road and aviation and subsequently the case study is limited to these two transportation options. All transports are bought from third part logistics companies and therefore some aspects that are hard for Lantmännen Maskin to control, such as utilization rate of both primary and return transports, are considered to be in the outskirts of the case study scope and will therefore not be thoroughly examined.

1.5 Target Group

This report is directed to the employees of Syncron and Lantmännen Maskin and also to academics, especially students within logistics. The target group for this thesis also includes NGIL's researchers since this is a preliminary study of a larger project. To some extent the project can also be of general interest to the public.

1.6 Disposition and Reader's Guide

Beneath, the different chapters included in the report are described in short. The report consists of two different parts, which can be read independently of each other. The first part, *Part 1*, is a general mapping of existing and future economic control measures and it provides the reader with a theoretical framework in the areas of interest to the research. *Part 2* presents the case study performed at Lantmännen Maskin. The carry through of *Part 2* is influenced by the findings from *Part 1.* Combined, *Part 1* and *Part 2* give answers to the problem formulation of the thesis, but the parts stands for themselves and can be read separately.

Chapter	Title	Description
1	Introduction	*This chapter gives an introduction to the thesis, including background, problem discussion and purpose. The scope and target group are defined. The disposition of the report is also presented.*
2	Company Presentation	*A brief presentation of the companies included in the thesis, Syncron and Lantmännen Maskin, is provided in this chapter.*
3	Methodology	*This section presents the research approach, the research methods and the data collection methods used in the project.*
	Part 1	
4	Introduction – Part 1	*A short introduction to Part 1 of the thesis is given in this section. The motive for separating Part 1 and Part 2 from each other is given and directives on how to treat the different parts are provided.*
5	Today's Situation	*In the following chapter a general overview of condition, trends and political incentives affecting the transport industry are presented.*
6	Economic Control Measures	*Taxes, fees and other transport related regulations and restrictions are identified and described in this section.*
7	External Methods of Adaption	*By adapting the infrastructure, shifts in means of transportation can be enabled and motivated. New technology is vital for reducing the emission of greenhouse gases. External incentives within those areas are presented and explained here.*
8	Internal Methods of Adaption	*A few examples of how companies internally can change their logistic structure in order to achieve higher efficiency with respect to environment and transport costs are given in this chapter.*

9	Analysis of Potential Consequences of New Control Measures	*This chapter briefly describes scenarios that have been created in order to provide an idea of the impact possible control measures could have on a company's expenses.*
10	Evaluation of Green Supply Questionnaire	*In order to get an understanding of different companies' attitude towards environmental issues, a survey was distributed to some of Syncron's customers. The result from the survey is presented in this chapter.*
Part 2		
11	Introduction – Part 2	*Part 2 and the disposition of the case study section are briefly introduced below. The chosen structure is motivated and associated with the problem formulation of the thesis.*
12	Theory	*This section aims to complete the theoretical framework in the report. Terms within the areas of logistics and production management are defined and discussed with the goal to provide the reader with a theoretical base before reading the analysis.*
13	Empirics	*The information needed to perform a deep analysis of Lantmännen Maskin's supply chain is introduced in this chapter. First, an overall view of the aftermarket is given. Further, a more detailed description of the supply of spare parts to the retailer is presented.*
14	Internal and External Methods of Adaption	*The internal and external methods of adaption that are included in the scope of the case study are presented and discussed. Lastly the adaption methods' influences on company specific matters are presented.*

15	Analysis	*The findings from the case study are analyzed in this chapter, with the aim of answering the two problem questions related to Lantmännen Maskin's supply chain. The adaption methods presented in the previous chapter will here be related to company specific aspects.*
16	Conclusions	*A final discussion regarding the outcome of the project and the fulfillment of the purpose is presented in this last chapter. Furthermore, recommendations to the involved companies as well as to further research studies are given.*

2 Company Presentation

Syncron's value chain mainly consists of information flows and one of their customers, Lantmännen Maskin, has been studied more in detail with respect to their physical flow of goods. This study has been carried out in order to fulfill the purpose of the project. Below, a brief presentation of Syncron and Lantmännen Maskin is provided.

2.1 Syncron AB[2]

Syncron is a multinational software company offering software and services for global supply chain planning, fulfillment and supply. The company was founded in 1999 and the headquarters is located in Stockholm. Today Syncron has 120 employees and ten offices spread all over the globe. The last couple of years the company has had a yearly growth of 20 percent, compared to the average of 5 percent for their line of business. The revenue for 2007 increased 14 percent compared to the previous year and amounted to a total of 121 million SEK.

2.1.1 Products

The software products provide supply chain optimization by linking systems, functions and geographically dispersed company sites together and also by creating synergies. More in detail, the products support order and supply processes and create efficient goods flows throughout the entire value chain. Factors affecting the optimization outcome are tied-up capital and service level. The costs for transportation are currently not taken into consideration.

The solutions can easily be integrated with the customer's IT systems independent of technical structure and the existing business system. Mainly, the software solution is adapted to multinational manufacturing and distribution companies and it is very flexible regarding adaption to new market demands, strategies and structures.

2.1.2 Services

Apart from software solutions, Syncron offers a range of services in order to support the entire process of implementing a total IT solution for the

[2] All information about Syncron originates from their homepage www.syncron.com or Nils Oppelstrup at Syncron.

customer's value chain. The services consist of consulting; all the way from business assessment to implementation and rollouts. Furthermore helpdesk, training and education are offered to the customers. Follow ups and modification of the implemented software is also a part of Syncron's service package.

2.1.3 Customers and Partners

Syncron's customers are well known, successful companies such as Lantmännen Maskin, Volvo and Tetra Pak. A common factor between these companies is that they have a complex supply chain structure, which requires professional forecasting, planning and replenishment solutions. In order to increase the value for their customers, Syncron is involved in a number of partner programs. These strategic alliances enable Syncron to collect more knowledge, grow as a company and extend the customer support and at the same time also improve its quality.

2.2 Lantmännen Maskin AB[3]

The business concept at Lantmännen Maskin is *to offer the agricultural sector, and sectors with similar needs, Scandinavia's most profitable business relationship for machinery, services and spare parts*. Lantmännen Maskin offers tractors, threshing machines and tools used for farming. They import, promote and sell new as well as used machinery. In addition to this they offer their customers service and spare parts. The company was founded in 2005 after merges of several existing actors in the industry. Today the company has about 900 employees and the headquarters is located in Malmö. Lantmännen Maskin is a part of the Lantmännen group and contributes with one eighth of the group's total turnover.

2.2.1 Business Divisions

Lantmännen Maskin is divided into three different business divisions; premarket, service and aftermarket. The divisions and their main activities are shown in Figure 2-1. The premarket division focuses on sales of new machinery. The tractor selection consists of the brands Claas, Valtra and Fendt, which together cover the agricultural market's needs. The threshing machines offered all belong to the brand Claas, which is Western Europe's

[3] All information about Lantmännen Maskin originates from their homepage www.lantmannenmaskin.se or Klas Merkel at Lantmännen Maskin.

largest manufacturer of threshing machines and they offer a wide range of models.

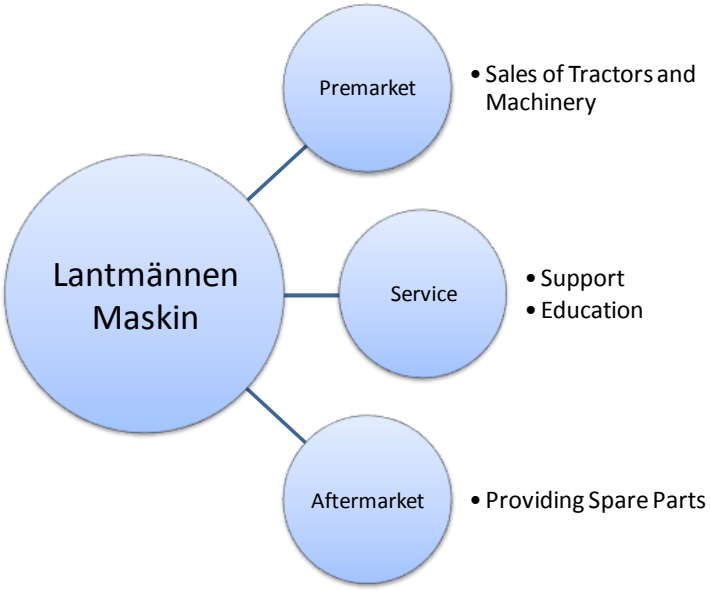

Figure 2-1. *The three business divisions at Lantmänen.*

The service division provides support and education to the customers. Maintenance of the machinery is offered to the customers at numerous service locations all around Sweden. Another service that Lantmännen Maskin offers their customers is a forum for trading of second-hand machinery.

Spare parts to tractors, threshing machines and other equipment are provided by the aftermarket division. Most of the spare parts are stored in the central warehouse, with an area of 5 000 m^2, located in Malmö. The central warehouse provides about 200 retailers, with the largest one located in Staffanstorp, all over Scandinavia with spare parts every day.

2.2.2 The Group

The group Lantmännen, to which Lantmännen Maskin belongs, has been more or less active within sales and service of agriculture machines since the start more than 100 years ago. Lantmännen is owned by 42 000 Swedish farmers and employs about 13 000 persons. Lantmännen is one of Scandinavia's largest groups within agriculture, food and energy. A

selection of their brand portfolio is Axa, Start, Kungsörnen and Kronfågeln. The group is currently active in 19 countries and had a turnover of 36 billion SEK in 2007.

Since most of the group's activities are related to the environment in some way, their environmental awareness is proportionately large. Lantmännen is Sweden's single largest buyer of transports and accounts for one percent of all truck transports performed on Swedish roads. As a group, Lantmännen has set the goal that the CO_2 emissions related to transports should be reduced by 20 percent before 2010. This goal is transferred to Lantmännen Maskin and in order to reach it, modifications in habits and transport patterns have to be discussed and realized.

3 Methodology

This section presents the research approach, the research methods and the data collection methods used in this project. Careful and relevant planning of a project is a key aspect to a successful performance and this section aims to present the authors intentions with the chosen procedures.

3.1 Research Approach

A suitable way to distinguish different research approaches from one another is to divide them in an analytical, systems and actors approach. The approaches differ in how they interpret the surrounding world and what presumptions they make about it. The differences subsequently result in varying manners of proceeding with the research and affect the final result.

3.1.1 Analytical Approach

One of the most commonly used approaches within supply chain management and logistic research is the analytical approach.[4] This approach studies the surrounding world objectively and considers it to be built up of independent parts that can be summarized to describe the whole. The different parts are also thought of as independent of the actors connected to them. To explain the surrounding world, the approach seeks to find causal relationships with given cause and effect.[5] The most appropriate method for this approach is quantitative data analysis, for instance statistical procedures, but for validation also qualitative methods can be used.[6] The analytical approach coincides with the so called positivistic approach to a high degree and actually originates from it. The positivistic approach claims that reality is objective, possible to decompose and tangible. Reality is understood by observing cause-effect relations and results obtained with the approach are considered to be unaffected by specific contexts and individual opinions.[7]

[4] Gammelgaard (2003): Schools in logistics research? A methodological framework for analysis of the discipline, p 488.
[5] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 80.
[6] Gammelgaard (2003): Schools in logistics research? A methodological framework for analysis of the discipline, p 481.
[7] Ibid, p 479.

3.1.2 Systems Approach

Unlike the analytical approach, the systems approach seeks to understand the surrounding world by objectively investigating systems of different elements. In contrast to the analytical approach, the systems approach considers the elements to be mutually dependent. The dependencies lead to synergies between the elements, which has to be taken into consideration when shaping the picture of reality.[8] A research performed using the systems approach aims to understand a specific system in the surrounding world by identifying system parts, links and goals. Theory used for this purpose is contextual rather than universal, as in the analytical approach.[9] Relations in the system are described and understood by connecting main driving forces of the system to the effects of the forces. An adequate method to use in a research with systems approach is case studies. A case study can involve both quantitative data gathering, from simulations etcetera, and qualitative from role plays or similar. The systems approach is also frequently used within logistic research.

3.1.3 Actors Approach

In contrast to both the analytical and systems approach with objective perspective, the actors approach perceives reality to be constructed of social contexts. In more detail, reality consists of socially constructed abstraction levels and is described by determining the importance of the different abstraction levels. The importance is affected by how individuals acting in the surrounding world interpret, act in and experience the different abstraction levels.[10] Preferably the researcher using the actors approach should study the focus area from within, in order to understand it. Studies should mainly be of qualitative character.[11]

The actors approach suggests that supply chain management must be understood and implemented differently depending on the organization in focus. This is an appropriate approach since supply chain concerns to a

[8] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 86.
[9] Gammelgaard (2003): Schools in logistics research? A methodological framework for analysis of the discipline, p 481.
[10] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 94.
[11] Gammelgaard (2003): Schools in logistics research? A methodological framework for analysis of the discipline, p 488.

wide degree depend on the surrounding environment. In spite of this, the approach is rarely used within logistic research.[12]

3.1.4 Chosen Approach for the Thesis

The mapping in *Part 1* is performed with an analytical approach since it describes the focus area by objectively investigating the parts shaping it. The parts are considered independent of each other and of individuals related to them. As an example, regulations are connected to the different transportation modes and are not related to each other, but presented and discussed separately to create a framework for the conditions the transport industry faces.

The case study in *Part 2* instead uses a systems approach. The case study on Lantmännen Maskin intends to objectively identify and analyze the logistic subsystem of interest to the thesis. Mapping of links and relations between the components in the subsystem helps to understand the system as a whole and to draw proper conclusions. The procedure of the thesis (excluding *Part 1*) follows the steps presented below, and the key words in each step is written in italics:

1. Making the choice of using a *case study* as method
2. Defining a *wider system*, in this case the supply of spare parts at Lantmännen Maskin
3. Limiting the scope further by defining *subsystems*
4. Identifying internal and external *components* in the subsystems, such as regulations and transport modes
5. Identifying *synergies* between the components in the subsystems, for example regulations and choice of transport modes
6. *Analysis* with starting point in the defined system
7. Drawing of *conclusions*, based on the analysis

3.2 Research Method

A method describes the procedure used when collecting, structuring and analyzing data. In contrast to the research approach, the methods may

[12] Gammelgaard (2003): Schools in logistics research? A methodological framework for analysis of the discipline, p 488.

differ between parts in the project depending on what is appropriate for the studied area.

3.2.1 Inductive, Deductive and Abductive Methods

The choice of which method to use should in part be based upon the abstraction level, which can be anything from very general to highly concrete.[13] When taking the relation between theory and empirical information into consideration, two main approaches can be identified: inductive and deductive methods. An inductive method has its origin in the collected, empirical data and tries to form more general and theoretical conclusions based on the data.[14] In contrast the starting point of a deductive method is the theory. Hypothesis are formed, based on the theory and if possible verified by the collected data.[15] Abduction is a combination of the earlier mentioned methods. The abductive method is a way to find causes for an observed state.[16] It has the same origin as the inductive method (the empirics) but instead of only moving towards the theories the abductive method circulates between the theories and the empirics. An illustration of the relation between theory and empirics in the different methods can be seen in Figure 3-1.

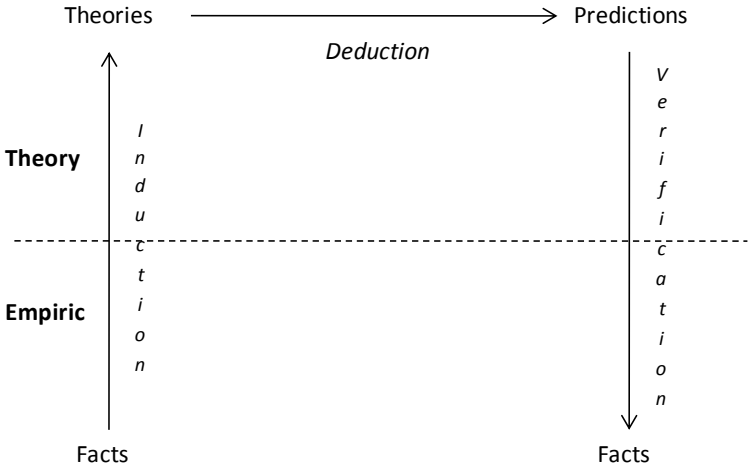

Figure 3-1. ***Illustration of inductive and deductive approach.***[17]

[13] Björklund & Paulsson (2003): *Seminarieboken,* p. 62.
[14] Wallén (1996): *Vetenskapsteori och forskningsmetodik,* p. 47.
[15] Björklund & Paulsson (2003): *Seminarieboken,* p. 62.
[16] Wallén (1996): *Vetenskapsteori och forskningsmetodik,* p. 48.
[17] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära,* p 107.

Initially in the project a theoretical base was required in order to identify which areas to target in the study, hence an inductive approach was rejected. Further, deductive methods were not applicable since the project does not originate in a hypothesis. Instead the abductive method was used. The authors' initial knowledge in the area of environmental sustainable supply chains was limited and the project began with a mapping of present and future environmental regulations in order to create an initial framework. This gave a useful understanding of the subject and served as basis when gathering empirical information. The initial theoretical framework was later complemented in order to follow up the empirical work.

3.2.2 Qualitative and Quantitative Studies

Depending on the aim of the study, qualitative or quantitative methods may be used. The difference between the two can be found in the nature of the collected data and the approach of the analysis.[18] A quantitative method gathers information that can be measured or estimated numerically and later analyzed in a statistical way.[19] A quantitative method is preferred if the study aims to result in generalizations. If the aim of the study is to create a deeper understanding for a specific subject, event or situation, a qualitative method is preferred.[20] Here the information mostly consists of words or pictures, often collected in interviews and by observation and the analysis is in a reasoning form.[21]

Mostly qualitative information will be used in the thesis since comparative quantitative data is difficult to obtain. Figures regarding transport costs are often unreliable and the variation between different companies is considerable. For the mapping made in *Part 1,* mostly qualitative information in the form of reports was used. For the case study both qualitative and quantitative information was used. A qualitative approach was used in the beginning in order to deepen the authors' understanding of the studied supply chain. Later on, quantitative data was gathered from Lantmännen Maskin's business system, enabling a deeper analysis of their

[18] Lekvall & Wahlbin (2001): *Information för marknadsföringsbeslut*, p. 213.
[19] Ibid.
[20] Björklund & Paulsson (2003): *Seminarieboken,* p. 63
[21] Lekvall & Wahlbin (2001): *Information för marknadsföringsbeslut*, p. 213.

specific situation. Worth remembering is that every supply chain is unique and comparison between different supply chains has to be done with great caution.

3.3 Procedure in Thesis

A very important part in a research project is the choice of method, therefore it was natural to start the project by making a plan and create an outline reaching over the entire time that the project covers. One recurrent activity in the project is meetings with our supervisors, where the produced material is presented and discussed. A number of different segments of activities can be identified from the project plan and an overall view of them can be found in Figure 3-2.

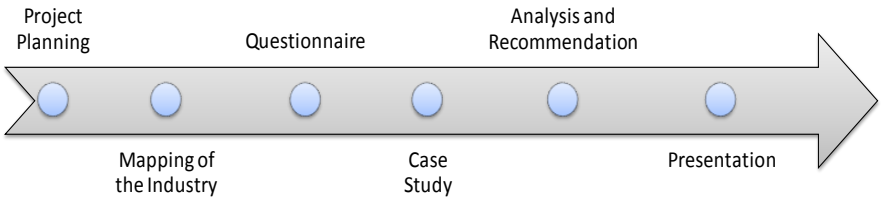

Figure 3-2. ***Outline of the master thesis.***

3.3.1 Data collection

Data can be either primary, where the data is collected directly from the source, or secondary meaning that the data is gathered and compiled for another context than the performed study.[22] When using secondary data it is particularly important to question the credibility of the source. One has to keep in mind that the material might be intended for another purpose and that it might be biased. Literature and seminars are examples of secondary sources while interviews, questionnaires and observations are ways of collecting primary data.

When wanting to map an area where existing knowledge is available a literature study is a good approach. It has the advantage of providing much information in a short period of time to a low cost. The downside is that the sources are secondary and that the aim and methods used are not always presented. Therefore it is very important to question the relevance

[22] Lekvall & Wahlbin (2001): *Information för marknadsföringsbeslut*, p. 212.

of the material.[23] This study started with a thorough literature study where publications made by the Swedish government and the European Union were the main sources. Since the studied system is dynamic it is very important to find sources that are up to date. It is also important to realize that some publications regarding the predictions of the future might be inaccurate, especially if the reality has changed since the publication was written. To complete the mapping in *Part 1* and to gain specific information, email correspondence with influencing authorities were carried out.

A questionnaire enables its creators to gather a lot of primary data with a relatively low amount of effort. A disadvantage of the method is the anonymity of the respondent and not knowing if he or she has the right knowledge in order to give the most accurate answers. There is also a risk of having too low answering frequency which might make the questionnaire unusable.[24] A small questionnaire was created in this study and handed out to Syncron's customers at the yearly User Summit in October 2008. The aim of the survey was to create an understanding of which environmental aspects Syncron's customers find most interesting, and which aspects they predict will have the most effect on their supply chains in the future. The formulation of the questions was of yes or no type and after each question the possibility of motivating the answer was given, which enables a comparative analysis of the answers.

Interviews give access to primary data with direct relevance for the study. It also enables a deeper understanding of the system since the questions asked can be adjusted to the situation and the respondent's previous answers. The disadvantage is that it is often very time consuming and sometimes also expensive due to travels.[25] Several interviews have been conducted during the course of the project, aiming to find the most accurate answers from the most appropriate persons. The interviews have been open in the sense that the respondent has been encouraged to speak freely and to give detailed answers.

[23] Björklund & Paulsson (2003): *Seminarieboken,* pp. 69.
[24] Ibid*,* p. 70.
[25] Ibid*,* p. 70.

3.3.2 Case study

A case study can be defined as *a research strategy which focuses on understanding the dynamics present within single settings.*[26] It is a suitable method when relatively unknown areas are to be examined and when the researchers have little or no control over the studied area. It is justified to choose the case study as a research method when the problem formulation consist of 'how' and 'why' questions regarding a contemporary set of events in a real life context.[27] An indirect aim of the study in this thesis is to extend the existing theoretical framework in the area of 'green' supply. Furthermore, the main aim of the case study is to answer the questions related to Lantmännen Maskin, presented in the problem formulation and repeated below.

- How can Lantmännen Maskin's supply chain be adapted to the changes in transport related regulations, in the sense that it is optimized with respect to environmental as well as economical aspects?
- With respect to Lantmännen Maskin, what additional costs are associated with new environmental legislations and how much can these costs be reduced, by modifying the supply chain?

A case study can include a single or multiple cases.[28] This case study will include one single case at Lantmännen Maskin. This choice will enable the study to deepen its focus and it will allow analysis of both quantitative and qualitative data. The limited time is another aspect when deciding on a single case in the study. Different supply chains have varying design and are affected by different factors, which make comparisons between different supply chains complicated. Such a study would demand a larger scope and more time.

Lantmännen Maskin is chosen as the case for this study for several reasons. Mainly it is because they are one of Syncron's customers, meaning that conclusions and recommendations might possibly have an impact on the update of Syncron's software and thereby also be implemented at

[26] Eisenhardt (1989): Building Theories from Case Study Research, p 534.
[27] Yin (2003): *Case Study Research – Design and Methods*, p. 9.
[28] Eisenhardt (1989): Building Theories from Case Study Research, p 534.

Lantmännen Maskin. Another reason for the choice is the design of their supply chain. It will most probably be affected by future environmental regulations, hence a proactive approach is preferable in order to lower future transport costs.

The data collection during a case study often combines several methods such as archive exploration, interviews, questionnaires and observations.[29] Primary qualitative data has been gathered through observations and through interviews with relevant persons at both Lantmännen Maskin and Syncron. Numerical (quantitative) data has been collected directly from their business system.

3.3.3 Analysis

The aim of the analysis is to answer the questions presented in the problem formulation. The first question is of more theoretical character and is answered by the framework given in *Part 1*. The second and third questions are answered with support from the case study. The theoretical framework, including both the mapping of the area and accepted logistics definitions, and the findings from the case study are combined in order to identify environmental and transport efficient solutions for the specific supply chain at Lantmännen Maskin.

The analysis made is primarily done in order to examine the sensitivity of the studied system. Costs and levels of today are compared to possible future developments within the studied area. How the system will be affected by different probable scenarios is discussed in order to give satisfying reasoning regarding the questions in the problem formulation.

3.4 Credibility

A convincing scientific study requires all choices, in any way related to the thesis, to be accounted for and the results to be well motivated in order to enable the reader to create his or her own opinion of the study's credibility. There are mainly three measures deciding the credibility of the study; validity, reliability and objectivity.

[29] Eisenhardt (1989): Building Theories from Case Study Research, p 534.

3.4.1 Validity

The validity of a study describes how well the chosen method actually measures the intended characteristics,[30] and it can be defined as *lack of systematic bias.*[31] A way of increasing the validity is to use several different methods examining the same phenomenon; called triangulation. A way to do this is by gathering information from different people and by studying a lot of secondary material.

During the thesis project discussions with the involved parties have been carried out regularly to ensure consistency regarding the purpose of the thesis. Therefore, a clear and steady objective was created and the content of the thesis was in line with the purpose, leading to high validity. Furthermore, calculations stem from general, accepted theories, commonly used in logistic research. The questionnaire used in order to get a picture of companies' attitude towards environmental concerns had well formulated questions without subjective features. The validity of the thesis was further increased by an extensive study of both primary and secondary sources.

3.4.2 Reliability

If a study is repeated and its findings are found to be coherent, the study has a high reliability.[32] A low reliability can be caused by several factors, such as difficulties using the measurement instruments and mere chance. A higher reliability can be obtained, for instance, by using control questions in surveys and by the use of triangulation. If a result or measure is valid, it is also reliable, whereas a reliable result or measure does not guarantee validity, which is illustrated in Figure 3-3. To the left in Figure 3-3 the reliability is high, but the validity is low. In the middle both validity and reliability are high and to the right neither validity nor reliability are sufficient.

[30] Lekvall & Wahlbin (2001): *Information för marknadsföringsbeslut*, p. 304.
[31] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 251.
[32] Lekvall & Wahlbin (2001): *Information för marknadsföringsbeslut*, p. 306.

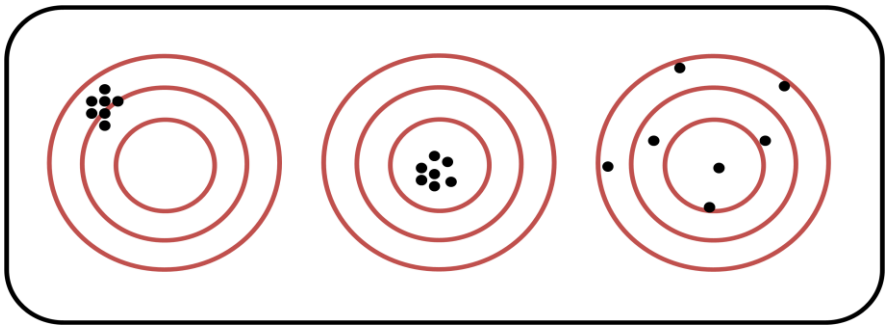

Figure 3-3. *Illustration of the dependence between the reliability and validity.*[33]

To obtain a high level of reliability, the data material and analysis have been studied by supervisors at both Syncron and Lund Institute of Technology in order to detect weak assumptions and statements. The performing of the thesis is well described to the reader, which enables the reader to assess the credibility of the presented material. To simplify the evaluation of the questionnaire it was designed using mainly yes or no answers. This also reduced the risk of misinterpreting the outcome. The reliability connected to the questionnaire could have been improved further by presenting the evaluation of the questionnaire to the persons who answered it and by trying to increase the answering frequency.

To ensure high reliability in the data material, several sources were used to investigate the coherency. Data gathered from Lantmännen Maskin's business system can be considered reliable. It is numerical and if someone else would have requested the same data, they would have received the same figures. Moreover, interviews were conducted with personnel, at Lantmännen Maskin, believed to be able to contribute with detailed and reliable information.

3.4.3 Objectivity

The objectivity of a study aims to describe to which extent personal opinions may affect the outcome of the study.[34] The objectivity is enhanced by presenting motivations for the choices made in the study and by clearly stating the references. If objectivity is not taken into

[33] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 250, revised version.
[34] Björklund & Paulsson (2003): *Seminarieboken*, p. 59.

consideration, the risk of obtaining false knowledge, due to biased results, emerges.[35]

The authors of this thesis have no previous connection to Syncron or Lantmännen Maskin, which is why no incentives for being subjective exist. The secondary sources essentially originate from fairly objective sources, well presented to the reader, such as authorities and accepted literature within the area. The authors were aware of the fact that a lot of the predictions regarding transport regulations are more or less uncertain and have tried to focus on the most realistic forecasts. Since the persons interviewed at Lantmännen Maskin could not be regarded as fully objective, several persons were interviewed to obtain different points of views.

[35] Arbnor & Bjerke (1994): *Företagsekonomisk metodlära*, p. 266.

4 Introduction – Part 1

A short introduction to Part 1 of the thesis is given in this section. The motive for separating Part 1 and Part 2 from each other is given and directives on how to treat the different parts are provided.

The increasingly obvious climate changes create severe concerns and are constantly subject for discussions all over the globe. Governments introduce new control mechanisms as they are trying to reach national environmental related goals. On the international scale, a vast cooperation is undertaken to decrease the environmental pollution. The transport industry has been highlighted as an important source to the increased emission of greenhouse gases. Therefore, this industry can expect changes in the near future as a response to new external conditions and the increasing environmental awareness. Such changes will involve many components of the supply chain, such as the transport planner, the transport buyer and the transport supplier. The logistics within the supply chain will have to adapt to new requirements.

The first part of the thesis includes chapters five through ten and is a mapping of existing and future economical control measures used to deal with the transport industry's huge contribution to the greenhouse effect. *Part 1* provides a thorough and detailed theoretical framework, which is closely connected to the case study in *Part 2*. In spite of this, the different parts can without problem be read independently of each other, since they separately contribute to the whole of the thesis.

If a deeper understanding of the interaction between environmental concerns and the transport industry is sought or if the reader has insufficient knowledge in this area, the authors recommend the reader to start with *Part 1* when studying the thesis. If the mapping in *Part 1* is the only section of interest to the reader, *Part 2* can be left out without loss of continuity.

Findings in *Part 1* answer the first question in the problem formulation and have given guidelines on where to focus attention when doing the case study. Furthermore, the content of *Part 1* was used as a pre study to a customer event Syncron organized in October 2008.

5 Today's Situation

In the following chapter a general overview of condition, trends and political incentives affecting the transport industry are presented. Today the surrounding world is incredibly dynamic and new factors with impact on transport performance emerge continuously.

Our earth is continuously getting warmer. During the last hundred years the average temperature has increased by 0.74 degrees Celsius.[36] Throughout the 20th century the average increase was 0.6 degrees, so the speed of the global warming has been intensified.[37] The largest reason for the global warming is the emission of greenhouse gases. About 70 percent of the greenhouse effect is caused by emission of CO_2.[38] Some of the other gases contributing to the effect are methane and nitrogen oxides. The gases have different impact on the atmosphere and in order to compare their effect a Global Warming Potential can be determined. It measures how much CO_2 that would have to be emitted in order to have the same greenhouse effect as the emission of the other greenhouse gases.[39]

The emission of CO_2 made in the transport industry amounts to 28 percent of all CO_2 emissions in the EU. 84 percent of the emission made in the industry comes from road transports and 13 percent comes from the aviation sector.[40] Forecasts reaching for 2020 are predicting an increase of freight transports by 21 percent.[41] With these numbers in mind the importance of actively addressing the environmental aspects connected to the transport industry, in order to lower the emission of greenhouse gases, can easily be understood.

5.1 Conditions and Trends

A trend within the transport industry is transportation of smaller volumes but over longer distances. One reason for this is the globalization of

[36] Intergovernmental Panel on Climate Change, IPCC (2007): Climate Change 2007: The Physical Science Basis.
[37] Ibid.
[38] Miljöportalen (2008): Växthuseffekt och växthusgaser – vad är det egentligen?
[39] Ibid.
[40] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[41] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.

production which is enabled by low costs on transportation of goods. Another reason for this is the customers' demand of always getting the right goods at the right time and location, often with a short time span.

To deal with environmental problems due to transport related emission and to be able to reach the environmental goals that have been set within the EU, shifts in means of transportation will be necessary. For instance, road transports will have to be reallocated to rail and water and air transports to rail without losing in efficiency and speed. Combinations of different means of transport, so called combined transports, must become more common.[42] Another approach to lower the transport related emission and reaching the environmental goals is to develop more energy efficient engines and increase the usage of renewable fuels which emit CO_2 that does not contribute to the greenhouse effect. In order to reach the environmental goals all approaches have to be explored thoroughly.

5.2 Environmental Agreements

The importance of treating the environment with respect has risen into awareness among the earth's population and the topic has high priority on the governors' agendas. Sweden, as a country, takes part in several international environmental agreements. Today more than 200 countries have signed the United Nations Framework Convention on Climate Change (UNFCCC).[43] This international treaty aims to prevent climate changes in the future and it has been valid since 1994. In 1997 several industrial countries signed the Kyoto Protocol, which is a more specified treaty. The European Union (EU) signed as a region and assured to lower the region's emissions of six specific greenhouse gases with 8 percent before 2012, compared to the emission levels in 1990.[44] Specific goals on the sizes of the emissions have been made within the EU for each member, due to its specific situation and capability.

The European Commission established the European Climate Change Programme in 2000, with the goal to ensure that the EU meets its targets

[42] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[43] The Swedish Environmental Protection Agency (2007): Förenta Nationernas ramkonvention om klimatförändringar.
[44] The European Commission (2008): Mål för Kyoto-avtalet i EU.

stated in the Kyoto Protocol. It aims to identify the most cost and environmental effective policies and measures that can be used in order to lower the level of greenhouse gas emissions. A second program was launched in 2005 in order to enable synergies between the lowering of emissions and the Lisbon Strategy, which is a revision of the existing EU treaty.[45]

During the spring of 2007, the European Council of Ministers decided on further environmental goals for the EU. The greenhouse gas emissions should be cut by at least 20 percent in 2020, again compared to the emission levels of 1990. Also the goal that the usage of renewable energy should stand for 20 percent of all energy usage in 2020 was set.[46] In order to reach the goals the European Commission launched a package of proposals. One part of the proposal discusses the present EU Emission Trading System (EU ETS), its future evolvement and ways of enforcing the directives.[47] The Swedish Environmental Protection Agency agrees with the package of proposals and has already presented possible actions and control measures to the Swedish government.[48]

The Swedish government has given the Swedish Rail Administration, the Swedish Energy Agency, the Swedish Civil Aviation Authority, the Swedish Environmental Protection Agency, the Swedish Maritime Administration and the Swedish Road Administration the task of developing a strategy for more Efficient Energy Use and Transport, the so called EET mission. The outcome of this mission contains several proposals on control measures which could be used in order to limit the transport and energy industries' negative effects on the environment. The EET-report from November 2007 gives a forecast on future levels of emission. The emission of greenhouse gases in Sweden is believed to increase until 2020. The main reason is increased road transports, but sea and air transports are also assumed to

[45] The European Commission (2006): EU Action against Climate Change, the European Climate Change Programme.
[46] The European Commission (2008): Kampen mot klimatförändringen ger ökad tillväxt och nya jobb.
[47] The Ministry of the Environment (2008): EU:s klimatarbete.
[48] The Swedish Environmental Protection Agency (2008): Yttrande över remiss från miljödepartementet angående EU kommissionens energi- och klimatpaket.

increase. Goals set in the report are to be realized before 2020.[49] The EET strategy aims to reach the environmental goals on a national level. The national environmental goals are set in accordance to international agreements, and they are all related.

5.3 Certificates and Markings

Environmental certificates can be applied on different levels in companies. An entire company may earn a certificate, such as ISO 14001. Another form of certificates is the ones connected to a specific product or service, for example Bra Miljöval and Svanen, whom both have started working with transport related markings. An active approach in environmental areas might not only bring positive effect to the environment but also to the company, as strengthened competitive force. Certificates of different kinds might render more contracts if the customer has environmental demands. A recently made survey shows that 85 percent of the Swedish companies that have introduced an environmental management system think that they have benefitted financially from it.[50]

5.3.1 Corporate Level

Environmental management systems function as an organizer of a company's environmental work. It makes it easier to prioritize goals, communicate and delegate responsibilities in aspects concerning the environment. The baseline for the systems is that the company fulfills the existing law and that they have a corporate environmental policy. The systems also require that the company documents its environmental work and has plans on how continuously improvements can be made. The systems have no requirements on specific levels, for example of emissions.

The most commonly used systems are ISO 14001 and EMAS (Eco Management and Audit Scheme). ISO 14001 is an international acknowledged standard for environmental management systems and the EU version, EMAS, is based on it. The main difference between the systems is that EMAS requires the company to publicly present its environmental

[49] Government Authorities (2007): Strategin för effektivare energianvändning och transporter, EET.
[50] Miljöbyrån (2008): Miljöcertifiering ISO14001:2004 – av affärsmässiga skäl.

work while ISO 14001 does not have that demand.[51] The future of environmental management systems is hard to predict, but since the environment is on the agenda it is likely that the importance of working systematically with environmental questions and improvements will only increase.

5.3.2 Product and Service Level

Bra Miljöval is the only independent certification on transportations in use today and it makes several demands with a lifecycle perspective. The demands concern emissions, energy usage and elimination of old vehicles. Specific levels of admitted emissions for long distance transportation must be fulfilled in order to get a transportation certificate. The combined maximum emission level of nitrogen oxide and sulphur oxides is 0.20 grams per ton kilometer. The corresponding level for carbon hydrogen is 0.01. There is also a set limit for the usage of fossil based energy of 0.10 kWh per ton kilometer.[52]

The environmental certification Svanen is about to launch the first marking on environmentally friendly fuel in the world. The thought behind the labeling is that the fuel should have significantly lower impact on the environment compared to other fuels on the market. The marking will point out the best alternatives among ethanol, biodiesel, biogas and other mixtures. It will consider the entire chain from raw material to the pump at the gas station. Moreover, the marking considers the CO_2 emissions both during the production and usage of the fuel and a combined maximum level is set. Svanen hopes to make the marking available to the customers during the fall of 2008.[53]

5.4 Euro Classifications

Since most emissions from the transport industry come from the road sector, most effort is put on how to reduce the emissions from trucks. In Europe, emission levels from heavy trucks' engines are regulated since

[51] The Swedish Agency for Economic and Regional Growth (2007): Mer om ISO 14001 och EMAS.
[52] The Swedish Environmental Protection Agency (2005): Godstransport – Kriterier för Bra Miljöval-märkning.
[53] Svanen (2008): Världens första miljömärkning av drivmedel.

1982, which was the year when limitations on emission of nitrogen oxides, carbon oxide and hydrocarbons were established for the first time.[54] A few years later a limitation on emission of particles was included and through the years the requirements on emissions from new engines have become more and more strict. Today there exist five different Euro classes, each with different requirements on emission levels. The latest class, Euro 5, will be compulsory from October 1st 2009 and includes decreased levels of emission of nitrogen oxides compared to Euro 4. The exact emission limits can be seen in Table 5-1. Several of the economic control measures that will be presented later in the report are differentiated on the basis of which Euro class they belong to.

Class	Compulsory from	NO_x g/kWh	Particles g/kWh	HC g/kWh	CO g/kWh
Euro 0	1990	14.4	-	2.4	11.2
Euro 1	1993	8.0	0.36	1.1	4.5
Euro 2	1996	7.0	0.15	1.1	4.0
Euro 3	2000	5.0	0.10	0.66	2.1
Euro 4	2005	3.5	0.02	0.46	1.5
Euro 5	2009 October[55]	2.0	0.02	0.46	1.5

Table 5-1. *Emission limitations on new heavy truck engines according to the Euro classification.*[56]

5.5 Limitations

Apart from political regulations and economical control measures, other limitations arise within the transportation industry due to the increased demand on transports. The increase will for instance cause a shortage of people working in the transportation industry. Each year, for the next five years to come, the Swedish transportation industry needs to recruit somewhere between 15 000 – 17 000 persons each year in order to

[54] Schenker (2005): Euroclass.
[55] Preem (2008): Nyheter och information om smörjmedel.
[56] Schenker (2005): Euroclass.

replace retirements and the increased demand of transports. Today the number of newly educated people in the transportation industry is 7 000 which causes a shortage of at least 8 000 positions every year.[57] Looking at the haulage sector alone, it will need to recruit approximately 5 000 – 7 000 persons each year, consequently a shortage of truck drivers will arise in the near future. This will lead to more expensive road transports and a higher demand than supply. Other sectors within the transportation industry will also experience a shortage of labor, especially of railway engineers and grounds staff at airports.

Moreover the infrastructure plays an important part as a limitation of transportation possibilities. An increased use of trucks will result in congestions on the road networks. The limited existence of rail and the already high usage level of the existing rail is another transport limitation due to infrastructure. Yet another infrastructural limitation is the lack of supporting infrastructure when it comes to combined transports. For instance, the road network in the surroundings of a rail freight terminal must be adjusted to support heavy truck transports. As the demand of transports increase and new economical control measures are implemented, the industry might discover new limitations.

[57] TransportNäringen i samverkan (2008): Rekrytering i transportnäringen – en jobbfråga i tiden.

6 Economic Control Measures

Taxes, fees and other transport related regulations and restrictions are identified and described in the section below. All of these are more or less affected by political measures to reduce the greenhouse effect by penalizing emission sources.

One approach when trying to fulfill different environmental goals is to establish economic control measures. The measures can be run on different levels; the ones presented in the following sections consider environmental related economic control measures on national and EU level. Measures on national level consist mainly of different fees and taxes while the main measure on EU level is the emission trading system. In addition to this comes the fuel price, which also in part can be used as a control measure.

6.1 Environmental Fees and Taxes

Fees and taxes based on environmental aspects in the transport industry can be split up between the different means of transport (road, rail, aviation and maritime), and they will be presented separately in this report. Emphasis will be put on the most significant fees and taxes with the largest impact on the transport industry in the present and nearest future.

6.1.1 Road Transport

The main environmental problem connected with trucks is the CO_2 emission. In the EU, freight transports on roads cause 84 percent of the transport industry related CO_2 emission. To deal with this problem, numerous control measures exist or are about to be introduced. The most common fuel used for trucks is diesel, and a truck approximately consume 4.5 liter diesel per 10 kilometers, which is equivalent to an emission of 11 kg of CO_2 for that same distance.[58]

In the EU 44 percent of all goods transports are performed with trucks.[59] Looking at Sweden only, almost half of the turnover in the transportation

[58] The Swedish Road Administration (2004): Underlagsrapporter till klimatstrategi för vägtransportsektorn.
[59] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.

industry lies within road transports.[60] One can easily draw the conclusion that truck is the most frequently used mean of transportation. This can be explained by its high grade of flexibility and relatively low price. Lately the use of road transports has increased immensely due to new trends within the manufacturing industry, such as outsourcing and placing production on geographically distanced places but to significantly lower costs. Because of the characteristics of the truck, it is often preferred when forwarding the goods in the supply chain. This attitude must be prevented in order to reach the environmental goals member states in the EU have agreed on. By introducing new or modifying existing economical control measures directly related to the emission of CO_2, the politicians hope to achieve a moderation of the increase. The most striking fees and taxes for the road sector are presented below.

Eurovignette Directive

The Eurovignette Directive is an agreement between Denmark, Sweden and the BENELUX-countries regarding road fees for motor vehicles used for goods transports. To be allowed to use the road infrastructure in the included countries, a certain road fees must be paid. The size of the fee is decided within each country and can vary depending on the type of vehicle (for example the number of axes on the vehicle) and the European environmental class to which the vehicle belongs. A cap of how large the yearly fee is allowed to be is set within the directive. All trucks with a total weight exceeding 12 metric tons are obliged to pay the fee when using the road networks in Sweden, Denmark or the BENELUX-countries. From 2012 this limit will be decreased to 3 500 kg.[61] After 2010 all fees must be differentiated with respect to Euro classification.[62] Countries are free to decide whether the fee is depending on distance or is fixed for a whole region. They can also choose to charge for using only a certain part of the network (for instance the highways), but are allowed to charge for using any part of the national network, such as smaller rural roads.

[60] SIKA (2008): Transportbranschen.
[61] The Ministry of Industry (2008): Faktapromemoria – Direktiv om vägavgifter för tunga lastbilar.
[62] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.

Swedish trucks pay a yearly fee to use the roads in the Eurovignette countries. In Sweden the fee is depending on the Euro Classification and on the number of axes that the vehicle has. The highest fee is paid by vehicles with four or more axes belonging to Euro 0, which in 2008 was 14 117 SEK per year.[63] The lowest fee is 6 831 SEK per year, paid by Swedish two or three axed vehicles belonging to Euro class 2, 3, 4 or 5.[64] The payment from Swedish trucks is considered a tax and is therefore controlled by the Swedish Tax Authorities. Non-Swedish vehicles also pay the Eurovignette fee and it can be paid for one day, one week, one month or one year.[65] In Sweden the incomes from the Eurovignette fee are approximately 600 million SEK per year.[66] Trucks with higher Euro classification pay the same fee as Euro 2, but a suggestion of a further diversification is under ratification at the moment.[67]

Germany was included in the cooperation until 2003 but from 2005 they instead charge a kilometer tax for vehicles using the German road infrastructure, a system that is not compatible with the Eurovignette Directive. The kilometer tax system will soon be described more closely.

Motor Vehicle Tax

Since 2006, motor vehicle tax in Sweden is CO_2 differentiated and it is paid on a yearly basis. This means that a vehicle that emits a smaller amount of CO_2 per kilometer pays less tax. If the vehicle is adapted to be able to use other more environmental-friendly fuels, the tax gets even lower. Other factors that influence the taxation level are weight, number of axes, Euro class and towing device. For Swedish trucks that are obliged to pay the Eurovignette fee, the motor vehicle tax is reduced.

A proposal from The Swedish Energy Agency and the Swedish Environmental Protection Agency is to make the CO_2 differentiation for

[63] The Swedish National Tax Board (2008): Vägavgift för svenska tunga fordon.
[64] Ibid.
[65] The Swedish National Tax Board (2008): Vägavgift för utländska tunga fordon.
[66] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.
[67] The Ministry of Finance (2008): Promemoria om höjd vägavgift m.m.

vehicles even stricter in order to lower emission and help reaching the emission target for 2020.[68]

Carbon Dioxide Tax

Fuels like petrol and diesel are charged with both a carbon dioxide tax and an energy tax. Directives from the EU control the minimum tax level for fuels. In 2007 the carbon dioxide tax in Sweden was 0.93 SEK per kg emitted CO_2which is equivalent to 2.16 SEK per liter for petrol and 2.66 SEK per liter for diesel since diesel contains more carbon than petrol.[69] One liter of regular petrol emits 2.21 kg of CO_2 while one liter of diesel emits 2.41.[70] Since 2000 the carbon dioxide tax has risen (see Figure 6-1) while the energy tax has decreased. This can be explained by the government's desire to keep a relatively constant total taxation level. Today, in 2008, the carbon dioxide tax for diesel amounts to 2.88 SEK per liter and 2.34 SEK per liter for petrol.[71] In the future this tax might be varying with the amount of CO_2 emitted by the vehicle, if methods for separation the CO_2 from the emission are developed. Today no such methods are implemented for transport emission.

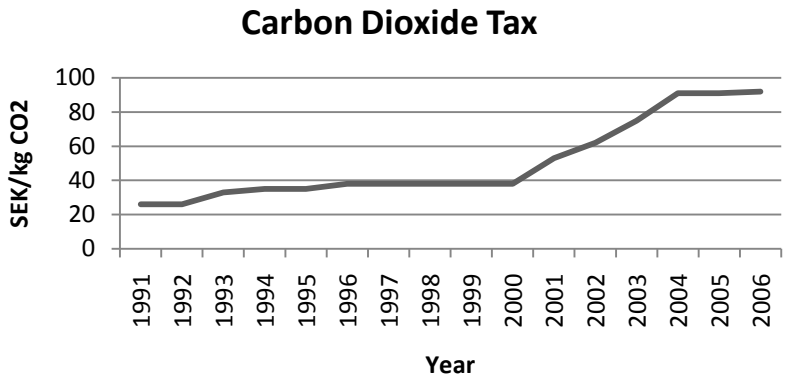

Figure 6-1. ***The growth of the carbon dioxide tax between 1991 and 2006.***[72]

[68] The Swedish Environmental Protection Agency & the Swedish Energy Agency (2007): Styrmedel i klimatpolitiken, delrapport 2.
[69] Ibid.
[70] Miljöbörsen (2008): Köpa Utsläppsrätter.
[71] SIKA (2008): Vilken koldioxidskatt krävs för att nå framtida utsläppsmål?.
[72] The Swedish Environmental Protection Agency & the Swedish Energy Agency (2006): Ekonomiska styrmedel inom miljöpolitiken. Revised version.

The carbon dioxide tax would have to be increased to 1.5-2.0 SEK per kg emitted CO_2 in order to be able to reach the transport related targets on emissions before 2010. This is a doubling of the current carbon dioxide tax and it is equivalent to an approximate price increase of 2.5 SEK per liter fuel.[73]

Energy Tax

Energy tax is paid on fuels depending on what environmental classification they belong to.[74] Today, in 2008, the energy tax on diesel is 1.28 SEK per liter and 2.95 SEK for petrol.[75] The underlying reason for this is to create even taxes on fuels (carbon dioxide and energy tax combined) for diesel and petrol. Heavy trucks are the most common consumer of diesel and some of these run international, which makes it possible for them to refill diesel abroad if the energy tax for diesel would increase in Sweden. Instead a kilometre tax for diesel trucks would be preferable, so that the tax is paid where the emission actually arises. In spite of this, an increase of the energy tax to 2.22 SEK per liter within five to six years is discussed.[76]

In order to compensate for the external costs for heavy vehicles operated with diesel (excluding the costs for CO_2 emission) the energy tax would have to increase with 2.4 SEK per liter according to a study made by Swedish Institute for Transport and Communications Analysis. [77] Another study states, however, that the energy tax on diesel would have to increase with 2.5-3.0 SEK per liter for trucks used in rural areas and more than 7 SEK per liter for trucks used in urban areas to compensate for the generated costs.[78] The two studies may not agree on the level of the energy tax needed to cover the external costs, but they do agree that it has to be higher than today's level.

[73] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.
[74] The Swedish Environmental Protection Agency & the Swedish Energy Agency (2007): Styrmedel i klimatpolitiken, delrapport 2.
[75] SIKA (2008): Vilken koldioxidskatt krävs för att nå framtida utsläppsmål?.
[76] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.
[77] SIKA (2007): Kilometerskatt för lastbilar – Kompletterande analyser.
[78] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.

Kilometer Tax

Today several countries in the EU have or are about to introduce a kilometer tax system in order to decrease the amount of road transports and thereby the congestions, costs for maintaining the road network and emissions of greenhouse gases. Countries already using kilometer tax as a control measure are Switzerland, the Czech Republic, Austria and Germany. The Netherlands are about to introduce it and will no longer be taking part in the Eurovignette cooperation. The United Kingdom, Russia and Slovenia are discussing an introduction.[79]

Kilometer tax is an efficient control measure, which is why Sweden probably will adopt this system in a near future as well.[80] A kilometer tax is not compatible with the Eurovignette Directive, since they have the same purpose; to decrease extern costs connected to noises, road wear down and emission. Therefore, the Eurovignette Directive would have to be revoked if the kilometer tax system was to be established. To create a feeling of how much the usage of the road network costs, the tax level would be equivalent to the external costs road transportation give rise to. Today this cost averages 1.08 SEK per kilometer in rural areas and 2.85 SEK per kilometer in urban areas.[81] Initially the tax would be kept low to prevent the consequences for industrial companies to be too radical. Eventually the tax would be adjusted to real costs and vary depending on the weight of the vehicle and the environmental classification of the vehicle.[82] The tax might also vary depending on what road area the vehicle is using; urban or rural. According to an investigation dealing with an introduction of a kilometer tax system, a kilometer tax on 1 SEK per kilometer would give rise to about 5-8 percent higher costs for heavy vehicles.[83] To cover the external costs caused by heavy trucks, excluding cost for CO_2 emission, the kilometer tax would have to be 1.4 SEK per kilometer, but since the energy tax accomplishes for some of these costs, 1 SEK per kilometer is sufficient when driving in rural areas. In contrast to

[79] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.
[80] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.
[81] SIKA (2007): Kilometerskatt för lastbilar – Kompletterande analyser.
[82] SIKA (2008): Kilometerskatt för tunga fordon.
[83] SIKA (2007): Kilometerskatt för lastbilar – Kompletterande analyser.

that, the tax would have to be 2.8 SEK per kilometer for urban areas.[84] The different tax levels presented in this section are all given in the price level of 2001.

The Swedish Institute of Economic Research opposes the proposition of a kilometer tax system and claims that it would not have the desired effect unless a kilometer tax on 7 SEK per km is introduced.[85] A comparison between the levels of the kilometer tax in countries where the system is used can be seen in Table 6-1. It gives an idea about how high a future tax in Sweden could be.

	Germany	Austria	Switzerland
Kilometer tax per km	0.12 €	0.22 €	0.67 €

Table 6-1. *Average kilometer tax levels in the countries using the system today.*[86]

The Swedish Tax Agency suggests that the kilometer tax should be introduced at the latest 2011 if certain assumptions are met.[87] For example, the income from the system must of course be greater than the costs for maintaining the system.

An introduction of a kilometer tax would increase the transport cost for transporting companies and subsequently for the companies using their services. A reaction to the increased cost will presumably be changes in the transportation routines. These changes include: [88]

- increased utilization ratio of the trucks
- different kind of vehicle fleet including bigger vehicles which are more adjustable to different kinds of loads
- more use of sea and rail
- development of vehicles emitting less gases, for instance with systems that help driving more efficient
- reduced demand for transports

[84] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.
[85] The National Institute of Economic Research (2008): En samhällsekonomisk granskning av Klimatberedningens handlingsplan för svensk klimatpolitik.
[86] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.
[87] SOU (2008:24): Skatteverkets yttrande om Svensk klimatpolitik.
[88] SIKA (2007): Kilometerskatt för lastbilar – Kompletterande analyser.

- increased usage of trucks of weight less than 3 500 kg, since those probably not will be comprised by the kilometer tax system

6.1.2 Railway Transport

The share of freight transports using rail decreased from 21 to 8 percent between 1970 and 2003 within the EU.[89] Today the ratio has increased a couple of units.[90] The ratio in Sweden is significantly higher with its 24 percents.[91] Railway engines using diesel represent 4 percent of the freight transports as a whole in Sweden and these are making almost all emission of CO_2 that originates from the railway sector. But the emissions made are negligible in comparison to those from other means of transportation[92], at least in Sweden where renewable energy is used for railway engines for the most part.[93] Since 2003 all electrical energy used has been renewable and originates from water and wind power. Since the emissions of greenhouse gases are so insignificant, there are no overall environmental-related fees or taxes with the aim of reducing them. Since 2007 only railway engines using diesel as a fuel have to pay a fee for their emission of nitrogen oxides and CO_2.[94] The aim of the fee is to promote electricity based engines and the decision was made on EU level.

The railway sector's main goal is to seize market shares from the road sector. In order to do that, capacity has to be available on the rails, which is a problem at some distances where passenger and goods trains are sharing rails.[95] Other problems with railway transports are the low speed (only 18 kilometers per hour on average for international goods trains that cross the EU-region), unreliable delivery times and week system integration

[89] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[90] The European Commission (2006): Hållbara transporter för ett rörligt Europa.
[91] The Swedish Rail Administration (2007): Uppföljning mot de Nationella Miljökvalitetsmålen.
[92] Ibid.
[93] Green Cargo (2007): Green Cargo Systemtransport.
[94] The Swedish Rail Administration (2007): Uppföljning mot de Nationella Miljökvalitetsmålen.
[95] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.

between standards used in different countries.[96] A recently made study by The Swedish Rail Administration predicts an unchanged ratio of the railway sector's market shares compared to the rest of the transport industry in 2020, assuming that the suggestions made by the Swedish Rail Administration on the infrastructure development are carried out.[97] This corresponds to an increase by 24 percent of freight transports on rail, since the transport industry in all will increase.

6.1.3 Aviation Transport

The main environmental aspect for the aviation sector is the emissions of CO_2, but several other emissions also have effects on both global and local level.[98] Air transports cause about 2 percent of the CO_2 emission in Sweden,[99] which corresponds to just over 10 percent of the CO_2 emission made in the transportation industry. The emission level for the EU is of the same magnitude.[100] In contrast to this is the actual transported distance, where the aviation sector only produces 0.1 percent of all freight transports made within the EU.[101] When comparing emissions made per transported distance, the air freight is not an environmentally friendly mean of transport. The technical development is continuously reducing the negative environmental consequences but at the moment several control measures are in action to control the current situation. The most interesting and likely changes in the future are the ones related to emissions, which are presented below.

Emission Fees

For planes departing from an airport owned by the Swedish government a fee for emission of nitrogen oxides is charged. The fee system is differentiated due to the actual emission made by the airplane. A possible

[96] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[97] The Swedish Rail Administration (2007): Uppföljning mot de Nationella Miljökvalitetsmålen.
[98] The Swedish Environmental Objectives Council (2007): Luftfartsverkets miljömålsarbete.
[99] The Swedish Civil Aviation Administration (2008): Flyget och klimatpåverkan.
[100] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[101] The European Commission (2006): Hållbara transporter för ett rörligt Europa.

future development is to charge the fee at all Swedish airports.[102] This fee is supposed to function as an incentive for airlines to buy new, 'greener' airplanes when renewing their fleet. Only Great Britain and Switzerland have corresponding fees. A study has shown that the emissions made at airports charging this fee is not lower than at other airports. Airlines have bought greener planes anyways. The effect of this fee is therefore very hard to quantify.[103]

Another fee related to emission of nitrogen oxides is the starting fee. The starting fee is supposed to cover maintenance of the airport and security, but if the airplane weighs over 5 700 kg it also has to pay for its emissions.[104] The fee is determined based on the actual emission made during landing, takeoff, approach and taxi.[105] There are discussions of introducing a carbon dioxide fee as well, but a possible design of it has not yet been presented. If this fee was to be introduced it would probably only be in use until the inclusion of the aviation sector in the EU ETS in 2012, which will be discussed closer in chapter 6.2.[106]

6.1.4 Maritime Transport

The maritime transport causes almost 40 percent of the entire flow of goods in Sweden[107] and the ratio is the same when looking at EU level.[108] When looking at the volume of traded goods between the EU and the rest of the world almost 90 percent is shipped by boat.[109] The largest environmental concerns for the maritime sector are the emissions of nitrogen oxides and sulphur oxide; hence the focus of the control measures is shifted compared to road transports. The maritime sector is the single largest emitter of nitrogen oxides and the second largest when it

[102] The Swedish Environmental Objectives Council (2007): Luftfartsverkets miljömålsarbete.
[103] Ibid.
[104] The Swedish Civil Aviation Administration (2008): LFVs avgifter.
[105] The Swedish Civil Aviation Authority (2007): Avgift för utsläpp av kväveoxider (NO_x).
[106] The Swedish Environmental Objectives Council (2007): Luftfartsverkets miljömålsarbete.
[107] SIKA (2008): Sjötrafik 2008 – kvartal 1.
[108] The European Commission (2006): Hållbara transporter för ett rörligt Europa.
[109] Ibid.

comes to sulphur oxide in Sweden.[110] Since CO_2 is the most prominent of the greenhouse gases, the emissions from the maritime sector have been disregarded to some extent.

There are several fees and taxes in use today to regulate the emissions in the maritime sector. Most of them will probably be intensified in the years to come, but not to the degree that it will cause a large impact on the total cost of shipping. Several of the regulations used today are differentiated depending on the sulphur level in the fuel and the ships capability of reducing its emission of nitrogen oxides.[111] No major changes in the economical control measures due to environmental aspects are to be expected in the near future.

6.2 Emission Trading System (ETS)

The EU emission regulations were formed in order to enable fulfillment of the Kyoto Protocol and at the moment it regulates the emission of CO_2. What distinguishes emission trading from most other economical control measures is the steering towards a total combined emission level. The costs of getting there are often very hard to predict. The system focuses on specific sectors which have large emissions, such as the power and heat generation industry and selected energy-intensive sectors.[112] The transport industry is not incorporated in the ETS at the moment. The included industries cover about 50 percent of the EU's total CO_2 emissions and around 40 percent of its entire greenhouse gas emission.[113] Concerned companies may, instead of buying extra emission allowances and develop existing factories, take other actions in order to lower their calculated emission level. Possible ways of doing this is by Joint Implementation (JI) and Clean Development Mechanism (CDM). A JI mechanism finances an emission reduction project and takes place in a country which has requirements of emission reduction (included in the Kyoto Protocol) while a CDM takes place in a developing country. Planting trees, increasing

[110] The Ministry of Industry (2008): En miljövänlig sjöfart.
[111] The Swedish Maritime Administration (2007): Farledsavgifter.
[112] Svensk Författningssamling, SFS (2004): Lag (2004:1199) om handel med utsläppsrätter.
[113] The European Commission (2007): EU Action against Climate Change, EU Emissions Trading — an Open System Promoting Global Innovation.

energy efficiency and lowering pollution from factories are examples of possible CDM projects.

Most allowances are free of charge and portioned out among the affected companies on national level. The cap of the system (number of allowances) will decrease every year in order to lower emission so that the European emission goals can be met. One allowance corresponds to one metric ton of CO_2 emission. Each year the companies have to account for their emissions and usage of allowances. If a company's emission is larger than stated on the allowances the company has to pay a fee of 40 EURO per extra emitted ton of CO_2. This fee will increase to 100 EURO for emissions made during 2008.[114] The price of the allowances, when trading, has been varying quite a lot since the introduction in 2005, see Figure 6-2. The distinction between phase 1 and 2 allowances is their usage period. Phase 2 allowances are usable from 2008-2012 and the phase 1 allowances are now too old.

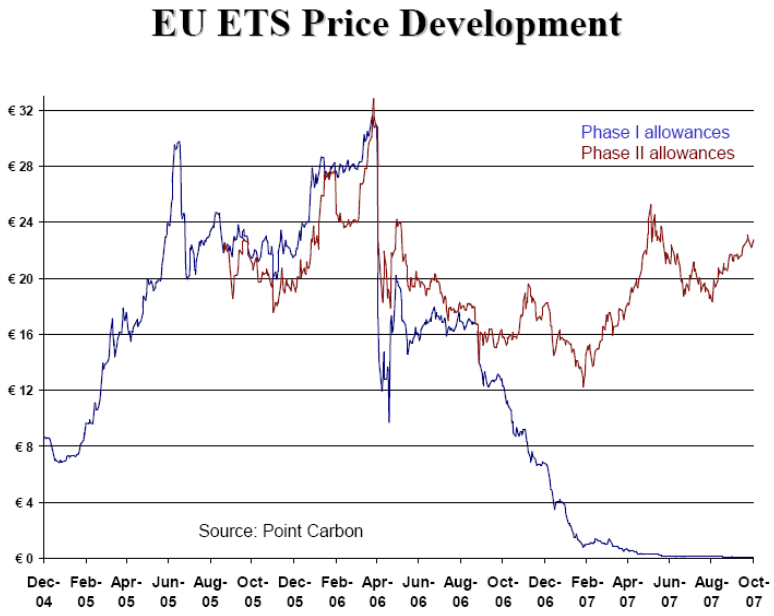

Figure 6-2. ***The price development of EU ETS allowances.***[115]

[114] The Swedish Environmental Protection Agency (2008): Överlämning av utsläppsrätter.

[115] Zapfel (2008): The EU Emission Trading Scheme (EU ETS), originally taken from Point Carbon.

The EU ETS will develop in several ways in the years to come. There are plans on expanding the system to also include nitrogen oxide within the closest time frame. Inclusion of the aviation sector in the CO_2 emission regulations in 2012 is another step. There are also proposals for 2013, from the European Commission, to broaden and strengthen the EU ETS to ensure its future role in the carbon market.[116] Also an investigation concerning the inclusion of the maritime sector has been conducted recently by Swedish authorities, on request by the Swedish Government.

6.2.1 Inclusion of the Aviation Sector

The CO_2 emission from aviation has increased by 87 percent since 1990 and it is not unlikely that the level of today will double before 2020 if no actions are taken.[117] An attempt to stabilize and reduce the emission on European level is the inclusion of the aviation sector in the EU ETS. All aviation traffic within the EU and flights with only takeoff or landing within the EU will be included in the EU ETS in 2012.[118] The system will not make any distinction between domestic and international flights.[119] The responsibility of meeting the obligations stated by the system will be put on the aircraft operators. To ensure a reasonable amount of administration for the operators and to avoid excessive work, a member state of the union will be responsible for specific aircraft operator's actions within the EU ETS. The administration of an aircraft operator will not be split among several member states.

The total amount of emission allowances will be based on the average emission level of 2004-2006. 85 percent of the emission allowances will be divided among the aircraft operators for free while the remaining part will

[116] The European Commission (2007): EU Action against Climate Change, EU Emissions Trading — an Open System Promoting Global Innovation.
[117] The European Parliament (2008): MEPs to debate putting aircraft emissions in trading scheme.
[118] The European Parliament (2008): MEPs and Council Presidency reach deal on airline emissions.
[119] The European Commission (2006): Förslag till Europaparlamentets och Rådets direktiv om ändring av direktiv 2003/87/EG så att luftfartsverksamhet införs i systemet för handel med utsläppsrätter för växthusgaser inom gemenskapen.

be auctioned out.[120] The European Commission strongly recommends that the revenue from the auctions should be used in related climate work. The aircraft operators will be able to purchase emission allowances from other sectors included in the trading system, and vice versa. The inclusion of the aviation sector in the existing EU ETS will not render too many new and extra administrational costs since the system is already in use today.

6.2.2 Inclusion of the Maritime Sector

Recently, several Swedish authorities carried out an investigation on a future possible Emission Trading System for the maritime sector. One purpose with the investigation was to see if a trading system could be more cost efficient than other economical control measures when it comes to lowering emissions. The system would include emissions from nitrogen oxides and sulphur oxides since these are most damaging when it comes to acidification and over-fertilization aspects. A challenge with a possible trading system is the complexity of combining emission made at sea and those made on land in connection to sea freight. A functional trading system for the maritime sector would enhance the chances of preserving the marine environment in the Baltic Sea.[121]

The investigation has focused on a geographically limited area; the Baltic Sea and the North Sea. But a larger international trading system would be preferable, due to different aspects of scale economy. If a system would operate only on national level, the maritime sector in that country might suffer volume losses if shipping companies choose other nearby ports to escape the emission trading system. The Baltic Sea is a possible area for a pilot project on a maritime emission trading system, since it is geographically limited and all adjacent countries are members of the EU except Russia. The investigators do not find a full scale introduction of a maritime emission trading system within the EU a likely future path,

[120] The European Parliament (2008): MEPs and Council Presidency reach deal on airline emissions.
[121] SIKA (2007): Infrastrukturplanering som en del av transportpolitiken.

because of the southern EU members' minor engagement in environmental questions.[122]

6.2.3 Complement of the EU ETS

Even though the transportation industry is not included in the EU ETS at the moment, it is not neglected. The EU has several other programs and goals regarding emissions due to transportation of goods. Some of the programs are economical control measures, such as the Eurovignette Directive, kilometer taxation and support of fuel diversification.[123] A diversification of the fuel usage aims to decrease the usage of fossil fuels and increase the usage of renewable ones. Another type of program is the Marco Polo Programme, which founds projects that help shifting the choice of transportation mode from road to rail and water. The program will be discussed more thorough later in this report.

6.3 Fuel Price

Since as much as 98 percent of the transportation industry is dependent on oil, its price has large impact on the industry. The fluctuating price of today stimulates development of new solutions, such as higher energy efficiency, diversification of fuel usage and political measures.[124] The price on oil can be seen as an economical control measure in the sense that a few actors make most decisions on the market. However, it is questionable if their decisions are made from an environmental point of view.

The fuel price for the customer depends not only on the actual oil price but also on the taxes and the gross margins taken by the seller. Figure 6-3 shows the ratio between the different parts of the sales price for diesel. As can be seen, the fuel tax and the diesel's purchase price sums up to almost the entire selling price.

[122] The Swedish Maritime Administration (2007): Handel med utsläppsrätter för svavel- och kväveoxider inkluderande sjöfart – redovisning av gemensamt regeringsuppdrag.
[123] The European Commission (2007): EU Action against Climate Change, EU Emissions Trading — an Open System Promoting Global Innovation.
[124] Europeiska kommissionen (2006): Hållbara transporter för ett rörligt Europa.

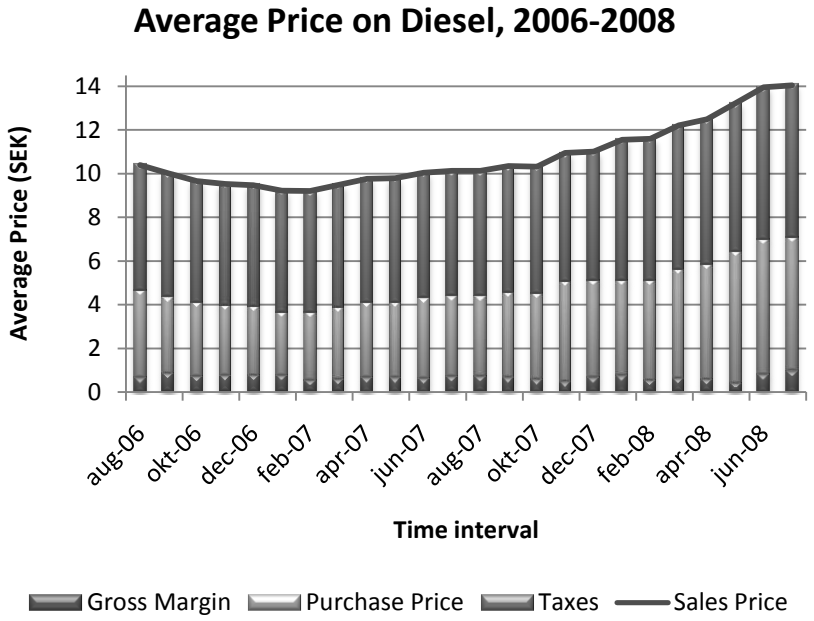

Figure 6-3. *The average price on Diesel in Sweden over the last 24 months.*[125]

In September 2008 the oil price was about $100 per barrel.[126] How it will evolve in the future is hard to predict and it depends on many different factors. One of the factors is the value of dollar relative other currencies. Most experts in the area agree that the oil price will increase substantially in the long run, but when it comes to how high the increase will be and the scaling of the time axis their opinions diverge; only more or less well motivated guesses exist. One aspect that speaks for an increase of the price in the future is that the supply of oil is limited. A couple of Swedish experts believe that the price will stabilize on in average $100 per barrel in the closest future. They do emphasize that there are forecasts guessing on anything between $50 and $200, so the predictions are not very reliable.[127] Another factor that affects the price is the demand. An example of this is that severe recessions lower the demand and also the price. Another example is a decrease in demand due to higher efficiency and alternative sources of energy.

[125] The Swedish Petroleum Institute (2008): Dieselpriser, månadsvärden. Adapted figure.
[126] The Swedish Petroleum Institute (2008): Brent råoljepris.
[127] Dagens Industri (2008): Experter: Så kommer oljepriset att utvecklas.

7 External Methods of Adaption

By adapting the infrastructure, shifts in means of transportation can be enabled and motivated. New technology is vital for reducing the emission of greenhouse gases. External incentives within those areas are presented and explained beneath.

All of the control measures presented in chapter six clearly put pressure on companies, especially those with an extended supply chain. In order to simplify the adaption of the supply chains and to make sure that the adaption moves in the intended direction, modified and new technologies are continuously developed. Mainly companies, governmentally supported projects and other organizations related to environmental concerns are taking part in the progress.

7.1 New Technology

To make transports less damaging for the environment, modifications of existing and development of new vehicles, engines and fuels are in progress. The most significant technologies and modifications are introduced below.

7.1.1 Fuels

The most commonly used fuels today; diesel for trucks, paraffin oil for aircrafts, heavy- and thin oil for vessels, all emit CO_2 and other greenhouse gases when being consumed. All of these are fossil fuels containing oil, and therefore connected with severe environmental problems. The definition of fossil fuels is an energy source containing hydrocarbons, which when being consumed produce CO_2, thus adding to the greenhouse effect.

In 2006 the transport industry was responsible for 71 percent of all oil consumption in the EU. 60 percent of the oil was used by trucks and 9 percent by aircrafts. The energy consumed by trains was to 75 percent electricity and to 25 percent fossil fuels.[128] One important topic in the environmental work is how to reduce the use of fossil fuels by finding alternative fuels. Biofuels are fuels produced from living organisms. Unlike fossil fuels, biofuels do not contribute to the greenhouse effect and the consumed quantity can, in comparison, easily be reproduced. Hence

[128] The European Commission (2006): Hållbara transporter för ett rörligt Europa.

biofuels, mainly including biodiesel and bioethanol, are an excellent substitute to fossil fuels.

In January 2008 the European Commission proposed a directive to the European Parliament and to the Council regarding use of renewable energy sources. Among other things, it was suggested that all EU member states ought to have at least a 10 percent usage of biofuels in their transport industry in 2020.[129] Decisions about whether or not to reformulate the suggestions into laws must be taken before the climate meeting in Copenhagen in the end of 2009.[130]

One solution to achieve 10 percent usage of biofuels is to at least initially mix fossil fuels with biofuels.[131] Today, biofuels are not used for aircrafts, but the method is under development. For example, research about using hydrogen gas and synthetic paraffin oil is ongoing.[132] Distillate fuels, such as gas oil and marine diesel oil are fuel options to the oil that is used for vessels today. These alternatives emit less nitrogen oxides, sulphur oxide and fewer particles.[133]

In August 2007 Volvo presented seven models of trucks that can be operated without emission of CO_2. Fuels used when driving the trucks can be biodiesel, biogas, ethanol, methanol, dimethyl ether, hydrogen gas in combination with biogas and synthetic diesel.[134] Scania also offers trucks using ethanol and they have been available on the market since 2008.[135] Fuels that do not contribute to the greenhouse effect are free from carbon dioxide tax and the usage of these fuels will probably increase in years to come.

[129] The European Commission (2007): Ny energipolitik bäddar för biobränsle.
[130] The Ministry of the Environment (2008): EU:s klimatarbete.
[131] The European Commission (2001): VITBOK – Den gemensamma transportpolitiken fram till 2010: Vägval inför framtiden.
[132] The Swedish Civil Aviation Authority (2008): Forskning och utveckling.
[133] The Swedish Maritime Administration (2008): Sjöfartsverkets redovisning av miljöledningsarbetet för 2007.
[134] Newsdesk (2007): Volvo visar upp koldioxidfria lastbilar.
[135] NyTeknik (2008): Scania först ut med etanoldriven lastbil.

7.1.2 Vehicles

Hybrid cars are no longer science fiction. They are becoming more and more widespread thanks to their low level of emission compared to diesel and petrol driven cars. A hybrid car uses both a regular internal combustion engine and an electrical engine. From 2009 Volvo will start serial producing hybrid trucks that use a combination of diesel and electricity.[136] When using the electricity engine, the truck becomes entirely emission free. Other positive aspects with the hybrid truck are the reduced costs for fuel and the possibility of making usage of created energy, for instance from braking.[137]

The maximum length and gross weight for trucks travelling in the European countries is 18.75 m and 40 metric tons. For trucks in Sweden the limits are 25.25 m and 60 metric tons. Tests with even longer trucks, exceeding the Swedish limitations on length and weight, are carried out in Sweden.[138] If the limitations were loosened, each truck would be able to transport more at a time and subsequently decrease the total number of transports. This would as a result reduce the emission of greenhouse gases.

7.1.3 Exhaust Emissions

Engines with higher efficiency and lower fuel consumption are constantly under development. The requirements on control of exhaust emissions for diesel driven trucks are getting increasingly strict. Devises such as catalytic converter and particle filter and methods like nitrogen oxide reduction is almost a must in order for new trucks to meet the constraints given by the law.[139] The above mentioned goal to use 10 percent biofuels in the transport industry can also be accomplished by simply lowering the usage of fossil fuels by using more efficient engines. Aviation researches believe that new engines in 2020 will use half as much fuel as today's models and hence only emit half as much CO_2.[140] The new engines are also believed to emit 80 percent less nitrogen oxides.[141]

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[136] Om miljöbilar (2008): Framtidens miljöbilar.
[137] Volvo Truck Corporation (2008): Volvo FE Hybrid.
[138] VTI (2008): Långa och tunga lastbilar effekt på transportsystemet.
[139] The Swedish Road Administration (2005): Tunga fordon (över 3.5 ton).
[140] The Swedish Civil Aviation Administration (2008): Flyget och klimatpåverkan.
[141] Ibid.

At the moment, no methods for separating the CO_2 from the emission generated by transports exist, but research on how this could be done is undertaken. A technique called Carbon Capture and Storage, CCS, is being developed and will initially be adapted to large point sources such as fossil power plants.[142]

7.1.4 Other

Within a near future new advanced technical support for transportation will be available. This will make real time control and capacity optimization as well as tracking of goods flows possible to a wider extent. Additionally, this kind of system will provide authorities with fast and detailed information about the need of infrastructure modifications and maintenance. [143]

7.2 Adaption of the Infrastructure

Political control measures cannot be introduced without simultaneously creating potential for the affected parties to change in the desired direction. National and international initiatives altering the infrastructure are really indirect control measures to steer traffic towards certain means of transport and to facilitate more economic driving behavior.

7.2.1 TEN Expansion

The EU runs the TEN-T program, Trans-European Networks Transport, which aims to develop, integrate and improve the infrastructures of the member states in the EU. The program includes several projects, a lot of them concerning expansion of the railway links. Marco Polo II, described below, is another program that illustrates how the EU supports TEN infrastructure projects financially.[144]

Building roads that allow drivers to operate the truck more economical with respect to fuel consumption is yet another way to create more environmentally friendly transports. An economical driving manner with slightly lower speed, less braking, more constant speed and fewer hill transits reduces the fuel consumption and consequently the emission of

[142] The Nordic Council of Ministers (2007): Carbon Capture and Storage (CCS).
[143] The European Commission (2006): Hållbara transporter för ett rörligt Europa.
[144] SOU (2007:59): Strategiska godsnoder i det svenska transportsystemet – ett framtidsperspektiv.

greenhouse gases.[145] Infrastructure that generates less congestion also lowers the emission.

7.2.2 Enabling of Railway Use

The wish to increase railway transports can only be accomplished by creating potential for it. At the moment, bottlenecks exist at some distances[146] and that is not compatible with the political intention of enlarging the use of railway. If requirements such as punctuality, speed and high frequency are not met, the usage of the railway will not increase to the desired levels. According to approximations, 20 percent (or 16 000 kilometres) of the entire railway network is congested.[147] A transport between Sweden and Spain involves six different railway operators, which makes the procedure quite complicated. In USA where those national obstacles do not exist, the railway sector has consistently captured 50 percent of the market since the 1970's. For a comparison between the railway's shares of goods transports in the EU, the USA and Sweden, see Figure 7-1.[148]

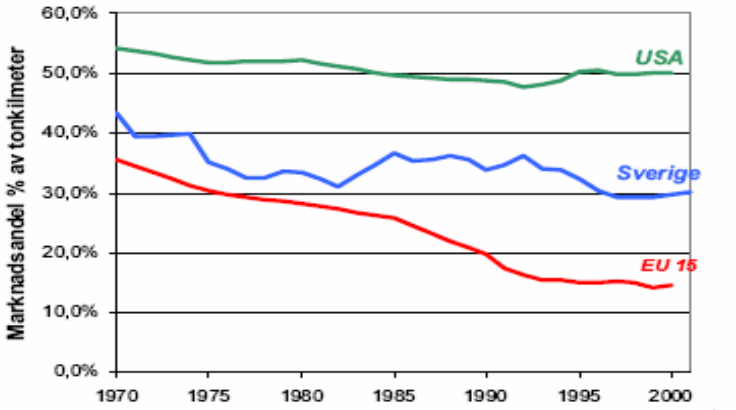

Figure 7-1. *Comparison of the railway's share of all goods transports.*[149]

[145] The Swedish Road Administration (2006): Vinst varje mil – tunga förare kan spara miljoner på att köra bränslesnålt.
[146] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.
[147] The European Commission (2001): VITBOK – Den gemensamma transportpolitiken fram till 2010: Vägval inför framtiden.
[148] SOU (2007:59): Strategiska godsnoder i det svenska transportsystemet – ett framtidsperspektiv.
[149] SOU (2007:59): Strategiska godsnoder i det svenska transportsystemet – ett framtidsperspektiv.

The EU has promoted three initiatives associated with making the railway option more attractive. One is the deregulation of the goods transport market to increase competition in the railway sector. Another is to prepare goods transport corridors that make railway transports more reliable and fast.[150] This for example involves electrification and straightening of the railway link, modernisation of the signal system and elimination of lever crossing. Yet another one is to simplify the use of combined transports by adapting terminals to combined traffic. From March 2008 any company may use the international railway network to perform railway transportations of goods.[151]

Another trend that can be seen is the mergers between railway operators in different countries. For instance, the German equivalent to the Swedish Green Cargo has taken over goods transport enterprises in the Netherlands and Denmark. In addition to this they have an extensive cooperation with Swedish Green Cargo.[152]

7.2.3 Marco Polo

Marco Polo is a funding program initiated by the EU. It offers financial supports to projects that focus on shifting road transports to rail and sea. Marco Polo II is the second program with a budget on 400 million €, lasting from 2007-2013.[153] Two for Sweden relevant projects supported by Marco Polo II is Scandinavian Shuttle and Motorways of the Sea.

Scandinavian Shuttle

For railway to become a more attractive transportation option, the Marco Polo financed project Scandinavian Shuttle was started. The aim of the project is to create a freight corridor between Scandinavia and central Europe.[154] The main focus lies on integrating the railway link connecting Sweden-Denmark-Germany and to simplify use of a combination of different means of transport.

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[150] SOU (2007:59): Strategiska godsnoder i det svenska transportsystemet – ett framtidsperspektiv.
[151] Ibid.
[152] Ibid.
[153] The European Commission (2007): Marco Polo.
[154] The Oresund Environment Academy (2008): Scandinavian Shuttle.

One part of the logistic solution is the method *Track and Correct*, where the goods are equipped with a GPS that allows the customer to locate the goods at any time and makes the transport very secure. Another part is to adapt locomotives so that they can be operated both in Sweden and Denmark, where different electricity and signal systems are used. [155]

Motorways of the Sea

A project concept aiming on extending the use of sea freight for long distance transports in Europe is the so called *Motorways of the Sea*, proposed in the Freight Transport Logistics Action Plan by the European Commission. Motorways of the Sea would be a part of the expansion of the Trans-European transport network and integrated with other means of transport it would offer door-to-door solutions. The frequency, reliability and quality on the transports would be high and positive outcomes include a smaller increase of road transports than expected, improved accessibility to remote regions and decreased road congestions. [156] Work that has to be done in order to implement the motorways of the sea is among other things coordination between European ports, design of transport corridors and development of new technologies that enable combined transports.[157] Several subprojects linked to the concept are in progress.

An example of a successful attempt to move transports from road to sea is an Italian ferry service from Genua to Barcelona that takes twelve hours. The service is fast and reliable using the combination of road and sea transports and has become very well utilized.[158]

[155] The Oresund Region (2008): Godstransporter på järnväg 100 procent just-in-time.
[156] The European Commission (2007): Report on the Motorways of the Sea.
[157] The Swedish Road Administration (2008): Utvecklingsprojekt.
[158] The European Commission (2003): Europa vid ett vägskäl – Behovet av hållbara transporter.

8 Internal Methods of Adaption

To make supply chains more efficient with respect to environment effects and transport costs, a variety of modification can be undertaken. A few examples of how companies internally can change their logistic structure in order to achieve higher efficiency are given in this chapter.

By changing how transportation is planned and executed, a company can become much more efficient in this area and therefore save money and reduce its negative impact on the environment. Decisions regarding location of production sites, inventory points and transshipment points shape the logistic structure. Choice of suppliers, distributors and customers determine the final goods flows. How orders are handled and what service levels the customers are offered or require also affect the characteristics of the logistic system.[159]

Costs for transportation will inevitably rise in years to come as a result of new fees, taxes and other control measures introduced to restrain the environmental pollution. Companies will have to revise their way of thinking of transport costs as negligible. Especially road transports will become more limited and traditional ways of performing transports must be adjusted and new methods considered. Below, several methods, which companies may use in order to adapt to the new environmental conditions, are presented.

Improved Coordination

By coordinating transports to nearby regions, a higher utilization ratio could be reached and a lot of transportation work could be saved. If the utilization increases from 50 percent to 100 percent, the fuel consumption increases with only 20 percent and the emissions with 10 percent.[160]

Another possibility with improved coordination is direct shipment. If the production site is located in Germany and the central warehouse in Sweden, transports to Germany and other close districts could go direct from the production site to the customer instead of first being shipped to

[159] Lumsden, Kenth (2006): *Logistikens grunder*, p. 703.
[160] Ibid, p. 716.

the central warehouse and then back to the customer. This requires well integrated IT systems.

Improved Forecasts

Upcoming demand could more easily be predicted by organizing and using gathered historical data together with other demand forecasts, such as forecast models and subjective opinions about the future demand. Emergency transports could be reduced and a logistics solution satisfying the goal with having right products at the right place at the right time could be achieved.

Improved Packaging

If the packaging of the goods is adjusted to the intended transportation mode, one can reduce the unused space in the transports and hence increase the utilization ratio. In addition to this, a well designed packaging simplifies reloading when changing transportation mode, which in turn enables combined transports.

Local Sourcing

Purchasing components and material from a local supplier decreases the need for long distanced transports. Today it is not rare that input material in a production process comes from all over the world, which of course creates more transports and as a consequence emission of greenhouse gases.

Means of Transport

The most frequently used mean of transport, truck, will become more expensive. Therefore, it might be necessary for companies to start using other transportation options or combinations of options, so called combined transports, to manage the cost increase.

Modification of the JIT Concept

The Just-in-Time concept requires high transportation flexibility. Often JIT is connected with frequent transports and poor utilization ratio. The purpose with JIT is to diminish inventory and thus tied up capital. When the transport buyer in a near future will be held responsible for the environmental costs of their operations, it might become cheaper to keep inventory anyhow.

Relocation of Inventory Points

Today production sites, inventory points and sales sites are spread all over the globe, because of economic reasons such as economies of scale. In the past, transport costs have been insignificant in relation to other cost and so distance was no obstacle. Increased transport costs might force companies to reallocate inventory points to be closer to the customer or the production site.

Return Transports

In 2006, 24 percent of all Swedish domestic road transports were empty loads.[161] It is easily realized that transports could be much more efficient if distribution of goods included gathering of return goods as well, i.e. a higher utilization ratio could be accomplished.

[161] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.

9 Analysis of Potential Consequences of New Control Measures

This chapter briefly describes three scenarios that have been created in order to provide an idea of the impact possible control measures could have on a company's expenses. The assumptions are more or less realistic; figures may vary a lot depending on the circumstances. The complete scenarios can be found in Appendix 1.

9.1 Scenario 1 - Air Transports Included in the Emission Trading System

Costs for emergency transports by air could increase with 50 000 SEK, or 1 percent, for a company buying 50 express transports per year when the aviation sector is included in the EU ETS. If the forecast system was improved and the emergency transports consequently could be reduced by half, 25 000 SEK could be saved.

9.2 Scenario 2 - Kilometer Tax for Trucks

If a kilometer tax is introduced in Sweden and the Eurovignette Fee is eliminated, the cost for a truck driving 50 000 kilometers per year on Swedish roads will increase. If the kilometer tax is 1 SEK per kilometer, the cost will rise with approximately 4 percent, if it is 3 SEK per kilometer it will rise with 14 percent and with 29 percent if it is 6 SEK per kilometer. If the utilization ratio is increased to 95 percent, resulting in reduced travel distance per year, the cost increase (for introducing the kilometer tax at any level) in percent is almost the same as with the original utilization ratio of 60 percent.

If costs caused by having 60 percent utilization ratio and the usage of the Eurovignette system are compared to costs caused by a kilometer tax system with an increased utilization ratio of 95 percent one can show that savings in the sizes of 33, 26 or 16 percent for kilometer tax 1, 3 or 6 SEK per kilometer can be achieve. Hence, a tax system generating additional costs does not necessarily mean larger costs in the end, assuming that the logistics system is made more efficient.

9.3 Scenario 3 - Increased Tax on Diesel

Carbon dioxide tax and energy tax for diesel will most likely rise in years to come. If the sum of those taxes increase by 8 SEK per liter, the cost for operating a truck 50 000 km per year would increase by 30 percent. If 50 percent of the transports were shifted to railway after the taxation increase, the costs for transport (rail plus road) would decrease by 1.7 percent.

A higher oil price results in similar calculations and hence cost consequences, therefore specific calculations for an increased oil price are left out. The reason for this is that the diesel price is built up by approximately even parts of taxes and the purchase price, which is depending on the oil price.

10 Evaluation of the Green Supply Questionnaire

In order to get an understanding of different companies' attitude towards environmental issues, a survey was distributed to some of Syncron's customers. The result from the survey is presented in this chapter and the questionnaire itself can be found in Appendix 2.

The questionnaire was distributed on Syncron's User Summit in October 2008 to 70 participators, representing 20 different companies. All companies are customers to Syncron and use Syncron's software in their organization. Nine of the participators chose to answer the questionnaire, which is a relatively low share. Therefore, the answers cannot serve as basis for stating average trends, but rather as examples of different company approaches and attitudes regarding environmental concerns.

The companies represent a variety of industries, such as the car industry, steel industry and forestry industry and differ in size and geographic location of for instance inventory and sales points.

10.1 Mean of Transport

The answers revealed that most of the companies filling out the survey mainly use road transports for their regular transports. The different shares for the transportation modes are presented in Table 10-1 below.

% of All Transports	0-20 %	21-40 %	41-60 %	61-80 %	81-100 %
Road	2	0	1	5	1
Air	8	0	0	0	1
Sea	8	0	0	1	0
Rail	8	1	0	0	0

Table 10-1. *Number of customers using a specific transportation mode, and to which extent.*

Since just a few of the answers included information about the choice of transportation mode for emergency transports, only tendencies could be told from them. One obvious tendency is that air freight is used to a wider extent for emergency transports than for regular transports.

10.2 Transport Efficiency

One third (three out of nine) of the interviewed companies outsource their logistic activities. Four of the six companies that keep transports in-house have an average fill-rate of 61-80 % and one between 81-100 %. Half of the companies that perform the transports themselves actively try to achieve a high fill-rate.

10.3 Environmental Awareness

Only one company states that they consider the environment when choosing transportation mode. Two companies think they will adapt their logistic activities to upcoming regulations and changes within the transport industry, the rest do not think they will adapt it. Two thirds of the responding companies will not or have not altered their transportation strategy because of increased transport costs. Worth mentioning though, is that optimization of fill-rate and location of inventory points are mentioned as methods used to increase cost efficiency.

10.4 Future Transportation Obstacles

Seven of the nine companies state that other factors have influence on the performance of the supply chain activities. The respondents gave the following examples of such factors: shortage of drivers, unsatisfactory infrastructure, congestions, inventory levels, fuel prices and customer requirements regarding timing. The general opinion is that the Just-In-Time concept will stay popular, in spite of more expensive transports and demand of increased efficiency.

10.5 Potentials

More than half the respondents (5/9) think it is possible to start using more environmentally friendly transportation modes, such as rail, but declare that this requires rail to become more competitive in comparison to other options of transportation mode. The companies do not feel pressure from the customers to become more environmentally friendly. In contrast to this, one third of the interviewed companies put pressure on their suppliers to become more environmentally friendly, for example by using more efficient engines.

11 Introduction – Part 2

Part 2 and the disposition of the case study section are briefly introduced below. The chosen structure is motivated and associated with the problem formulation of the thesis.

A case study is an excellent research method when the project's problem formulation relates to authentic and contemporary situations. By concentrating on one or a few real examples, a reliable base for an analysis can be obtained. Investigating documents, performing interviews and making observations are examples of ways to form an empirical base.

The second part of the thesis, which can be read separately from *Part 1*, presents the case study which has been performed to give answers to a part of the problem formulation. This is a so called single case study, thus focusing on one specific supply chain. Initially a necessary complementary theoretical framework to the one in *Part 1* is provided. Here, logistical knowledge and definitions are described in order to justify the use of them in the analysis. To give a sufficient case study description, *Part 2* further includes *Empirics,* where the studied case is presented and explained, *Analysis,* where proposals about how to modify the present structure are given and consequences of the proposed changes are discussed and evaluated, which leads to the final part *Conclusions & Recommendations*, where the problem formulation is clearly answered and recommendations of various kinds are given.

The two questions of the problem formulation, regarding modification of Lantmännen Maskin's supply chain, are answered by using the case study as a tool. Since it is unrealistic to achieve general answers, applicable to any supply chain and organization, the results from the case study will primarily hold for organizations similar to Lantmännen Maskin, with similar products and supply chains. Ideas about how to create a more sustainable supply chain at Lantmännen Maskin are analyzed and assessed, resulting in conclusions and recommendations about where to focus attention. The assessment is based on analysis of transport costs, environmental effects, service level, lead times, tied-up capital and total cost, all of which are important components when establishing a sustainable supply chain.

The reader is advised to start by reading *Part 1* to get an insight in the focus area of the thesis. However, since the parts are independent, *Part 1* may be omitted if the reader already has adequate knowledge within this area and only is interested in the outcome of the case study.

12 Theory

This section aims to complement the theory presented in Part 1 and to complete the theoretical framework in the report. Terms within the areas of logistics and production management are defined and discussed with the goal to provide the reader with a theoretical base before reading the analysis.

12.1 Sustainability

Sustainability in the widest sense means the ability to sustain a certain process or state at a certain rate or level. However, the concept depends on the context in which it is used.[162] When sustainability is discussed in connection with supply chain matters, several areas are concerned. Sustainability not only considers cost efficiency, productivity and the reduction of the negative environmental impact in the internal supply chain, but also sustainability in the execution of external activities that have been outsourced by the company. Areas such as pollution, health and safety, labor rights, human rights and anti-corruption have to be explored when working with the sustainability concept within a supply chain.[163] A general definition of sustainable supply chain management, that is methods used in order to create a sustainable supply chain, is

> *The means by which companies manage their social responsibilities across dislocated production processes spanning organizational and geographical boundaries.*[164]

This definition highlights the importance in taking responsibility for the entire supply chain, especially nowadays with the globalization of corporations, involving for example transfer of manufacturing to low-wage countries. The chain between raw material, finished products and the end customer engage subcontractors, suppliers, manufacturers, distributors and customers. It is essential that the dominating actors aim at creating sustainability in every part of the supply chain, not only in the internal

[162] Wikipedia (2008): headword *Sustainability*.
[163] Lerberg Jorgensen & Steen Knudsen (2006): Sustainable competitiveness in global value chains: how do small Danish firms behave, p.449.
[164] Ibid, p.450.

organization and at the suppliers and customers in the first tier. This can be done by encouraging first tier suppliers and customers to pass the sustainability requirements on to the second tier suppliers and customers.

Preserving the environment is one major component in creating sustainability. Since the transport sector has been pointed out to be a large contributor to the CO_2 emission, the logistic activities within a supply chain have become more and more exposed to inspection. Legislations have been introduced to create incentives to design a sustainable logistic network and companies are therefore challenged to balance profitability and environmental impact.[165]

One tool that can be used to design a sustainable logistic network is multi objective programming, MOP. For a start, activities and actors affecting the sustainability are identified. Quantifiable factors that are related to these actors and activities are then recognized. Subsequently, equations representing the trade-off between costs and environmental impact are constructed. These equations contain some or all of the factors identified in the first step, suitably weighted. Solutions fulfilling certain constraints on the factors are then calculated. The solutions balance the 'costs' for the factors in a more or less optimal way; the design of the equations affect the final result.[166] For example, increasing the usage of a particular transport mode might reduce the transport costs, but the same transport mode might simultaneously give rise to higher pollution, resulting in amplification of the pollution equation. Hence, a combination with other transportation modes could be the optimal solution in this case. This optimization method can be used to determine inventory and production points, transportations modes, transportation routes etcetera.

12.2 Service Level

Having a clear definition of the service level used at a company is very important. It is also of great importance that the service level is measured and compared to the set goal values. All articles are not equally important

[165] Quariguasi Frota Neto et al. (2006): Designing and evaluating sustainable logistic networks, p. 195.
[166] Quariguasi Frota Neto et al. (2006): Designing and evaluating sustainable logistic networks, pp. 197-198.

and the service demands on them vary, consequently it is often preferable to group similar articles and give them a set service level. When deciding on a service level, consideration of the underlying shortage cost and the cost of keeping a high service level, such as inventory cost, has to be taken. Large variation of the demand and long lead times are aspects that make it more costly to keep a high service level.[167] There exist two frequently used definitions of the service level concept, and they are defined below.[168]

$serv_1$ = The probability of not getting a shortage during an order cycle.
$serv_2$ = Share of the demand that can be supplied directly from stock.

$Serv_1$ describes the probability of receiving an incoming delivery before shortage arises during an order cycle. This definition is relatively easy to use but the downside is that no consideration is taken to the ordered quantity. On the contrary, the second definition, $serv_2$, is more complicated to use but the estimation is usually more in line with the actual customer service. Given that only one unit is demanded at a time, the second definition can be interpreted as the probability of not having to let a customer wait for a product.[169]

12.3 Tied-Up Capital

Inventory containing a variety of products give rise to tied-up capital, since the products' value cannot be used for other purposes until the products are released from the inventory. If the products were sold, the revenue would render possibilities for investments. Capital can also be tied-up in a production process, with the same motivation as for capital tied-up in inventory.

Companies keep inventory for different reasons; mainly to even out the production flow or to enable high service level to the customers. The inventories can be of various kinds depending on their purpose, the ones treated in the project are presented below.

[167] Axsäter (1991): *Lagerstyrning,* pp. 68-69.
[168] Ibid, p. 68.
[169] Ibid, p. 68.

12.3.1 Turnover Inventory

This kind of stock is kept to avoid too frequent order releases. The inventory level is decided by balancing and simultaneously minimizing costs for holding inventory and costs related to placing an order. The turnover inventory is illustrated by the thorny parts in Figure 12-1, since this is the inventory actually used, whereas the stock beneath is untouched if replenishment work as planned and if the demand correspond to the forecast.

12.3.2 Safety Stock

Safety stock is motivated by wanting to avoid stock-outs caused by incorrect forecasts, extended lead times, inaccuracies in inventory balance or faulty delivery quantities. In other words, safety stock is used to separate different processes in the supply chain to prevent interruptions, delays and inaccurate forecasts to spread along the supply chain and result in shortage. The idea is illustrated in Figure 12-1.[170]

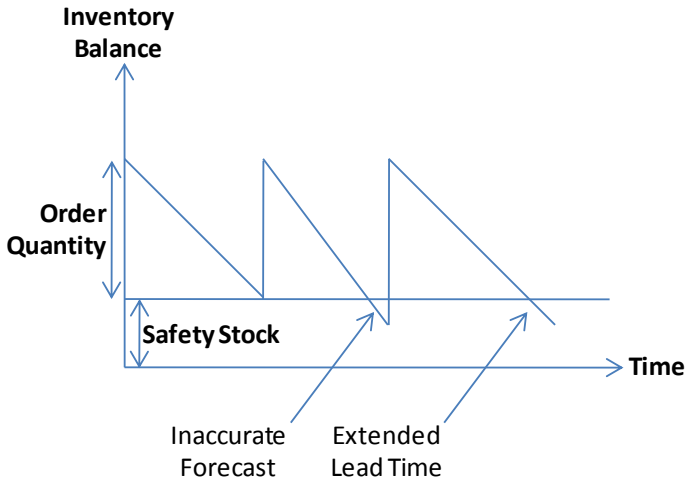

Figure 12-1. *Inventory level for an article with steady demand.*

It is the safety stock in combination with the expected demand during the lead time that sums up to the reorder point, if the system has continuous inspection. If the inspection is periodical the expected demand during the period has to be added to the reorder point if shortage is to be avoided.

[170] Lumsden (2006): *Logistikens grunder,* pp. 283-284.

When the inventory level reaches the reorder point it signals that it is time to place a stock replenishment order.[171]

12.4 Lead Time

The lead time concept includes several different descriptions, but in general it concerns the time for a certain process to be completed. Sometimes it refers to the time it takes for a product to go through all production stages and sometimes to the time required to do replenishment of an inventory. The later example can be measured as the time between the emergence of the need and the point when the need is fulfilled. The lead time is often used when determining reorder points in inventory control, since the reorder level usually exceeds the demand during the lead time. A replenishment process often involves numerous sub processes, for instance order placing, idle time in the supplier's order system, transportation time and delivery control. The lead time can be divided into internal lead times, such as administration and planning, and external lead times, such as the actual transportation lead time. The external lead time often offers potential for optimization, for instance by choosing another transportation option.[172]

12.5 Total Cost

The total logistics cost aims to summarize all costs associated with a certain decision in a specific context, since most decisions imply that some costs are reduced while others are increased. When choices are made, several costs often have to be compared to each other in order to find the most cost efficient solution. Some of the most significant logistics costs are described in detail in the following sections. Examples of other logistics costs that may have a considerable influence on the total cost, but will not be discussed further, are administrative, information, material and packaging costs.[173]

12.5.1 Order Cost

The total order cost for a certain period of time is dependent on the ordering cost for placing one order and the number of orders placed during

[171] Axsäter (1991): *Lagerstyrning,* p. 64.
[172] Mattsson & Jonsson (2003): *Produktionslogistik*, pp. 126-128.
[173] Oskarsson et al. (2006): *Modern Logistik – för ökad lönsamhet*, pp. 34-36.

the time period. The ordering cost for placing one order consists of the costs that are associated with the request and that are independent of the demanded quantity. The magnitude of the cost is complex to decide and it may vary from product to product. Examples of activities that usually are connected to an order are: order placement, delivery surveillance, material handling and transport planning. Knowledge regarding different articles' ordering cost is needed when deciding appropriate order quantities and to realize which parts of the logistic flow that are more costly than others.[174]

12.5.2 Holding Cost

The cost for keeping inventory can be divided into two separate parts. The first one concerns the fixed costs; such as space rental and inventory personnel. The second cost varies depending on the inventory level. Resources are being tied-up when inventory is kept, and that capital could have been used differently if it was not allocated in an article waiting on a shelf. There are also risks related with keeping inventory; waste, obsolescence, burglary and fire for instance. In order to calculate the varying holding cost a company set interest rate for capital tied-up in inventory is commonly used. This interest rate combines the capital and risk costs associated with keeping inventory. To obtain the holding cost, the interest rate is multiplied by the value of the articles kept in stock.[175]

12.5.3 Shortage Cost

If a demanded part cannot be delivered to the end customer due to a shortage, several different costs may occur. If the customer's order is backlogged extra costs due to additional administration, material handling and transports often occur. If the customer demanding a part decides to use another supplier when a shortage arises, the sale is lost. Independent of the customer's response to the shortage, a shortage usually means a loss of goodwill which generally affects the total sales in the long run. All of the mentioned shortage costs are often complicated to estimate.[176]

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[174] Oskarsson et al. (2006): *Modern Logistik – för ökad lönsamhet*, p. 222.
[175] Ibid, pp. 106-107.
[176] Axsäter (2006): *Inventory Control*, p. 45.

12.5.4 Transport and Environmental Costs

The transport cost amounts to almost 3 percent of the Swedish GNP[177] and it can be divided into two different categories. The first one contains the actual transports costs that arise when transporting, loading, reloading and unloading. The remaining transport costs are costs that cannot be directly associated with the transportation, such as temporary storage, packaging material, duties and so forth.[178] There exist several tools that aim to help companies to optimize their distribution setup and minimize their transport costs. A couple of them are vehicle route planning and efficient design of multi-echelon systems.

The cost for shipping goods is highly dependent on the transport mode used. Assuming a specific set of goods and a transport distance of 500 kilometers, road and rail have approximately the same costs. A waterway transport has slightly lower costs while an air fright cost roughly six times as much. National and international regulations may make a transport mode with lower actual cost more expensive to the end customer by adding fees and taxes.[179]

Future cost development within the transport industry are thoroughly presented in *Part 1*. Cost regulations such as taxes and fees are expected to be intensified due to an enhanced interest in the questions regarding preservation of the environment. These additional environmental costs will be added to the existing transport cost. The politicians hope that these control measures will change the transporters' behavior and thereby also render lower emission levels of the greenhouse gases.

12.6 Virtual Supply

Any network or chain which is connected via electronic links can be regarded as virtual. A virtual supply chain is more than just electronic links though, it also represent an organizational structure which enables effective and efficient flows of both physical goods and information in a

[177] Elger et al. (2008): Svensk Makrologistik – Sammansättning och kostnadsutveckling 1997-2005.
[178] Lumsden (2006): *Logistikens grunder*, pp. 665-666.
[179] Ibid, p. 666.

seamless manner.[180] The most prominent difference between a traditional supply chain and a virtual one is the flexibility to quickly respond to changes in the business environment. For example, a long term shortage at the regular supplier may be identified quickly and facilitate the search for an alternative supplier. The area of Internet-based information and communication technologies are still in the development phase and its maximum effect has not yet been experienced.[181]

A universal classification of the present cyber media, used in virtual supply chains, does not yet exist. An alternative approach is to classify the media after its function, but even here several classifications exist. A five part classification is presented in Table 12-1 below, describing the roles that the cyber media aims to fulfill in the virtual supply chain.[182]

Role	Description
Informational	Involves the provision of information about buyers, sellers and their products. This role has to function well in order to success with the virtual supply.
Transactional	Might be a direct transaction between buyer and seller, or possibly some kind of auction website.
Assurance	Provide quality assurance of the goods and legitimacy of the purchasing. Ways to achieve this is through reputation and warranties.
Logistical	Delivery of goods and services to the customers. If the goods are digital it can be done online, otherwise the cyber media's role is to facilitate delivery.
Customization	Tailoring of products and services to better meet the needs of individual customer.

Table 12-1. *The cyber media classification.*

A logistical virtual supply solution enables companies to implement more advanced supply structures, such as lateral transshipment. Lateral transshipment is defined as the redistribution of stock from retailers with

[180] Chanrashekar & Schary (1999): Toward the Virtual Supply Chain: The Convergence of IT and Organization, p.27.
[181] Barnes & Hinton (2007): Developing a framework to analyse the roles and relationships of online intermediaries, p. 63.
[182] Ibid, p. 65.

stock on hand from retailers that cannot meet customers demand or to retailers that expect significant losses due to high risk.[183] A lateral transshipment solution will become extremely complex, not to say infeasible, without electronic support.

12.7 Demand Model

Demand for products is rarely constant and without deviation, meaning that even if the demand per week normally amounts to around five units, it might as well be six, three or any number of units. The demand is then said to be stochastic. When doing forecasts, it is useful to be able to estimate the demand structure with an appropriate model. The model can be of two types; continuous or discrete. The discrete model only allows positive integers and is suitable for representing demands of low quantity, while the continuously allows shares of units and is preferable if the demand is high.[184]

12.7.1 Poisson Demand

For articles with low demand, for example spare parts, the discrete Poisson model is commonly used to approximate the demand during a certain time period. This model assumes that each customer requests one part only and that the point of time for the demand is stochastic. The probability for a demand of *k* units during one time unit, usually one day, one week or over the lead time, is calculated according to the equation below.

$$P(x = k) = \frac{\lambda^k}{k!} e^{-\lambda}$$

Here λ represent both the expected value, *E(x)*, and the variance, $E(x- \lambda)^2$, for the demand. The following condition should be fulfilled for the Poisson model to be appropriate to use

$$0.8 \times \sqrt{E(x)} < \sigma_x < 1.2 \times \sqrt{E(x)}$$

where

$$\sigma_x^2 = E(x - \lambda)^2$$

[183] Lee et al. (2007): "An effective lateral transshipment policy to improve service level in the supply chain", p. 115.
[184] Axsäter (2006): *Inventory Control*, p. 77.

If the condition is not satisfied or if the Poisson distribution for other reasons models the demand poorly, a normal distribution model or a more advanced Poisson model can be used.[185]

12.7.2 Normal Distributed Demand

To represent a relatively high demand, the continuous normal distribution is frequently used. The drawback with this model is that there is at least a small chance for negative demand and that the demand does not have to be whole units. The probability for negative demand is very small though, as long as the expected value is high compared to the standard deviation. Rounding of non-integer units will most often not render any problems since the rounding will be negligible in comparison to the high demand. For low demand, the presented downsides might cause inaccurate guidelines, which is the reason to use the normal distribution model for demands of high quantities primarily.

An advantage with the normal model is that it is pretty easy to work with. Moreover, it can often be shown that the behavior of a sum of several independent stochastic variables will approximately follow a normal distribution, which makes the distribution suitable for modeling a large sum of demands from independent customers.[186]

12.7.3 Compound Poisson Demand

Sometimes neither the Poisson nor the normal distribution represents the demand behavior in a good way and one alternative could be to use a compound Poisson distribution instead. If the customers request more than one unit at a time, the compound distribution could be advantageous to the regular Poisson distribution. When using a compound Poisson model the arrival of the customers is represented by a Poisson process and the amount each customer demand by another stochastic variable.

[185] Axsäter (1991): *Lagerstyrning,* pp. 65-67.
[186] Ibid, pp. 65-66.

13 Empirics

To enable an analysis of Lantmännen Maskin's supply chain considerable knowledge of it is needed. The empirics of interest are introduced in this chapter. First an overall view of the goods flow for the aftermarket is given. Further, a more detailed description of the supply of spare parts to the retailers is presented, since this is the focus of the case study. The information provided is gathered from interviews with representatives at Lantmännen Maskin and Syncron, if nothing else is indicated. The interview guide from the main interview performed at Lantmännen Maskin is attached in Appendix 3. Costs for transports with Jetpak and HIT are considered sensitive data and therefore disguised with the letters X, Y and Z throughout the report.

13.1 The Supply Chain

The supply of spare parts at Lantmännen Maskin is a push-based system, meaning that the production of the spare parts is based on historical ordering patterns. Inventory control at the central warehouse and at the retailers is performed by the use of forecasts based on historical data.

When the end customers need spare parts to their machinery they contact one of Lantmännen Maskin's retailers. If the retailer has the requested part in stock, the customer need can be satisfied instantly. If not, the retailer must place an order to the central warehouse in Malmö or directly to the manufacturer of the part in question. Direct contact with the manufacturer is taken when the requested part is unique and not frequently used; for example spare parts to snowmobiles are only demanded in the north of Sweden and are therefore not supplied by the warehouse in Malmö. Lantmännen Maskin offers spare parts to all machinery that they sell and 60 percent of all parts available at the retailers are supplied by the central warehouse.

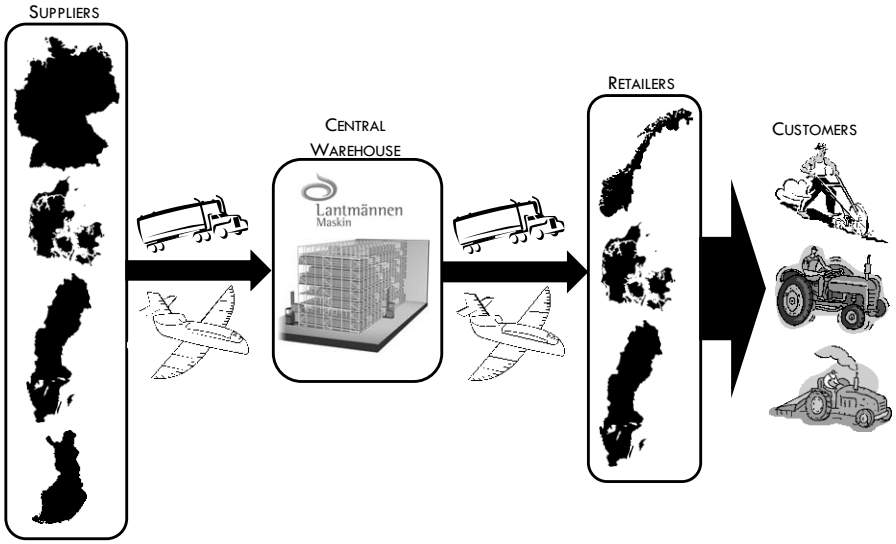

Figure 13-1. ***The supply chain for the spare parts at Lantmännen Maskin.***

The physical flow of the spare parts supplied by the central warehouse can be seen in Figure 13-1 above. Inbound logistics to the warehouse consist of four main flows; from Germany, Denmark, Sweden and Finland. Both trucks and airplanes are used to ship the goods to the warehouse. The central warehouse has about 300 suppliers and 10-15 of them are considered to be main suppliers. These main suppliers provide the warehouse with goods on a daily or weekly basis. The central warehouse keeps about 50 000 parts in stock and approximately 10 percent of the parts make up for 90 percent of the entire stock value, which is 80 million SEK. The interest rate for capital tied-up in inventory is the same for the entire Lantmännen group; 9 percent.

The outgoing goods from the warehouse are shipped by truck or plane depending on the urgency of the order and the location of the retailer that placed the order. The number of retailers is approximately 200 and they are located in Norway, Denmark and Sweden. In Sweden, Lantmännen Maskin owns 54 of the 84 retailers they provide with spare parts. At the retailer the goods are sold directly to the end customer.

The service level of the outgoing goods from the central warehouse is about 94 percent, meaning that 94 percent of all order lines can be delivered in accordance with the set lead time. In the future the service

level at the retailer will be measured in the same way as at the central warehouse, but currently it is defined as the amount of times an end customer's entire demand of parts can be supplied directly from stock. Before the introduction of Syncron's software the service level at the retailers was about 30-40 percent, and the goal is to reach a service level of 60-70 percent to the end customer. Lantmännen Maskin has noticed an improved service level at the retailers, but they do not measure the exact value of it.

13.2 Supply of Retailer

The central warehouse receives 525 000 order lines per year from the retailers and an average order consists of four order lines. The orders are shipped from the central warehouse to the retailers in Scandinavia five days a week; delivered on Tuesday through Saturday. One retailer may have several orders placed for a specific delivery day and those are combined into one shipment. An average shipment has a mean weight of 45 kg. About 75 percent of the retailers receive deliveries on a given day, which is equivalent to an average of 150 shipments from the warehouse every day.

Most of the retailers have a service workshop, which is located in connection to the retailer's store, in order to facilitate the offering of service and maintenance work to the end customers. The service workshop places orders directly to the retailer, whom in turn places orders to the central warehouse. Generally these internal customer's orders amounts to approximately half of the order volume at the retailer.

Orders from the retailers to the central warehouse are divided into four different categories, which can be seen in Figure 13-2. The order classification depends on the urgency of the order. If a demanded part is not in stock, the order from the retailer will be classified as an emergency or supplement order. If an order is placed with the intent of replenish the inventory, the order will be classified as a stock or season order.

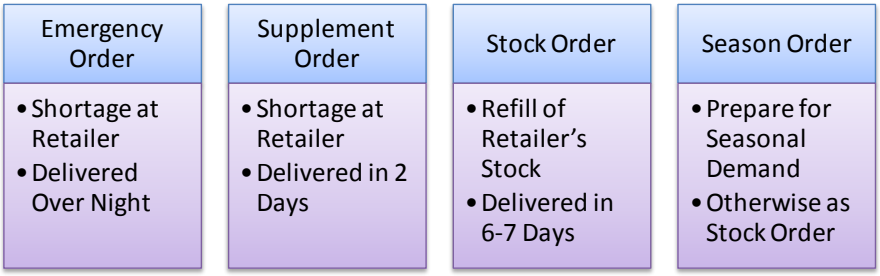

Figure 13-2. ***The four different order categories and their main characteristics.***

Currently more than 40 percent of all orders are categorized as emergency orders. The goal at Lantmännen Maskin is to lower that ratio to less than 35 percent. Another goal is to increase the stock order's share to at least 50 percent of all orders. Season orders have significantly smaller shares than the others and will not be discussed further. Since the case study focuses on emergency, supplementary and stock orders a further description of these follows in the next sections.

13.2.1 Emergency and Supplement Orders

An emergency or supplement order is placed when the retailer gets a shortage due to a demand from the end customer. If the order is extremely urgent, an emergency order is placed and if the order is slightly less urgent, a supplement order is placed. The order is sent manually, without using Syncron's software, to the central warehouse and the requested spare part arrives at the retailer before 7 am the next day if it is classified as an emergency order and before 7 am two days later if it is classified as a supplement order. The two day delivery time enables all supplement orders to be transportation by truck, but in spite of that, they are frequently shipped by air. Emergency orders are either transported by truck or air depending on the location of the retailer. Retailers that are located north of Karlstad and Örebro are supplied by a combination of air freight and trucks. Emergency orders to retailers in the south of Sweden are all transported by truck, except for Visby, where air freight is used.

Emergency and supplement orders that are to be shipped by air are collected by truck at 2.30 pm every Monday through Friday and transported to Malmö Airport from where they are flown to Stockholm and

the north of Sweden. This enables delivery before 7 am the next day, no matter where in Sweden the retailer is located.

To avoid the long notation 'emergency and supplement orders' the generic term 'rush orders' will from now on be used to denote these types of orders.

13.2.2 Stock Orders

A stock order is placed by the retailer to the central warehouse when the inventory level reaches the predetermined reorder point. Stock orders can be of two types; pure stock order and refill order. The only difference between those is that stock orders are placed by the retailer manually and refill orders are placed using the proposal from Syncron's software. The reason for not using Syncron's software for all stock orders is that some retailers are too small for it to be profitable to implement the software at their location.

Incoming stock orders to the central warehouse is registered in the system every day at 6 pm. After that, the orders rest in the system until they are picked and packed five days later. The orders are picked up by truck at 4.30 pm on the fifth day and delivered at the retailer before 7 am the next day or two days later, depending on the retailer's location. Consequently, the lead time for the retailer sums up to six or seven days. The central warehouse keeps most of the spare parts in stock and the reason for having such a long lead time is that it enables flexibility and optimizing of the picking. Lantmännen Maskin is currently planning to reduce an order's waiting time in the system, thus decreasing the lead time at the retailers with the hope of lowering the amount of rush orders,.

13.3 Syncron's Software

At the retailers owned by Lantmännen Maskin, Syncron's software is used for stock replenishment, by placing so called refill orders; it is not used for emergency orders. Syncron first decides which articles to keep in inventory, by classifying them into stocking and non-stocking categories. Stocking articles meet the criteria set on picking frequency and the expected annual sales value. An article with a high expected value of the annual usage needs a high picking frequency in order to be classified as a stocking article. Consequently, non-stocking articles are articles that the

software classifies as to expensive to keep inventory of, in relation to the expected demand pattern. Today Syncron classifies about one fourth of all spare parts as stocking articles and takes the responsibility to govern the supply of them at the retailers. Approximately 70 percent of the customer demand at the retailers concerns the spare parts governed by Syncron.

The software gives daily suggestions, on stocking articles, about which articles to order and to which quantity. The suggestions are based on information about orders already placed but not yet delivered, historical demand twelve months back in time and present stock levels. This information helps to decide whether or not it is time to replenish the stock; that is, if the reorder point is reached. The computation of the reorder point is described below.

- Safety stock for the articles is calculated by assuming a Poisson demand and 95 percent service level on articles controlled by Syncron.
- Reorder point for each of the articles are calculated by adding safety stock and predicted demand during lead time, which is forecasted using historical demand.

Even though the historical demand reaches twelve months back in time, primarily the last three months' demand is used when doing the forecast. The refill order suggestions are presented to the retailer, whom has to confirm them before they are released and thereby processed by the central warehouse.

Syncron's software is not used for making forecasts for supply of the central warehouse, but only for determining reorder points, safety stock and order quantity. Order release at the central warehouse is done without the use of Syncron’s software.

13.4 Sales Region 2

The retailers in Sweden are divided into seven different sales regions. The case study is limited to sales region 2, which comprises retailers in Borlänge, Bollnäs, Uppsala, Västerås, Enköping, Kungsgården, Tierp, Norrtälje, Sala, Hedemora, Mora and Hedenäset. The retailers are of different size and significance but located in a limited geographic area, in

the midst of Sweden. The retailers in Hedenäset, Sala, Mora and Hedemora are not using Syncron's software since they are too small and of less importance. They are therefore excluded from the case study and will not be taken into any further consideration. A map showing the geographical location of the retailers included in the case study is found in Figure 13-3.

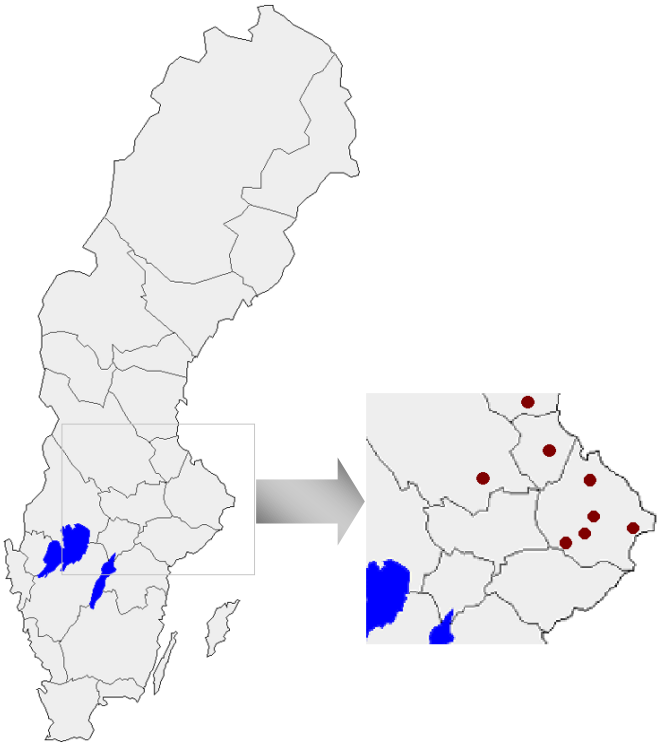

Figure 13-3. ***The geographical location of the retailers using Syncron's software in sales region 2.***

The distance between Malmö and the different retailers in sales region 2 is approximately 700 km, but more exact values can be found in Table 13-1 below. The same table also provides information about the value of the spare parts purchased between 1st October 2007 and 30th September 2008, and to some extent these values give an indication of the retailers' size and signification.

Retailer	Distance from Malmö (km) [187]	Purchased Value (SEK)	Air Transports
Uppsala	680	3 490 000	No
Västerås	601	2 560 000	No
Borlänge	665	2 344 000	Yes
Enköping	664	2 237 000	No
Bollnäs	877	1 782 000	Yes
Norrtälje	682	1 389 000	Yes
Tierp	738	942 000	Yes
Kungsgården	812	838 000	Yes

Table 13-1. *Information about location, purchase value and transport mode for the retailers in sales region 2.*

The retailers in sales region 2 that are discussed in the case study use the order types emergency, supplement and refill orders. To which extent each type was used during 2007 can be seen in Figure 13-4. It is easily detected that emergency orders represent a large share of all placed orders. Taking the fact that both emergency and supplement orders are rush orders into consideration, regular orders only represent a small part of all the orders. For sales region 2 in total, the refill orders only stand for 27 percent of all orders.

[187] Eniro (2008): *Kartor, Vägbeskrivning*.

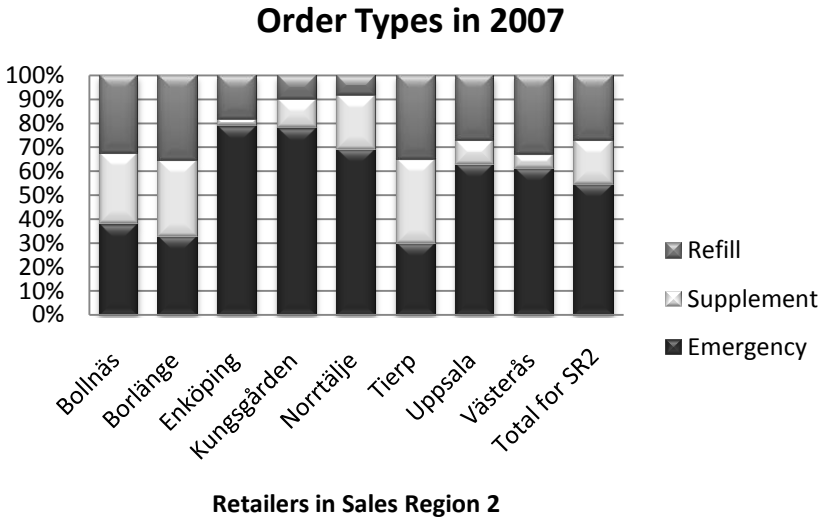

Figure 13-4. *Ratio of the usage of different order types during 2007.*

As indicated in Table 13-1, the retailers are of varying size, judging from purchase value. Another way to measure the sizes of the retailers is by looking at their inventory levels, which can be found in Figure 13-5 below. Uppsala is found to be the largest retailer in the sales region, both regarding inventory levels and purchase value. The non-stocking articles that are included in the inventory levels are articles that used to be stocking articles and have changed classification or articles that are manually kept in stock without a governing support from the software provided by Syncron. A trend of increasing inventory levels can be seen when looking at historical data for the total inventory level at each retailer, meaning that the amount of tied-up capital has grown the last year. According to Lantmännen Maskin, this can partly be explained by a modification in the way that the articles are valued, depending on where in the supply chain they are located, which means that it is rather the value of the articles and not the amount in stock that has increased.

Figure 13-5. *Inventory levels on the 24th of October 2008.*

13.5 Transport Suppliers

Lantmännen Maskin uses third-party logistics for all their transports and the transport cost for the outbound logistics, between the central warehouse and the retailers, sums up to about 4 percent of the total product value of the spare parts. For supply of the central warehouse transporters such as DHL and Schenker are used. Road transports to the retailers are performed by a company named HIT. If transport by air is needed the service is bought from Jetpak, but the final road transport between the airport and retailer is still done by HIT. The selling price of the spare parts, to the end customer, is independent of the distance between the central warehouse and the retailer, but is usually higher if the order was an emergency order shipped by air.

13.5.1 HIT

HIT, a subsidiary company to Posten Logistik, collects packages at the central warehouse in Malmö. Lantmännen Maskin's goods normally amount to between one fifth and one third of the truck's utilized capacity.[188] HIT then brings the goods to a terminal in Jönköping where the goods are sorted. Packages with similar destinations are loaded on the same truck and delivered before 7 am the next day or two days later,

[188] Tannér (2008).

depending on the retailer's distance from Jönköping. In sales region 2, the delivery time for Tierp, Norrtälje, Borlänge, Kungsgården and Bollnäs is two days, while Västerås, Uppsala and Enköping have a delivery time of only one day.

Before the goods are distributed in sales region 2, the goods are brought to a terminal in Stockholm, where a last sorting is made, and after that distributed to the different retailers. The final distribution also includes emergency orders that have been picked up by HIT at Bromma Airport. For the trucks used in HIT's business, the average consumption of diesel is 0.26-0.27 liter per km.[189]

For every shipment to a specific retailer, a fixed transport cost (drop cost) on X SEK is charged. If the shipment exceeds 40 kg, Y SEK per kg exceeding 40 kg is charged. For example, if at a certain day one shipment with weight 43 kg has destination Borlänge and another shipment with weight 50 kg has destination Uppsala the cost sums up to:

$$Total\ cost = (43 - 40) \times Y + X + (50 - 40) \times Y + X = 13Y + 2X\ SEK$$

HIT has recently informed Lantmännen Maskin about a probable price increase, which they motivate by referring to the higher fuel price and fees and taxes within the transport industry. Future introductions of new taxes and fees will likewise be added to the price of the transport.[190] Lantmännen Maskin is aware of fact that they currently have very favorable prices at HIT, compared to HIT's other customers.

13.5.2 Jetpak

Air freight is used for emergency orders that have to be delivered before 7 am the next day. Since some retailers are located far away from the central warehouse, air transport is the only way to reach those retailers in such a short time. The fee for air freight is related to the weight of the shipment and it consists of both a fixed and a varying part. If the shipped goods are bulky, the volume may also be a factor when the price is set. Approximately, Lantmännen Maskin pays Z SEK per kg for air freight to the retailers in sales region 2. Jetpak arranges air freight with Malmö Aviation

[189] Tannér (2008).
[190] Ibid.

to Bromma and with SAS to Arlanda and then transfer flights to Umeå, Skellefteå, Visby and Luleå. A fix cost is paid each time transport to Malmö Airport from the central warehouse is needed and half of that sum can be allocated to sales region 2.

13.6 Logistics and the Environment[191]

The large-scale environmental project called GreenLine at the group Lantmännen aims to develop sustainable logistics by making the group more environmentally friendly, economical and secure. A quantified goal in the project is to reduce the emission of CO_2 with 20 percent until 2010. Today Lantmännen Maskin does not know how much CO_2 emission their transports cause, but their transport supplier will in short have to report their emission levels. Within the near future, Lantmännen will start classifying their transport supplier in different levels based on which environmental actions the supplier has taken. Examples of actions are the usage of biofuels, eco-driving and increased fill rate of trucks. To simplify calculations of the emissions due to transports, Lantmännen has decided on a common base for the entire group. For transports performed by trucks, the CO_2 emission per ton kilometer is set to 0.048 kg.

[191] Brishammar (2008): *Miljö och Säkerhet*.

14 Internal and External Methods of Adaption

This chapter introduces and discusses the internal and external methods of adaption that are included in the scope of the case study at Lantmännen Maskin. The knowledge gained in the theoretical framework is applied on the specific supply chain studied in the case. Lastly the adaption methods' influences on company specific matters are presented.

Lantmännen Maskin may affect their environmental footprint and transport costs by altering and developing their way of distributing spare parts. Other aspects that influence the size of the environmental footprint and the transport costs are taxes and fees, which can be seen as external control measures since companies alone have no possibility of changing the size of those economical control measures.

Several areas have been identified as cost and emission drivers in the distribution system at Lantmännen Maskin. These are *delivery frequency, order types, article classification, virtual supply and taxes and fees*. How these can be modified to achieve a more sustainable supply chain, is discussed in the following chapter.

14.1 Delivery Frequency

The delivery frequency of spare parts to the retailers is very high; deliveries of refill orders occur Tuesday through Saturday. On average, every retailer gets a replenishment delivery four out of five days a week. Since Lantmännen Maskin uses third party transport suppliers, they can only indirectly influence the actual transport frequency of HIT's trucks. If the delivery frequency was reduced to only include deliveries on Tuesdays, Thursdays and Saturdays or on Wednesdays and Fridays for sales region 2, several aspects in the spare part supply would be affected. There are two ways of conducting this change in reality; either by combining two or three incoming refill orders at the central warehouse or by changing the order placement pattern at the retailers.

14.2 Order Types

Lantmännen Maskin chooses transport mode depending on the order type. The general mode is truck, but for emergency and sometimes supplement orders airplane is used if the retailer is located in an area where HIT needs

two days to make a road delivery. These retailers are Bollnäs, Borlänge, Kungsgården, Norrtälje and Tierp. As soon as a customer requests a part that is not in stock, a rush order is placed. This happens frequently and gives rise to high transport costs and negative environmental impact.

By simply extending the lead time for emergency and supplement orders, the quantity transported by air can be reduced significantly. Other actions that can be taken in order to lower the amount of rush order, thus also decreasing air transports, are modification of the forecast system and increased stock levels to diminish the risk of shortage, which effects the service level positively.

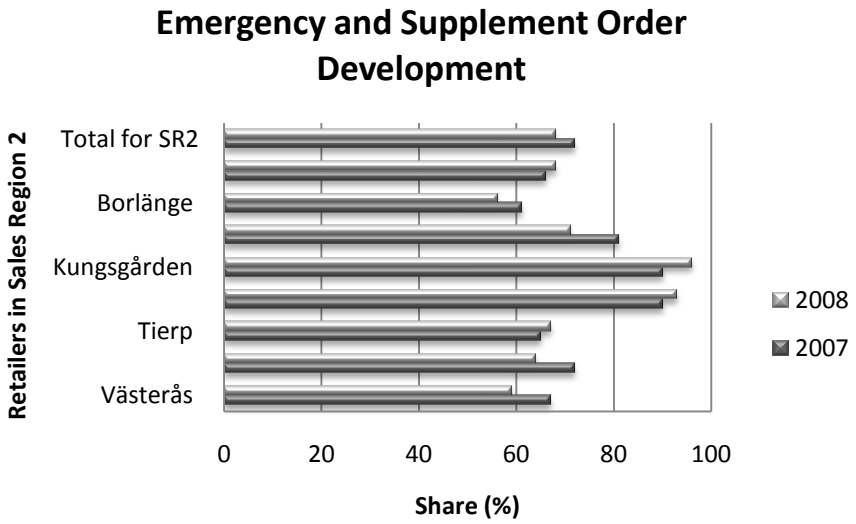

Figure 14-1. *Comparison of the rush orders placed in 2007 and 2008.*

Lantmännen Maskin is aware of that the emergency and supplement orders represent a large part of the total amount of placed orders. The administrative functions at the central warehouse are trying to mediate the importance of classifying the orders correctly to the retailers, since they suspect that some refill orders actually are placed as rush orders and vice versa. The change in number of rush orders is shown in Figure 14-1 above. For sales region 2 as a whole the amount of placed rush orders have decreased a couple of units, comparing 2007 and 2008.

14.3 Article Classification

Currently about one fourth of the spare parts provided by Lantmännen Maskin is categorized as stocking articles and accordingly governed by Syncron's software. If more articles were to be classified as stocking articles at the retailers, it would have several consequences. A possible and likely way to implement such a change is to use Syncron's system to control a larger amount of articles than today. These new stocking articles should be governed towards a relatively low service level, only causing a slight increase of the tied-up capital, but still being available instantly when a customer requests them.

The decision of which articles to change classification on is very complex. It mainly depends on three aspects; the value of the article, the yearly demand and the customer's need of receiving the article quickly after ordering.

14.4 Virtual Supply

A possible way for Lantmännen Maskin to influence their environmental effect is to start using some kind of extended virtual supply solution. Since the software provided by Syncron is in use today, it is possible to argue that some kind of virtual supply chain solution already is in use. When discussing an introduction of a virtual supply solution in this section and in the analysis, an introduction of a logistical role of the cyber media is the considered subject. In the studied system, a logistical virtual supply solution, in the form of a lateral transshipment concept, would mean that if a shortage occurs at one retailer, the replenishment software would check if any other retailer in the sales region has the requested spare part in stock at the moment. If that is the case, it will not be necessary to place a rush order to the central warehouse. The demand can instead be satisfied by a nearby retailer, thus decreasing the usage of air freight.

The main consequence of a lateral transshipment solution in Lantmännen Maskin's case is the shift in order types. Less rush transports have to be placed and non optimized picking at the central warehouse can be avoided to some extent. If the software supported by Syncron would support this kind of virtual supply solution, the method could quite easily be implemented without any larger investments.

To make the change in routines less complicated, only Uppsala could be used as 'first hand' supplier, since Uppsala is the retailer with the highest inventory level and purchase value. Moreover, Uppsala has a central geographical position within the region, making it accessible to all of the other retailers without too time consuming transports. The lateral transshipment solution implies that if a shortage on an article in Kungsgården arises, the article will in the first place be sent from Uppsala, assuming that the requested article is available there. No rush orders supplied by Uppsala should cause stock-outs in Uppsala though, meaning that the quantity in stock in Uppsala, must be large enough to satisfy the rush order and still be able to satisfy upcoming demand in Uppsala. If the inventory level at Uppsala is zero or too low to satisfy the rush order in question, the order should as usually be supplied by the central warehouse. This concept would make Uppsala function as a regional support warehouse, which is why an increase in inventory level would be necessary in order to handle the increased demand.

To investigate the possibilities of implementing the proposed routine, four stocking articles, see Table 14-1, with high rush order frequency were analyzed, by looking at historical data. This revealed that many of the rush orders could have been supplied by Uppsala instead of the central warehouse, which would have lowered the usage of air transports. Approximately 75 percent of the rush orders shipped by air could instead have been satisfied by sending the requested article with truck from Uppsala. This suggests that savings both related to environmental concerns and transport costs could be achieved.

Article Description	Average Price (SEK)	Weight (kg)	Rush Orders with Air Freight
Bearing	72	0.235	7
Start Engine	1308	8.92	11
Share	31	0.56	8
Filter	176	0.354	17

Table 14-1. *The four analyzed articles.*

14.5 Taxes and Fees

The external methods of adaption in this area play a significant role in transport cost structure. Lantmännen Maskin has no possibility to influence the design or size of the taxes and fees since they are all regulated on a governmental level. Since all transports in the studied system are performed by truck or airplane, the regulations of interest are the kilometer tax, the fuel taxes and the EU ETS.

14.5.1 Kilometer and Fuel Taxes

An introduction of the kilometer tax, alone or in combination with increased carbon dioxide and energy taxes on fuel, will increase the transport costs for Lantmännen Maskin, assuming that the increased costs for the transport supplier are directly transferred to the transport buyer. The magnitudes of the increased tax levels are very hard to predict and therefore a couple of realistic scenarios are used when calculating possible future cost increases. Several sources predict a kilometer tax in the ranges of 1-10 SEK and a probable increase of the fuel related taxes with up to 6 SEK.[192]

14.5.2 EU ETS

The European Union Emission Trading System will include the aviation sector in 2012 and hence bring about a cost increase for airlines due to purchase of emission allowances. Lantmännen Maskin uses air traffic for some of their emergency orders and will therefore be influenced by the emission system. The magnitude of the cost increase that will be transferred to the buyer of the transport service is difficult to predict since numerous factors affect it, such as the state of the market and the design of the allowance distribution. The Finnish ministry of environment predicts a cost increase of 2 percent as a result of including the aviation sector in the EU ETS.[193] This value has been used as a guideline when calculations on cost increases related to the emission trading system have been performed.

[192] For a wider reasoning concerning the tax levels, see chapter 6 (*Part 1*).
[193] Finska Miljöministeriet (2007): Flygtrafiken med i EU:s utsläppshandel år 2012.

14.6 Consequences

The adaption methods of areas that have been identified as costs and emission drivers in Lantmännen Maskin's distribution system are presented in the vertical column in Table 14-2. The horizontal top row shows examples of important consequences that are caused by modification of the cost and emission drivers. The connections that will be further investigated are the ones marked with an X in Table 14-2 below, the others are considered to have negligible impact on the sustainable supply chain performance at Lantmännen Maskin.

The analysis presented in the following chapter focuses on the consequences on transport cost and environmental effects, since those are the most central areas in the scope of the thesis. Other areas on which the adaption methods have a less significant effect, but still noticeable, are also discussed in the analysis, but not as thoroughly as the transport cost and the environmental influence. These areas are service level, tied-up capital and lead time.

Methods of Adaption	Transport Cost	Environ-mental Effects	Service Level	Tied –Up Capital	Lead Time
Delivery Frequency	X	X	X		X
Order Types	X	X	X		X
Article Classification	X	X	X	X	
Virtual Supply	X	X	X	X	
Taxes and Fees	X				

Table 14-2. *Significant connections between adoption methods and consequences that are to be analyzed.*

15 Analysis

The findings from the case study are analyzed in this chapter, with the aim of answering the two problem questions related to Lantmännen Maskin's supply chain. The adaption methods presented in the previous chapter will here be related to company specific aspects. All calculations made in order to support the analysis are presented in detail in Appendix 4.

15.1 Transport Cost

To enable a sensitivity analysis of the transport cost, for the supply of spare parts at Lantmännen Maskin, the current costs have to be determined. The retailers included in the study are all primarily supplied by the transport companies HIT and Jetpak why negligible costs, from business parcels for example, are not included in the calculations. An inclusion of them would not have made any noticeable difference, since those shipments are rare and only contribute insignificantly to the total cost. In Table 15-1 below, the transport cost, stretched for a whole year, for each retailer is shown. The table also shows to which extent the retailers use the transport modes at hand; truck or airplane. Lastly the table presents how large share of the products' purchase value that the transport cost makes up for. In interviews at Lantmännen Maskin, 4 percent was said to be the ratio. The reason that sales region 2 have a slightly higher value is that the usage of air freight is above average compared to the other sales regions. On average the transport cost per kg for Jetpak transports is 4 times larger than for transports performed by HIT.

Retailer	Total Transport Cost (SEK)	HIT Cost (%)	Jetpak Cost (%)	Share of Purchase Value (%)
Bollnäs	167 000	27	73	9
Borlänge	163 000	28	72	7
Enköping	60 000	100	0	3
Kungsgården	106 000	6	94	13
Norrtälje	80 000	67	33	6
Tierp	121 000	28	72	13
Uppsala	69 000	100	0	2
Västerås	60 000	100	0	2
Transport to Sturup	52 000	-	-	-
Total	**878 000**	**43**	**57**	**6**

Table 15-1. *Transport cost from the central warehouse to the retailers, use of transportation mode and transport costs' share of the purchased value.*

15.1.1 Delivery Frequency

One way to lower the high delivery frequency Lantmännen Maskin offers today is to decrease the number of order release days at the retailers. Assuming that the retailers would have released refill orders on Mondays, Wednesdays and Fridays only and not Monday through Friday, as was the case last year, this would have reduced the number of shipments and subsequently the cost for road transports. Since Uppsala, Enköping and Västerås are three of the four retailers with largest purchase value and since they use truck for rush orders as well, these retailers are excluded from the modification scenario with less frequent order releases. Kungsgården was excluded as well, because they mainly use air transports and thus get refill order deliveries by truck very seldom. For the other retailers, refill shipments from last year were initially combined two and two, in order to create a scenario where orders were released every second day. Calculations on the transport costs in this scenario confirmed that costs for shipment of refill orders, at the retailers using both road and air freight, would decrease according to Figure 15-1.

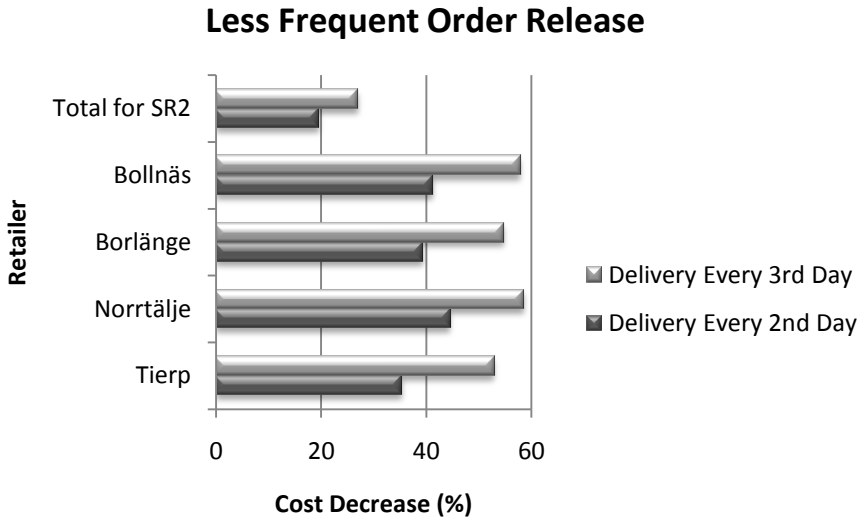

Figure 15-1. *The decrease of road transport cost, due to a lower delivery frequency.*

If the retailers using both air and road transports decreased their release frequency for refill orders to release every second day, savings in the size of 40 percent could be achieved on costs for road transportation. Looking at the entire sales region 2, this would render a cost decrease of the road transport cost on approximately 20 percent. The effect on the total transport cost (including both road and air freight) sums up to an 8 percent cost reduction. Reducing the order release frequency even more, by only placing orders every third day, would reduce road transport costs with around 50 percent, which also can been seen in Figure 15-1. The effect on the transport cost for entire sales region in this case is a 27 percent reduction for road transports only and a 12 percent reduction when looking at the total transport cost.

The current average shipment weight for road transports is 40-45 kg. Some refill orders that are shipped are as small as 11 grams. A shipment of 11 grams generates a drop price of X SEK, a cost that could be eliminated if the shipment was sent together with the shipment of the next day shipment instead. At most, an additional cost for the weight of 11 grams would be added to the price of next day's shipment, but this cost is negligible compared to the drop price of X SEK.

15.1.2 Order Types

It is only rush orders that are supplied by air freight, which enables delivery within 24 hours after the order is placed. For some of the retailers no air freight is used, since the location of those retailers enables HIT to deliver by truck within 24 hours. If the supplement or emergency orders placed at the retailers that call for air transport were instead shipped by truck, air transports could be eliminated. Since an order shipped by truck always can be delivered within 48 hours, the end customers would have to wait one day extra for their spare parts. If that was acceptable, considerable savings of the transport cost and environment could be made. The magnitude of the possible savings can be found in Table 15-2 below. Notable is that if no air freight were used in the sales region, the transport cost for the region could be decreased by as much as 48 percent, which is equivalent to more than 400 000 SEK.

Retailer	Savings if no Air Freight (%)
Bollnäs	66
Borlänge	64
Enköping	0
Kungsgården	54
Norrtälje	31
Tierp	58
Uppsala	0
Västerås	0
Total	**48**

Table 15-2. *Possible savings if no air freight were used for rush orders.*

Another way to reduce the amount of air transports is to simply avoid shortage situations. Since 50 percent of the orders placed by the retailers originate from the service workshop, accurate and early guidelines regarding the workshop's future demand would enable the retailer to put refill orders on these articles in advance, thus preventing expensive air transports.

15.1.3 Article Classification

By including more of the articles in the stocking category, shortage situations could be avoided and the need for rush transports by air decreased. The transport costs would consequently shrink and could at most be reduced by 48 percent, which is the saving if no air freight at all is used. Air freights are not expected to be entirely eliminated though, since rush orders will still be placed when shortage arises. Therefore savings in the range 0 and 48 percent are to be anticipated, depending on how well dimensioned the inventory is and how good the modified stocking criteria are.

15.1.4 Virtual Supply

The logistical virtual supply concept, with Uppsala working as an unofficial region warehouse, would reduce the need for air transports since part of the rush orders would be shipped from Uppsala by truck instead of flown from Malmö. The effect this would have on transport costs was estimated by calculating the weight related costs for the rush orders on four different articles. In some cases, the drop-price on X SEK, arising when collecting the shipment at Bromma Airport, and the cost for bringing the orders to Malmö Airport will be eliminated. However, a fair estimation of the cost reduction due to this is hard to obtain, therefore no such estimation was made. The calculated cost reduction in this scenario, including weight related costs only, is consequently lower than what can be expected in reality. One thing to keep in mind is that additional road transports will be necessary when distributing orders between Uppsala and the other retailers. This will generate new costs, but those will unlikely be higher than the costs for bringing the goods to and from the airport, which were neglected in the calculations even though they to some extent will vanish. Therefore, no consideration was taken to the additional costs of shipping orders from Uppsala.

75 percent of the weight related air transport costs were assumed to be removed since this was the approximate share that could be supplied from Uppsala. For each of the four articles, this cost reduction roughly corresponds to the present holding cost for these articles in Uppsala. This enables an allocation of costs, which is preferable in order to optimize the virtual supply solution. Savings achieved if reducing air transport with 75

percent allows approximately a doubling of the inventory levels in Uppsala without increasing the sum of the present costs for transportation and holding inventory.

The analysis of the concept calls for a few comments. Since the analyzed spare parts are articles with high rush order frequency, they are not representative for an average spare part. In addition to this, the concept focuses on stocking articles, since having the articles included in the virtual supply solution in stock is compulsory in order to succeed with the concept.

15.1.5 Taxes and Fees

Costs for performing road transports will inevitably rise in years to come. A realistic scenario is that a kilometer tax at 1-10 SEK will be introduced, and so an analysis of how this tax would alter the costs for Lantmännen Maskin has been performed. Assumptions that have been made to reach a feasible ground for calculations are:

- The deliveries to sales region 2 take up 5 % of the capacity of one truck.
- Retailers in sales region 2 get deliveries Tuesday through Saturday.
- No additional cost for return transports are paid by Lantmännen Maskin.
- The average distance to retailers in sales region 2 from the central warehouse is 700 km.
- A kilometer tax is introduced.
- Introduction of the kilometer tax only affects the drop price per shipment.
- The variable cost per kg, for shipments exceeding 40 kg, is not affected.
- The Eurovignette Fee is removed.

The cost increase in percent for transports to retailers in sales region 2 can be seen in Figure 15-2 and Figure 15-3. Those results are attained by:

- Calculating the total cost increase for using one truck on a distance of 700 km every day.

- Reducing the cost increase with the Eurovignette Fee currently paid by HIT.
- Multiplying the remaining cost increase with 5 % to get Lantmännen Maskin's share of the increase.
- Splitting the cost increase on the total amount of truck shipments during the last year.
- This results in a cost increase for the fixed drop price.
- The new drop price is used to calculate a new cost for HIT transports as well as the total transport cost during the last year if a kilometer tax would have been charged.

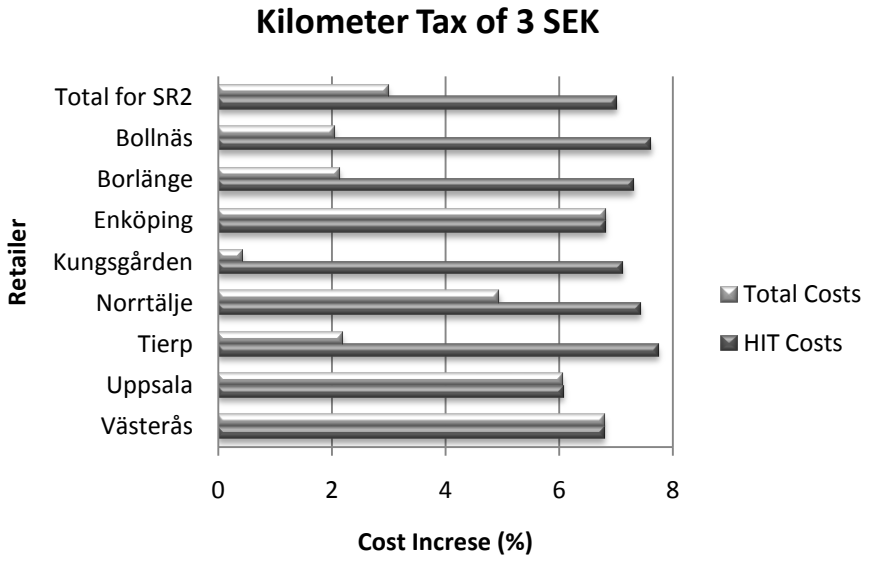

Figure 15-2. *Cost changes when kilometer tax of 3 SEK is charged.*

Obviously, the proposed tax would influence the transport costs, but not to a considerable extent. For sales region 2 as a whole, see Figure 15-2, costs for road transports with HIT would increase with about 7 percent, while in total, the transport costs would increase with 3 percent if the tax was 3 SEK per km. If the tax would be 7 SEK per km, which is reasonable since this is the kilometer tax charged in Switzerland, a cost increase on 17 percent for HIT transports and on 7 percent for transports altogether would be likely, see Figure 15-3. Analysis of how the drop price would change in order to meet a higher cost when performing transports, due to the kilometer tax,

shows that the price would have to increase by 8 percent in order to cover a kilometer tax on 3 SEK per kilometer, and by 19 percent to cover a kilometer tax cost on 7 SEK per kilometer. A 19 percent higher drop price would mainly affect transport costs to retailers receiving a lot of shipments less than 40 kg, due to the cost structure of the HIT transports.

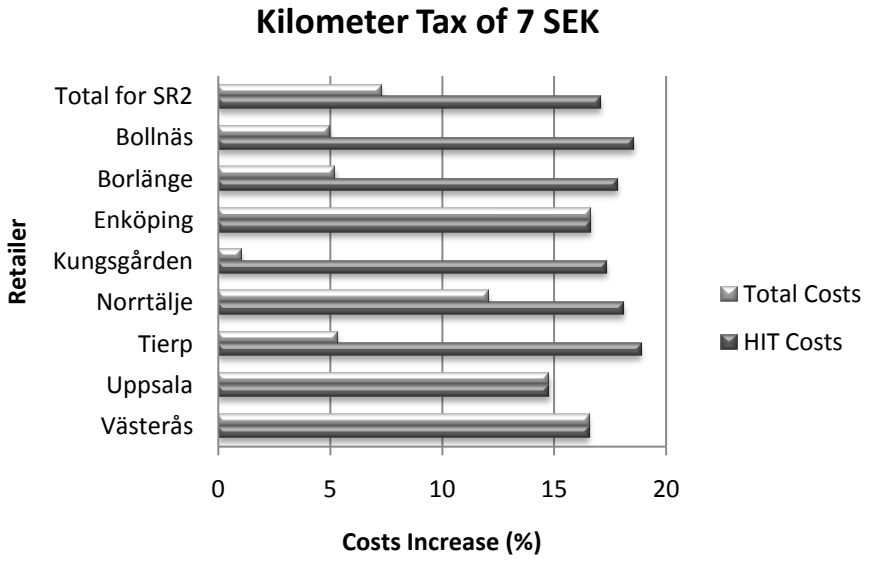

Figure 15-3. *Cost changes when kilometer tax of 7 SEK is charged.*

One cost driver for road transports is the travelled distance. If a kilometer tax was charged, the total cost for this would grow if the travelled distance was extended. The same goes for fuel costs, since fuel consumption in part depends on the travelled distance. From this reasoning follows that a higher fuel price, caused by increased purchase price on diesel or taxes, would increase the total transport costs as much as a certain kilometer tax would, assuming everything else, such as engine efficiency, is unchanged. An average truck driven by HIT consumes approximately 0.3 liter diesel per km. The transport cost increase generated by a kilometer tax on 2 SEK or 4 SEK per km would thereby be equivalent to a 6.70 SEK or 13.30 SEK higher diesel price. Today the diesel price is approximately 12 SEK per liter, where about 6 SEK is taxes and 6 SEK is the purchase price for diesel. It is not likely that both the diesel purchase price and the taxes will more than double and result in a diesel price about 12 SEK higher than today, which roughly corresponds to a 4 SEK kilometer tax. On the other hand, a

duplication of the taxes OR the diesel price is not unrealistic. Consequently a 6.70 SEK higher diesel price, resulting in cost consequences in the same magnitude as from a kilometer tax on 2 SEK per kilometer, may seem like a possible future scenario.

To compensate for the increased costs, due to introduction of a kilometer tax, Lantmännen Maskin could reduce or entirely stop shipping rush orders by air, since this transportation option is four times more expensive per kg. Calculations show that the total cost for transports would be reduced by 39 percent if no air freight were used and if the kilometer tax was 7 SEK per km, which can be compared to the saving of 48 percent if no kilometer tax was charged in combination with no air freight. The cost change at each retailer can be seen in Figure 15-4. Since Enköping, Uppsala and Västerås already use only road transports, their costs will subsequently increase.

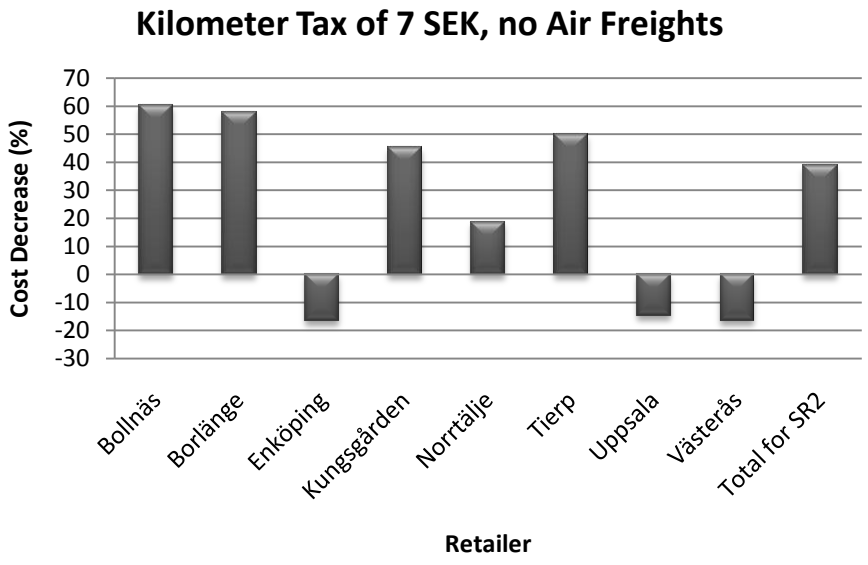

Figure 15-4. ***Cost changes when kilometer tax of 7 SEK is charged and no air freight is used.***

An economical control measure that will have consequences on transport cost for air freight is the inclusion of the aviation sector in the EU ETS. As mentioned in the previous chapter, a possible effect of this will be 2 percent higher prices for air transports. To analyze how a slightly higher

increase on 4 percent would change Lantmännen Maskin's total transport costs, the price per kg for air freight was multiplied by 1.04, leading to the price 1.04Z SEK per kg. This renders a 2 percent higher total cost for transports and 3.5 percent higher cost for air freight, which indicates that this economical control measure will have no significant influence on Lantmännen Maskin's transport costs. The cost for air freight is already high in comparison to other transportation options and a cost increase due to the EU ETS will become negligible in relation to the current price.

15.2 Environmental Effects

The yearly CO_2 emission made with the current transportation setup at Lantmännen Maskin is presented in Table 15-3. From the numbers presented it is found that air freight emits about 25 times more CO_2 per transported ton than road freight, which is why every ton that is not sent by air is helping to decrease Lantmännen Maskin's negative effect on the environment. For every ton of goods that are shipped by truck instead of airplane from the central warehouse to sales region 2, the CO_2 emission made is reduced from approximately 880 kg per transport to 35 kg.

Transport Mode	Shipped Weight (ton)	CO_2 Emission (ton)
Road	76	2.5
Air	25	22
Total	**101**	**24.5**

Table 15-3. *Yearly shipped weight and CO_2 emissions divided on the used transport modes.*

The emission figures for road freight are calculated based on the emission level of 0.048 kg per transported ton kilometer, which is a set value for the entire Lantmännen group. The air freight emission derives from a webpage[194] calculating the emissions made from airplanes. Before using the page for calculating the air freight emission, several other sources were investigated, such as emission guidelines from the Swedish Civil Aviation Administration and they all provided emission levels in the same magnitude, hence the result can be seen as credible.

[194] Climate Care (2008): Business Calculator.

Actions taken by Lantmännen Maskin, regarding an improved environmental performance, would not directly affect the actual number of transports performed by HIT and Jetpak. However, their contribution to the emission of CO_2 would be reduced and therefore the environmental comparison only regards their share. If more transport buyers would adopt the suggested adaption methods, the actual number of transports could be decreased by improving the coordination.

15.2.1 Delivery Frequency

When altering the delivery frequency of refill orders the transport related environmental effects are not changed. The reason for this is that the emissions are based upon the total transported weight and distance, which are not affected by a decreased delivery frequency.

Since Lantmännen Maskin uses third-party logistics companies for all their transports, they have little possibility to affect the transporters behavior. If Lantmännen Maskin decided to only have shipments on specific days of the week, the trucks would still be driving since HIT's other customers need their goods delivered. An imaginable way to decrease the number of trips to the area around sales region 2 is if several of HIT's customers joined together, demanding higher fill rate of the trucks. This scenario is not likely to occur, for this reason it can be concluded that an altering of the delivery frequency would not have any environmental effect in the studied system within a reachable time horizon.

15.2.2 Order Types

If no air freight was used, thus prolonging the lead time for emergency and supplement orders by 24 hours, the CO_2 emission level would drop drastically. The total CO_2 emission level would decrease to 3.4 ton per year which corresponds to a lowering of the emission by 86 percent. Keeping this in mind, the internal goal at Lantmännen Maskin to decrease the emission by 20 percent seems very reachable, if only Lantmännen Maskin's customer could accept a 24 hour longer delivery time for emergency and supplement orders.

15.2.3 Article Classification

One consequence of classifying more articles as stocking articles is less rush orders and accordingly less air transports. Enabling more use of truck

gives a positive effect on the environment, since trucks emits only a fraction of the CO_2 emitted by airplanes during an equally travelled distance. As discussed in the section above, the total emission of CO_2 could be reduced by 86 percent if no air freights were used at all. It is not a realistic scenario that all air transports would vanish, but a reduction of the CO_2 emission should be expected and its cap is 86 percent. The emission decrease depends on to which extent the usage of air transports can be reduced. In turn, this corresponds to the amount of requested articles that are available to the customer immediately, not requiring the placement of a rush order shipped by air.

15.2.4 Virtual Supply

A functioning logistical virtual supply solution will reduce the need for rush orders sent as air freight, since many of the rush orders can be supplied by the retailer in Uppsala. If more goods are shipped by trucks, the emissions related to the spare part supply can be decreased considerable. How much air freight that can be eliminated depends on how often the lateral transshipment solution manages to supply the retailers locally.

15.3 Service Level

The service level to the end customer, as Lantmännen Maskin defines it, is directly related to whether or not all of the requested spare parts are available at the retailer straight away. This means that if the demand on any of the requested parts cannot be fully satisfied, a rush order has to be placed and the service level on this specific demand is zero.

The lead time to the customer does not affect the service level directly, meaning that longer or shorter lead time on rush orders will not have any influence on the service level, using the current definition at Lantmännen Maskin. On the other hand, the relatively long lead time on refill orders could actually cause shortage while the retailer is waiting for the refill, leading to decreased service level.

In the analysis, focus has been on the service level to the end customer and not to the retailers, since shortage at the retailer can cause more damage to the end customer than shortage at the central warehouse can cause to the retailer. The retailers are not actual customers, since they are owned by Lantmännen Maskin, therefore the replenishment of the retailers can

be seen as internal inventory control. How well this control works of course has impact on the service level to the end customer, which is why the aspect of service level to the retailer will indirectly be comprised when analyzing the service level to the end customer.

15.3.1 Delivery Frequency

Intuitively, it is easy to believe that less frequent deliveries will deteriorate the service level, since some refill orders ought to arrive later than they do with every day deliveries, leading to higher risk for shortage. Combining a reduced delivery frequency with shorter idle time for the order in the system would actually lead to the opposite. Some refill orders will instead arrive earlier than with today's routines, since they will be sent from the central warehouse after three or four days instead of five, and thus be available to the customers earlier. By looking at Figure 15-6, this reasoning is obvious. According to the figure, orders placed every second or third day will arrive at the retailer one or two days earlier than with today's routine. Today, there is a chance that the stock is emptied at day five after the refill order has been placed. If a customer then comes in and requests the article, a shortage and service level decrease will emerge. If instead the idle time in the system would have been three or four days, in order to match the delivery days, the article would have been delivered and available to customer at day five.

Even if rush orders are not affected by a decreased delivery frequency for refill orders, it would not make any difference to the service level if the delivery frequency for rush orders were lowered as well. This can be explained by the fact that the shortage, resulting in a service level of zero, has already occurred.

15.3.2 Order Types

As mentioned in the previous section, the service level is not affected by longer lead times on rush orders. Therefore, a shift in order types from rush orders shipped by air to orders shipped by road will not have any effect on the service level, when measured as the share of demand that can be entirely satisfied at once.

15.3.3 Article Classification

Lantmännen Maskin has a wide range of articles which make decisions, about what to keep in stock and how much, difficult. Parts classified as non-stocking articles will more or less always generate a rush order whenever a customer requests it, and thus lower the service level, since no stock exists which means that the demand cannot be fulfilled immediately. Stocking articles will require a rush order if the stock is insufficient to satisfy the demand, in general due to replenishment failure. This normally occurs when the forecast and real demand disagrees. An important aspect that affects the service level is consequently the ability to decide which spare parts to classify as stocking articles and how much inventory to keep. If high inventory levels would be held for all spare parts, no shortage would arise and the service level would be 100 percent, but the holding costs would be extremely high.

As mentioned before, only 25 percent of the spare parts are classified as stocking articles. By introducing more articles to the stocking category, less shortage would occur and the service level would ascend. The number of units in stock would not necessarily have to be high, just high enough to be able to satisfy a higher share of the demand directly, with higher service level as an outcome.

15.3.4 Virtual Supply

Once again, changes in routines for rush orders have no effect on the service level. The logistical virtual supply solution mainly concern the supply of rush orders, but since a modification of inventory levels is included in the solution, the fulfillment of customer demand in general will be affected. If the inventory levels at all retailers except Uppsala are unchanged, the solution will not have any impact on the service level at these retailers. However, if the inventory level at Uppsala is enlarged, the likeliness for shortage ought to decrease at this location. On the other hand, the demand will increase, since the other retailers will use Uppsala as supplier to some of their rush orders. An increased risk for stock-outs will nevertheless be avoided since Uppsala will only be used as supplier under the condition that their current inventory level for the demanded article is big enough.

15.4 Tied-Up Capital

The tied-up capital for stocking articles in sales region 2 amounts to about 3.7 million SEK and almost one fourth of that value (0.9 million SEK) is located in Uppsala. This makes it the largest and most significant retailer, when looking at the spare parts governed by Syncron's software. Several of the suggested adaption methods have no effect on the inventory levels, and thereby not the tied-up capital either. Aspects that do affect the amount of tied-up capital are a change in article classification and an introduction of a virtual supply system.

15.4.1 Article Classification

If articles classified as non-stocking at the retailers were to change classification and become stocking articles, the inventory levels in sales region 2 would increase. If the inventory levels at the different retailers get higher, the total amount of tied-up capital will increase. This will also render a higher holding cost for the spare parts. The inventory level at the central warehouse is not affected noticeable. The demand is still the same, and articles that are classified as non-stocking articles at the retailers are often already stocking articles at the central warehouse.

A typical illustration of the inventory for a product with steady demand can be seen in Figure 15-5. This figure shows the inventory level for one of the articles analyzed in connection with the virtual supply solution. Comparing to Figure 12-1 in the theoretical section 12.3, the safety stock seems to be around 15 units and the order quantity around 25 units.

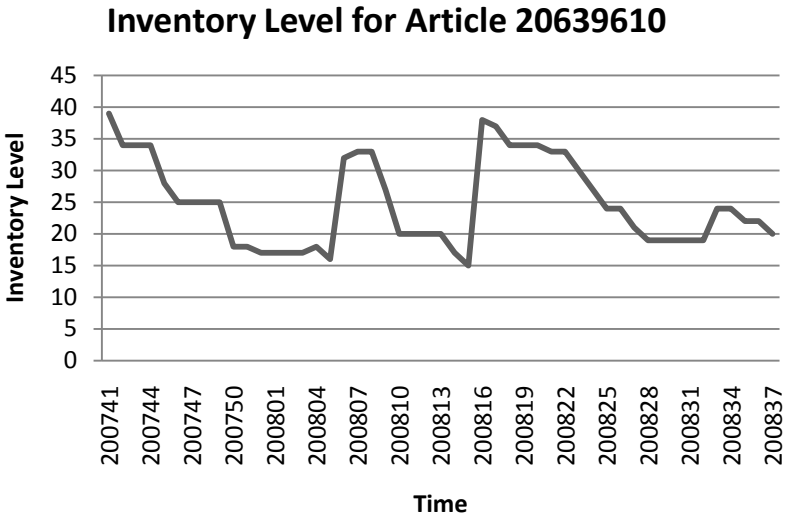

Figure 15-5. *Inventory level for one of the analyzed articles.*

15.4.2 Virtual Supply

As mentioned in section 15.1.4, the lower cost due to less air freight can be balanced with an increased inventory holding cost. This holding cost can be translated to the possibility of keeping a higher inventory level at Uppsala without increasing the total cost for the spare part supply, and this would enable a lowering of the inventory level at the central warehouse in Malmö. It is not possible to lower the inventory level at the central warehouse with the same amount that is transferred to the retailer though, if the current service level to all the retailers is to be kept the same. This, in combination with the fact that the articles have a larger stock value at the retailer in Uppsala than at the central warehouse give rise to a larger total amount of tied-up capital if the logistical virtual supply concept was introduced.

For the four specific spare parts, which were studied and analyzed with the intent of expanding the virtual supply system, it was found that the placed rush orders could have been supplied by Uppsala instead of the central warehouse in three out of four cases. This potential diminishing of air freight use renders the opportunity of a doubling of the inventory levels at Uppsala, without increasing the sum of sales region 2's transportation and holding costs. Inventory would then be allocated geographically closer to

the end customer. For articles with a lower amount of rush orders, a doubling of the inventory level at Uppsala is not necessary, in order to meet the demand. A smaller increase might be sufficient, enabling fewer rush orders sent by air. An introduction of a lateral transshipment solution would require an overlook of the safety stock levels, both at the retailers and at the central warehouse.

15.5 Lead Time

The lead time for a placed order varies depending on the order type, from 24 hours on emergency orders up to seven days for a refill order, which is to be delivered to a retailer far from the central warehouse. The adaption methods that affect the lead time are changes in the delivery frequency and order types. The influence on the lead time takes different shapes depending on which adaption method that is taken into consideration.

15.5.1 Delivery Frequency

Most of the retailers in sales region 2 have deliveries almost every day and many of these contain refill orders. The effect that a changed delivery frequency of the refill orders would have on the lead time is limited. A halved frequency would mean delivery of refill orders every other day at the retailers and a frequency decreased by two thirds means deliveries every third day, see Figure 15-6.

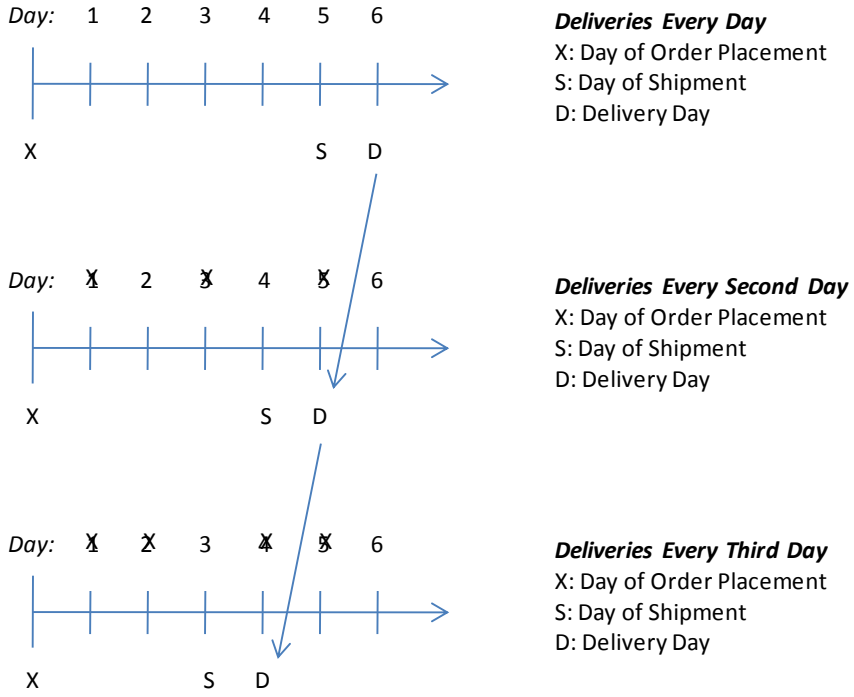

Figure 15-6. ***A changed delivery frequency's effect on the lead time to the retailer.***

A halved frequency is possible to achieve without a deterioration of the experienced lead time at the retailer, instead it would actually improve for some of the orders. The only downside is that the idle time the order has in the computer system will be decreased by one day for some of the orders. Since the only work done during this idle time is optimization of the picking at the central warehouse, this time ought to be able to shorten without any severe effects, which would enable a lower delivery frequency without prolonged lead time. Lantmännen Maskin actually intends to decrease the idle time in the system with a couple of days, which speaks for the potential of the proposal.

Assuming that approximately the same amount of orders are placed every day, then the lead time of 50 percent of the refill orders would be influence if the frequency was to be reduced to half. The effect would be a decrease by one day of the lead time, on 50 percent of the orders. A similar reasoning holds if the frequency is to be decreased to a third, se Figure

15-6 above. The perceived lead time at the retailer would then either be the same as today, one day shorter or two days shorter.

15.5.2 Order Types

If air freight is to be excluded as a transport mode, this leads to a prolonging of the lead time by 24 hours for the orders that are shipped by air today, thus causing a longer shortage time at the retailers. The aspect that Lantmännen Maskin has to consider is if their end customers are willing to wait an extra day when placing emergency and supplement orders or if they would take their business elsewhere if the lead time was prolonged.

15.6 Evaluation of the Internal Adaption Methods

In order to assess the suggested internal adaption methods and their overall influence, a ranking was made for each of the consequences. The method with the largest positive impact on the consequence in question was ranked with a positive high number, while a method with large, negative impact got a high negative number. Methods with similar impact got the same ranking. The previously presented analysis was used as decision base for the ranking.

After the ranking, the figures were summed row wise resulting in a ranking for each of the methods. This ranking indicates which methods that involve the smallest and largest trade-offs between the different consequences. A change of article classification for instance, where more articles are classified as stocking-articles, leads to slightly decreased transport costs, improved service level and environmental performance but has the trade-off of larger tied-up capital. This trade-off results in a low ranking for the method, compared to the other investigated methods.

The ranking, which can be seen in Table 15-4, implies that a change of the delivery frequency results in considerable positive overall impact, since it got the highest sum; ten points. Ranked secondly, but with a noticeably lower sum of six points, is the virtual supply solution.

When evaluating the potential of the different adaption methods separately, the ranking and the effort needed to implement the method have to be taken into consideration. A change of the delivery frequency is a

method which is relatively easy to implement, in comparison with the logistical virtual supply concept. However, the method with reduced delivery frequency is only compatible with retailers using air freight for rush orders, since rush orders to the other retailers will anyhow be delivered by truck on a daily basis and a daily refill order delivery will then not affect the transport cost or the environmental influence. If changes of order types or article classification were to be implemented, it would be on the same degree of difficulty as the implementation of a changed delivery frequency. However, these two methods have a relatively low ranking and an implementation of these would not give raise to a significant overall positive effect.

Methods of Adaption	Transp. Cost	Environ-mental Effects	Serv. Level	Tied–Up Capital	Lead Time	Rank
Delivery Frequency	4	1	2	0	3	**10**
Order Types	5	5	0	0	-5	**5**
Article Class.	3	3	3	-4	0	**5**
Virtual Supply	3	3	1	-1	0	**6**

Table 15-4. Ranking of the suggested adaption methods.

With this ranking in mind, discussions were held with individuals from Lantmännen Maskin,195 representing both the retailer in Staffanstorp and the logistics at the aftermarket division. The different retailers have very similar routines why the retailer in Staffanstorp was visited instead of a retailer in sales region 2. The most substantial difference between the retailer in Staffanstorp and the ones in the studied area is their closeness to the central warehouse in Malmö. All transports to Staffanstorp are made by truck and customers with very urgent orders may be asked to go to the central warehouse to collect the demanded spare part. This difference regarding the transport routines were accounted for while discussing the potentials of the adaption methods.

[195] Svensson & Merkel (2008).

Generally, too many refill orders of too small quantities are placed, which renders lots of small packages and opposes economies of scale at the central warehouse. An implementation of a reduced delivery frequency would be quite easy to perform, which is an aspect that speaks in favor for the method. This method would mainly target the smaller retailers using air freight for their rush orders, hence not the larger retailers using trucks for both refill and rush orders, since these retailers are offered daily deliveries of rush orders anyway.

Representatives from Lantmännen Maskin emphasize that at a possible future reduction of the delivery frequency, it would be important to secure an even flow of goods at the central warehouse, which enables an even workload. This can easily be obtained by packing orders to specific sales regions every other day. An aspect that has to be investigated before an reduction is made is HIT's reaction to the changes of transport routines. Moreover, each delivery would be bigger and the unpacking on days of delivery would consequently take more time. According to the representatives from Lantmännen Maskin, a reduced delivery frequency of refill orders would however not cause any major difficulties of importance or have significant impacts on the current way of working at the retailers.

A change of the order types, aiming to decrease the rush orders sent by air, is easy to implement since the only thing needed is to prolong the lead time on emergency orders sent as air freight by 24 hours and send all orders with truck. The representatives from Lantmännen Maskin oppose this idea though and argue that emergency orders have to arrive within one day; anything else would not be acceptable by the customers. Whether or not the customers actually need the spare part the next day, or if they just are used to the high service standard at the retailers, is arguable. A possible way to decrease the amount of orders shipped by air is to introduce some kind of cost incentive. A possible way to design the incentive is to give a discount to the customers that accept a prolonged lead time, alternatively to add a fee for time sensitive customers that corresponds to the increased cost that a rush order give rise to. It can be concluded though that air freight cannot be avoided if an important shortage arises, due to the customers' needs. It is more important to counteract the arising of shortages than extending the lead time, if the

goal is to lower the transport cost and the negative environmental influence due to rush orders sent by air.

One observation during the visit at the retailer in Staffanstorp is that they have spare inventory space at hand, meaning that the possibility of classifying more articles as stocking articles is easy to implement. The personnel confirm that this is the case at most of the retailers. Since most rush orders concern the non-stocking articles, this approach could be a way of improving the service level to the end customer. However, the problem is that rush orders on non-stocking articles seldom concern the same article several times. If more articles were to be kept in stock in spite of this, the wanted service level for these, rarely requested, spare parts should be quite low. The underlying reason for this is that a high service level requires high inventory levels and to avoid too much tied-up capital, the service level has to be kept lower than for frequently demanded articles.

The retailers' representative could find no immediate obstacles with the proposed logistical virtual supply solution. The introduction of a region supplier of rush orders is possible as long as the inventory levels are adapted to the higher demand.[196] This would of course call for an enlarged work force at the region supplier due to extra work with packaging and administration, but might simultaneously enable a reduced work force at the central warehouse. This adaption method is an effective approach when it comes to lowering the current transport cost and the negative effect on the environment, without affecting the lead time or the service level negatively. The method's weaknesses are that it calls for proximity among the retailers in the extended virtual supply solution and the risk of getting higher transport cost if the new distribution setup is not supported by HIT. The method is most favorable for regions situated some distance from the central warehouse. By incorporating emergency orders into Syncron's software and letting it choose if the article are to be supplied by the region supplier or the central warehouse, this extended virtual supply solution could quite easily be implemented.

[196] Svensson (2008)

The most important factors related to the four adaption methods are summarized in Figure 15-7 and Figure 15-8. Their strengths and weaknesses are compiled separately in order to give a clear general view.

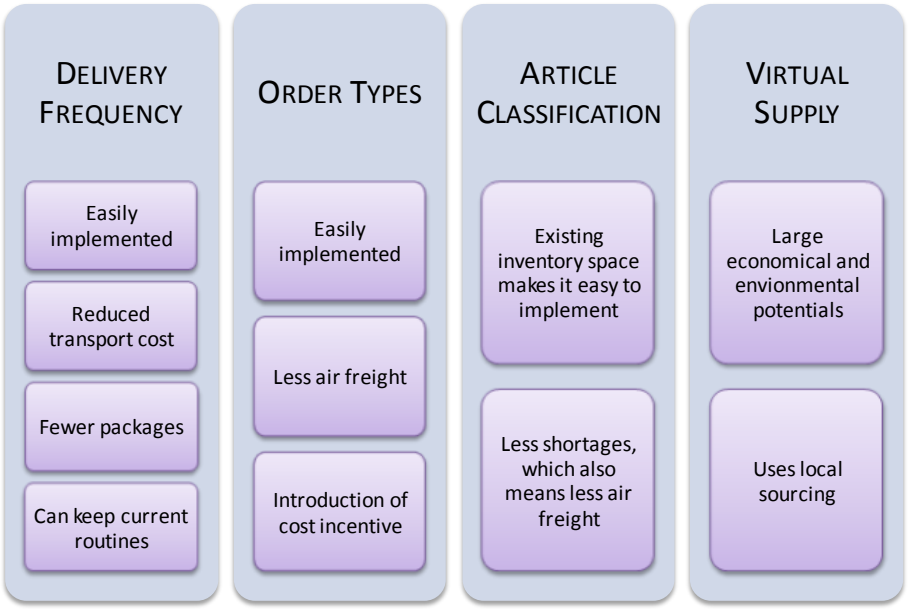

Figure 15-7. ***Most prominent strengths of the adaption methods.***

The strengths presented in Figure 15-7 above and the weaknesses presented in Figure 15-8 below, take the transport and environmental consequences as well as present conditions and implementation work into consideration.

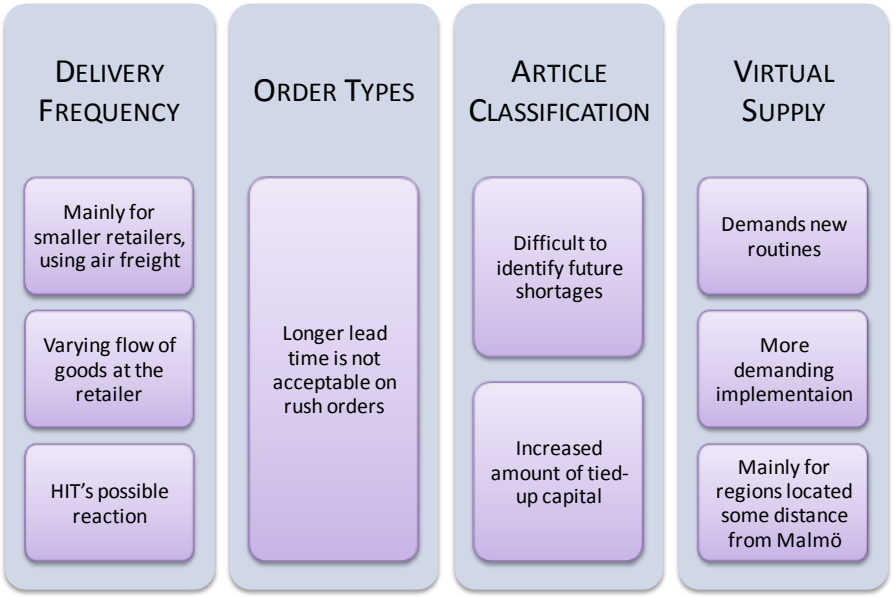

Figure 15-8. *Most prominent weaknesses of the adaption methods.*

The most beneficial approach for Lantmännen Maskin would probably be to combine two or several of the discussed adaption methods. Looking at the ranking, a combination of a reduced delivery frequency and an extended virtual supply solution would be most profitable. The potentials of these methods would only increase if they were to be combined. An approach could be to implement the methods consecutively in order to avoid too much disturbance in the daily routines. The key drivers to these adaption methods and the benefits of them can be seen in Figure 15-9.

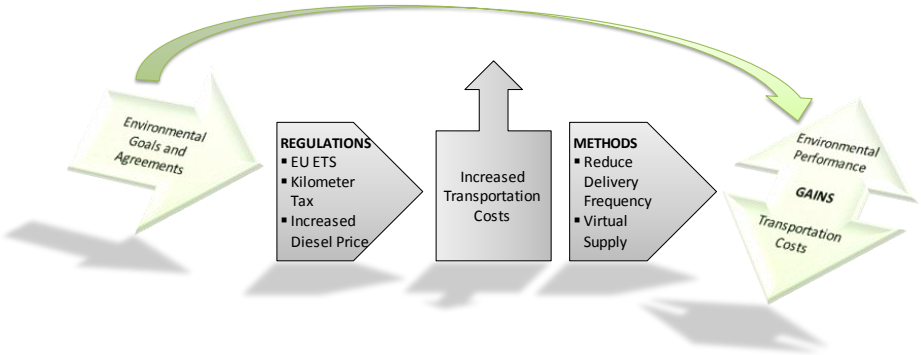

Figure 15-9. *Consequence flow with starting point in political initiatives.*

15.7 Total Cost

An additional aspect that has to be taken into consideration when evaluating the adaption methods and their consequences is the total cost. The total logistics cost at Lantmännen Maskin consists of several more or less independent components. A proposed adaption method may influence several costs in both positive and negative ways, therefore the total cost approach is needed in order to evaluate the final cost effect. The separate logistics costs that are affected by the analyzed adaption methods are examined in more detail in the following sections.

15.7.1 Order Cost

The overall order cost depends on the number of placed orders, assuming that the specific ordering cost is constant. The adaption methods that suggest a change of the ordering pattern are change of the delivery frequency and article classification, and also to some extent the lateral transshipment solution. A reduction of the delivery frequency can be obtained either by letting the retailers change their ordering pattern or by combining placed orders at the central warehouse. A change of the retailers' behavior would have the largest impact on the order cost, since less order related work has to be done at both the retailer and the central warehouse. If the retailers keep acting the same way, an order cost saving will only occur at the central warehouse since they will have less orders to handle.

A change in the article classification aims to lower the amount of rush orders by keeping more articles in stock. The number of rush orders would decrease significantly while the number of regular refill orders would increase slightly, both in size and number of placed orders. As a result, the total amount of orders would decrease, hence causing a lower total order cost.

15.7.2 Holding Cost

The fixed part of the holding cost will not change to any considerable extent due to any of the suggested adaption methods. If anything, it would increase slightly in the case of an extended virtual supply solution. The reason for this is that the inventory in Uppsala would have to increase, hence probably needing extra personnel and space.

There are more adaption methods that affect the variable holding cost than the fixed one. When discussing the variable holding cost, one has to take into consideration that finished articles, such as spare parts, are more expensive to keep in stock close to the end customer since value is added to the article during its refinement through the logistics network. Transportation is an example of an activity that adds value to the requested article.

If the delivery frequency is lowered by reducing the time the order waits in the system, some refill orders will arrive to the retailers earlier than they do today. If the current safety stock level is kept, a slightly higher inventory level at the retailers will occur, rendering a higher variable holding cost. A change in the article classification means that more spare parts are to be kept in stock at the retailer, hence increasing the variable holding cost at the retailers. An extended virtual supply solution would not only cause a change of the fixed holding cost, as mentioned earlier, but also of the variable cost. The variable holding cost would increase in Uppsala since the inventory levels are raised. Parallel to this, the inventory level at the central warehouse can be lowered, since more stock is kept closer to the end customer. The holding cost at the central warehouse can therefore be lowered slightly.

15.7.3 Shortage Cost

The current shortage cost for Lantmännen Maskin is considerable, since as much as approximately 70 percent of all orders are rush orders today. A form of shortage cost arises if a customer at the retailer chooses another supplier if the demanded spare part is not in stock. Another form of shortage cost arises if the customer decides to place an order and wait for the rush delivery. Retailers as well as the central warehouse would get higher handling and administration costs. The growth would be largest at the central warehouse, since most of the packing and administrative work is done there. Besides these costs, the transport cost increases for the retailers that use air freight for rush orders and this can be seen as a shortage cost.

A reduced delivery frequency or a changed article classification would increase the service level to the end customer and thereby lower the shortage cost. The retailer is more often able to satisfy the customer's

demand directly. An extended virtual supply solution would mainly result in less air freight for rush orders, hence lowering the extra transport cost due to shortage. The handling and administrative work at the central warehouse, and the costs associated with these activities, would be reduced. At the same time these costs would increase with approximately the same amount at the retailer in Uppsala, leading to no significant change of that part of the shortage cost.

15.7.4 Transport and Environmental Costs

The transport and environmental costs are becoming more and more integrated as new and stricter regulations and control measures are established. The environmental aspect that is being priced is the emission of CO_2 and since transports are an important cause of the emission made, the environmental cost is added to the existing transport cost. This gives a total transport cost for the end customer that consists of the actual transport cost and the environmental cost, represented by various taxes and fees.

The total transport cost and the environmental effects are discussed in detail in the previous analysis. Since the analysis aims to minimize the transport cost and the negative environmental effect, all of the discussed adaption methods lead to lower cost and environmental effect, except for the external method concerning taxes and fees. Lantmännen Maskin is not able to control or affect the external methods, but they may balance the higher transport cost that arises due to them by implementing one or more of the internal adaption methods. By doing so, Lantmännen Maskin may meet the changed conditions, with higher taxes and fees, avoiding palpable cost increases.

15.8 General Observations During Data Analysis

While conducting the data analysis, a few observations regarding the inventory control routines for stocking articles were made. The observations concern manners that imply a lack of understanding for the importance of efficient supply chain management. Among other things, it was found that several rush orders were placed in spite of the fact that the inventory levels were high enough to satisfy the demand. This behavior can be explained by the fact that the articles in stock are reserved by a specific

customer but might also follow by the personnel's disrespect for rush orders. Since the only visible difference for a retailer putting a rush order is that the order arrives earlier than refill orders, nothing really motivates the retailer to avoid placing rush orders. Incentives, such as information and extra fees, are necessary to show that rush orders generate higher transport costs and negative environmental impact.

Moreover, some articles had high inventory levels although the demand was low. For example, one article with a yearly demand of 61 units in Uppsala, and between 1 and 13 units per demand occasion, had a mean stock of 36 units, which is far too high and gives an inventory turnover on less than two times a year. This can be the effect of manually placed orders or system settings and insufficient historical data leading to unreliable forecasts. Today the articles are assumed to follow a Poisson distribution, which is much more appropriate than for example the normal distribution since the demand pattern is low frequent. The extended version of the Poisson distribution, the compound Poisson distribution is also not suitable because it is unnecessarily complex. Since the distribution model, the Poisson, is justified to use for the spare parts, there probably exists another reason for the steering towards high inventory levels. One explanation can be a too high service level, which is why this perhaps has to be lowered for some articles. The predetermined settings in the system should consequently be overlooked and the personnel encouraged to follow the system´s recommendations.

Some of the low frequent articles had a safety stock of zero units. This can probably be explained by the low demand of only one unit at the time, a few times a year. The low demand results in a recommended safety stock between zero and one units, thus a decision whether to round of upwards or downwards has to be made. Rounding off downwards, to zero, is most likely the best option in many cases, since the likelihood for shortage during the lead time is extremely small even if the safety stock is zero. The reorder point was thus zero and the order quantity, for several articles with these characteristics, one.

16 Conclusions

A final discussion regarding the outcome of the project and the fulfillment of the purpose is presented in this last chapter of the thesis. Furthermore, recommendations to the involved companies as well as to further research studies are given.

To reach the goal and purpose of the thesis, a set of mutually complementing parts have been produced. These parts have been developed in a natural chronological order with the broad theoretical base first out. Secondly, the empirical part was outlined by conducting interviews, making field trips and investigations, analyzing data and having continuous contact with the contact persons at Syncron and Lantmännen Maskin. By building a clear and comprehensive empirical framework, influenced by the input from the theoretical part, an analysis could eventually be conducted. The purpose with the case study analysis has been to find answers to the second and third question in the problem formulation, whereas the first question could be answered directly after the completion of the theoretical part. All of the questions are considered to have been answered throughout the report and the purpose to provide Syncron with input, regarding how to modify their software for logistic planning in order to meet future customer needs, is fulfilled.

Results for each of the questions in the problem formulation are discussed below. The findings related to question two and three are unique for Lantmännen Maskin. This is something that has to be taken into consideration if adapting Syncron's software to the results. Yet, with a few modifications, the results might to a certain degree be applicable at other similar supply chains as well.

What upcoming legislations and other transport related obstacles will have impact on the design of the supply chain?

New regulations, fees and taxes will almost certainly steer companies to adjust their supply chains in order to avoid costly charges. Sea and rail transports will not be noticeably affected though, since no significant charges are expected in those areas. On the contrary, those are regarded to be transportation options with relatively small negative environmental

impact and consequently, a shift from road and air to rail and sea is encouraged. Road and air transports will for that reason be exposed to more legislation in years to come. Today road freight is the primary transportation mode within Europe. Compared to rail freight, trucks emit significant amounts of CO_2. To create incentives for truck using companies to use more rail and sea freight, fees and taxes such as the kilometer tax and increased diesel prices, due to oil price and taxes, are to be expected. The cost consequences of these charges will gradually become obvious for the transporter and in the extension the transport buyer and the product's end customer.

Even though air freight is used in a smaller degree than road freight, it is a heavy contributor to the emission of greenhouse gas. The reason for this is that airplanes emit much more CO_2 per transported ton kilometer. In an attempt to reduce the emission of CO_2, this sector will be included in the EU ETS in 2012. The effect this will have on the transport buyer is somewhat hard to predict since it depends on several factors, such as how many additional emission allowances that have to be purchased and how the cost for this will be transferred to the customers. However, scenarios with specific assumptions indicate that the percentage cost increase for the end customer will not be more than a few units, since the cost for extra allowances will be limited and because the present cost for air transport is already high.

How can Lantmännen Maskin's supply chain be adapted to the changes in transport related regulations in the sense that it is optimized with respect to environmental as well as economical aspects?

All the proposed and discussed methods of adaption aim to co-optimize environmental gains and transport costs. Due to taxes and fees, introduced to restrain emission of greenhouse gases, this optimization effort will be favored and optimization of one aspect will automatically generate improvement of the other.

Among the suggested and analyzed methods for adaption of the supply chain, the reduced delivery frequency was found to be the one with the highest potential. Not only is it fairly easy to implement, but it also renders savings in transportation and ordering costs and reduces the average lead

time, provided that the idle time in the system after the order has been placed is reduced. Smaller retailers that get deliveries daily could compress their refill orders and hence enable economies of scale in the packaging work at the central warehouse. Retailers with higher turnover should preferable receive deliveries more often than the small retailers, since they on average have larger order quantities. To specify this solution, a couple of retailers in each sales region could be chosen to get replenishment deliveries every second day and the others could get the refill deliveries every third day.

One thing to bear in mind is that introducing this concept without combining it with other solutions requires the retailer to get rush orders by air freight and not road. Combining a reduced delivery frequency with the extended virtual supply solution would make the benefits from the decreased frequency more general and the concept would be applicable on a wider range of retailers, not only those that receive rush orders by air. Even though the virtual supply concept is more complicated to implement, it might pay off in the long run, when new taxes and fees strike the transport buyers. In combination with the frequency suggestion discussed above, the environmental performance would improve significantly since air freight then could be avoided to a larger extent. The consequence flow due to future regulations in combination with the proposed adaption methods are illustrated in Figure 16-1.

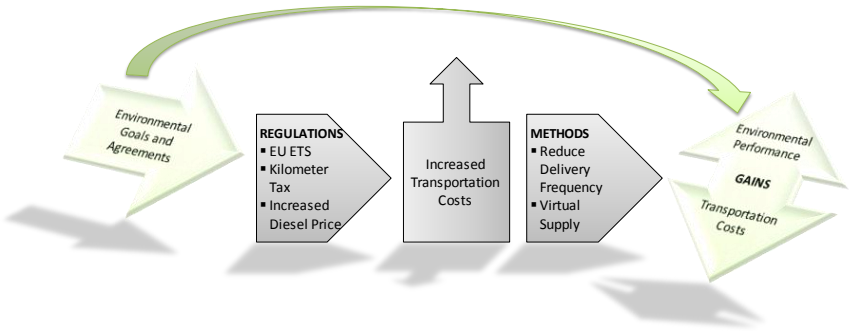

Figure 16-1. ***Consequence flow with starting point in political initiatives.***

The high amount of rush orders transmitted between the retailers and the central warehouse trigger expenses and emission of greenhouse gases when air transports are used. Moreover, since rush orders have to be

picked and packed within a short time frame, the packaging work gets disturbed and optimized picking and packing is harder to accomplish. These aspects justify the desire to extensively reduce the number of rush orders. Since Lantmännen Maskin's selection of spare parts is broad, the rush orders seldom concern the same non-stocking article several times in a row, otherwise they would have been stocking articles. Putting more articles in stock by classifying them as stocking articles is therefore not a good way to master the shortage problem. Primarily, shortage situations have to become more unusual. Since roughly 50 percent of all orders, several of these being rush order, are placed by the service workshops located at the retailers, improved planning in advance is preferable. If the service workshop could predict upcoming demand in an earlier stage, the required parts could be ordered as refill orders and delivered in time for the demand.

A secondary approach to improve the environmental performance and lower the transport costs is to modify the routines for the placement of rush orders. Today the customers are offered delivery within one day without extra cost whenever a shortage occurs, which often requires air freight in the studied sales region. The customers should instead be motivated to estimate the value of their shortage cost by having to pay an extra fee for getting the spare part on the next day instead of receiving it a few days later. High shortage costs will then motivate the customer to pay the extra cost for placing a rush order, whereas shortage that not give rise to significant shortage costs might make the customer choose the cheaper delivery option with longer lead time, enabling road transport.

With respect to Lantmännen Maskin, what additional costs are associated with new environmental legislations and how much can these costs be reduced, by modifying the supply chain?

This third question combines the outcomes of the two previous questions and it also aims to quantify the consequences to some extent. Lantmännen Maskin can expect increased costs related to their road freight due to the probable introduction of the kilometer tax or to a higher fuel price. A kilometer tax on 7 SEK would render a 17 percent cost increase for the road transports performed to meet the spare part demand. If the delivery frequency was to be halved, a lowering of the same cost to an amount of

20 percent would occur. If the kilometer tax and the reduced delivery frequency concepts were to be realized at the same time, the result would be a practically unaffected level of the transport cost, meaning that Lantmännan Maskin could meet the intensified regulations by implementing a relatively easy adaption method.

Currently 57 percent of the transport cost originates from air transports, which is roughly four times as expensive as road transports when comparing the costs per transported kilo. The introduction of the EU ETS will increase the costs for using air freight, but it will probably not have a large impact on the already high price. A considerable reduction of the usage of air freight is desirable since air freight is both expensive and harmful to the environment. If all air transports were to be made by trucks instead, the total transport cost would be reduced by 48 percent. By shifting transport mode, Lantmännen Maskin could meet an even stricter kilometer tax regulation and at the same time keep the total transport cost lower than the current levels.

The central aspect when applying general regulations and influences to a specific supply chain is the total cost. A combined implementation of a reduced delivery frequency and an extended virtual supply solution would target to meet the stricter regulations on both road and air freight without significant cost increases. The total transport cost could actually be lowered even if the economical control measures are increased significantly. The key is to optimize the total cost and to strive after the most efficient logistical solution – both regarding the transport cost and the environment.

16.1 Recommendations

The recommendations that are to be presented are all based on the findings from the analysis and the impressions gathered from the interviews. Suggestions on how to adapt to future changes in the surroundings are presented for Lantmännen Maskin and Syncron separately. Lastly, ideas for further studies at the involved companies and research projects are presented.

16.1.1 Suggestions to Lantmännen Maskin

In a long-term perspective, Lantmännen Maskin should strive to lower their environmental influence by altering their supply chain so it becomes more efficient. A solution combining a reduced delivery frequency and an extended virtual supply solution would be very advantageous, for both the environment and the transport cost, without causing any significant negative consequences.

On a more detailed level, the repair workshops should try to improve their forecasts and long-term planning. The reason for this is the large amount of rush orders originating from their own service workshops. Another detail that the retailers have to address is the rush order placements. Less emergency and supplement orders could be placed if the retailers trusted the system's refill suggestions and if customers were asked how urgent the order actually is. To better improve the ability to follow up the experienced service level of the spare parts, a more nuanced measurement is needed. It might be preferable and clearer to measure the service level of stocking and non-stocking articles separately and with the help of different definitions.

16.1.2 Suggestions to Syncron

For the specific supply chain design that Lantmännen Maskin has, it turns out that a less expensive transport also is the most environmental efficient alternative. If Syncron is to develop their software, to take environmental effects into consideration, it could be by introducing a transport cost optimizing criterion which can be adapted to new and altered economical control measures. The transport cost in combination with present optimizing criteria; the service level and the amount of tied-up capital, are to be balanced and weighted against each other in order to provide Syncron's customers with environmental aware logistic solutions. For customers with an even larger environmental focus, the importance of the transport cost would be ranked higher. The transport cost criteria would preferably co-optimize the choice of transport mode, the shipment frequency and the choice of internal supplying location.

Currently Syncron only governs about 25 percent of Lantmännen Maskin's spare parts. It is the non-stocking articles, which Syncron does not govern, that cause most of the transport cost and have a considerable

environmental impact. If Syncron is to be involved in Lantmännen Maskin's environmental work they have to get more control of the handling of rush orders. If the extended virtual supply solution is to be implemented effectively, Syncron has to have the responsibility for the rush orders as well, otherwise the adaption method would result in lots of unnecessary administrative work at the retailers.

16.1.3 Ideas for Further Studies

The areas of interest for further studies regarding the sustainable supply chain concept are numerous. The thesis is limited to only focus on the outbound logistics, but in order to fully incorporate a sustainable approach the entire supply network has to be investigated further. All recommendations presented in previous sections must be evaluated more thoroughly before an implementation takes place, in order to avoid difficulties.

From Syncron's point of view it would be of great interest to investigate if the adaption methods that agree with Lantmännen Maskin's supply chain also coincide with the other companies using the software provided by Syncron. If the methods are generally applicable this would facilitate some kind of universal optimizing criterion which focuses on the environmental effect. It is not very likely though, that separate and specific supply chains can be generalized to a sufficient level so that an all-including software solution can be created. But a thorough research regarding similarities in different supply chains might provide Syncron with enough information to enable a standard design of the software, which would provide the customers, which want to implement an environmental optimization criterion in their supply chain planning, with a solution.

This thesis mainly concerns road and air transports. An inclusion of rail, seaway and intermodal transports would make the framework more complete. Further, an extension of the geographical scope would be of interest for additional studies. Inclusion of multinational supply chains, which concern regulations from several different countries, would create a more extensive platform and understanding of the existing and future environmental regulations. For Lantmännen Maskin this could lead to a study that concerns the sustainability concept for the entire supply of spare parts, all the way from the suppliers all around the world, via the

central warehouse, to the retailers all around Scandinavia. Another interesting area for Lantmännen Maskin to investigate is the possibility of shifting transport mode. In the long term, when continuously stricter regulations on road and air transports have been implemented, it might be favorable to start using rail or sea transport.

A general perspective that would be of large interest for future investigation is the connection between transport cost and environmental impact. This case study has concluded that in the studied system at Lantmännen Maskin, the less expensive transport choice is also the most environmentally friendly choice. Further research concerning the general applicability of this thought would be very interesting. If it shows that this is not the reality in the transport industry today, it would be of great interest to examine the future economical control measures' design and impact deeper. Of specific interest is research regarding the likelihood that environmental related fees, which are added to the transport cost, are about to make the total transport cost proportional to the emissions made during the transport.

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Appendix 1 – The Impact of Different Control Measures

Scenario 1 – Air Transports Included in the Emission Trading System

Assumptions:

- The scenario only considers emergency transports.
- The airline company has consumed all its emission allowances and has chosen to buy extra emission allowances.
- The extra cost for the allowances are all transferred to the transport buyers.
- The price for one emission allowance is a realistic average price, based on prices in the industry sector. The price is set to 300 SEK per emitted 1 000 kg of CO_2.
- No extra costs connected to administration affect the transport buyer.
- The single transport buyer in this scenario will pay for 25 % of the increased cost due to the purchase of allowances. The assumption is that the cost is split on four transport buyers.
- Estimated savings do not take the alternative cost (for regular transportation) into consideration.

Using a tool provided by the Swedish Civil Aviation Authority the average CO_2 emission for an air freight transport between Stockholm Arlanda and Frankfurt is calculated to 13 000 kg with a utilization of 65 percent.[197] Due to the purchase of allowance the cost per flight would increase by

$$13 \times 300 = 3900\ SEK$$

Today the cost for an express air freight between Stockholm Arlanda and Frankfurt for four pallets, each with a weight on 500 kg and dimension 1.5X1.5X2 m, amounts to about 100 000 SEK.[198] This is without door to door delivery; the goods are only delivered to the airport.

[197] emis.sweweb.se, 2008-09-11.
[198] www.ups.se, 2008-09-11.

If the transport buyer must pay an additional cost for emission allowances, the price will be

$$100\,000 + 3\,900 \times 0.25 \approx 101\,000\,SEK$$

In other words, the price will increase with 1 % if emission allowances have to be bought in this scenario. Another voice[199] that will be affected by an inclusion of the aviation sector in the emission trading system predicts a price increase of 2 %. This confirms and strengthens the reliability of our calculations. An inclusion of the aviation sector will most likely render a small price increase in the magnitude of a couple of percent.

Assuming that the company buys 50 express air transports each year, the total additional cost per year will be

$$1000 \times 50 = 50\,000\,SEK$$

If the company would improve its logistic coordination so that the number of emergency transports could be cut in half, they could save 25 000 SEK per year.

[199] www.environment.fi, 2008-11-03.

Scenario 2 – Kilometer Tax for Trucks

Assumptions:

- The Eurovignette Directive will no longer be used if the kilometer tax is introduced.
- The truck in the scenario is only traveling on Swedish roads, where it is obliged to pay kilometer tax.
- The yearly amount of transported good by the truck in the scenario is 3 000 000 kg.
- The maximum load on the truck is 30 000 kg.
- The truck has two axes and belongs to Euro 2 class, therefore the Eurovignette is 11 385 SEK per year.
- A loaded truck has an average fill rate of 60 %.
- All return transports are empty.
- The cost of driving a truck is constant and not depending on the utilization rate.

The average traveling distance for Swedish trucks in 2006 were 50 000 km per year, and so this value is used for the truck in this scenario.[200] The assumption that the utilization rate is 60 % gives the following number of transports made each year

$$\frac{3\ 000\ 000}{30\ 000 \times 0.60} \approx 170\ per\ year$$

This gives an average traveling distance of

$$\frac{50\ 000}{170 \times 2} \approx 150\ km\ per\ one\ way$$

The cost of driving 150 km with a loaded truck is about 2 900 SEK.[201] Since the kilometer tax is not in use yet its magnitude is not yet decided, therefore the following calculations are divided into three different scenarios where the tax is 1, 3 or 6 SEK. The increased fees and transport costs can be found in Table 5.

[200] SIKA (2007): Kilometerskatt för lastbilar – Effekter på näringar och regioner.
[201] Based on information from Björn Ekstedt at DHL and the assumption that the marginal income ratio is 5 %.

	1 SEK per km	3 SEK per km	6 SEK per km
Eurovignette	11 385	11 385	11 385
Kilometer Tax	50 000	150 000	300 000
Increased Fee	**38 615**	**138 615**	**288 615**
Transport cost			
With Eurovignette[202]	986 000	986 000	986 000
With Kilometer Tax[203]	1 024 615	1 124 615	1 274 615
Increased Cost	**3.9 %**	**14.1 %**	**29.3 %**

Table 5. *Increased fees and transport cost when introducing the kilometer tax and the utilization rate is 60 %.*

The cost increase when introducing a kilometer tax is linear and it is presented in Figure 2. It can be seen that for every 2 SEK of a kilometer tax corresponds to a cost increase for the transport of 10 %.

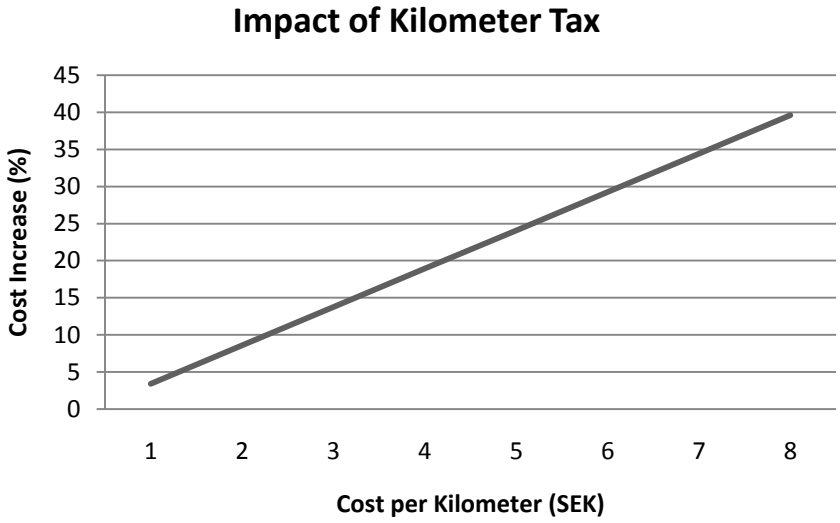

Figure 2. *The cost increase when a kilometer tax is introduced.*

[202] The cost for one shipment multiplied by the number of transports made each year (incl. return transports).
[203] Addition of the increased fee and the transport cost with Eurovignette.

Better coordination resulting in a higher utilization rate, for instance 95 %, would reduce the number of transports and subsequently the total cost for the kilometer tax. The number of needed transports would instead be:

$$\frac{3\ 000\ 000}{30\ 000 \times 0.95} \approx 110\ per\ year$$

The new yearly distance travelled by the truck would be:

$$110 \times 2 \times 150 = 33\ 000\ km\ per\ year$$

The transport cost decreases when the utilization ratio increases. The fees and costs when the rate is 95 % can be seen in Table 6.

	1 SEK per km	**3 SEK per km**	**6 SEK per km**
Eurovignette	11 385	11 385	11 385
Kilometer Tax	33 000	99 000	198 000
Incresed Fee	**21 615**	**87 615**	**186 615**
Transport cost			
With Eurovignette[204]	638 000	638 000	638 000
With Kilometer Tax[205]	659 615	725 615	824 615
Increased cost	**3.4 %**	**13.7 %**	**29.3 %**

Table 6. *Increased fees and transport cost when introducing the kilometer tax and the utilization rate is 95 %.*

One can see that the percentage of the increased costs is very similar for the trucks with different utilization ratio, even though the costs themselves vary quite a bit. It is therefore interesting to compare the cost when the utilization rate is changed and the kilometer tax is used, see Table 7. More than a third of the transport costs can be saved only by increasing the fill rate.

[204] The cost for one shipment multiplied by the number of transports made each year (incl. return transports).
[205] Addition of the increased fee and the transport cost with Eurovignette.

Transport cost	1 SEK per km	3 SEK per km	6 SEK per km
Kilometer Tax, 60 %	1 024 615	1 124 615	1 274 615
Kilometer Tax, 95 %	659 615	725 615	824 615
Difference	365 000	399 000	450 000
Possible Savings	**36 %**	**35 %**	**35 %**

Table 7. *The impact of using a higher utilization rate when having kilometer tax system.*

Another interesting comparison is the one between today's situation with the Eurovignette (utilization rate of 60 %) and the situation where kilometer tax is implemented with the fill rate increased to 95 %. The figures are shown in Table 8. The comparison shows that the higher costs related to the kilometer tax can easily be compensated by increasing the utilization of the trucks.

	1 SEK per km	3 SEK per km	6 SEK per km
Eurovignette, 60 %	986000	986000	986000
Kilometer Tax, 95 %	659615	725615	824615
Difference	326385	260385	161385
Possible Savings	**33 %**	**26 %**	**16 %**

Table 8. *Comparison between today's situation and the kilometer tax system with a utilization rate of 95 %.*

Scenario 3 – Increased Tax on Diesel

Assumptions:

- The price per liter diesel is approximately 12 SEK.[206]
- A possible increase of carbon dioxide tax plus energy tax is 8 SEK per liter, which result in a diesel price on 22 SEK per liter.
- The extra costs generated by the increased taxes are all transferred to the transport buyer.
- The possibility to refill diesel abroad does not exist in the scenario.
- The average traveling distance for a Swedish truck per year is still 50 000 km.
- On average, a truck use 4.5 liter diesel per 10 kilometers[207].
- No lead time restrictions prevent from switching road transports to rail.
- The transport cost on roads for different distances is linear.

An increased tax on diesel would cause an increased cost for operating a truck that travels 50 000 km per year:

$$4.5 \times 5\,000 \times 8 = 180\,000\ SEK\ per\ year$$

If half of the goods transported by the truck would be shipped by rail instead, the cost increase due to taxes would be less obvious. This since rail transport is cheaper than transports made on roads. The cost for using rail 25 000 km is approximately 200 000 SEK if each transportation distance is 500 km and the weight of the goods is 18 000 kilo. [208] The cost for using truck under similar presumptions is about 300 000 SEK.[209]

If dividing the transports between the modes, as mentioned above, the transport cost would be 500 000 SEK if the tax level of today is used. If the sum of the carbon dioxide tax and the energy tax is increased by 8 SEK the cost would be:

$$4.5 \times 2\,500 \times 8\ + 500\,000 = 590\,000\ SEK\ per\ year$$

[206] Around the time when the scenario was constructed, 2008-10-25.
[207] Lumsden, Kenth (2006): *Logistikens grunder*, p. 714.
[208] Information provided by Hamed Manesh, Marketing and Sales, Green Cargo.
[209] Information provided by Björn Ekstedt, DHL.

If all transportation is made on roads the cost would sum up to 600 000 SEK with today's tax levels and to 780 000 SEK if the tax increase occur. A summary of the costs can be seen in Table 9 where possible savings when shifting to rail also are presented.

Modes of Transport	Today's Tax Situation	Inclusion of Possible Tax Increase	Difference
100 % Road	600 000	780 000	**30 %**
50 % Road, 50 % Rail	500 000	590 000	**18 %**
Difference	100 000	190 000	**-**
Possible Savings	**17 %**	**24 %**	

Table 9. Summary of the different transport costs when increasing the tax on diesel.

Comparing today's tax situation using only road transports with the shift in transport mode and the new tax situations shows that a company actually can make savings even though the taxes are increased.

Extension of the Scenario

The diesel price consists of three different parts; the taxes (discussed above in the scenario), the purchase price and the gross margin. If the purchase price would increase due to a higher oil price it would have the same affect on the transport costs as when the taxes are raised. Therefore no extra (parallel) calculation showing this is made. Worth noting is the possibility of a simultaneously occurring tax and oil price increase. This would cause much higher transport costs for companies using a lot of road transports.

Assuming that the fuel price for diesel is 12 SEK the following graph, Figure 3, shows which effect on the transport cost a higher diesel price would have. Both the scenarios, using only road or a combination of road and rail, are illustrated. The figure shows that companies may meet an increased fuel price by shifting transport mode. If all transports are performed by road initially a company may meet an increase of the diesel price to 21 SEK simply by transferring half of the road transports to rail, without having any increased transport cost.

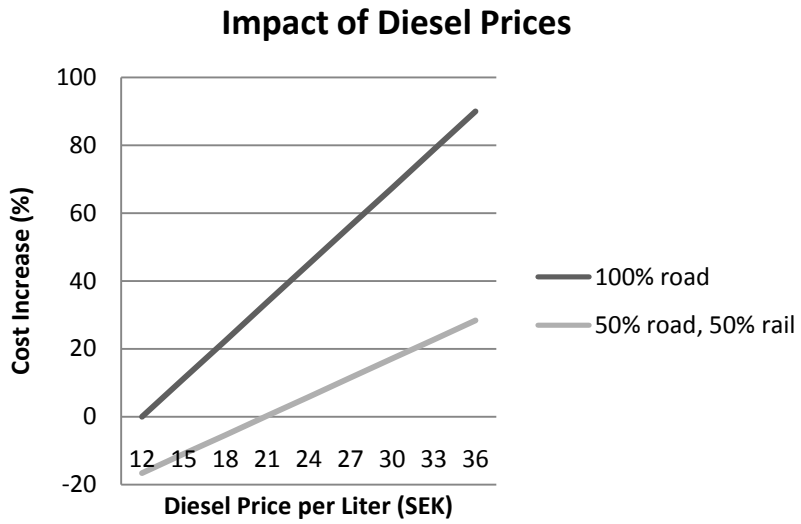

Figure 3. ***The impact on the transport cost if the diesel price is increased for any reason.***

Appendix 2 – Questionnaire

Green Supply Questionnaire

Syncron is one of several participating organizations in the long-term research partnership NGiL (Next Generation Innovative Logistics), at Lund Institute of Technology. Several projects are performed under supervision of NGiL, all of them aiming to provide knowledge, methods, techniques and tools for companies and organizations to increase supply chain visibility and to manage deviation in logistics systems. For the specific project ***Design and Control of Sustainable Supply Chains****, your answers on this survey would be of great value.*

Tanja Ling & Sara Gertsson

1. How much does your organization use the following modes of transportation for both regular and emergency logistics?

Regular:	Road___%	Air___%
	Sea___%	Rail___%
Emergency:	Road___%	Air___%
	Sea___%	Rail___%

2. Does your organization currently consider the environment when deciding which modes of transportation to use for logistics?

   Yes ❑ (Please give details) No ❑

3. Is your organization expecting to make changes regarding your logistics activity to adapt to new political directives surrounding transportation?

   Yes ❑ (Please give details) No ❑

   _____

   _____

   _____

4. Are increasing transport costs causing your organization to implement different transportation strategies?

   Yes ❑ (Please give details) No ❑

   _____

   _____

   _____

5. Do you know of any other factors regarding logistics that is expected to impact your organizations performance? (e.g. capacity, availability of resources)

   Yes ❑ (Please provide details) No ❑

   _____

   _____

   _____

6. Do you think it could be possible to move some parts of your organization's transport activity to greener modes of transport?

   Yes ❑ (Please provide details) No ❑ (Please provide details)

7. Regarding your organization's supply chain, how may production sites, distribution centers, and sales offices do you have globally?

   Production:

   Distribution centers:

   Sales offices:

8. Do your customers put pressure on your organization to consider the environment when planning your transport activity?

   Yes ❑ (Please provide details) No ❑

9. Does your organization put pressure on your suppliers to consider the environment when planning their transport activity?

   Yes ❑ (Please provide details) No ❑

10. On average, how much of your transport capacity do you utilize?

    0-20% ❑ 21-40% ❑ 41-60% ❑ 61-80% ❑ 81-100%❑

11. Does your organization have a strategy to achieve high utilization levels of your transport capacity?

    Yes ❑ (Please provide details) No ❑

    _____

    _____

    _____

12. Do you think the Just-In-Time concept is becoming obsolete?

    Yes ❑ (Please provide details) No ❑ (Please provide details)

    _____

    _____

    _____

Thank you!

Appendix 3 – Interview Questions to Lantmännen Maskin

Intervjuunderlag till 17 oktober

Personinformation

Namn:
Avdelning:
Titel:
Ansvarsområde:
Tidigare ansvarsområde:
Tid på nuvarande tjänst:
Tid inom koncernen:

Allmän företagsinformation

1. Vad har Lantmännen Maskin för mål och vision?
2. Vilka affärsområden finns?
3. Hur många är anställda på Lantmännen Maskin och vilka ansvarsområden finns?
4. Hur ser den geografiska spridningen av företaget ut?
5. Vilka funktioner finns i Malmö?
6. Hur många är anställda på logistikavdelningen?
7. Hur stor andel av den totala produktkostnaden utgör transportkostnaden?

Affärsområden

1. Hur stor del av omsättning utgör respektive område?

Förmarknad

2. Hur lång är ledtiden för maskinerna?

Eftermarknad

3. Är reservdelssortimentet heltäckande för era produkter?
4. Hur många reservdelsartiklar finns?
5. Hur är tillgängligheten på reservdelar?

Service

6. Vilken typ av service erbjuder ni?
7. Var erbjuds dessa tjänster?

8. Vem erbjuds tjänsterna, endast de som köpt hela maskiner?

Nuvarande försörjningskedja av reservdelar

1. Hur många lagerpunkter har ni?
2. Hur fungerar orderprocessen?
3. Är försörjningen av reservdelar order- eller lagerstyrd?
4. Var ligger orderpunkten?
5. Har ni ett prognossystem? Hur fungerar det?
6. Hur är reservdelarna förpackade, stora och små kollin?

Leverantörer

7. Hur många leverantörer har ni?
8. Var har era leverantörer produktion respektive lager?
9. Hur lång är ledtiden?
10. Har ni långvariga samarbeten med era leverantörer?

Kunder

11. Var finns era kunder lokaliserade?
12. Hur många slutkunder har ni?
13. Vilka avtalsmässiga krav ställs på er rörande reservdelsförsörjning?

Försörjning av centrallager

14. Utförs transporterna i egen regi eller anlitas tredjepartslogistiker?
15. Vilka transportmedel används?
16. Vem planerar transporterna?
17. Med vilken frekvens kommer inleveranserna?
18. Hur bestäms lagernivåerna i centrallagret?

Försörjning av regionlager

19. Utförs transporterna i egen regi eller anlitas tredjepartslogistiker?
20. Vilka transportmedel används?
21. Vem planerar transporterna?
22. Med vilken frekvens kommer inleveranserna?
23. Utnyttjas returtransporterna?
24. Hur bestäms lagernivåerna i regionlagrena?

Pågående miljöarbete

1. Vad har Greenline projektet gett för effekt på koncernen Lantmännen?

2. Hur och när ska Lantmännen Maskin involveras i Greenline projektet?
3. Vad hoppas ni uppnå med Greenline projektet inom Lantmännen Maskin?
4. Vilka andra satsningar har gjorts för att minska Lantmännen Maskins miljöskadliga utsläpp?
5. Vet Lantmännen Maskin hur stora deras utsläpp är? Kan CO_2 utsläpp mätas?
6. Ställer kunderna miljörelaterade krav på Lantmännen Maskins verksamhet?

Förändringar av försörjningskedjan

1. Hur arbetar Lantmännen Maskin för att bli mer kostnadseffektiva i sin logistik?
2. Vilka satsningar har gjorts för att uppnå högre kostnadseffektivitet tidigare?
3. Vilka satsningar görs idag för att uppnå högre kostnadseffektivitet?
4. Vilka satsningar planeras för att uppnå högre kostnadseffektivitet?
5. Har betydande förändringar av försörjningen skett de senaste åren?
6. Används andra transportslag idag jämfört med tidigare?

Framtid och utveckling

1. Avsätts resurser för kontinuerligt utvecklingsarbete inom transportfunktionen?
2. Vilka transportrelaterade tankar har du om framtiden på kort och lång sikt? (t.ex. rörande kommande regleringar)
3. Vilka möjligheter finns att modifiera försörjningskedjan?

Koppling till Syncron

1. Vilka funktioner fyller Syncrons mjukvaran för Lantmännen Maskin?
2. Hur länge har mjukvaran använts?
3. Vilka förbättringar har uppnåtts?
4. Vilka optimeringsparametrar används idag?
5. Om ni får ge önskemål på modifiering av mjukvaran, hur skulle dessa då se ut?

Kvantitativ data

1. Vilken lagerränta använder ni?
2. Vilken servicenivå garanterar ni era kunder och vilken ställer ni på era leverantörer?
3. Finns en ordersärkostnad framtagen? Om ja, hur stor är den?
4. Hur är fördelning mellan de olika transportslagen?
5. Vad är kostnaden för transport med olika transportslag?
6. Hur många sändningar till de olika lagerpunkterna skickas per dag?
7. Hur stort är lagervärdet på de olika lagerpukterna?

Appendix 4 – Calculations Supporting the Analysis

The calculations that the analysis are based on are presented in detail in this appendix. Each area that affects the supply of Lantmännen Maskin's spare part distribution in a quantitative significant way is presented. The mathematical reasoning is described and the formulas used are shown.

Transport Cost

First the calculations regarding the actual transport cost is described. After that the calculations regarding the different adaption methods are presented separately.

Actual Total Cost for Transports in the Period 2007-10-01 – 2008-09-30

The total transport cost for refill and rush orders with ordinary road and air freight was calculated in two steps; representing the road and air transport costs separately. The cost for the road transports are described first.

Road Transport Cost

For each day, the weights for orders with same destination and loading date were added, generating a shipment. The fixed drop cost for one shipment is X SEK and if the shipment's weight exceeds 40 kg, an extra fee of Y SEK per kg exceeding 40 kg is charged. A shipment on w kg then generates a cost of:

$$Shipment\ Cost = X + \max(0, w - 40) \times Y\ SEK$$

Subsequently the cost for all shipments over the period 2007-10-01 – 2008-09-30 was summed and thus the total cost for road transports were attained.

Air Transport Cost

The total weight for all orders shipped by air was calculated. Days when no orders were shipped by truck to the destinations of the air freight, an extra charge on X SEK was added to the transport cost, since the transport from the airport in Stockholm to the retailer had to be ordered by HIT. If HIT already had truck deliveries to the destination of the air freight on the actual day, no extra cost was added since the drop price for that destination had then already been paid. The transport from the central

warehouse to Malmö Airport was a fix cost, FC SEK, per day. Half of this cost can be assigned to sales region 2, since approximately half of the goods shipped by air goes to sales region 2. Consequently, the cost for air transports consists of three parts; distribution to airport, weight related cost, on Z SEK per kg, and distribution to retailer. If the total weight of orders shipped by air is W kg, the number of days when air transports were used is D and the N is the number of times when an air shipment had a destination where no truck was delivering on the same day, the total air transport cost over the period 2007-10-01 – 2008-09-30 could be achieved by the calculation below.

$$Total\ Cost\ for\ Air\ Transports = W \times Z + D \times \frac{FC}{2} + N \times X\ SEK$$

Cost Consequence Due to Decreased Delivery Frequency

When deciding transport cost after reduction of delivery days, only refill orders at retailers using air transports for their rush orders were studied. Truck shipments for two or three days were combined to create a scenario where orders were delivered on every second or third day only. Next, the same procedure as in the section 'Road Transport Cost' was used to determine the decreased cost for road transports, due to the lower delivery frequency. An example of the calculation method is demonstrated in Table 1 below.

Date	Shipment Weight to Tierp (kg)	New Shipment Weight (kg)	Old Shipment Cost (SEK)	New Shipment Cost (SEK)
9th October 2007	4.25	-	X	-
10th October 2007	4.32	-	X	-
11th October 2007	7.80	16.37	X	X
Total Cost			3X	X

Table 1. *Example of the procedure when the delivery frequency was reduced.*

Cost Consequence Due to Removal of Air Transports

If truck was the only transportation mode, the total transport cost could be acquired in similar way as in the section 'Road Transport Cost'. The difference is that the weight of orders previously shipped by air is added to the weight of the previous truck shipments. This will of course give rise to a few entirely new shipments, but most previous air transported orders would just be added to an existing truck shipment, and thus at most only generate an extra cost for the additional weight.

Cost Consequences Due to a Virtual Supply Solution

Reducing the number of air transported orders by using the retailer in Uppsala as first hand supplier of rush orders would decrease the transport cost. To get a feeling of the magnitude of this decrease, four articles were studied with respect to their rush orders. The rush orders placed for the article 1651413670 in the period 2007-10-01 – 2008-09-30 can be seen in Table 2.

Quantity	Unit Price (SEK)	Date	Retailer	Unit Weight (kg)
18	30.48872	20080924	Kungsgården	0.56
1	32.9741	20080103	Borlänge	0.56
1	30.48872	20080225	Borlänge	0.56
6	30.48872	20080314	Borlänge	0.56
14	30.48872	20080331	Borlänge	0.56
7	30.48872	20080430	Borlänge	0.56
10	30.48872	20080515	Borlänge	0.56
12	30.48872	20080516	Borlänge	0.56

Table 2. *All rush orders placed by retailers in sales region 2 on one specific article.*

The weight related transport cost was calculated by multiplying the unit weight with the quantity and price per kg, which is Z SEK for air freight. This yields costs according to Table 3.

Quantity	Unit Weight (kg)	Transport cost (SEK)
18	0.56	10.08Z
1	0.56	0.56Z
1	0.56	0.56Z
6	0.56	3.36Z
14	0.56	7.84Z
7	0.56	3.92Z
10	0.56	5.6Z
12	0.56	6.72Z
69		**38.64Z**

Table 3. *Weight related costs for air transport of the rush orders, with the sum shown in the bottom row.*

Hence, a saving in the size of about 28.98Z SEK, 75 percent of 38.64Z SEK, could be achieved. Lantmännen Maskin uses a 9 percent interest rate for capital tied-up in inventory, which leads to the following equation for the holding cost:

$$Holding\ Cost = 0.09 \times Article\ Value \times Quantity\ in\ Stock$$

Working backwards, this equation can be used to decide how much the holding cost for inventory can increase without exceeding the saving on 28.98Z SEK. Solving the equation below shows that the inventory could more than double without resulting in an inventory cost exceeding the present cost more than 28.98Z SEK. In Uppsala the average stock of the article in focus is 155 units. Thus, the inventory could more than double.

$$Quantity\ in\ Stock = \frac{Holding\ Cost}{0.09 \times Article\ Value}$$

Similar calculations were conducted for the three other articles, resulting in findings that confirmed the possibility to keep higher inventory without obtaining a higher total cost for holding and transport.

Cost Consequence Due to a Kilometer Tax

If a kilometer tax would have been introduced and charged last year, the costs for road transports would have been different. The calculation of the

new cost was done in the same way as described earlier, but with a larger drop price.

The new drop price was calculated by estimating the total distanced travelled by one truck during the examined period, 2007-10-01 – 2008-09-30. It is estimated from the collected data that a year consists of 261 shipment days. The total travelled distance was then multiplied by 3 or 7 SEK and the Eurovignette Fee (denoted E) for one truck was subtracted from the product. Since Lantmännen Maskin roughly uses 5 % of the truck's capacity, 5 % of the resulting cost increase was allocated to them. Those 5 % was then divided by the total number of shipments over the studied period to get the new drop price. Calculations followed as described below, where T is the kilometer tax rate.

$$Travelled\ Distance, D = 700 \times 261\ km$$

$$Total\ Kilometer\ Tax, C = D \times T\ SEK$$

$$New\ Drop\ Price = \frac{0.05 \times (C - E)}{Nbr\ of\ Shipments} + X\ SEK/shipment$$

The variable cost for shipments exceeding 40 kg is not affected by a kilometer tax. This can be explained by the fact that this cost is not linked to the travelled distance, but rather to the work of handling the goods.

If the new drop price, after an introduction of a 7 SEK kilometer tax, is used in the calculations described under the headline *Cost Consequence Due to Removal of Air Transports,* the cost consequence due to removal of air freight in connection with a 7 SEK kilometer tax is obtained.

Cost Consequence Due to Increased Fuel Price

The calculations regarding the impact an increase of the fuel price would have on the transport cost are closely related to the calculations made when introducing a kilometer tax since both aspects are depending on the travelled distance. It is therefore more interesting to calculate how large the increase of the fuel price can be, in order to correspond to a transport cost increase generated by a specific kilometer tax. The finding that a kilometer tax on 2 SEK generates the same transport cost increase as 6.70

SEK increase of the fuel price was found by using the formula below. The abbreviations used are defined in the previous section.

$$Increased\ Fuel\ Price = \frac{C \times 0.05}{700 \times 261 \times 0.05 \times 0.30} = \frac{T}{0.30}\ SEK$$

Cost Consequence Due to the EU ETS

The air transport sector will be included in the ETS in 2012. If it had been comprised last year, air transport costs would most likely have been higher. A cost increase on 4 % was therefore added to the weight related fee. The cost for the transports made to and from the airport would not be affected, since they are performed by truck.

$$New\ Cost\ per\ Kg = Z \times 1.04 = 1.04Z\ SEK/kg$$

The same approach as in section 'Air Transport Cost' was used to calculate the new air transport cost.

Environmental Effects

A deeper explanation for the calculations concerning the CO_2 emission will be given in the following sections. First, the actual emissions are described and calculated, and after that are the possible alternatives shown.

Emission Levels of Today

The emission of today comes from both truck and air transports. Both of them are depending on the shipped weight and the travelled distance, but they are attained in different ways in this case study.

Emission Due to Road Transport

Lantmännen has decided to use the same base for the entire group when it comes to calculating the emissions made. The set level for the emission made while transporting 1 ton 1km (also known as ton km) is 0.048 kg CO_2. When calculating the emission made the total weight of the spare parts was summed up and multiplied by the distance to sales region 2. The total ton km was then obtained and multiplied with the factor 0.048 kg, in order to reach the emission made during the last year.

$$CO_2\ Emission = Weight \times Distance \times 0.048\ kg$$

Emission Due to Air Transport

Lantmännen as a group does not use air freight to a wide extent and does not have a corresponding air emission factor, as is the case for road transports. The shipments that are sent by air are placed on regular passenger airplanes, consequently it is very hard to determine the size of the emission that can be connected to the shipped goods. The webpage provided by the organization Climate Care[210] was used in order to determine the size of the air freight related CO_2 emission. The total weight of the shipped spare parts and the flown distance of 544 kilometers (i.e. 340 miles) were put into the 'environmental calculator' at the webpage and in return it gave an approximation of the emitted CO_2 level. The used distance is the distance between the airports in Malmö and Stockholm.

Environmental Effect Due to Removal of Air Transports

If no air transports were to be used all transports would be made on the roads. The same mathematical reasoning, as recently described, can therefore be applied:

$$Total\ CO_2\ Emission = Total\ Weight \times Distance \times 0.048\ kg$$

Environmental Effect Due to a Virtual Supply Solution

If a virtual supply solution was to be implemented on the spare part supply, less air and more road freight would be used. For every ton that is transferred from air to road a decrease of the negative environmental effect can be measured. The calculation made for the truck's emission when transporting 1 000 kg from the central warehouse to sales region 2.

$$Truck\ Emission = 1\,000 \times Distance \times 0.048 \approx 35\ kg$$

The Climate Care webpage was once again used to find the air freight related CO_2 emission. The corresponding distance leads to an emission of 880 kg according to the online calculator. The air freight emits approximately 25 times as much as road transports.

[210] https://www.climatecare.org/business/business-co2-calculator/, 2008-11-03.