"CO₂ Allocation in Road Transportation for Alwex Transport AB"

A comparison of mathematical frameworks

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I. Abstract

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Title: CO2 Allocation in Road Transportation for Alwex Transport AB – A comparison of mathematical frameworks

Background: Global warming and the awareness of environment forces companies nowadays to offer environmental friendly and ethical products and services. Customers are eager to know where their products are from, how they are manufactured and to what extent they harm the environment. Environmental accounting became more and more important. It allows companies to allocate carbon dioxide on the transported products and thus to provide their customers with transparency.

Research Questions: How can a company allocate correctly the CO2 emissions to the respective product which were effectively caused during the product’s transportation? Which framework should be chosen? The easiest, the less costly or the most precise?

Purpose: This paper is dedicated to investigate the Alwex Transport AB’s calculations of CO2 emissions in order to find a useful framework that allows a better allocation of carbon emissions as the current calculation method.

Method: The empirical data and research outcomes are based mainly on quantitative data. A short interview providing qualitative data was carried out as well. The outcomes base on the comparison between two different mathematical methods. The thesis is based on the positivistic perspective and on a deductive approach.

Conclusions: Due to the nature of medium-sized companies, restrictions do not allow to implement sophisticated frameworks with high precision and accuracy for calculating and allocating CO2 emissions. Thus, a suitable framework that allows guarantees simplicity, accuracy and a flexible use is required. The new method presented in the thesis provides the company with a suitable method fulfilling its restrictions.
II. Preface

The research for finding an appropriate method for allocating CO2 emissions for the medium-sized Swedish transport company, Alwex Transport AB, has been an interesting challenge for the author in several regards.

The calculation and allocation of CO2 emissions in the transportation sector is a modern phenomenon that gains more and more attention from the scientific literature as well as the praxis. Therefore, it was an academic challenge to find adequate literature and useful suggestions.

The fact that the thesis refers to literature in three different languages made the research very challenging and interesting as well. The cooperation with a Swedish company helped the author to discover the Swedish business culture and gain more interest for Sweden and its culture.

Therefore, I would like to thank all who helped me actively to overcome the problems I faced during the last ten weeks.

I would like to thank especially my academic tutor Peter Berling and the examiner Helena Forslund at the University of Linnaeus for their academic support, their rapid replies to my questions, the constructive critics and their indispensable suggestions that contributed actively to the thesis’ quality.

Furthermore, I would like to thank Diana Unander Nordle, the Samverkanskoordinator at the University of Linnaeus, who helped me actively to find and contact Alwex Transport AB.

Last but not least, I would like to thank Peter Hildingsson from the Swedish transportation company Alwex Transport AB for his cooperation and his patience.

Växjö, 2010-05-24

Andreas Sichwardt
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<tr>
<td>AB</td>
<td>Aktiebolaget (Swedish)</td>
</tr>
<tr>
<td>AG</td>
<td>Aktiengesellschaft (German)</td>
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<tr>
<td>AFC</td>
<td>Absolute Fuel Consumption</td>
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<td>aFC</td>
<td>Average Fuel Consumption</td>
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<td>C</td>
<td>Celsius</td>
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<tr>
<td>CH4</td>
<td>Methane</td>
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<tr>
<td>CO</td>
<td>Carbon monoxide</td>
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<tr>
<td>CO2</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
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<tr>
<td>EcoTransIT</td>
<td>Ecological Transport Information</td>
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<tr>
<td>EF</td>
<td>Emission Factor</td>
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<tr>
<td>e.g.</td>
<td>Exempli gratia (Latin) stands for: for example</td>
</tr>
<tr>
<td>e-mail</td>
<td>Electronic mail</td>
</tr>
<tr>
<td>et al.</td>
<td>Et alii (Latin) stands for: and others</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>EUR</td>
<td>Europe, European</td>
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<tr>
<td>g</td>
<td>Gram(s)</td>
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<tr>
<td>GEMIS</td>
<td>Global Emission Model for Integrated Systems</td>
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<tr>
<td>GHG</td>
<td>Green House Gas</td>
</tr>
<tr>
<td>GHGP</td>
<td>Green House Gas Protocol</td>
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<tr>
<td>GHGPI</td>
<td>Green House Gas Protocol Initiative</td>
</tr>
<tr>
<td>GJ</td>
<td>Giga-Joule</td>
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<tr>
<td>GRI</td>
<td>Global Reporting Initiative</td>
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<tr>
<td>HC</td>
<td>Hydro carbon(s)</td>
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<tr>
<td>i.e.</td>
<td>Id est (Latin) stands for: this is, this means</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>IFEU</td>
<td>Institut für Energie- und Umweltforschung Heidelberg GmbH</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram(s)</td>
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<tr>
<td>km</td>
<td>Kilometer(s)</td>
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<tr>
<td>l</td>
<td>Liter(s)</td>
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<td>m</td>
<td>Meter(s)</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>N2O</td>
<td>Nitrous Oxide</td>
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<td>NOx</td>
<td>Mono-nitrogen oxide(s)</td>
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<tr>
<td>pkm</td>
<td>Person kilometer(s)</td>
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<tr>
<td>PM</td>
<td>Particulate mater</td>
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<tr>
<td>SCB</td>
<td>Statistika Centralbyrån</td>
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<tr>
<td>SCM</td>
<td>Supply Chain Management</td>
</tr>
<tr>
<td>SIKA</td>
<td>Statens institut för kommunikationsanalys</td>
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<tr>
<td>SMB</td>
<td>Small and medium-sized business(es)</td>
</tr>
<tr>
<td>SME</td>
<td>Small and medium-sized enterprise(s)</td>
</tr>
<tr>
<td>UNFCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>TREMOD</td>
<td>Transport Emission Model</td>
</tr>
<tr>
<td>GJ</td>
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1 Introduction

This chapter is dedicated to the background knowledge about the global warming problematic and its impact on the business world. The importance of Green Supply Chain Management and the right allocation of CO₂ emissions on products during their transportation will be illustrated as well. The chapter will be developed in the problem discussion. Research questions and the purpose give the reader clear information about the author’s research field. The limitations part is dedicated to the restrictions that are set by the transportation company Alwex Transport AB.

1.1 Background

Global warming became during the last decades a serious problem (Masui 2010, 161). Natural devastated catastrophes resulting from El Nino or ice melting are evidence for the increasing global warming, which cannot be anymore ignored (Neelin et al. 2000, 2) and (UNFCC, 1992, 2). One of the main factors for the global warming results from the human beings’ activities:

“Human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, [...] the warming of the Earth’s surface and atmosphere.” (UNFCC, 1992, 1).

This means, that human activities are closely related to Green House Gases (GHG) as well as to the warming of the Earth’s surface. Toxic elements such as Carbone Dioxide (CO₂) or Nitrous Oxide (N₂O) have to be considered as toxic gases that cause the Green House Effect and, thus, the global warming. The National Aeronautics and Space Administration (NASA) report annually the evidence of the increase in surface temperature due to GHG (NASA, 2011).
In order to slowing down the global warming and protecting the human being form toxic gases, the United Nations decided to conclude agreements where the industrial countries oblige themselves to reduce their toxic emissions. Consequently, the United Nations Framework Convention on the Climate Change (1992) and the Kyoto Protocol (1997) were signed by 190 countries in order stabilize the greenhouse gas concentration in the atmosphere. Thus, as signatories to the 1997 Kyoto Protocol, the European Union countries agreed to an 8 % reduction of CO₂ emissions relative to 1990 levels (Albrecht and Arts, 2005, 1). Since CO₂ and N₂O emissions are the results of burning fossil fuels, which are used as energy resources for vehicles, and, thus, for the road freight transportation, the connection of the greenhouse effect with the logistics, is very interesting from the Supply Chains Management’s (SCM’s) point of view. Since the 1990s, the European Union publishes annually the so-called White Papers that are dedicated to harmonize the members’ legislation in social, environmental and economical aspects within the Union (Europa.eu, 2011). In 2001 the European Union recognized the growing
trend of transportation within the Europe and dedicated the annual White Paper to the transport policy (Europa.eu, 2001). Different recommendations are demonstrated how to harmonize the transportation systems between the members, how to develop and extend the infrastructure and how to avoid environmental and health risks (Europa.eu, 2001). Thus, environmental aspects in transportation reveal a new research area with various questions and elements. Enarsson (2006, 234) shows the structure of the problem area in environment and transportation as follow:

![Figure 1-2 : Structure of the Environmental and Transportation Area](source: Enarsson, 2006, p. 234.)

As an entire member of the European Union, Sweden is also concerned by the White Paper for the European transport policy. Sweden, for example, where the Energy sector caused in 2008 about 73 % of the GHG emissions, recorded that 44, 34 % of GHG emissions within the Energy sector were due to the transportation sector (UNFCCC, 2008, 2-3). In 2009, more than 340 million tons of goods reached their destinations via the freight transport within the country (SIKA, 2010, 8). And despite the Financial Crisis in 2008, the Swedish transportation sector delivered almost the same volume of goods in that year as in 2006, i.e. over 342 million of tons (SIKA, 2010, 10). Despite the constant rate of goods delivered by the road transportation,
Sweden achieved to reduce its CO₂ emissions in the transportation sector by almost 9 % during the last two decades (UNFCCC, 2008, 3). This shows evidence that the transportation sector in Sweden plays a big role in aiming to fulfill the Kyoto Protocol’s requirements.

![Figure 1-3: Breakdown of GHG emissions within the Swedish energy sector](image)

Source: (UNFCCC, 2008, 3)

During the last 18 years, the Swedish transportation sector achieved to reduce the CO₂ emissions about 9 % while the energy industries increased their carbon emissions by 2.79 %. This shows evidence how the transportation sector can help the energy sector to fulfill the Kyoto Protocol’s requirements.

However, incentives to reduce the CO₂ emissions do not have to come only from the government as a stakeholder. Enarsson (2006, 234) illustrates that the transport sector is also influenced by the demand on the market – see figure 1-3. In the world of globalization, fast moving information and shorter life cycles, consumers ask more and more for environmental friendly products, ethical responsibility and transparency in their products’ manufacture and transportation (Balan et al., 2009, 228), (Boyd et al., 2007, 346) and (New, 2010, 77). Thus, it is also in the respective company’s economical interest to reduce its emissions and, thus, to green its logistics (Ubeda et al., 2011, 44).

However, greening the Supply Chain and, thus, the company’s logistics can be costly. Bowen et al. (2001, 45) state that organizations are only willing to adopt green supply chain management if
this will result in financial and operational benefits. Installing costly filters in order to absorb toxic emissions, investing in new technologies and buying new machineries in order to reduce or even re-use waste are in evidence costly ventures. Nevertheless, if the source of income, i.e. the customer, asks for a greener supply chain management, there is nothing else for the company but to obey the king’s rules, i.e. to obey the customer’s rules. According to Peter Hildingsson, the manager for quality, information systems and environmental issues in the Swedish transportation company Alwex Transport AB, big food retailers in Sweden such as ICA or COOP do not only want to know how their products were produced, but also how much their products’ transportation emitted CO₂ (Hildingsson, 11.03.2011). This means, on one hand, that customers ask for a transparent and environmental friendly transportation. But implicitly, on other hand, that environmental friendly transportation can also lead to competitive edges:

“Organizations are enhancing their competitiveness through improvements in their environmental performance to comply with mounting environmental regulations, to address the environmental concerns of their customers, and to mitigate the environmental impact of their production and service activities.” (Rao and Holt, 2005, 898)

By service activities, Rao and Holt mean a Supply Chain’s service activities, i.e. transportation, since the transportation of goods belongs to the main processes within a Supply Chain (Cooper et al., 1995, 5).

The Swedish medium-sized transportation company, Alwex Transport AB, recognized the global trends of the need of environmental friendly transportation and uses the sustainability-reporting framework of GRI – The Global Reporting Initiative. The GRI framework is used to demonstrate a company’s sustainable development and its performance with respect to the environment, laws, norms, standards and voluntary initiatives (GRI, 2008, 5). Using the GRI framework, Alwex Transport AB commits itself for installing environmental friendly process in the transportation system. Thus, environmental accounting such as the precise and fair allocation of emissions to the right product transported belongs to the company’s responsibilities (Hildingsson, 11.03.2011). Doing so, the company does not only fulfill its customers’ wishes but gives also a direct contribution to achieve the Kyoto Protocol’s aim – an evident reduction in CO₂ emissions.
Based on the background information above, this paper is dedicated to find a suitable framework for Alwex Transport AB that allows the company to calculate and allocate the CO₂ emissions to customers’ products as precise and fair as possible in order to satisfy its clientele as well as to fulfill the GRIs’ discloser principles. As an ecological and quality aware company, Alwex Transport AB is certified with both the ISO-14001 and ISO-9001 certifications and, thus, responds through the core business to its customers’ high requirements on environmental friendly quality.

The Master thesis is generally structured as follow. The first chapter is dedicated to the Introduction including the subject’s background information, problem discussion, research questions, purpose, limitations and disposition. In the following chapter, the methodology will be introduced, discussed and the choice of the right methods will be supported with arguments. The third part of the paper is dedicated to the Theory where the transportation system within a Supply Chain and the emission of CO₂ will be theoretically discussed and several calculation models of measuring introduced. The fourth chapter is dedicated for the empirical part: Alwex and its core business will be described. In the fifth chapter the empirical data and the theoretical facts will be used in the Analysis, i.e. CO₂ emission calculations and allocations will be done based on the given empirical data. In the last chapter, the author will conclude its findings and answer directly the research questions based on arguments from the chapters before.

1.2 Problem Discussion

In the world of globalization and highly competitive environment, environmental friendly processes and green logistics are gaining more interest in the scientific literature as well as in business life (Bowen et al., 2001, 43). Nevertheless, discussions about issues concerning the green logistics, such as environmental accounting, are rare in the scientific literature (Ubeda et al., 2011, 44). Srivastava (2007, 53) literature review of green supply chain management shows that the theme environmental accounting is not widely discussed even though it was early considered as a social and economical relevant issue.

As stated above, logistics represents an important part of supply chain management. Hoffman (2007, 15) constitutes that progressive companies such as Wal-Mart try to reduce their carbon
emissions in order to get the supply chain greener. Thus, frameworks helping companies to allocate correctly the carbon emissions on products transported can be regarded as aids for the entire supply chain. A correct allocation of emissions on products, customers or locations requires a detailed investigation in the logistics processes. Such investigations help managers to understand and detect problems within the processes. However, it is far from easy to undertake such investigations in order to be able to allocate the emissions correctly. Thus, controlling and measuring carbon emissions stay still a challenge for companies today (Sundarakani et al. 2010, 43).

A challenge which the Swedish transport company Alwex Transport AB accepts and meets. The Stakeholders’ pressure for environmental friendly and ethical products and services demands the company for continuous improvements and implementations of greener processes. Certifications such as ISO-14001 and ISO-9001 are a seal of quality for which the company has to work hard. Thus, achieving these certifications can help the company to increase its positive image and, thus, to attract more clients (Hildingsson, 11.03.2011). Since the company’s clientele is dispersed around Sweden, it makes it difficult for Alwex Transport AB to find an optimal distribution system – even though it has several distribution terminals in the South of Sweden. Therefore, the company divided its distribution network in different tariff zones in order to lower the complexity of the distribution system. Figure 1-4 depicts briefly the different distribution zones with the central terminal in Växjö as an example.

Figure 1-4: Simplified Illustration of Alwex Transport AB’s distribution zones with the central terminal Växjö as an example
Source: (Peter Hildingsson, 11.03.2011)
Alwex Transport AB charges its clients for the transportation of their products. The costs depend on the distance of transportation. Alwex Transport AB divided the southern part of Sweden in several tariff zones in order to install a simple cost structure. Växjö is depicted as tariff zone number one, red dot, while the furthest tariff zone is colored in yellow. The further a tariff zones, the more costs occur and, thus, CO₂ emissions.
Transportation for the furthest tariff zone, depicted as yellow circle, causes the highest costs in both aspects financial as well as environmental.

Within these tariff zones, the company adopted the sweep method for its route planning (Hildingsson, 11.03.2011). This means, that the truck leaves the terminal with the largest amount of goods as possible and delivers them in sequence. The truck can contain goods of several clients who are situated in the same tariff zone but at different locations. Thus, the good which has to be delivered at least will record the longest transportation way and the most CO₂ emission burden. This fact reveals a dilemma in both economical and environmental aspects. On one hand, the division in tariff zones and the sweep method allow the company to allocate easily their costs to the respective products. But, on other hand, a fair and precise allocation of CO₂ emissions on products is not possible. Products that are delivered at the last sequence have the longest transportation way but are not supposed to bear all the CO₂ emissions caused during the entire transportation. Contrarily, the respective product is supposed to bear the carbon emissions that its transportation caused effectively, i.e. the CO₂ emissions which would have been occurred during a direct transportation to the respective client. Figure 1-5 illustrates briefly the problem of an effective allocation of carbon emissions by using the sweep method for route planning.

Based on the dilemma explained above, Alwex Transport AB faces a current and challenging problem: How to allocate the effective CO₂ emissions to the respective product?

However, due to the company’s structure and size it can be stated that sophisticated methods, which require high investments, cannot be put into consideration. Due to the nature of a medium-sized company, the company manifests several restrictions such as the fact that few people are involved in several job positions and bear different responsibilities, that the company’s financial situation and the workers’ skills do not permit to implement sophisticated processes and tools for calculating and allocating CO₂ emissions and that the company uses the sweep method for its transportation system. Thus, the restrictions ask for a more practical, i.e. useful and simple, solution.
The truck leaves Växjö with three different products. The first product is delivered after 7.5 km at ICA. Thus, ICA’s product caused CO₂ emissions for the effective 7.5 km. After the delivery at ICA, the truck continues its route with products of COOP and AB. After 7.5 km, COOP’s products are delivered. Thus, COOP’s products were transported in total 15 km but caused effectively CO₂ emissions for 7.5 km. AB’s products were transported in total 30 km since they are delivered at the end of the sequence. However, AB’s products should account CO₂ emissions for only 15 km – the effective direct distance between Växjö and AB.

1.3 Research Questions

Putting the information from the background and the problem discussion in consideration, following research questions can be stated:

How can the company Alwex Transport AB allocate correctly the CO₂ emissions to the respective product that were effectively caused during the product’s transportation?
Which framework should be chosen? The easiest, the less costly or the most precise?

1.4 Purpose

This paper is dedicated to investigate Alwex’s Transport AB CO₂ emissions in order to find a useful framework that allows a better allocation of carbon emissions as the current calculation method.

1.5 Limitations

Due to the company’s structure and business nature, the author’s research is restricted on practical solutions. Alwex Transport AB is a medium-sized company. Thus, high-tech and information system based frameworks cannot be considered in the solution finding part. Furthermore, the company’s distribution system and method will be considered as given and cannot be changed. In addition to these facts, the scientific literature discusses the allocation of CO₂ emissions as a new phenomenon and, thus, cannot offer standardized models for resolving the problem. Thus, the research bases widely on information found on the Internet.

1.6 Time Schedule

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Table 1-1: Time plan for the Master Thesis
Source: Own illustration
The blue colored boxes represent the due time for the respective chapter(s).
1.7 Disposition

Figure 1-6: Disposition of the Master Thesis
Source: Own illustration
2 Methodology

This chapter is dedicated to the description of scientific approaches that are relevant for this thesis. First, different scientific perspectives in the social science will be introduced. Important aspects such as research methods, empirical data collection, selection of methods and data and the research elements such as credibility and validity will be explained. The importance and selection of the aspects described will be motivated by the author’s explanation. A figure of the scientific approaches applied in the thesis gives the reader a short overview.

2.1 Science Perspective

Science helps people to observe and understand the reality (Seifert, 1997, 174), or better to say, to describe the reality with the help of empiricism (Kromrey, 1998, 21). However, the description of reality can base on different scientific perspectives depending on the school of thought (May, 1997, 8). Arbonor and Bjerke (1994, 62) argue that there are mainly two different scientific perspectives: the positivism and hermeneutics.

2.1.1 Positivism

According to May (1997, 10) and Burns (2000, 7), positivists study the social phenomena like natural scientists, i.e. they observe the reality objectively with the help of logical models such as mathematics and conclude their results through the logic. The experiments and tools used to observe the phenomenon base on empirical data and must provide objectivity in order to help the scientist to describe and anticipate the respective phenomenon (May, 1997, 10). In this process, positivists explain the human behavior in terms of cause and effect (Arbnor and Bjerke, 1994, 62) and (May, 1997, 10). Thus, conclusion through logic and mathematical models help in our reality to investigate problems, find solutions for these problems and apply the respective solution for other problems, i.e. to generalize the results.

2.1.2 Hermeneutics

The antipode of positivism came up in the 19th century and was “determined to show that the generalizing of the natural science model of knowledge to all spheres of knowledge was unacceptable” (Anderson et al., 1986, 65). Originally, the scientific perspective of hermeneutics
helped German philologists to interpretate Latin, Greek and Sanskrit texts whose meanings were confusing or incomplete (Anderson, 1986, 63). Hermeneutists emphasize the fact that ideas and thought of human beings are not measurable and, thus, require a subjective interpretation in order to understand the reality (Anderson, 1986, 65).

2.1.3 Explanation (das Erklären) and Understanding (das Verstehen)

It is important to make a distinction between the terms understand and explain. The necessity came up with the development of both schools of thought: the Positivism and Hermeneutics. In science the term explanation is rooted in the German term “erklären” and can be understood as explain, illustrate or describe something. While understanding means “verstehen” in German and stands for to realize, understand or catch something. In this respect, scientists distinguish between understand and explain. While positivists use empirical data and experiments in order to explain the reality, especially the natural laws like gravity, hermeneutists try to understand the reality, especially the social cultural world, through the inclusion of historical and social events and interpretation (Arbnor and Bjerke, 1994, 63) and (Frankfort-Nachmias and Nachmias, 1996, 12). Thus, positivists assume that the world is complex and the science has to simplify and reduce it in order to find explanations for phenomena. Hermeneutists, on other hand, assume that the world is already simplified by its actors and has to be understood through models (Arbnor and Bjerke, 1997, 63).

2.1.4 Scientific Perspective Applied

This thesis is dedicated to find a solution in allocating CO₂ emissions for the middle-sized transport company Alwex Transport AB. Thus, the thesis is based on collecting empirical data and the author used mathematical frameworks as well as logic in order to find and develop a suitable model that helps to resolve the problem. Accordingly to that, this thesis has a positivist perspective.

2.2 Scientific Approach

The term theory has its root in the ancient Greek term θεωρία and means description, cognition, and assumption. Kromery (1998, 21), May (1997, 27) and Seiffert (1997, 174) state that theory
helps to explain and understand research findings in a conceptual framework, i.e. to explain and understand our reality. Thus, theory is a system of evidence and conclusion based on empirical data and logic which helps to explain and understand the world.

The scientific literature explains two main ways of how theory can help to obtain knowledge (Arbnor and Bjerke, 1997, 107), (Dooley, 1995, 66), (May, 1997, 30) and (Schnell et al., 2008, 58). As explained in figure 2-1, the approach of induction helps to build a theory from data collection, while the approach of deduction starts from the respective theory and is verified or falsified by empirical data.

2.2.1 Deduction

With the approach of deduction, the theorizing part comes before the research (May, 1997, 30), i.e. the scientists base their research on an existing theoretical framework that is the base to test empirical data (Schnell et al., 2008, 59). The analysis of the empirical data allow the researcher to falsify or verify a specific hypothesis, i.e. a prediction about relations among operational terms (Dooley, 1995, 67) and (Schnell et al., 2008, 60). After having testified the hypothesis, the researcher concludes the findings that can mean that the testified hypothesis was wrong or right (Dooley, 1995, 68).

2.2.2 Induction

As shown in figure 2-1, the approach of induction allows the researcher to derive a theory form examinations of particular aspects in social life (Arbnor and Bjerke, 1994, 107) and (May, 1997, 31). Thus, in this approach, no clear framework exists and collected empirical data help the researcher to develop a theory. This approach is often used for explorative investigation such as interview that helps e.g. marketing departments to know their clients’ opinions about a specific product (Dooley, 1995, 67).
Figure 2-1: Scientific Approaches  
Source: Own illustration, based on (Arbnor and Bjerke, 1994, 107)  
Theoretical and empirical hypotheses can be verified or falsified through models. The approach can be deductive or inductive. Induction implies the fact that hypotheses are tested from the theory. If theoretical hypotheses are tested through empirical data, the approach is called deductive.

2.2.3 Scientific Approach Applied

This thesis focuses on the deductive approach. Empirical data base on both interviews and measures (section below). Theoretical frameworks for the allocation of CO₂ emissions were examined. Based on them and the empirical data, the theories were testified. The thesis will base only on the deduction approach. If the theoretical frameworks cannot contribute to a useful solution for the company Alwex Transport AB, a new framework will be developed.

2.3 Research Method

The collection of data can base on two different methods – on the quantitative method or qualitative method (Arbnor and Bjerke, 1994, 310). The difference between both methods is their basis on facts and statistics (May, 1997, 171).
2.3.1 Quantitative Method

The research objects in the quantitative method are illustrated as numbers, i.e. the objects are quantifiable and measurable (Hair et al., 2003, 74). In the business research, quantitative data often occur as statistics in form of a company’s financial statement or sales records. Using hard data, i.e. quantitative data, allows the researcher a high level of objectivity and control of the research itself since numbers have to be seen as evidence or facts given, instead of interpretations (Hair et al., 2003, 74). Thus, the quantitative method is often used by natural scientists, where phenomena are measurable and explained in form of numbers such as rapidity, weight, volume or length.

2.3.2 Qualitative Method

Where researches have to explore a new field which concerns immeasurable and uncontrolled objects, such as the opinion of people, the qualitative method is presented as an edge (Hair et al. 2003, 74). The qualitative method is described as

“a particular tradition in social science that fundamentally depends on watching people in their own territory and interacting with them in their own language, on their own terms.” (Kirk and Miller, 1986, 9)

Thus, the qualitative method is focused on the interaction and two-way communication, furthermore, on interviews between the researcher and her respondent (May, 1997, 173). As an antipode to the quantitative method, the qualitative methods can be regarded as a statement that in the reality not everything is measurable or can be expressed in numbers (Kirk and Miller, 1986, 10). The qualitative method is not as structured as the quantitative method and, thus, provides the researcher with less objectivity (Hair et al., 2003, 74). Nevertheless, a pure objectivity does not exist since even objective instruments lose their capability to measure precisely in certain circumstances, such as temperature changes. Furthermore, the aim of qualitative researcher is not to “objectify the subject by over-measurement” (Kirk and Miller, 1986, 11), but to understand and investigate the reality where “the researcher’s subjective opinion must be used to resolve the ambiguous meaning” (Hair et al., 2003, 74).
2.3.3 Methods Applied – A Case Study?

The thesis is based on types of data coming from interviews as well as measures. Finding the right framework for the problem solution requires calculations of CO₂ emissions that are based on kilometers driven by the respective trucks in the respective area, i.e. which are based on numbers. Since these data are expressed in numbers and statistics, the quantitative methods such as mathematical calculations are used for finding the useful framework. The transport company Alwex Transport AB’s restrictions and its structure were explored through interviews with the company’s manager Peter Hildingsson, the responsible for environment, quality and information system issues at Alwex Transport AB. Therefore, an investigation through the qualitative methods was done and answers expressed in numbers. This means, that restrictions concerning the company’s transportation system and CO₂ calculations can be quantified.

As explained above, the research bases on real life experience and problems in the Swedish transport company Alwex Transport AB. The given problem requires an appropriate study where several calculations frameworks for the CO₂ emissions are investigated, specific calculations examined and decisions taken with the help of the company’s restrictions that are expressed in a quantitative form.

This investigative part, where restrictions were found out by an interview bases, on qualitative methods. The other part, where a suitable framework has to be chosen, bases on mathematical models, i.e. also on a quantitative method. Case studies help to combine both methods in one and, thus, to find accurately solutions for a specific problem under real life circumstances (Bryman and Bell, 2011, 60), (Yin, 1981, 58) and (Yin, 2009, 133). Case studies are helpful in observing the processes of the analysis and, thus, can help to find solutions faster (Bryman and Bell, 2011, 67). Furthermore, the problematic in a case study is very specific, it is not granted that the solution of the respective problem can also be applied for other actors, i.e. the solution cannot be generalized (Yin, 2009, 15).

Even tough, this thesis is dedicated to find a suitable framework for a specific real life problem it cannot be stated that this thesis is a case study. As mentioned above, this thesis emphasizes the quantitative methods by using mathematical methods in order to calculate CO₂ emissions.
Mathematical methods and sophisticated frameworks for that exist already (Zadek and Schulz, 265). Thus, the author bases his results on calculations, i.e. on hard numbers and takes a rational decision. Therefore, this thesis is not to be regarded as a case study.

2.4 Empirical Data Collection and Selection

Empirical data collection is the crucial part in a research process. The scientific literature presents several methods of data collection: interviews, observations, content analysis and so-called non-reactive measurement methods (Schnell et al., 2008, 13). Empirical data are anchors in this thesis since they provide the respective information on which the calculations and, thus, the right choice of a useful framework is based.

2.4.1 Interviews

Data can occur as primary data, i.e. the author has collected them by himself, or secondary data, i.e. the author uses data having been collected from other researchers or coming from other sources (Arbnor and Bjerke, 1994, 241). Interviews, observations and experiments are the best research methods for collecting primary data (Arbnor and Bjerke, 1994, 241) and (Hair et al., 2003, 124). Interviews, furthermore, can be executed impersonally by mail or e-mail, or personally by a face-to-face interview, by telephone or through a computer dialogue such as Skype (Hair et al., 2003, 125). The interview can vary in its intensity of structure: high-structured interviews present pre-determined questions in a specific order, while low-structured interviews present open-questions on which the interviewee can respond openly and even take the form of a conversation (Schnell et al., 2008, 330). Data collected with the help of interviews are seen as qualitative data since the output are answers which almost cannot be quantified, i.e. cannot be measured in numbers. Quantitative data can be obtained by high-structured interviews through the use of various numeric scales, e.g. a Likert-scale where the respondent has to decide between 1 as very good or 5 as very bad (Bortz and Döring, 2006, 224). The analysis of quantitative interviews is timesaving since they are high-structured. This allows them also to contain a big number of respondents (Hair et al., 2003, 124). Contrarily, open interviews that allow the interviewees open answers are to be considered as qualitative interviews that are more time- and cost-consuming than high-structured interviews. Despite the high costs, researchers
recommend to use qualitative interviews in order to obtain reliable and usable data (Hair et al., 2003, 124).

### 2.4.2 Selection and Sampling

Due to the research method’s feasibility, it is recommended to do a necessary selection of objects to study (Hair et al., 2003, 209). The selection of a specific group for the research method is called sampling (Dooley, 1995, 133) and (Hair et al, 2003, 208). By sampling, researchers have to consider that their study has to be representative. In many cases, it is not possible to study the entire research field and to find the desired population to observe (Hair et al., 2003, 209). Thus, the right choice that also permits the study the desired level of objectivity is required. For that reason, scientists base their choice of population on two different sampling designs: the non-probability and probability sampling (Hair et al., 2003, 208). In general, it can be said, the more specific the study is, the less randomly is the population to be chosen, i.e. non-probability sampling is done for interviews that require deep knowledge from the respondents (Hair et al, 2003, 212). Probability sampling, which has the prerequisite that all objects in the populations have the same chance to be chosen, allows a certain level of confidence to generalize the target population since the studied object are chosen randomly (Hair et al., 2003, 212).

In this thesis, the selection of data collection is based on non-probability sampling. An open interview with the time frame of more than two hours was held with Mr. Hildingsson, the responsible manager for environmental and quality issues as well as the information systems. The intention of the interview was to get know the company itself, its structure, the specific distribution system and the problem of the allocating CO₂ emissions. The open discussion allowed Mr. Hildingsson to describe accurately the company’s restrictions and his old and new ideas that should help to resolve the problem. The interview was held entirely in Swedish.

Moreover, secondary data are used to test the theoretical frameworks on their feasibility in the real life circumstances. These data are based on measures of kilometers and CO₂ emissions recorded by the trucks’ measurement instruments such as tachometer or odometers.
2.5 Analysis

The analytical part in the thesis is one of the most important parts, since data collected have to be analyzed with the help of mathematical frameworks used. Even though it was stated that this thesis has not to be regarded as a case study, it does not mean that analytical tools for the quantitative part differ totally (Yin, 2009, 127). Thus, it is seen as helpful to refer also on authors and literature examining case studies. In the business research field a wide range of analytical tools are presented that have to be chosen by the problem’s nature. Most of them base on mathematical and statistical methods. Thus, it is not surprising when Ying (2009, 127) recommends to chose first the right analytical formulas and tools in order to have the right analytical results. Yin introduces two analytic techniques which are helpful in quantitative studies.

2.5.1 Pattern Matching

In quantitative studies pattern matching is often used to analyze predicted outcomes (Yin, 2009, 137). If the study is explanatory, the patterns may be related to dependent or independent variables of the study (Yin, 2009, 136). Multivariate methods such as the linear regression are helpful tools to estimate predictions (Timm, 2002, 185). Furthermore, multivariate regression and testing hypothesis allow the scientists to examine whether the hypothesis, i.e. the predicted outcome, is verified or falsified (Timm, 2002, 187). Thus, relationships or hypothesis such as an increase in CO\textsubscript{2} emissions by driving faster can be tested by multivariate methods. Since multivariate methods base on mathematical and statistical methods, mathematical techniques can also be regarded as pattern matching.

2.5.2 Logic Models

Creating logical models that enable scientists to match empirically observed events to theoretically predicted events became increasingly useful in recent years (Yin, 2009, 149). Models are constructions that help to explore and explain the causal links in the science theory. The German Institute for Energy and Environmental Research developed a model, Transport Emission Model (TREMOMD), which allows calculating CO\textsubscript{2} emissions and building future
scenarios (see in Chapter 2). TREMOD bases its results and calculations on quantitative data and, thus, can be regarded as an analytical tool for quantitative studies which helps to explain the air pollution phenomenon. As well as pattern matching, logic models can base on mathematical methods. Sundarakani et al. (2010, 43), e.g. base their model for calculating carbon footprints on the Lagrangian and Eulerian methods.

### 2.5.3 Analysis in this thesis

The analysis in this master thesis is based on quantitative data that are applied in mathematical frameworks. For the calculation of CO$_2$ emissions given mathematical frameworks were applied and calculated with the data presented in the empirical part of this thesis. Based on the results and the restrictions given by the Swedish transportation company Alwex Transport AB, the most useful mathematical framework was developed and recommended to use. Due to the company’s restrictions the thesis does not include neither multivariate methods nor logical models since the thesis is not dedicated to find out any relationships between the variables or to explore a new distribution system or a completely new calculation framework of CO$_2$ emissions. The master thesis is based on quantitative data and mathematical methods. Therefore, the master thesis can be regarded as a solution finding based on comparisons of mathematical frameworks for the calculation of CO$_2$ emissions.

### 2.6 Scientific Credibility

A research or study representing and testing logical statements and theories has also to fulfill a standard of quality (Dooley, 1995, 76) and (Yin, 2009, 40). Only studies that fulfill the specific quality criteria can be judged and qualified (Bühner, 2006, 33), (Bryman and Bell, 2010, 41), (Dooley, 1997, 77) and (May, 997, 68). The key words for representative study are objectivity, validity and reliability. However, several authors also mention other criteria which can help to develop a credible study: Bryman and Bell (2011, 41) name replication as a criterion for a study’s high quality. Bühner (2006, 34) embraces all quality criteria mentioned above and divides them into two parts: the main quality criteria and secondary quality criteria see in figure 2-2.
2.6.1 Main Quality Criteria – Objectivity, Reliability, Validity

Objectivity

The term objectivity was discussed implicitly above and connected with the fact that a pure objectivity does not exist. However, within the research methods objectivity stands for the quality criterion that permits to achieve results that are independent from the researcher (Bühner, 2006, 34). In an interview, the researcher has to aim the objectivity in carrying out the interview, in analyzing the interview and in interpreting the interview. This means, the interviewer has to be consistent in the meaning of questions and free from subjective opinions towards the respondents (Bühner, 2006, 35).

Reliability

Reliability refers to the degree to which observed scores are free from errors of measurement, i.e. whether the results are repeatable or not (Bryman and Bell, 2011, 41), (Bühner, 2006, 35) and (Dooley, 1995, 77). This requires the researchers that the calculations and the sampling are done on the right way without any errors. Reliability is mainly connected with the quantitative research (Bryman and Bell, 2011, 41). A reliable research has to be consistent in its calculations and stable, i.e. tests and retests will have the same results (Bryman and Bell, 2011, 41 and 157) and (Bühner, 2006, 41).

Validity

Bryman and Bell (2011, 42) argue that validity is the most important criterion for business research methods. Validity refers to the degree to which a test actually measures what it is supposed to measure and to the degree to which the finding is interpreted correctly, i.e. it proves its usefulness of the specific measurement (Bühner, 2006, 36), (Dooley, 1997, 78) and (Kirk and Miller, 1986, 11). Researchers indicate that three types of validity should be considered within a
study: internal validity, construct validity/measurement validity and external validity (Bryman and Bell, 2011, 42), (Bühner, 2006, 36-39) and (Yin, 2009, 41).

The internal validity emphasizes the cause and effect relationship, i.e. it is concerned with the question whether conclusion incorporates a relationship between an independent and dependent variable (Bryman and Bell, 2011, 42). In order to achieve a high level of internal validity, it is recommended to base the conclusion on logical models (Yin, 2009, 43).

Construct validity permits an accurate measure of the object’s attributes or characteristics, i.e. it identifies the correct operational measures for respective method (Bühner, 2006, 39) and (Yin, 40). Construct validity permits an objective judgment of the data being collected (Yin, 2009, 41). Case studies have attracted much criticism and were accused not to provide enough objectivity due to the lack in installing sufficient operational measures (Yin, 2009, 41). However, Yin (2009, 41) suggests to use multiple sources of evidence and to establish a chain of evidence during the data collection in order to create sufficiently objectivity.

External validity deals with the question whether the results of the study can be generalized or not (Bryman and Bell, 2011, 43) and (Yin, 2009, 41). A high external validity is achieved when the results can be applied in other cases with similar characteristics in similar circumstances (Bryman and Bell, 2011, 158).

2.6.2 Secondary Quality criteria – Standardization, Comparability, Economy, Usefulness

Bühner (2006, 43) explain the secondary quality criteria as a study’s quality measures that are strongly connected to the quality criteria discussed above. A research study has to allow a certain level of standards, i.e. samplings and results have to be representative, see 2.4 Empirical Data Collection and Selection). By comparability, the author emphasizes that results coming from the research study have to be comparable, i.e. test and re-test should end up with the same results, see Reliability the section above. In the same section the main quality criterion validity was connected to the research study’s usefulness. By usefulness, Bühner (2006, 44) means that a study has to respond to realistic needs, i.e. it has to be useful in the real life. Finally, the research study has to be carried out in a way that consumes time and costs as less as possible, i.e. it has to
be economical (Bühner, 2006, 44). All secondary quality criteria were already discussed implicitly above and, thus, will not be discussed deeply.

![Figure 2-2: Quality criteria for a research study](source)

The credibility of a research study is based on main quality criteria and secondary quality criteria. Validity refers to the degree to which a test is actually measuring what it is supposed to measure. Validity proves the usefulness of the research study. Reliability refers to the degree to which the observed scores are free of errors. Reliability permits to compare the data and study with other studies and data. Objectivity is given when the results do not depend on the researcher. Standardization helps to install objectivity in the research study.

### 2.6.3 Objectivity, Reliability and Validity in this thesis

The objectivity in this thesis is based on the fact that the author has no personal bonds neither to the company nor to the respondent. The nature of the problem, the allocation of CO₂ emissions, requires a quantitative approach, i.e. calculations that are based on mathematical models. This fact strengthens also the degree of validity. Interviewing more people could have increased the validity. However, Mr. Hildingsson is the only expert in the company who is dealing with environmental issues and, thus, has to be considered as the only capable to answer the questions presented in the interview, see Appendix.
The high degree of reliability in this thesis is given by the fact that the problem solution is based on calculations and mathematical models. Thus, consistent calculations and mathematical models that can be tested and re-tested guarantee a high degree of stability as required by Brymann and Bell (2011, 41) and Bühner (2006, 41).

2.7 Scientific Approaches in the Master Thesis

Figure 2-3: Summary of the thesis scientific approaches
Source: Own illustration
3 Theory

This chapter is dedicated to provide the reader with the necessary theoretical information about the transportation and transport planning applied in the logistics. Furthermore, different frameworks for the calculation of CO₂ emissions will be introduced. The theory chapter is to be regarded as support for the empirical part where the company’s transportation and distribution systems will be presented. Thus, terms such medium sized-enterprises, Swedish legal business forms and constraints of medium-sized enterprises will be illustrated and explained briefly. Calculations of CO₂ emissions in the empirical part of the Swedish transportation company Alwex Transport AB will base on the frameworks introduced in this chapter.

3.1 Transportation

The principal aim of vehicles is to transport passengers or goods between geographically two separated points (Jonsson, 2008, 63). Since more and more customers require their logistics service providers to allocate the CO₂ emissions accurately on the products transported (Sundarakani et al., 2010, 43), the choice of the right transport mode and the organization of the transportation plays an important role. There are four main traffic modes: sea, rail, road and air. If the good changes the transportation mode during its movement a combined transportation or intermodal transportation has been achieved (Jonsson, 2008, 67). In order to assure clarity and due to the master thesis’ theme, it was focused only on the freight transportation within Sweden, i.e. the traffic mode road.

The most recent statistics from the transportation sector, published in 2010 by the Swedish Institute for Communication Analysis (SIKA, 2010, 4), state that in 2009 more than 73 million ton of goods were transported with more than 8 million transportation vehicles within Sweden. The traffic performance was 605 million kilometers and almost 8 billion ton kilometers were driven (for the definition of ton kilometers see below). This shows how important it is to plan precisely the transportation of goods in order to achieve high efficiency that, in turn, allows more precise CO₂ calculations and, thus, a higher customer satisfaction. An optimal calculation of
transportation includes issues that allow, on one hand, an economically beneficial transport, including the calculations for the truck’s length, height, volume and weight. But, on other hand, the optimal calculation of transportation requires also the consideration of factors which affect the calculation of CO₂ emissions directly, such as the vehicle’s engine category, the infrastructure, geography and the respective fuel category. Thus, a trade off between economical and environmental issues has to be found.

3.1.1 Truck masses and dimensions

The main advantage of road transportation is the wide accessibility to customers. Due to the well structured and developed infrastructure in Europe, trucks can achieve almost all suppliers and customers – in contrast to ships and air planes that depend on geographical issues (Jonsson, 2008, 65). However, the road transportation has two main disadvantages: An economic disadvantage in comparison to rail transport in case of low-value goods and a delivery time disadvantage in comparison to air transport for very high-value goods (Jonsson, 2008, 66). Furthermore, the environmental impact in form of CO₂ emissions, noise and road safety makes the road transport less attractive in comparison to air or ship transportation (Jonsson, 2008, 66). Therefore, vehicles that have the right load capacity, an efficient use of resources and causing low environmental impacts are required. Nevertheless, it is generally accepted that trucks using fully their capacity are likely to be more economically efficient than those that do not use their load capacity (IFEU, 2008, 11-12). Therefore, a theoretical overview of the truck’s masses and dimensions should be given.

Length

The national regulations for truck sizes vary by country. However, the EU presents in its Directive regulation 96/53/EC the maximum authorized truck length (Directive 96/53/EC, 1996) and categorizes the trucks in four categories:

<table>
<thead>
<tr>
<th>Length</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 m</td>
<td>Motor Vehicle</td>
</tr>
<tr>
<td>12 m</td>
<td>Trailer</td>
</tr>
<tr>
<td>16.5 m</td>
<td>Articulated Vehicle / Semitrailer Combination</td>
</tr>
<tr>
<td>18.75 m</td>
<td>Road Train</td>
</tr>
</tbody>
</table>

Table 3-1: Categorization of the maximum truck length by the EU.
Source: (Directive 96/53/EC, 1996)
The EU Directive divides the trucks in four categories based on their length. The road train can be explained as a rigid truck train with trailer that can be combined with a regulated maximal total load of the area length of 15.65 m or 2x7.82 m.

Beside this categorization, the Directive 96/53/EC allows modular concepts which vary nationally. Sweden and Finland e.g. are allowed to have one short and one long module in the same vehicle combination.

Figure 3-1: Modular concept trucks used in Sweden and Finland.
Source: (Lumsden, 2004, 24) with own modification.

<table>
<thead>
<tr>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Sweden the height of trucks is not regulated. The EU directive limits, however, the height to 4 m (Directive 96/53/EC, 1996).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>The trucks can also be categorized according to their weight. The weight is often perceived as a limit to enter a specific region or to transport specific goods. Lumsden (2004, 24) divides the trucks in several groups and describes their limitations in the transportation system:</td>
</tr>
<tr>
<td>Masse in tones</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>More than 3.5 tones</td>
</tr>
<tr>
<td>7.5 tones</td>
</tr>
<tr>
<td>12 tones</td>
</tr>
<tr>
<td>16 tones</td>
</tr>
<tr>
<td>18/19 tones</td>
</tr>
<tr>
<td>26 tones</td>
</tr>
<tr>
<td>40 tones</td>
</tr>
<tr>
<td>44 tones</td>
</tr>
<tr>
<td>60 tones</td>
</tr>
</tbody>
</table>

Table 3-2: Classification of trucks due to their masse and description of limitations due to the masse. 
Source: (Lumsden, 2004, 24)

As it can be seen, trucks with the masse of 12 tones have to pay the road fees penetrating the German Autobahn. Trucks carrying more than 20 tones are not allowed in Europe but only authorized in Sweden and Finland.

### 3.1.2 Infrastructure and Geography, Fuel and Engine category

It should be noticed that truck masses and dimensions such as the truck’s weight have also a direct impact on the CO₂ emissions (IFEU, 2008, 12), but are considered to influence more the economical part of the transportation since the right loading will allow the right delivery to the customer and, thus, higher the customer satisfaction. The engine category, infrastructure and the truck’s fuel, contrarily, are to be considered to influence less the economical than the environmental issues since these factors are given and cannot vary or changed by the truck owners as the truck lorries. Thus, these factors are put less into account when logistics service providers plan the daily transportation.

**Infrastructure and Geography**

As stated above, Europe has a well-developed and structured infrastructure. That is why the road transportation is being considered as an economical advantage of transporting goods (Jonsson, 2008, 65). However, thinking environmentally, it is noticeable to consider the country’s
geography when calculations of CO₂ emissions are planned (McKinnon and Piecyk, 2009, 3734). Thus, flat roads are more favorable than hilly roads since flat roads consume less fuel and, thus, contribute to less CO₂ emissions.

The gradient expresses the respective country’s average topography (IFEU, 2008, 20). The Institute for Energy and Environmental Research, IFEU, states a difference of energy losing in transportation due to the gradient (IFEU, 2008, 20). Due to the gradient, the IFEU categorizes the country’s topography as follow:

- Flat, i.e. less than 5 % of the energy during the transportation is lost due to the country’s topography
- Hilly, i.e. an additional consumption of energy between 5 % - 10 % in the transportation is recorded
- Mountains, i.e. transport in these countries consume more than 10 % of energy

According to IFEU (2008, 22) Sweden’s topography is categorized as flat and, thus, has no considerable negative impact on the CO₂ emissions.

**Fuel and Engine Category**

In the transportation of goods mainly two sorts of fuels are used: diesel and gasoline (Zadek and Schulz, 2010, 265). CO₂ emissions are caused by burning organic energy carriers such as fuels (IFEU, 2000, 11). Nowadays, it can be measured how much CO₂ emissions are caused by burning one liter of diesel or gasoline. Burning one liter of diesel causes e.g. 2, 7458 kg CO₂ emissions (see table 3-4). The exhaust of CO₂ emissions can also be expressed per kilometer, e.g. a heavy truck having consuming 33, 6 l diesel per 100 km exhausts 0, 9226 kg of CO₂ per km (see below table 3-5). The results of the calculations presented, i.e. how many kg of CO₂ emissions per 100 km or one liter are caused by the transportation, are called Emission Factors (IFEU, 2000, 9). These Emission Factors are used to calculate CO₂ emissions (IFEU, 2000, 9) and (Zadek and Schulz, 2010, 265). Another worldwide accepted Emission Factor for the calculation of CO₂ emissions is the ton kilometer or tkm (EcoTransIT, 2010, 23). The ton kilometer is a satisfactory parameter for describing the physical materials flow and the utilization of truck (Lumsden, 2010, 8) and can be calculated through the multiplication of tons transported.
and kilometers driven with the truck, i.e. ton x kilometers = tkm. The calculation of tkm can be criticized in the manner that the roads topography and the truck’s load value are not included. Thus, a truck driving 400 km with a load of 20 tons will have 8000 tkm and another truck transporting 40 tons and driving 200 km will have the same 8000 tkm. This, calculation illustrates that there is a need to develop further parameters taking the load value, time or load volume into account. Nevertheless, the tkm is a basic parameter which is accepted and used worldwide and, thus, will be considered in further calculations below when it comes to the methods of CO₂ calculations.

The engine category is a further important indicator presenting how many toxic emissions the respective truck exhausts during the transportation of goods (IFEU, 2010, 11). The European Union classifies the truck’s engines according to their year of production. The engine categories vary from EURO 0 till EUR V – the lower the category the less toxic emissions are exhausted by the truck. It is recorded that CO₂ emissions depend on the weight of trucks, other toxic emissions such as NOₓ emissions depend contrarily on the truck’s engine category (IFEU, 2010, 15).

The following table illustrates the EURO classes and the respective amount of toxic emissions:

<table>
<thead>
<tr>
<th>Engine category per euro class</th>
<th>CO₂ (g/l)</th>
<th>NOₓ (g/l)</th>
<th>HC (g/l)</th>
<th>CO (g/l)</th>
<th>PM (g/l)</th>
<th>SOₓ (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 0</td>
<td>2410</td>
<td>40,85</td>
<td>1,58</td>
<td>4,21</td>
<td>3,43</td>
<td>0,0260</td>
</tr>
<tr>
<td>Euro 1</td>
<td>2410</td>
<td>26,69</td>
<td>1,68</td>
<td>3,25</td>
<td>0,53</td>
<td>0,0163</td>
</tr>
<tr>
<td>Euro 2</td>
<td>2410</td>
<td>23,25</td>
<td>1,07</td>
<td>1,97</td>
<td>0,49</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 3</td>
<td>2410</td>
<td>19,08</td>
<td>0,75</td>
<td>2,55</td>
<td>0,31</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 4</td>
<td>2410</td>
<td>10,57</td>
<td>0,45</td>
<td>1,75</td>
<td>0,07</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 5</td>
<td>2410</td>
<td>6,50</td>
<td>0,05</td>
<td>1,58</td>
<td>0,07</td>
<td>0,0065</td>
</tr>
</tbody>
</table>

Table 3-3: Allocation of toxic emissions per liter and Euro class of trucks. Source: (Hildingsson, 11.03.2010).
As it can be seen, the engine category of trucks has no impact on CO₂ emissions, but on the other toxic emissions such as carbon monoxide (CO). The lower the engine is classified the more toxic emissions it exhausts.

As illustrated in the table 3-3, the CO₂ emissions have no direct connection to the engine’s classification and, thus, will not be considered in the mathematical calculations of CO₂ emissions. The table above was presented as an illustration in order to show the relationship between toxic emissions and the truck’s engine category.
3.2 Transport Planning

A company’s distribution system must be planned in the manner it allows the company to deliver the products efficiently, i.e. to fulfill the customers’ requirements in the shortest time with the minimum of energy used or of kilometers driven (Jonsson, 2008, 321). Therefore, strategic transport planning gained an important role for economical and environmental issues (Jonsson, 2008, 320). Transport planning determines the structure of transport networks and the flow of traffic (Jonsson, 2008, 320). It has the aim to determine which routes provide the highest overall capacity utilization of vehicles, customer visits and the largest amount of products delivered as possible (Jonsson, 2008, 329). On other hand, transport planning has to minimize the delivery time, the distance traveled and the impact on the environment (Jonsson, 2008, 329).

The transportation planning is related to the company’s business nature. However, it is generally agreed that unique and direct transportations of low quantities to several customers within a region causes high transportation costs and, thus, has a negative impact on the environment (Jonsson, 2008, 321). Therefore, a coordination of deliveries within the respective area or region is required. The methods used for the coordination depend on the nature and difficulty of the problem and can be resolved manually or computer based (Rushton et al., 2006, 459). However, the most common approach is the heuristic approach by using routing and scheduling algorithms (Rushton et al, 2006, 459). There are three simple methods that are mainly used to implement efficient transporting routes. All three will be illustrated shortly.

The Sweep Method

The sweep method is a simple transport-planning method where a geographical sweep is conducted clockwise in relation to the terminal T, as illustrated in figure 3-2 (Jonsson, 2008, 330). The sweep, i.e. the transportation, ends there where a restriction is met, e.g. the truck has delivered all products and has to return to the terminal to refill (Jonsson, 2008, 330).
Savings Method

If the transport system’s nature is characterized by the distribution via terminals, the problem requires a solution for the transportation between the terminal and customers. The most common algorithm used is the so-called saving method where the shortest distance is chosen for the respective routing (Rushton, et al., 2006, 459). The savings method can also be applied for cost savings. Thus, it represents the distance or cost savings that the company achieves instead of driving directly to single customers (Jonson, 2008, 331). Even though the Savings Method and the Sweep Method are not designed explicitly for the allocation of CO₂ emissions, both methods help companies to reduce their CO₂ emissions, since the shorter a transportation route is the less CO₂ emission are exhausted by the truck. The formula for the savings method is depicted in figure 3-3:

\[
\text{Savings (A,B)} = \text{Distance (Terminal to Customer A)} + \text{Distance (Terminal to Customer B)} - \text{Distance (Customer A to Customer B)}
\]
According to the saving method formula above, the calculation is explained as follow: The distance between terminal and customers are illustrated between the respective entities (Terminal, Customer A and Customer B). If each customer is served by a single vehicle from the terminal, then the total distance would be 2x15km and 2x12km = 54 km. If only one vehicle is used in a single trip then the total distance would be 15 km + 5 km + 12 km = 32 km. Thus, the savings achieved by linking together both customers are thus: Savings (A,B) = 15 km + 12 km – 5 km
Savings (A,B) = 22 km

Clark-Wright Method

A more sophisticated approach is the utilization of the saving matrix called as Clark-Wright method (Jonsson, 2008, 330). The route-planning algorithm contains four steps and will be illustrated briefly:

1. Identify the full truckload deliveries

2. Calculate the distance between and all customers using the following Distance-Matrix:

\[
\text{Distance (A,B)} = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2}
\]

x- and y- coordinates can be derived from a map. A stands from the terminal and B for the customer. Thus, the terminal has the coordinates X_A Y_A and the customer X_B Y_B.

3. Develop a savings matrix that represents the distance savings that occur instead of driving directly to single customers (see above Savings Method)

4. Assign and sequence customer and nodes to routes
The advantage of this method is the fact that it calculates the shortest transportation way and, thus, the way that causes the lowest amount of CO$_2$ emissions. However, the biggest drawback of heuristic methods is their complexity while the advantage is the possibility of fast re-scheduling and re-planning in different situations where the routes differ (Jonsson, 2008, 329). Another drawback with the methods presented is the fact that accurate and precise carbon footprints of road freight transport as required by customers are difficult since the products from the customer being delivered as the last will travel the entire route instead of being delivered directly. Thus, a fair allocation of CO$_2$ emissions to this respective product is not given. Therefore, logistics service providers are struggling to find an accurate method that allows both an efficient transportation planning and the precise allocation of CO$_2$ emissions to the respective products.

However, since these three transportation-planning methods (Sweep, Savings and Clark-Wright Method) are widely used and strongly connected to the problem discussed in this thesis, an illustration of the three methods was necessary in order to demonstrate the problematization of calculating CO$_2$ emissions in the road freight transportation. This appears to be a reasonable trade-off between giving the reader the required theoretical information that will be applied in the next chapter and the focus on calculating and allocating CO$_2$ emissions.

3.3 Methods for the Calculation of CO$_2$ Emissions in Road Transportation

According to the International Energy Agency (IEA) the transport sector is responsible for almost 60% of oil consumption in OECD countries and for approximately 23% of the global carbon dioxide emissions (IEA, 2011) and (Zadek and Schulz, 2010, 263). Thus, the relevance of the calculation of CO$_2$ emissions in the transportation sector is growing since an accurate calculation of carbon emissions allows the logistics service providers to allocate the CO$_2$ to products.

The Green House Gas Protocol (GHGP) is the most widely used accounting tool for government and businesses to quantify and understand greenhouse gas emissions (GHGPI, 2011). The GHGPI (2011) distinguishes between direct and indirect emissions. Direct emissions occur from
sources owned and controlled by the company (Zdek and Schulz, 2010, 264). Indirect emissions can occur from two other sources:

1. From the purchased electricity for own use

2. The production of purchased materials

Zadek and Schulz (2010, 264) state that the most important activities in the logistics sector cause indirect emissions which occur from the production of purchased materials. However, since the thesis focuses on the Swedish transportation company Alwex Transport AB that owns and controls the transportation trucks, mathematical methods and calculation tools will be presented focusing on the calculation of direct CO₂ emissions as illustrated in figure 3-2.

![Figure 3-4: Direct and indirect emission sources. Source: Own illustration based on (Zadek and Schulz, 2010, 264).](image)

Indirect emissions come from the purchased electricity for the own use and from the use of products. Direct emissions come from the production and from the direct transportation through trucks which are owned and controlled by the company.
There is a number of calculation frameworks, methods and software tools that help companies to measure their carbon emissions during the transportation (Zadek and Schulz, 2010, 268). However, Zadek and Schulz (2010, 268) conclude in their research that there are no elaborated and standardized tools which the companies can rely on. Therefore, the most accepted CO₂ calculation methods should be presented in this chapter in order to acquaint the reader with the subject and deepen the discussion in the empirical part.

3.3.1 Mathematical Methods for the Calculation of CO₂ emissions

The GHGP presents two different mathematical methods to calculate the CO₂, CH₄ and N₂O emissions (GHGPI, 2009):

1. The Fuel Based Method
2. Distance Based Method

The Fuel Based Method provides the company with the most accurate calculation of CO₂ emissions while the Distance Based Method is more accurate for the calculation of CH₄ and N₂O emissions. Both methods calculate the emissions from freight lorries, public transport by road, rail, air and water. Furthermore, emissions from mobile machinery such as agricultural and construction equipment can also be calculated by both methods (GHGPI, 2009). The GHGPI (2009) allows the inclusion of other variables such as vehicle distance or weight distance data for the calculation of CO₂ emissions for on-road freight transports. Thus, both methods are useful for the logistics sector, as Zadek and Schulz (2010, 264) state out.

Both methods base their calculations on emission factors (EFs) which are provided by different databases collected by different associations such as the Handbook Emission Factor for road transport (HBEFA) or the Global Emission Model for Integrated Systems (GEMIS) (Zadek and Schulz, 2010, 265-266). The emission factors express the calculated ratio between the GHG emissions and the activity data, i.e. the distance traveled or the fuel consumption (Zadek and Schulz, 2010, 264). Since the thesis is dedicated to find a useful framework for the allocation of CO₂ emissions on products for the logistics company Alwex Transport AB that holds only diesel
trucks in its fleet, emission factors and calculations will base on diesel engines classified by Euro classes from 0 to 5.

**The Fuel Based Method**

The Fuel Based Method can be used if the average fuel consumption (aFC) and the absolute fuel consumption (AFC) or distance traveled (d) is available (Ubeda et al., 2011, 45) and (Zadek and Schulz, 2010, 264). In formula (1), the calculation of the absolute fuel consumption of a company’s truck fleet is illustrated:

\[
(1) \\
\sum_{t=1}^{T} AFC_{t,n,m} = \frac{1}{T} \sum_{t=1}^{T} (dt_{t,n,m} \times aFC_{t,n,m})
\]

**Notation:**
- \( t \) Number of trucks with \((t = 1, \ldots, T)\)
- \( \sum_{t=1}^{T} AFC_{t,n,m} \) Absolute fuel consumption in \([l/100km]\) for the number of trucks \((t = 1, \ldots, T)\) and sort of truck \((n = \text{Scania, Volvo…})\) and Euro class \((m = 0, \ldots, 5)\)
- \( dt_{t,n,m} \) Distance traveled in kilometers for the number of trucks \((t = 1, \ldots, T)\) and sort of truck \((n = \text{Scania, Volvo…})\) and Euro class \((m = 0, \ldots, 5)\)
- \( aFC_{t,n,m} \) Average fuel consumption for the number of trucks \((t = 1, \ldots, T)\), the truck \((n = \text{Scania, Volvo…})\) and Euro class \((m = 0, \ldots, 5)\)

The \( CO_2 \) emissions in this method depend on the heating value of the specific fuel and the emission factors that can be expressed in \( CO_2 \) kilograms per Giga Joule (kg\( CO_2/GJ \)) or \( CO_2 \) kilograms per liter (kg\( CO_2/l \)) (Ubeda et al., 2011, 45) and (Zadek and Schulz, 2010, 264). Formula 2 illustrates the calculation for \( CO_2 \) emissions with the Fuel Based Method:

\[
(2) \sum_{s} CO_{2,\text{emission}} = \sum_{t=1}^{T} (AFC_{t,n,m} \times hv \times EF)
\]
Notation:

\[ AFC_{t,n,m} \] Absolute fuel consumption in [l/100km] for the number of trucks (t = 1,…,T) and sort of truck (n = Scania, Volvo…) and Euro classes (m = 0,…,5)

\[ hv \] Heating value of fuel expressed in [GJ/l]

\[ EF \] Emission factor expressed in [kgCO₂/GJ] or [kgCO₂/l]

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Heating Value [GJ/l]</th>
<th>Emission Factor [kgCO₂/GJ]</th>
<th>Emission Factor [kgCO₂/l]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline / Petrol</td>
<td>0.0344</td>
<td>69.25</td>
<td>2.3822</td>
</tr>
<tr>
<td>Diesel</td>
<td>0.0371</td>
<td>74.01</td>
<td>2.7458</td>
</tr>
<tr>
<td>Propane</td>
<td>0.0240</td>
<td>62.99</td>
<td>1.5116</td>
</tr>
</tbody>
</table>

Table 3-4: Examples of heating values and emission factors for different fuel types.
Source: (Zadek and Schulz, 2010, 265)
As it can be seen, Diesel has the highest heating value and produces the most CO₂ emissions per liter and Giga Joule.

The Distance Based Method

If the average fuel consumption (AFC) is missing but the distance traveled is available, the Distance Based Method for the calculation of CO₂ emissions can be applied (Ubeda et al., 2011, 45) and (Zadek and Schulz, 2010, 265). The company’s fleet records or the record of odometer logs give the necessary information for applying the Distance Based Method (GHGPI, 2009). In contrast to the used emission factors in the Fuel Based Method, the Distance Based Method requires emission factors that are expressed in ton kilometers (tkm), person kilometers (pkm) or vehicle kilometers (vkm) (Zadek and Schulz, 2010, 265). The GHGPI (2009) recommends using tkm for the calculation of CO₂ emissions for the transportation of freight, person kilometers for the public transportation and vehicle kilometers for private transportation or small business use. Thus, for the logistics sector ton kilometers will be used as variables for the calculation of CO₂ emissions. Based on the respective emission factors (see table below), the formula (3) expresses the calculation of CO₂ emissions with the Distance Based Method:
\[ (3) \sum CO_2 \text{emissions}_s = \sum_{t=1}^{T} (d_{t,n,m} \times EF) \]

Notation:

\( t \) Number of trucks with \((t = 1,\ldots,T)\)

\( d_{t,n,m} \) Distance traveled in kilometers for the number of trucks \((t = 1,\ldots,T)\), sort of truck \((n = \text{Scania, Volvo}...)\) and Euro class \((m = 0,\ldots,5)\)

\( EF \) Emission factor expressed in \([\text{kgCO}_2/\text{km}]\)

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Average Fuel Consumption ([\text{l}/100\text{km}])</th>
<th>Emission Factor ([\text{kgCO}_2/\text{km}])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel light truck</td>
<td>15,7</td>
<td>0,4311</td>
</tr>
<tr>
<td>Diesel heavy truck</td>
<td>33,6</td>
<td>0,9226</td>
</tr>
</tbody>
</table>

Table 3-5: Examples of emission factors for different diesel truck types in the Distance Based Method. Source: (Zadek and Schulz, 2010, 265)

**Activity Based Method**

Zadek and Schulz (2010, 265) suggest a third method, an alternative to the both methods presented above. The Activity Based Method uses cargo transport activity based Emission Factors and variables such as weight. Formula (4) illustrates the calculation with the Activity Based Method:

\[ (4) \sum CO_2 \text{emissions}_s = \sum_{t=1}^{T} (Q_{t,n,m} \times d_{t,n,m} \times EF) \]

Notation:

\( t \) Number of trucks with \((t = 1,\ldots,T)\)

\( Q_{t,n,m} \) Transported weight by the number of trucks \((t = 1,\ldots,T)\), sort of truck \((n = \text{Scania, Volvo}...)\) and Euro class \((m = 0,\ldots,5)\)
\( d_{t,n,m} \) Distance traveled in kilometers for the number of trucks \((t = 1, \ldots, T)\), sort of truck \((n = \text{Scania, Volvo,} \ldots)\) and Euro class \((m = 0, \ldots, 5)\)

\( EF \) Emission factor expressed in \([\text{g/tkm}]\)

As it can be seen, Zadek’s and Schulz’ formula bases its calculations on the Distance Based Method formula (3) and contains weight as an additional variable. Already the method’s name implies that this method is strongly related to the idea of the activity based costing method. The activity based costing “segregates the expenses of indirect and support resources by activities” (Cooper and Kaplan, 1991, 131) and, thus, allows an accurate allocation of expenses to the drivers of activities. The theoretical connection of this formula and the idea of the activity-based costing can be done by replacing the variable costing by the \(\text{CO}_2\) emissions which can also be regarded as costs.

Other authors use the activity-based costing approach and the Distance Based Method in order to develop new methods to create models for measuring and calculating \(\text{CO}_2\) emissions (Sunderkani et al., 2010, 45) and (Ubeda et al., 2011, 46). Both Sunderkani et al. (2010, 45) as well as Ubeda et al. (2011, 46) go even a step further and develop their models by using sophisticated algorithms based on the Eulerian and Lagrangian transport models.

The Activity Based Method and the sophisticated algorithms are useful for the calculation of \(\text{CO}_2\) emissions where the company’s logistics have the following characteristics: (1) the fleet size is known, (2) the fleet is homogenous (all trucks load the same weight and pallet sizes), (3) single terminal and depot, (4) deterministic demand, (5) oriented network and (6) the goal to minimize the distance (Ubeda et al., 2011, 47). Consequently, for medium-sized companies, such as the Swedish transportation company Alwex Transport AB, where the fleet is not homogenous (2), the demand of transported products is not deterministic (4) and the goal to minimize the distance is not given (6), this method would fail due to the company’s restrictions. Therefore, both methods, Fuel Based Method and Distance Based Method, still provide the companies with a suitable and useful method to calculate their carbon emissions. Both methods have their advantages and drawbacks, illustrated in the table below. However, in general it can be said, that the Fuel Based Method is more reliable but not easy to calculate, whereas the Distance Based
Method is the easier but also an uncertain alternative. In this case, managers have to decide and find a trade-off between their priorities in order to choose the right method.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Fuel Based Method</th>
<th>Distance Based Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>More reliable</td>
<td>Easy to obtain data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drawbacks</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not easy to calculate if only data on fuel consumption are available</td>
<td>High levels of uncertainty</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data by vehicle type</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Distance traveled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Fuel consumption factor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Heating values</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data collection resource</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Fuel receipts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Fuel expenditure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Direct measurement records, including official logs of vehicle fuel gauges or storage tanks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculation emissions</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Collect data on distance traveled by vehicle type and fuel type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Convert distance traveled data into fuel use values based on fuel economy factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Convert fuel estimate to CO₂ emissions by multiplying fuel use values by fuel-specific factors.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Collect data on distance traveled by vehicle type and fuel type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Convert distance estimate to CO₂ emissions by multiplying distance traveled by distance-based emission factor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3-6: Comparison of Fuel Based Method versus Distance Based Method.
Source: (Ubeda et al., 2011, 47)

Both methods require Emission Factors for the respective calculation of CO₂ emissions. These can be provided by different databases that will be presented in the following section.
3.4 Emission Factors, Databases and CO₂ Calculation Models

Databases provide the companies with Emission Factors that are needed for the calculation of CO₂ emissions and, thus, help the companies to install transparency in their daily business. In the following, two main databases will be introduced as an orientation of resource for the Emission Factors.

3.4.1 The Handbook Emission Factor for Road Transport - HBEFA

As mentioned above, the Handbook Emission Factor for Road Transport (HBEFA) is one main database of Emission Factors. The HBEFA was originally a cooperative project of Germany, Switzerland and Austria and was developed on the behalf of their Environmental and Protection Agencies (HBEFA, 2011). The HBEFA provides Emission Factors for heavy-duty vehicles (diesel) and light-duty vehicles (diesel and gas). Furthermore, data for several air pollutants such as CO₂, hydrocarbons (HC), nitrogen oxides (NOₓ) and particles based on gram per vehicle kilometer are provided by HBEFA. The results of calculations depend on the fuel type (gas or diesel) as well as the base year (from 1990 to 2020) can be calculated. Additionally, the HBEFA distinguishes between different traffic situations such as pitch attitudes and the driver’s driving style (HBEFA, 2011). It should be noticed, that HBEFA is a database for Emission Factors and, thus, do not calculate the CO₂ emissions.

<table>
<thead>
<tr>
<th>Year</th>
<th>Vehicle category</th>
<th>Pollutant</th>
<th>Fuel</th>
<th>Emission factor</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Heavy-duty vehicle</td>
<td>CO₂</td>
<td>Diesel</td>
<td>685.63</td>
<td>[g/vkm]</td>
</tr>
<tr>
<td>2005</td>
<td>Light-duty vehicle</td>
<td>CO₂</td>
<td>Diesel</td>
<td>245.997</td>
<td>[g/vkm]</td>
</tr>
<tr>
<td>2005</td>
<td>Light-duty vehicle</td>
<td>CO₂</td>
<td>Gas</td>
<td>250,959</td>
<td>[g/vkm]</td>
</tr>
</tbody>
</table>

Table 3-7: Sample Emission Factors from HBEFA based on year 2005. Source: (Zadek and Schulz, 2010, 266)

3.4.2 Global Emission Model for Integrated Systems – GEMIS

GEMIS is a database for energy, material and transport system and is freely available (GEMIS, 2011). The database and life cycle analysis program helps companies to assess emissions and resource consumption over the life cycle of processes and products (GEMIS, 2011). Thus, all important processes for the transportation are included in the calculation, i.e. from the raw
material sourcing to the waste treatment (GEMIS, 2011) and (Zadek and Schulz, 2011, 266). The database considers efficiency, power, capacity factors, lifetime, direct air pollutants (SO₂, NOₓ, CO), GHG emissions (CO₂, CH₄, N₂O, etc.), solid wastes, liquid pollutants as well as the use of land (GEMIS, 2011). GEMIS allows the companies also to calculate and analyze costs since respective data fuels and energy systems are available on the homepage (GEMIS, 2011).

The databases introduced above allow companies to develop sophisticated models that, in turn, allow more accurate and precise calculations of CO₂ emissions as the mathematical methods presented above. Thus, the two most used Model tools should be shortly presented in order to give the reader a brief overview.

### 3.4.3 Transport Emission Model – TREMOD

The Transport Emission Model, TREMOD, was developed in 1993 by the Institute For Energy and Environmental Research in Germany (IFEU, 2011). The model takes into account all traffic performances on road, water, rail and air (IFEU, 2011). Companies are able to build scenarios from 1960 to 2030 and, thus, get a clear picture about the future CO₂ emissions. The model distinguishes between direct and indirect emission. Indirect emissions occur upstream in the supply chain, while direct emissions are coming from the vehicles’ operations (IFEU, 2011). TREMOD uses the database from HBEFA for calculating CO₂ emissions. Furthermore, primary energy consumption in Mega Joule and the end energy consumption in t or kWh can be calculated (IFEU, 2011).

### 3.4.4 The Ecological Transport Information Tool – EcoTransIT

Analogically to TREMOD, the Ecological Transport Information Tool (EcoTransIT) is available on the Internet and is free of charge (EcoTransIT, 2011). EcoTransIT was developed in 2000 with the help of IFEU, the Rail Management Consultants GmbH and by several European rail companies (Zadek and Schulz, 2010, 267). The tool calculates environmental impacts such as energy consumption, CO₂ and exhaust emissions caused by rail, road, water or air transportation.
The tool enables companies to calculate precisely the ecological impacts of their transportation within Europe (EcoTransIT, 2011). Variables such as the flow direction of rivers, the energy mix in the respective country, the topography, infrastructure and the transportation distance are included in the calculation of CO2 (EcoTransIT, Guided Tour, 2011).

Both models can be regarded as sophisticated tools since accurate and precise CO2 emission calculations are possible. Companies that cannot provide the required data due to their business nature, size or budget can choose the mathematical methods presented above as alternatives to these tools. It should be noticed that both tools are not designed for allocating CO2 emissions on products, customers or locations. Since this thesis is dedicated to find a suitable solution to the allocation of CO2 emissions for the medium-sized transportation company Alwex AB, it will be focused on the mathematical methods in the next chapter. Therefore, sophisticated CO2 calculation models such as TREMOD and EcoTransIT were presented briefly and will not be discussed in detail. For further information, the author suggests read the literature and visit the homepages used as references.

Since this thesis is dedicated to find a solution for a medium-sized company with the Swedish legal form of Aktie Bolag, the terms medium-sized enterprises and Swedish legal forms should be explained in the following section before turning to the Analysis.

### 3.5 Medium-Sized Enterprises in Sweden within the Transportation Sector

Medium-Sized Enterprises are seen as the economical motor of the Europe Union’s economy. Thus, they play a predominant role in the Swedish economy and contribute actively to the country’s CO2 emissions. This section is dedicated to explain the term medium-sized enterprises, to illustrate the different legal forms of medium-sized enterprises in Sweden and the constraints and problems that medium-sized companies have to face due to their nature. The chapter will also give a short statistical outlook of medium-sized transportation companies in Sweden and their role as active CO2 contributors.
Medium-Sized Enterprises

The international term Small and Medium-Sized Enterprises (SME) or Small and Medium-Sized Businesses (SMB) is an umbrella term for companies that do not exceed the quantitative levels of headcount, turnover or the balance sheet total given by the European Commission (EU Commission, 2003). Companies that exceed these borders are so called big enterprises. The classification is carried out independently of the company’s legal form.

The European Commission has the following recommendation to classify a company:

<table>
<thead>
<tr>
<th>Enterprise category</th>
<th>Headcount</th>
<th>Turnover</th>
<th>Or</th>
<th>Balance sheet total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-sized</td>
<td>&lt; 250</td>
<td>≤ € 50 million</td>
<td>Or</td>
<td>≤ € 43 million</td>
</tr>
<tr>
<td>Small</td>
<td>&lt; 50</td>
<td>≤ € 10 million</td>
<td>Or</td>
<td>≤ € 10 million</td>
</tr>
<tr>
<td>Micro</td>
<td>&lt; 10</td>
<td>≤ € 2 million</td>
<td>Or</td>
<td>≤ € 2 million</td>
</tr>
</tbody>
</table>

Table 3-8: Recommendation 2003/361/EC regarding the SME definition. Source: EU Commission, 2003)

Furthermore, the enterprises are not allowed to be owned over more than 25 % by any other business unit, which is not classified by the table above (EU Commission, 2005, 11).

In the European Union, micro, small and medium-sized businesses provide 75 million jobs and represent almost 99 % of all business (EU Commission, 2005, 5). The European Union counts more than 23 million SMEs in its 25 member countries. Thus, SMEs play a fundamental role in the European Union’s economy and, thus, are a major source of innovation and employment (EU Commission, 2005, 5).

Sweden reflects these trends. The Nordic country’s micro, small, and medium-sized enterprises represent 99,9 % of all businesses (SCB, 2011a, 21). Furthermore, 99,4 % of the Swedish economy is driven by companies which count less than 50 workers (SCB, 2011a, 21). The recommended table above by the European Commission can be extended by one more company type that is widely common in Sweden and where the owner is also the employee: enmansföretag, i.e. the sole proprietorship. The Swedish form of sole proprietorship is the homologue of the German Ich-AG and represents 74 % of all business companies in Sweden (Ekonomifakta, 2011).
As mentioned before, the company’s size is independent from its ownership and its legal form. Thus, it is to be mentioned that the Swedish *enmansföretag* is not a legal form as the English translation to sole proprietorship could implicate but has to be considered as a company’s size type. Since the thesis is dedicated to resolve a problem of a medium-sized company with the Swedish legal form of *Aktiebolag*, the most common legal forms in Sweden should be introduced briefly.

**Legal Forms of companies in Sweden**

Sweden distinguishes between four widely used legal forms: Aktiebolag, Enskild näringsidkare, Handelsbolag and Kommanditbolag (Bolagsverket, 2011).

**Aktiebolag**

The Swedish Aktiebolag is a legal entity and can be divided into two categories: the private and the public Aktiebolag. As a private company it can be built by one or more persons with the initial capital investment of 50 000 Swedish Kronor. For the public Aktiebolag the share capital has to be 500.000 SEK (Bolgsverket, 2011). Only public Aktiebolag can offer their shares on the stock market. The company’s owners are shareholders and, thus, commonly accountable for the company’s debts by their initial investment, i.e. there are not liable for the company’s debts personally (Bolagsverket, 2011). Thus, this legal form offers the highest economical protection for private persons as owners. However, owners act in this companies as shareholders and influence the company’s decision-makings through their voting at the annual general meeting. Thus, the Swedish legal form of Aktiebolag can be compared to the American private limited company or the German Aktiengesellschaft or GmbH. As such a legal form, an Aktiebolag has to be registered and quoted on a Stock Exchange Market. However, compared to its international homologues, the Swedish Aktiebolag has to nominate an independent auditor who audits also the board of directors and is only liable to the shareholders at the Annual General Meeting (Bolagsverket, 2011).
Enskild näringsidkare

This legal form is the homologue to the Anglo-Saxon version of Sole Trader and the German form of Einzelkaufmann where the owner and employee are incorporated in the company. Thus, the owner is personally accountable for the company’s debts, i.e. for his own debts, and cannot be seen as a legal entity (Bolagsverket, 2011).

Handelsbolag

Handelsbolag can be translated as a partnership (in German Offene Handelsgesellschaft) which is driven by one or more partners (Bolagsverket, 2011). In this legal form both partners are personally accountable for the company’s entire debts. As the legal form of Aktiebolag this type of companies has to reflect all their assets and liabilities according to their balance sheet. This legal form has its advantages in the low initial investment and the simple ownership structure compared to the Aktiebolag.

Kommanditbolag

This legal form can be regarded as the homologue to the German Kommanditgesellschaft or the English Limited Partnership where at least one partner (general partner, in German Komplementär) is unlimited liable for the company’s debts, i.e. the general partner is accountable with its personal capital (Bolagsverket, 2011). The limited partners, i.e. kommanditdelägare (in German Kommanditist) are limited liable for the company’s debts, i.e. accountable with their initial investment.

Constraints and problems of SMEs

According to Sousa and Aspinwall (2010, 477), SMEs offer in four major aspects diverse advantages: Structurally, SMEs are considered to offer a better communication flow since short term decision processes allow to install faster information flow. The fact that SMEs are often owned by a small group of shareholders allows that new changes and innovations in processes can be implemented faster than in big companies. This has also a direct impact on the cultural aspect of SMEs, i.e. a better communication and the involvement of few owners in the daily business allow to reduce bureaucracy, which in turn helps the company to manage efficiently
their processes. Furthermore, SMEs are characterized by the employee’s general skills, i.e. narrow specialist views which can harm the company’s problem solutions can be avoided (Sousa and Aspinwall, 2010, 477).

Nevertheless, SMEs are also characterized by limited resources in time, money and limited manpower (Sousa and Aspinwall, 2010, 478). By limited manpower Sousa and Aspinwall implicitly mean that several employees are often involved in a greater number of jobs and take more responsibilities than specialists in big companies (Hudson et al., 2001, 1105). This illustrates the fact that SMEs often face to a lack of human resources. This, in turn, does not permit the staff to have any extra time for additional activities such as supplement data gathering or analyzing processes (Garengo et al., 2005, 29). This also affects the company negatively when it comes to implement sophisticated processes or tools. Thus, employees in SMEs often prefer to use tables rather than graphs and estimations rather than exact calculations which help them to interpret their outcomes more easily (Garengo et al., 2005, 29). Due to the tacit knowledge, less attention is given to software tools or the formalization of processes than to estimations. This, in turn, implies the fact that SMEs have a poor strategic planning (Garengo et al., 2005, 30).

Another big constrain of SMEs is their financial situation, often characterized by the lack of monetary safety (Hudson et al., 2001, 1105). Since SMEs are raised by few owner high investments in sophisticated tools or operational models are not possible (Garengo et al., 2005, 27, 28) and (Sousa and Aspinwall, 2010, 477).

**Statistical Data of Medium-Sized Transportation Aktiebolag in Sweden**

The Swedish Institution for Statistics, reports that the registration of Aktiebolag between 2000 and 2009 is increasing continuously (SCB, 2011b, 162). The number of transportation companies in Sweden accounts totally 28.552 business units in 2007 while almost the half of them, 13.879 is Aktiebolag (SCB, 2011b, 169). Compared to the total number of Aktiebolag in Sweden 289.385, the transportation sector holds almost 5 % of all Swedish Aktiebolag. These 13.879 Aktiebolag in the transportation sector account 188.729 employees, i.e. over 7,5 % of all employees are employed at a Swedish Aktiebolag in the transportation sector (SCB, 2011b, 170).
Even though these numbers and percentage seem to be low, the impact on CO₂ emissions from the transportation sector should not be underestimated. According to SIKA, 8 million transports and 73 million ton of goods were transported in Sweden in the third quartile of 2009 (SIKA, 2010, 4). And from the global perspective of view, the transportation sector is the field where the energy is used mostly. The International Energy Agency (IEA, 2009, 43) forecasts a double of CO₂ emissions in this sector from 2006 till 2050. Back to Sweden, the statistical information of SIKA and the International Energy Agency show evidence that Swedish Aktiebolag in the transportation sector have a deep impact on the CO₂ emissions in Sweden and, thus, are interesting for further research on CO₂ calculation methods.

In the next chapter an analysis of CO₂ emissions of the Swedish transportation company Alwex Transport Aktiebolag will be presented and thus serve as an example to calculate CO₂ emissions and to improve the method for a more precise and simple method of calculation.
4 The company Alwex Transport AB

This chapter is dedicated to introduce the Swedish transportation company Alwex Transport AB as well its core business, activities and aims. Based on that, the company’s problem of calculating CO₂ emissions and allocating them on products and/or locations will be illustrated. Thus, the company’s own calculation system will be outlined and explained.

4.1 Organization and business of Alwex Transport AB

Alwex Transport AB is a private limited company that was founded in the year 2000 as a Joint-Venture by 89 other companies which are the company’s clients, suppliers and service providers (Alwex Hållbarhetsredovisning, 2010, 4). The company employs 70 salaries and, thus, has to be seen as a medium-sized company. The company is mainly operating in the Swedish county Kronobergs Län where its headquarters and main terminal is situated in Växjö and other operating offices in Alvesta, Kalmar, Uddevalla and Älmhult. Alwex Transport AB is a group and owns three subsidiary enterprises: Alvesta Intermodal AB, Elitfrakt i Älmhult AB and Alwex Fastighets AB with its subsidiary Växjö ÅC AB. Alvesta Intermodal AB’s core business is the transshipment of containers, Elitfrakt i Älmhult AB is handling the transportation in the recycling sector and Alwex Fastighets AB operates in the building sector (Alwex Hållbarhetsredovisning, 2010, 4).

Alwex Transport AB has in its core business three main activities which are named as: Thermo, Fjärr och Parti and Bygg och Anläggning. Thermo activities concern the transportation of dangerous cargo such as gas. Fjärr och Parti activities are about the service to resolve wholesalers’ problems in transportation of their goods, i.e. Alwex Transport AB transports their goods from Växjö to the desired terminal. Bygg och Anläggning activities concern the leasing and renting of tower cranes, trucks for the construction industry or trucks for transporting containers or the waste transport (Alwex Hållbarhetsredovisning, 2010, 7).

The company operates in the southeastern part of Sweden and has a fleet of 300 trucks that it leases from its shareholders and that it leases to their customers (Hildingsson, 11.03.2011). The activities and services for wholesalers are offered mostly in the county Kronobergs Län. The transportation for wholesalers is delivered mostly by heavy trucks of 3, 5 tons, i.e. one short
module vehicles (see pages 27-28). The entire fleet of Alwex Transport AB consists of all Euro-
class motor vehicles, i.e. from Euro-class number 0 to Euro-class number 5. The company
perceives environment as very important and incorporated environmental issues in its
organization. Thus, the calculation of CO₂ emissions is one of the most important activities for
the company (Alwex Hållbarhetsredovisning, 2010, 23). In the year 2010, the company’s
business consumed about 25,909 liter of fuel which caused circa 64 tons of CO₂ emissions.
Although the company could decrease their fuel consumption compared to the year before, it is
aware that it still has to work on the reduction of CO₂ emissions (Alwex Hållbarhetsredovisning,
2010, 23). In the year of 2010, the company started investigative interviews with clients.
Environmental issues belonged to the top issues the clients asked for (Alwex
Hållbarhetsredovisning, 2010, 18). Even though the company is already certified by ISO
14001:2004 that stands for environmental friendly business activities, the managers of Alwex
Transport AB seek to improve environmental friendly processes within the company’s business
(Alwex Hållbarhetsredovisning, 2010, 21). Alwex Transport AB recognized the global trends of
the need of environmental friendly transportation and uses therefore the sustainability-reporting
framework of GRI – The Global Reporting Initiative. The GRI framework is used to demonstrate
a company’s sustainable development and its performance with respect to the environment, laws,
norms, standards and voluntary initiatives (GRI, 2008, 5). Using the GRI framework, Alwex
Transport AB commits itself for installing environmental friendly process in the transportation
system. Thus, environmental accounting such as the precise and fair allocation of emissions to
the right product transported belongs to the company’s responsibilities (Hildingsson,
11.03.2011). Hereby the company tries to improve on both regards: getting a better reputation
and reducing costs at ones. Certifications that classify the company as an environmental friendly
enterprise help to allure new clients. Thus, new systems and methods that allow reducing CO₂
emissions will help growing the company, on one hand. On other hand, so Peter Hildingsson,
this will help the company also to reduce its costs, since CO₂ emissions are directly related to
fuel consumption (Hildingsson, 11.03.2011). However, even though the company regards
environmental issues as very important, due to its nature of a medium-sized company and its
little budget of investment, the manager Peter Hildingsson is the only responsible for
environmental issues in the company. Furthermore, he is also responsible for the company’s
information systems and the products’ quality. This fact emphasizes that especially a simple method that allows calculating fast and precise CO₂ emissions is necessary for the company in order to achieve its own aims. The following section will illustrate the calculation method of CO₂ emissions that is used at Alwex Transport AB. The illustration of the company’s applied calculation method of CO₂ emissions needs a recall of the company’s transportation procedure. Therefore, a brief and a deeper illustration than in the problematisation part about the company’s given problem will follow.

4.2 Alwex Transport AB’s distribution system

As mentioned above on page 7, the company operates in all regions of Sweden but its main business is concentrated on the Swedish county Kronobergs Län. Especially the transportation of goods to wholesalers is carried out in Kronobergs Län from the main terminal in Växjö. The company divides the county in 6 tariff zones. Depending on the freight’s weight and the distance from the terminal to the client’s desired destination point, the transportation is classified in the specific tariff zone and price, as it can be seen in the tables and the figure below.

<table>
<thead>
<tr>
<th>Weight in kg</th>
<th>Tariff 1</th>
<th>Tariff 2</th>
<th>Tariff 3</th>
<th>Tariff 4</th>
<th>Tariff 5</th>
<th>Tariff 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-50</td>
<td>132</td>
<td>181</td>
<td>225</td>
<td>249</td>
<td>298</td>
<td>350</td>
</tr>
<tr>
<td>51-150</td>
<td>181</td>
<td>242</td>
<td>290</td>
<td>338</td>
<td>400</td>
<td>458</td>
</tr>
<tr>
<td>151-250</td>
<td>225</td>
<td>273</td>
<td>324</td>
<td>377</td>
<td>434</td>
<td>499</td>
</tr>
<tr>
<td>251-500</td>
<td>291</td>
<td>304</td>
<td>355</td>
<td>408</td>
<td>482</td>
<td>552</td>
</tr>
<tr>
<td>501-750</td>
<td>380</td>
<td>402</td>
<td>427</td>
<td>519</td>
<td>634</td>
<td>728</td>
</tr>
<tr>
<td>751-1000</td>
<td>438</td>
<td>465</td>
<td>490</td>
<td>625</td>
<td>763</td>
<td>862</td>
</tr>
<tr>
<td>1001-1500</td>
<td>595</td>
<td>627</td>
<td>661</td>
<td>788</td>
<td>961</td>
<td>1068</td>
</tr>
<tr>
<td>1501-2000</td>
<td>714</td>
<td>739</td>
<td>762</td>
<td>898</td>
<td>1095</td>
<td>1206</td>
</tr>
</tbody>
</table>

Table 4-1: Distribution Pricelist of Alwex Transport AB.  
Source: (Alwex AB pricelist, 2011, p. 1)

The tariffs zones are built up as follow:

<table>
<thead>
<tr>
<th>Tariff</th>
<th>Distance from the Terminal in Växjö</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tariff 1</td>
<td>0-24 kilometers</td>
</tr>
<tr>
<td>Tariff 2</td>
<td>25-50 kilometers</td>
</tr>
<tr>
<td>Tariff 3</td>
<td>51-75 kilometers</td>
</tr>
<tr>
<td>Tariff 4</td>
<td>76-100 kilometers</td>
</tr>
<tr>
<td>Tariff 5</td>
<td>101-140 kilometers</td>
</tr>
<tr>
<td>Tariff 6</td>
<td>141-170 kilometers</td>
</tr>
</tbody>
</table>

Table 4-2: Tariff zones of Alwex Transport AB.  
Source: (Alwex AB pricelist, 2011, p.1)
Alwex Transport AB charges its clients for the transportation of goods. The costs for the transportation depend on the distance from the main terminal in Växjö to the desired destination points in Kronobergs Län. In order to install a simple costing scheme, Alwex Transport AB divided the county into 6 different tariff zones. The further the tariff zone and the heavier the freight, the more costs occur and, thus, CO₂ emissions. In this example, tariff zone 3 is the furthest zone from Växjö.

Within these tariff zones, the company adopted the sweep method for its route planning (Hildingsson, 11.03.2011). The routes vary every day. Thus, a standardization of route planning is almost impossible (Hildingsson, 11.03.2011). Applying the sweep method means that the truck leaves the terminal with the largest amount of goods as possible and delivers them in sequence (see also chapter 3.2 Transport Planning). The truck can contain goods of several clients who are situated in the same tariff zone or different tariff zones, i.e. in the same or different towns/villages. Since Alwex Transport AB applies the sweep method, the goods that are delivered at the end, will also record the longest transportation way. Thus, the good that has to be delivered at least will record the highest CO₂ emission burden. Alwex Transport AB applies the division of its clients in distribution zones and the sweep method for reasons of simplicity and the cost structure. The division in tariff zones and the sweep method allows the company to allocate easily their costs to the respective products. However, simplicity has also disadvantages: A fair and precise allocation of CO₂ emissions on products is not possible. Products that are delivered at the last sequence have the longest transportation way but are not supposed to bear all the CO₂ emission caused by the entire transportation. Contrarily, the respective product is supposed to bear the carbon emissions that its transportation causes effectively, i.e. the CO₂ emissions which would have been occurred during a direct transportation to the respective client.
Figure 4-2 illustrates briefly Alwex Transport AB’s problem of an effective allocation of carbon emissions by using the sweep method for its daily route planning.

The respective truck leaves the terminal Växjö full charged with goods. The destination points can be different clients or even the same client with different locations. For the distribution system and the calculation of CO₂ emissions, this fact has no importance. The distribution system is based on the sweep method. Here, the blue arrows illustrate the sweep method, i.e. the first products are delivered at Uppvidinge and the last products in Gemla. The distances between the respective destination points are as followed: Växjö-Uppvidinge = 49,4 km, Uppvidinge-Lessebo = 63,6 km, Lessebo-Tingsryd = 35 km, Tingsryd-Älmhult = 59,6 km, Älmhult-Markaryd = 46,3 km, Markaryd-Diö = 58, 6 km, Diö-Gamla = 45, 4 km, Gemla-Växjö = 14, 4 km. The route is in total about 372,3 km. According to figure 4-2 above, the first products are delivered after 49, 4 km. This means, that the products that are delivered in Uppvidinge caused
effectively CO₂ emissions for 49.4 km. The problem of precise CO₂ emission allocation starts already with the delivery of the products at Lessebo. This products were transported effectively from Växjö to Uppvidinge and then to Lessebo and, thus, were transported 49.4 km + 63.6 km = 113 km. While the effective distance, i.e. the direct route from the terminal Växjö to Lessebo is 35.5 km (illustrated in the figure 4-2 with a red arrow). This means, products that are supposed to be delivered in Lessebo should be accountable for CO₂ emissions for a transportation of 35.5 km instead of 113 km. The problematisation and the evidence of the necessity to find an appropriate and simple method to calculate precisely the CO₂ emissions occur when the transportation way of products is calculated for the client situated in Gemla. According to the sweep method, products that are delivered in Gemla are transported in total 357.9 km (49.4 km + 63.6 km + 35 km + 59.6 km + 46, 3 km + 58, 6 km + 45, 4 km = 357.9 km) while the direct distance from the terminal Växjö to Gemla is only about 14.4 km. This example illustrates evidently that the sweep method is a useful method for cost and fuel saving transportation of goods, but does not provide the company with an appropriate calculation and allocation of CO₂ emissions. Thus, an alternative has to be found which allows a more precise and fair allocation of CO₂ emissions on products.

However, due to the structure and budget of medium-sized companies it can be stated that sophisticated methods for CO₂ emission calculations such as TREMOD and EcoTransIT, which would require the company high investments in budget, time and education, cannot be put into consideration. Furthermore, both tools do not allow the allocation of CO₂ emissions during the transportation of products. Alwex Transport AB’s restrictions such as the sweep method, costing system, plants and budget ask for a more practical, i.e. useful and simple, solution. The following section will illustrate precisely the CO₂ emissions calculation method of Alwex Transport AB.

4.3 Alwex Transport AB’s calculation method of CO₂ emissions

According to Peter Hildingsson, manager for quality, information systems and environmental issues, the most transportation of goods for wholesalers is carried out by trucks with the Euro-class number 3 (Hildingsson, 11.03.2011). In order to calculate its CO₂ emissions, the company
relies mostly on statistical data provided by the shareholders who are the owners of the trucks and run itself their business of transportation already longer than Alwex Transport AB (Alwex Hållbarhetsredovisning, 2010, 9). Thus, the illustration of Alwex Transport AB’s CO₂ emission calculation method will base on secondary and primary empirical data which the company collected itself and got from its shareholders. Since the transportation routes vary daily. The selection of the route and the client who will serve as a representative example for the calculation of CO₂ emissions will base on one unique client and on one specific day.

For the calculation of toxic emissions per truck class, the company uses means which it gets from its owners (Hildingsson, 11.03.2011). The table 4-3 shows the mean values of toxic emissions for each truck class (see also table 3-3).

<table>
<thead>
<tr>
<th>Engine category per euro class</th>
<th>CO₂ (g/l)</th>
<th>NOx (g/l)</th>
<th>HC (g/l)</th>
<th>CO (g/l)</th>
<th>PM (g/l)</th>
<th>SOx (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 0</td>
<td>2410</td>
<td>40,85</td>
<td>1,58</td>
<td>4,21</td>
<td>3,43</td>
<td>0,0260</td>
</tr>
<tr>
<td>Euro 1</td>
<td>2410</td>
<td>26,69</td>
<td>1,68</td>
<td>3,25</td>
<td>0,53</td>
<td>0,0163</td>
</tr>
<tr>
<td>Euro 2</td>
<td>2410</td>
<td>23,25</td>
<td>1,07</td>
<td>1,97</td>
<td>0,49</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 3</td>
<td>2410</td>
<td>19,08</td>
<td>0,75</td>
<td>2,55</td>
<td>0,31</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 4</td>
<td>2410</td>
<td>10,57</td>
<td>0,45</td>
<td>1,75</td>
<td>0,07</td>
<td>0,0065</td>
</tr>
<tr>
<td>Euro 5</td>
<td>2410</td>
<td>6,50</td>
<td>0,05</td>
<td>1,58</td>
<td>0,07</td>
<td>0,0065</td>
</tr>
</tbody>
</table>

Table 4-3: Allocation of toxic emissions per liter and Euro class of trucks.
Source: (Hildingsson, 11.03.2010).
As it can be seen, the engine category of trucks has no impact on CO₂ emissions, but on the other toxic emissions such as carbon monoxide (CO). The lower the engine is classified the more toxic emissions it exhausts.

The company counts its CO₂ emissions by using both mathematical methods: the Fuel Based Method and the Distance Based Method. According to these methods, the CO₂ emissions are calculated by using emissions factors (see 3.3.1 Mathematical Methods for the Calculation of CO₂ emission on pages 37 and 39). The emission factor is calculated in CO₂ grams per kilometer. Thus, Alwex Transport AB calculates the CO₂ emissions in two steps:

1. CO₂ Emission Factor in grams per kilometer:

   \[
   \text{CO₂ grams per liter} \times \text{average fuel consumption per km} = \text{CO₂ grams per km}
   \]

   \[
   \text{CO₂ g/l} \times \text{l/km} = \text{CO₂ g/km}
   \]
2. CO₂ in grams:

\[
\text{CO}_2 \text{ grams per km } \times \text{ the distance traveled in km} = \text{CO}_2 \text{ grams}
\]

\[
\text{CO}_2 \text{ g/km } \times \text{ km} = \text{CO}_2 \text{ g}
\]

The data for the average fuel consumption of vehicles are gathered by Alwex Transport AB. During the last years, the company was able to establish its own statistical tables where it reports for each specific vehicle the average fuel consumption. In order to simplify the calculation of CO₂ emissions or the fuel consumption, the company relies on average values from historical data recorded monthly in the past few years (Hildingsson, 11.03.2011). Other data such as the emission factor CO₂ g/l are gathered from the company’s shareholders who in turn base their statistical data on their own measurements (Hildingsson, 11.03.2011). Thus, it is not surprisingly that the company uses the same emission factor of CO₂ g/l for all truck classes, illustrated in table 4-3. This means, that the CO₂ calculations are counted for all trucks at Alwex Transport AB with the CO₂ emission factor of 2410 g/l. In the following, the truck type Scania P 114 from the year 2000 and EUR class number 3 will serve as an example in order to calculate the CO₂ emissions for the client AB for the year 2010. It should be noticed that Alwex Transport AB asked to preserve their client’s name anonymous. This will be respected in this thesis.

The table below illustrates the client’s locations that Alwex Transport AB delivers by goods. The last column indicates in which tariff zone the respective location is situated. The locations were driven up by the sweep method from the order given, i.e. from the top to the bottom (see also the illustration of the sweep method in 3.2 Transportation planning). The distribution began at the terminal in Växjö and ended there (see columns Starting Point (From) and Destination (To). Thus, the vehicle started from Växjö to Gemla and ended its route coming back to Växjö from Kristianstad. For reasons of simplicity the respective destination points were named in letters (see the 4th column). This, points can be seen in the figure 4-3. The route was driven within one day in a row without departure to other locations not listed in the table and the figure 4-3. In
order to avoid confusions it should be noticed that the table contains also two towns that are not located in Kronobergs Län but in the south-eastern part of Sweden, in Skåne.

<table>
<thead>
<tr>
<th>Vehicle Type and Motor Type</th>
<th>Starting Point (From)</th>
<th>Destination (To)</th>
<th>Points on the map</th>
<th>Tariff Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>GEMLA, Gransholms Gård</td>
<td>A-B</td>
<td>T1</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>GEMLA, Gransholms Gård</td>
<td>VEDERSlöV, Kinnevaldsvägen 12</td>
<td>B-C</td>
<td>T1</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VEDERSlöV, Kinnevaldsvägen 12</td>
<td>VISLANDA, Olvågen 11</td>
<td>C-D</td>
<td>T2</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VISLANDA, Olvågen 11</td>
<td>DIÖ, Växjövägen 303</td>
<td>D-E</td>
<td>T2</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>DIÖ, Växjövägen 303</td>
<td>MOCKELSNAS, DIÖ</td>
<td>E-F</td>
<td>T3</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MOCKELSNAS, DIÖ</td>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>F-G</td>
<td>T3</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>ALMHULT, Ikeagatan 1</td>
<td>G-H</td>
<td>T3</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>ALMHULT, Ikeagatan 1</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>H-I</td>
<td>T5</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>I-J</td>
<td>T5</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>HÄSSLEHOLM, Södra Kringelvägen 1</td>
<td>J-K</td>
<td>T5</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>HÄSSLEHOLM, Södra Kringelvägen 1</td>
<td>HÄSSLEHOLM, Järnvägsgatan 21</td>
<td>K-L</td>
<td>T5</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>HÄSSLEHOLM, Järnvägsgatan 21</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>L-M</td>
<td>T5</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>M-N</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-4: Transportation route of goods to different locations for client AB. Source: (Hildingsson, 11.03.2011)

As it can be seen, the transportation route is driven by the order of tariff zones. This means that locations which are situated nearest to the terminal in Växjö are served first. The furthest location, here situated in Kristianstad (M), in the street Mäster Bonggatan 4, is served as the last location. From that destination, the truck drives empty back to the terminal in Växjö, in Stora Räppevägen 62 (A=N).

The route driven is illustrated in blue on the map in Figure 4-3. The starting point (the terminal in Växjö) and the destinations are illustrated in green letters that can also be red of the table above (table 4-4). It is to be noticed that the starting point A and the destination point N are the same locations. Due to the software applied for depicting the route below, these points had to be
chosen differently. The illustration in Figure 4-3 shows that the chosen transport planning for this route is based on the sweep method.
Figure 4-3: Alwex Transport AB’s driven route for the client AB.
Source: (Google Maps, 2011)
As mentioned earlier, the company Alwex Transport AB prefers to work with average values in order to calculate simply their routes and, thus, the CO₂ emissions. Therefore, it uses tariff zones. This means that the distances between the destination points and the terminal in Växjö are not measured and calculated precisely, but further by tariff zones. Thus, Alwex Transport AB estimates the kilometers driven from the terminal in Växjö to the respective destination points and does not consider the effective traveled distance between the locations themselves. The table below summarizes how Alwex Transport AB calculates the total kilometers driven for a route.

<table>
<thead>
<tr>
<th>Tariff Zones</th>
<th>Number of deliveries</th>
<th>Average of km driven</th>
<th>Total driven km in the tariff zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>2</td>
<td>12 km</td>
<td>2 × 12 km = 24 km</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>40 km</td>
<td>2 × 40 km = 80 km</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>63 km</td>
<td>3 × 63 km = 189 km</td>
</tr>
<tr>
<td>T4</td>
<td>0</td>
<td>88 km</td>
<td>0 km</td>
</tr>
<tr>
<td>T5</td>
<td>5</td>
<td>120 km</td>
<td>5 × 120 km = 600 km</td>
</tr>
<tr>
<td>T6</td>
<td>0</td>
<td>0 km</td>
<td>0 km</td>
</tr>
</tbody>
</table>

**Table 4-5: Total kilometers driven for the client AB.**

Source: (Hildingsson, 11.03.2011).

As it can be seen, five destination points on the map in figure 4-3 are situated in the tariff zone T5. Alwex Transport AB does not measure the exact distance to these points. The company uses estimations such as the average driven kilometers to this points. The sum of all deliveries and the estimated kilometers driven add up to the total distance traveled by the truck used for the route. In this case, Alwex Transport AB counted 893 km for the route driven illustrated on the map in figure 4-3.

As illustrated in table 4-5 the total amount of deliveries completed are 12. The table shows that the most deliveries were done in the tariff zone T5. According to table 4-2 on page 52, destination points situated in tariff zone T5 are situated from 101-140 km from the terminal in Växjö. As it can be seen in table 4-5, Alwex Transport AB uses the average kilometers driven in order to count the route simply. Since transport routes change daily and the company’s budget does not allow high tech measure instruments, this method seemed to be useful for the company.

In this case, the company accounts for 120 km in average for transportation in the tariff zones T5. Respectively, for deliveries in the tariff zone T3 (situated from Växjö 51-75 km) it counts in
average 63 km for a delivery. With the help of estimations and averages, the company accounts consequently for the route presented above 893 km in total.

Taken this information and the emission factor of CO₂ presented above, the company calculates the CO₂ emissions with the help of the Fuel and Distanced Based Methods. For reasons of clarity all information needed for the calculation is listed briefly:

Vehicle used: Scania P 114, Motor Type EU-3, year 2000
Vehicles average fuel consumption per km: 0, 2 l/km
Emission factor CO₂ g/l: 2410 g/l
Total distance traveled: 893 km

Alwex Transport AB calculates the CO₂ emissions as follow:

1. Emission Factor in grams per kilometer:
   \[ \text{CO}_2 \text{ grams per liter} \times \text{average fuel consumption per km} = \text{CO}_2 \text{ grams per km} \]
   \[ \text{CO}_2 \text{ g/l} \times \text{l/km} = \text{CO}_2 \text{ g/km} \]
   \[ 2410 \text{ CO}_2 \text{ g/l} \times 0.2 \text{ l/km} = 482 \text{ CO}_2 \text{ g/km} \]

2. CO₂ in grams and kilograms:
   \[ \text{CO}_2 \text{ grams per km} \times \text{the distance traveled in km} = \text{CO}_2 \text{ grams} \]
   \[ \text{CO}_2 \text{ g/km} \times \text{km} = \text{CO}_2 \text{ g} \]
   \[ 482 \text{ CO}_2 \text{ g/km} \times 893 \text{ km} = 430426 \text{ CO}_2 \text{ g} = 430.426 \text{ CO}_2 \text{ kg} \]

Using the data and methods presented above, Alwex Transport AB accounts consequently its client AB for 430,426 kg of CO₂ emissions that were caused during the entire transportation.

For the allocation of these CO₂ emissions on specific products (here illustrated as locations B…M) Alwex Transport AB had no appropriate solutions. Thus, a new framework of calculating
the CO₂ emissions and allocating them to the respective product (or here destination points) will be presented in the following section.
5 The new method – an Analysis

This chapter is dedicated to the analysis part of this thesis. Thus, a new method for CO₂ calculations and allocations as an improved alternative to the method introduced in chapter 4 will be illustrated. Calculations based on the new method will be done. Furthermore, both methods will be compared based on their results. After that a discussion about the relevance of the new method and the possible consequences for the company will follow. The chapter ends with the illustration of the requirements for applying the new method, with critics of the new method and the recommendation for Alwex Transport AB.

5.1 The new method to calculate and allocate CO₂ emissions

This section is divided in two parts: The new method of calculating CO₂ emissions and the allocation of CO₂ emissions on products or destination points.

The new method of calculating CO₂ emissions for Alwex Transport AB

In order to present this method as simply and clearly as possible, data and restrictions given by the company will be used as already done in the chapter before. Divergences and differences to the calculation method applied currently by Alwex Transport AB will be explained. The calculation of CO₂ emissions is divided in the same calculation steps as before: Calculating the route and the effective total distance traveled and calculating the effective total CO₂ emissions. The following information will be used for the new method:

The route and all information from table 4-4

The truck: Scania P 114 from the year 2000 and Motor type of EU-3

The trucks average fuel consumption of 0,2 l/km

The CO₂ emission factor of 2410 g/l

1. Step: Calculating the route and the effective total distance traveled

Taking the information from the table 4-4 and using a route planer software, the route and the total distance traveled for the client AB can be calculated as depicted in figure 4-3 and figure 5-1. In this case, the author used the free of charge route planer of Google Maps that is available on
Internet. Other free of charge route planning software such as hitta.se can also be used for calculating distances between geographical points in Sweden. The author used Google Maps because it is internationally known.

![Google Maps from: Stora Råppevägen 62, Växjö, Sweden to: GRANSHOLMS HERRGÅRD, Maps-Suche](image)

**Figure 5-1: Transportation route of Alwex Transport AB for the client AB.**

Source: (Google Maps, 2011)

On the right, the map and the transportation route in blue. The destination points are marked in green. On the left, the locations are listed in a table in the same order as in table 4-4. The locations are named by letters, refer to table 4-4 and are illustrated on the map to the right and in figure 4-3. Down left corner, the reader can see the calculated total distance traveled for the transportation route, i.e. 349 km.

Having used the free of charge route planning software, the necessary output data can be read and used for the new method. The table on the left includes the desired locations. These are listed in the same order as in table 4-4. The map on the right is identical to figure 4-3 and depicts the transport route. In the left down corner, the reader can see the calculated total distance traveled. The transportation route for the client AB accounts a total traveled distance for 349 km.

Comparing this output (349 km) with the total distance traveled above (893 km) based on Alwex Transport AB’s pricelist and, thus, its estimations, it can be concluded that Alwex Transport
AB’s calculation method overestimated the total distance traveled by 544 km (893 km – 349 km = 544 km). As mentioned already before, this huge difference is due to the company’s estimations and the fact that the distances were calculated each directly from Växjö, i.e. the calculation of Alwex Transport AB was not based on the effective traveled distance but, further, on a fictive total distance traveled. While Google Maps counts the distance between the locations (e.g. location K and L) directly, Alwex Transport AB counted this distance twice coming from the terminal Växjö, i.e. each distance was counted separately from Växjö terminal to location K and from Växjö terminal to location L.

2. Step: Calculating the effective total CO₂ emissions

Taking the information from Alwex Transport AB and the new total distance traveled, the total amount of CO₂ emissions for the transportation route can be calculated analogously to the calculation presented above:

1. CO₂ Emission Factor in grams per kilometer:

   CO₂ grams per liter × average fuel consumption per km = CO₂ grams per km
   CO₂ g/l × l/km = CO₂ g/km

   2410 CO₂ g/l × 0.2 l/km = 482 CO₂ g/km

2. CO₂ in grams or kilograms:

   CO₂ grams per km × the distance traveled in km = CO₂ grams
   CO₂ g/km × km = CO₂ g

   482 CO₂ g/km × 349 km = 168218 CO₂ g = 168,218 CO₂ kg

Comparing the results from the new method with the method Alwex Transport AB applies, it can be seen that the new method accounts the client for more than 39 % less CO₂ emissions: (168,218 CO₂ kg / 430,426 CO₂ kg) ×100 = 39,082 %

This difference is due to the fact that the software used measured the total distance traveled effectively, i.e. as it was carried out according to the sweep method. Whereas Alwex Transport
AB transported the goods in the same way as Google Maps counted, i.e. according to the sweep method, but calculates the total distance traveled fictively, i.e. based on the pricelist and estimations. This means, that Alwex Transport AB’s calculations bases on summing up all distances between the locations and the terminal in Växjö. Thus, the route planning software calculates precisely. Since the allocation of CO₂ emissions is based on precise CO₂ calculations, this distortion of information shows evidently how important it is to calculate precisely the effective total traveled distance in order to get a fair calculation of CO₂ emissions. In the following, a simple method will be presented which allows Alwex Transport AB to allocate the counted CO₂ emissions on the respective clients, destination points or even products.

The new method of allocating CO₂ emissions for Alwex Transport AB

The new method is based on the idea to calculate firstly the CO₂ emissions effectively caused during the transportation. And, secondly, to calculate the fictive direct distances between the delivery locations and the terminal in Växjö, to weight them and to multiply the respective percentage of km traveled with the CO₂ emissions caused in total. In order to avoid any confusion and to guide the reader clearly through the calculations, the new method will be explained and illustrated briefly in four steps as follow:

1. **Step:** Calculation of the effective total distance traveled by a route planning software (seen in figure 4-4) or metering from the truck’s odometer after each transportation route. Calculating the total CO₂ emissions with the help of the Distance or Fuel Based Method (seen in 3.3 Methods for the Calculation of CO₂ Emissions in Road Transportation).

2. **Step:** Calculating the fictive total distance traveled. This means, measuring direct distances between each location and the terminal and sum them up.

3. **Step:** Weighting each direct distance from the terminal to the respective location based on the total fictive traveled distance from Step 2. This means:
Percentage of distance for location $Y = \frac{\text{direct distance from location } Y \text{ to terminal}}{\text{fictive total distance traveled.}}$

4. **Step:** Allocation of CO$_2$ emissions on the respective product or/and location by multiplying each weighted factor from Step 3 with the total CO$_2$ emissions calculated in Step 2.

**The Calculations**

In order to avoid confusion it should be noticed that in this example CO$_2$ emissions will be allocated on products delivered at the locations presented in table 4-4. For clarification and a better understanding, table 4-4 will be used and extended to another column which will stand for products. Since the products in this example are not known, small letters referring to the locations where they have to be delivered will be used:

<table>
<thead>
<tr>
<th>Vehicle Type and Motor Type</th>
<th>Starting Point (From)</th>
<th>Destination (To)</th>
<th>Points on the map</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>GÉMLA, Gransholms Gård</td>
<td>B</td>
<td>b</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>GÉMLA, Gransholms Gård</td>
<td>VEDERSLOV, Kinnevaldsvägen 12</td>
<td>C</td>
<td>c</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VEDERSLOV, Kinnevaldsvägen 12</td>
<td>VISLANDA, Olvägen 11</td>
<td>D</td>
<td>d</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VISLANDA, Olvägen 11</td>
<td>DIÖ, Växjövägen 303</td>
<td>E</td>
<td>e</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>DIÖ, Växjövägen 303</td>
<td>MÖCKELNSAS, DIÖ</td>
<td>F</td>
<td>f</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MÖCKELNSAS, DIÖ</td>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>G</td>
<td>g</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>ALMHULT, Ikeagatan 1</td>
<td>H</td>
<td>h</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>ALMHULT, Ikeagatan 1</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>I</td>
<td>i</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>J</td>
<td>j</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>HASSLEHOLM, Södra Kringlevägen 1</td>
<td>K</td>
<td>k</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>HASSLEHOLM, Södra Kringlevägen 1</td>
<td>HASSLEHOLM, Järnvägsatan 21</td>
<td>L</td>
<td>l</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>HASSLEHOLM, Järnvägsatan 21</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>M</td>
<td>m</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5-1: Transportation route of goods to different locations for client AB.**

**Source:** Own illustration based on (Hildingsson, 11.03.2011)

Since the starting and ending points, i.e. the terminal Växjö AB, do not belong to the client’s locations, these locations have no products.

By searching an appropriate method for a fair, i.e. effective, allocation of CO$_2$ emissions on goods, it will be referred mostly to table 5-1 and figure 4-3. Since Alwex Transport AB is a medium-sized company with a budget that does not allow high investments in measuring tools a
simple method was elaborated to allocate the total CO₂ emissions during one transportation route on the respective products. The allocation of CO₂ emissions is done by weighting. The following steps illustrate the simple method to allocate CO₂ emissions. Furthermore, since the method bases on the transportation planning method called sweep method, the calculations will be carried out for a single transportation route. Thus, if the entire transportation is carried out four times a month and the calculation has to be done for one year, the amount of CO₂ emissions have to be multiplied by $4 \times 12 = 48$.

1. **Step: Calculation of the effective total distance traveled and the total CO₂ emissions**

When customers demand for a fair CO₂ emission allocation, they mostly want to know how much CO₂ emissions their products are accountable for, i.e. the allocation of CO₂ emissions requires the consideration of the effective total distance traveled during the transportation (Hildingsson, 11.03.2011). Therefore, in this example, the total distance traveled which was counted in figure 5-1 can be used, i.e. 349 km. This implies also the fact that a fair CO₂ allocation has to be based on the effective CO₂ emissions that were caused during the transportation route. In this example, the total CO₂ emissions for a total distance traveled of 349 km were calculated as 168,218 CO₂ kg. This means, that 168,218 CO₂ kg emissions have to be allocated on the deliveries for the locations.

2. **Step: Calculating the fictive total distance traveled by measuring direct distances between the terminal and locations**

In order to obtain a fair allocation of CO₂ emissions on the products, the transportation company has to know how much the transportation of the respective good would have caused CO₂ emissions if the product had been transported directly to the respective destination point. This can be done by using the route planning software applied above. Taking table 4-4 into account the distances from the terminal in Växjö to the respective location are as follow:
### Table 5-2: Distances between the terminal in Växjö and the locations.

**Source:** Own illustration based on (Hildingsson, 11.03.2011)

Direct distances between the terminal in Växjö and the respective locations are calculated in the last column. A direct transportation of goods from the terminal to the respective location would have reported in total 822.9 km.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Starting Point (From)</th>
<th>Destination (To)</th>
<th>Points</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>GEMLA, Gransholms Gård</td>
<td>A-B</td>
<td>14.3 km</td>
</tr>
<tr>
<td>Scania P114 EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>VEDERSLÖV, Kinnevaldsvägen 12</td>
<td>A-C</td>
<td>13.6 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>VISLANDA, Olvägen 11</td>
<td>A-D</td>
<td>26.3 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>DIÖ, Växjövägen 303</td>
<td>A-E</td>
<td>46 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MÖCKELSNÄS, DIÖ</td>
<td>A-F</td>
<td>55 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>ALMHLUT, Silverdalsgatan 3</td>
<td>A-G</td>
<td>55.9 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>ALMHLUT, Ikeagatan 1</td>
<td>A-H</td>
<td>57.8 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>A-I</td>
<td>107 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>A-J</td>
<td>107 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>HASSLEHOLM, Södra Kringelvägen 1</td>
<td>A-K</td>
<td>109 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>HASSLEHOLM, Järnvägs gatan 21</td>
<td>A-L</td>
<td>110 km</td>
</tr>
<tr>
<td>Scania P114, EU-3</td>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>A-M</td>
<td>121 km</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>822.9 km</td>
</tr>
</tbody>
</table>

After having measured each transportation way from the terminal to the location, the total fictive transportation way can be summed up. In this example, Alwex Transport AB would have measured a total distance traveled of 822.9 km if the company would have transported the products separately to each location. Remarkably, it can be noticed that the total fictive distance traveled calculated above by 822.9 km reminds on the total distance traveled applied by Alwex Transport AB for the CO₂ emission calculation illustrated in table 4-5.

#### 3. Step: Weighting each direct distance from the terminal in Växjö

The total fictively measured distance traveled of 822.9 km is the basis for weighting the respective direct distances from the terminal to the respective location. Thus, in step 3, it will be calculated how many percents each direct distance weighs from the total 822.9 km. Table 5-3 illustrated the percentage of every direct distance:
### Table 5-3: Weighted direct distances between the terminal in Växjö and the locations.

<table>
<thead>
<tr>
<th>Starting Point (From)</th>
<th>Destination (To)</th>
<th>Points</th>
<th>Distance</th>
<th>Percentage of the total route</th>
<th>Accumulated percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>GEMLA, Gransholms Gård</td>
<td>A-B</td>
<td>14,3 km</td>
<td>14, 3 km + 822,9 km = 1, 738 %</td>
<td>1,738 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>VEDERSLÖV, Kinnevaldsvägen 12</td>
<td>A-C</td>
<td>13,6 km</td>
<td>1,653 %</td>
<td>3,391 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>VISLANDA, Olvägen 11</td>
<td>A-D</td>
<td>26, 3 km</td>
<td>3,196 %</td>
<td>6,587 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>DIÖ, Växjövägen 303</td>
<td>A-E</td>
<td>46 km</td>
<td>5,58 %</td>
<td>12,167 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MÖCKELSNAS, DIÖ</td>
<td>A-F</td>
<td>55 km</td>
<td>6,684 %</td>
<td>18,851 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>A-G</td>
<td>55, 9 km</td>
<td>6,793 %</td>
<td>25,644 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>ALMHULT, Ikeagatan 1</td>
<td>A-H</td>
<td>57, 8 km</td>
<td>7,024 %</td>
<td>32,668 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MARKARYD, Drottninggatan 1</td>
<td>A-I</td>
<td>107 km</td>
<td>13,003 %</td>
<td>45,671 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>MARKARYD, Kaplansgatan 27</td>
<td>A-J</td>
<td>107 km</td>
<td>13,003 %</td>
<td>58,674 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>HÄSSEHOLM, Södra Kringelvägen 1</td>
<td>A-K</td>
<td>109 km</td>
<td>13,246 %</td>
<td>71,92 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>HÄSSEHOLM, Järnvägs gatan 21</td>
<td>A-L</td>
<td>110 km</td>
<td>13,367 %</td>
<td>85,287 %</td>
</tr>
<tr>
<td>VÄXJÖ, Stora Räppevägen 62</td>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>A-M</td>
<td>121 km</td>
<td>14,713 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

822,9 km 100 % 100 %

The fifth column gives the output information of how many percents a direct distance between the terminal in Växjö and the respective location is. The last column illustrates that 58,674 % of the transportation was carried out in Kronobergs Län.

The weighting of direct traveled distances allows measuring the percentage of each single transportation. A multiplication of each percentage with the total CO₂ emissions allows to calculate the amount of CO₂ emissions for each location and, thus, to allocate the emissions appropriately to the respective location or product. This will be done in step 4.

**Step 4: Allocation of CO₂ emissions to the respective locations**

The allocation of the total CO₂ emissions is based on the division of the total CO₂ emissions on the respective location. This procedure is based on the results calculated above. Thus, the total amount of CO₂ emission, i.e. **168,218 CO₂ kg**, will be multiplied by the respective percentage taken from the table 5-3. The result is the correct allocation of CO₂ emissions on the location or the product. For the allocation of CO₂ for the location in Gemla (B) and the product b, this would be calculated as follow:

Percent of the total route × the total CO₂ emissions = CO₂ emissions for product b and location B

or

822,9 km 100 % 100 %

**Source:** Own illustration based on (Hildingsson, 11.03.2011)
This means that the transportation of product b to the location Gemla (B) caused 2,924 kg of CO₂ emissions. Table 4-5 includes the allocation of CO₂ emissions on all products and locations.

Table 5-4: The allocation of CO₂ emissions on products and locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Products</th>
<th>Distance</th>
<th>Percentage of the total route</th>
<th>Allocation of 168,218 CO₂ kg emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEMLA, Gransholms Gård</td>
<td>B</td>
<td>b</td>
<td>14,3 km</td>
<td>14.3 km ÷ 822,9 km = 1,738 %</td>
</tr>
<tr>
<td>VEDERSLÖV, Kinnevaldsvägen 12</td>
<td>C</td>
<td>c</td>
<td>13,6 km</td>
<td>1,653 %</td>
</tr>
<tr>
<td>VISLANDA, Olvägen 11</td>
<td>D</td>
<td>d</td>
<td>26, 3 km</td>
<td>3,196 %</td>
</tr>
<tr>
<td>DIÖ, Växjövägen 303</td>
<td>E</td>
<td>e</td>
<td>46 km</td>
<td>5,58 %</td>
</tr>
<tr>
<td>MÖCKELSÅS, DIÖ</td>
<td>F</td>
<td>f</td>
<td>55 km</td>
<td>6,684 %</td>
</tr>
<tr>
<td>ALMHULT, Silverdalsgatan 3</td>
<td>G</td>
<td>g</td>
<td>55, 9 km</td>
<td>6,793 %</td>
</tr>
<tr>
<td>ALMHULT, Ikeagatan 1</td>
<td>H</td>
<td>h</td>
<td>57,8 km</td>
<td>7,024 %</td>
</tr>
<tr>
<td>MARKARYD, Drottninggatan 1</td>
<td>I</td>
<td>i</td>
<td>107 km</td>
<td>13,003 %</td>
</tr>
<tr>
<td>MARKARYD, Kaplansgatan 27</td>
<td>J</td>
<td>j</td>
<td>107 km</td>
<td>13,003 %</td>
</tr>
<tr>
<td>HASSLEHOLM, Södra Kringlelängen 1</td>
<td>K</td>
<td>k</td>
<td>109 km</td>
<td>13,246 %</td>
</tr>
<tr>
<td>HASSLEHOLM, Järnvägsgatan 21</td>
<td>L</td>
<td>l</td>
<td>110 km</td>
<td>13,367 %</td>
</tr>
<tr>
<td>KRISTIANSTAD Mäster Bonggatan 4</td>
<td>M</td>
<td>m</td>
<td>121 km</td>
<td>14,713 %</td>
</tr>
</tbody>
</table>

Total | 822,9 km | 100 % | 168,218 kg CO₂ |

The new method to calculate the allocation of CO₂ emissions helps Alwex Transport AB to allocate the effectively caused CO₂ emissions on each product or/and location. This table illustrates e.g. that product k that was delivered to the location K caused during its transportation 22,282 kg of CO₂.

Table 5-4 illustrates the individual allocation of the total CO₂ emissions measured for the entire transportation route (depicted in figure 4-3). The company’s restriction such as the low budget in investments and the technology level are respected by this method.

5.2 Comparison of results

Both calculation methods, the new one and the current used by Alwex Transport AB, are based on statistical data and estimations given by the company Alwex Transport AB. The truck type Scania P 114 from the year 2000 and the motor Euro-class 3 and the locations listed in table 4-4 served as examples. Thus, the average fuel consumption of the vehicle (0,2 l/km) and the average
amount of CO₂ emissions caused by the vehicle (2410 CO₂ g/l as in table 4-3) were given by the company as data which are to be regarded as independent variables. Dependent variables were illustrated as distances between the locations and the terminal in Växjö as well as the total amount CO₂ emissions.

The biggest difference of both methods is the fact that Alwex Transport AB could not allocate the total CO₂ emissions on the products/locations.

Another big difference between both methods is the used database for calculating the transportation route. The fact that Alwex Transport AB uses its tariff price list for the calculation of the total distance traveled causes a distortion of information. While the truck is transporting the goods based on a sweep method, the company calculates the total distance traveled based on direct and single transportations of goods from the terminal in Växjö to each location. Thus, an imbalance occurs since the company uses for its CO₂ calculation a fictive total distance traveled instead the effective total distance traveled which would be logical as illustrated by calculations above. This means, the transportation route was driven effectively but the calculation was done fictively. Alwex Transport AB calculated for the transportation route a total distance traveled of 893 km (table 4-5). The calculation for 893 km was built up by the estimated sum of every single transportation from the terminal in Växjö to each location. Even though the truck drove effectively from location to location the calculation did not include this fact. Furthermore, Alwex Transport AB uses averages and estimations for calculating the distances between the terminal and the respective location (seen in table 4-5). This and the fact that the calculations of CO₂ emissions are based on the price list hindered the company to develop a method which allows an effective and simple allocation of CO₂ emissions on products/clients/locations.

Unlike the company’s method presented, the new method used the free of charge route planning software for tracking each location. Calculating the total distance traveled based on the software presented above, the route was about 394 km, i.e. more than a half less km than calculated by Alwex Transport AB (893 km). Calculating the fictive total distance traveled, i.e. the total km of transportation if each location was served individually from the terminal in Växjö, the result was about 822,9 km (seen in table 5-2). This is still (893 km – 822,9 km = 70,1 km) 70,1 km less than the Alwex Transport AB’s calculation based on the company’s pricelist and estimations.
Since the new CO₂ calculation method is not based on the price list it was possible to develop a method that allows a fair allocation of CO₂ emissions on products. The table below presents briefly the results calculated with both methods:

<table>
<thead>
<tr>
<th>Results</th>
<th>Method used at Alwex Transport AB</th>
<th>New method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total distance traveled</td>
<td>893 km</td>
<td>394 km</td>
</tr>
<tr>
<td>CO₂ emissions</td>
<td>430,426 CO₂ kg</td>
<td>168,218 CO₂ kg</td>
</tr>
<tr>
<td>Allocation of CO₂ emissions on products</td>
<td>Not possible</td>
<td>Possible through weighting</td>
</tr>
</tbody>
</table>

Table 5-5: Illustration of results calculated with both methods presented above.

The impact of the results stated out above will be discussed in the next section.

5.3 The relevance of the new method

The new method allows the company to calculate and allocate CO₂ emissions on products, customers or locations while other methods presented in the previous and theory chapter had only the function of calculating CO₂ emissions, i.e. they did not allow the allocation of emissions. Even sophisticated models and frameworks such as TREMOD (page 43) and EcoTransIT (page 44) that base their calculations on high developed databases such as HBEFA cannot provide the companies with a practical and suitable framework for allocating the emissions on transported products, customers or locations. This means clearly that no general and standardized models and frameworks for allocating emissions exist on the market. This means that even though the company would overcome its financial limits and the lack of human resources as a medium-sized company, it would still not be able to use general and reliable CO₂ allocation models since the market and the scientific literature cannot provide the companies with company specific solutions. Therefore it is not surprising that Alwex Transport AB bases its calculations and allocations of CO₂ on estimations. As discussed above and illustrated briefly in table 5-5, Alwex Transport AB’s current method causes even a high distortion of information. The company’s calculation method shows a total distance traveled and, thus, the total amount of CO₂ emissions which is about more than 40 % higher than the levels resulting from the new method. This is due to the fact that the company’s method is based on the price list and
estimations. For that reason, the new method does not even allow to develop a solution for the allocation of CO₂ emissions on products. Consequently, it is evidently recommended that the company use the new method for calculating its CO₂ emissions and allocating them on products, customers or locations.

However, the new method does not need to be the optimal solution for the company. As denoted in the theory chapter (p. 39) the allocation of CO₂ can also base on weight, volume or even vehicle. The GHGPI (2009) recommends for the fright transport to base their CO₂ calculations (and thus their allocation) on ton kilometers. The condition for such a calculation is an exact knowledge about the weight of each product transported on the truck. Therefore, if Alwex Transport AB could afford bar code readers and a high developed IT system it might not prefer completely to use the method suggested by the author, but rather only the principle combined with the CO₂ calculations based on ton kilometers and the high-developed database of HBFA. Furthermore, the new method’s principle for allocating CO₂ emissions could even be used for the public transport. The CO₂ would then be allocated not on products but rather on people transported. The CO₂ calculations would therefore base not on ton kilometers but on person kilometers. It is therefore highly recommended that the company conform its CO₂ calculations to the customers’ needs. If the customer requires to base the allocations of CO₂ emissions on weight or volume the company will need to base their CO₂ calculations on ton kilometers. Thus, the new method can be used differently and can be adjusted flexibly to the customers’ needs.

However, the application of the new methods entails further different advantages and drawbacks compared to the method used currently by Alwex Transport AB. These advantages and drawbacks will affect the company’s internal and external processes and will be discussed as follow:

**Revision of transport planning and reducing of CO₂ emissions**

The sweep method was introduced as a transport planning method that helps the companies to reduce their transportations costs, since one vehicle can be used to deliver several products on
one day. This means, accomplishing several deliveries by one vehicle asks for a smaller fleet of vehicles and, thus, shrink the company’s transportation costs (Jonson, 2008, 331).

On other hand, the sweep method’s drawback is the fact that a vehicle’s total capacity can only be used for a single transportation. This means, that full truckloads within a sweep method cannot serve every single location. This implies also the fact that the sweep method should only be used if the location has to be served with a small quantity and if the delivery is not to be carried out often. Deliveries that can be carried out by full truckloads will shrink the number of deliveries and, thus, the total distance traveled. This, in turn, will evidently shrink the company’s fuel consumption and, thus, the products’ CO2 emissions.

Referring to the calculation example above in table 5-4, if the location L in Hässleholm can be delivered once a month with the full truckload of 10 tons instead of four times a month with the truck load of 2.5 tons, the truck would have a total distance traveled of 218 km instead of $5 \times 349 \text{ km} = 1745 \text{ km}$ by using the current sweep method. This of course, has a deep impact on the company’s fuel costs and the CO2 emissions.

Since customers are interested to have products reporting low CO2 emissions (Bowen et al., 2001, 43) and (Hildingsson 11.03.2011), the customers will have big interest to ask Alwex Transport AB for full truckloads deliveries in the future. This is, of course, only considerable for products with a long storage life. Especially products in the food sector such as milk cannot be storage for long-term and, thus, have to be delivered more often. The sweep method is a suitable transportation planning method for the deliveries of such products. However, if customers ask Alwex Transport AB for direct deliveries the company will have to face new problems. Direct transportations require a bigger vehicle fleet and, thus, a higher flexibility from the logistic service providers. This, in turn will cause higher costs and an economic vicious circle starts, since the sweep method is used by companies in order to reduce the number of vehicles for the freight transport.

Thus, Alwex Transport AB should consider carrying out direct deliveries, if the total distance traveled with the sweep method within the respective period (week, month or year) is longer than the sum of direct distances traveled. To conclude, the new method allows the company to reduce
its CO₂ emissions by questioning the sweep method and, if so, using the direct transportation of products instead.

New Tariff Zones and Generalization

As illustrated above, medium-sized companies prefer to use simple methods and estimations to calculate and interpret their results (Garengo et al., 2005, 29) as does Alwex Transport AB (Hildingsson, 11.03.2011). Furthermore, it was illustrated that Alwex Transport AB uses tariff zones in order to calculate distances between the terminal and customers. Analyzing the depicted transportation route in figure 5-1 on page 63, it can be seen that the locations can be clustered. Thus, the locations B, C and D can be clustered for one tariff zone (0-29 km), locations E-H for the second (30-59 km), locations I-J (60-108) for the third and K-M (109-120 km) for the last tariff zone. If the company has several transportation routes with the same pattern, it can develop through clustering a new tariff zone model. However, it is to be noted that the company could not provide the author with more data in order to carry out a cluster analysis which would help to develop a new tariff zone model. Nevertheless, the implementation of new tariff zones can be carried out if the company pictures several representative routes through the new method by using the routing program available on the Internet and divides the locations in clusters. This would help the company to develop a general model by which it can calculate the CO₂ emissions and allocate them simply to the locations/products/customers.

Simplicity

As outlined in the previous chapter, the new method is simply to calculate. It bases on for steps and requires an Internet access. The effective total traveled distance can be measured by the program introduced above or even metered by the truck’s odometer. No measuring tools with high investments or an academic education level are required. Sophisticated tools such as TREMOD or EcoTransIT that require more detail information than often can be served by medium-sized companies are not required either. Thus, the new method can be seen as a simple
method and, thus, as a helpful framework for Alwex Transport AB to allocate CO₂ emissions on
products, clients or locations.

Accuracy

The new method bases on a free of charge software that is available on the Internet. This
software tracks locations and calculates the distances with the help of GPS (Global Positioning
System). Thus, it can be assumed that the system is reliable and precise. Based on the results of
calculating the total distance traveled, the company can develop more precise statistics and
abandon estimations which base on the employees feelings and led the company to over-
estimated results, as shown above. Therefore, it can be said that the new method leads to more
accuracy. Statistics and records built up with the new method will also help the company to
anticipate the costs more precisely. Thus, the investment in new vehicles, equipment and fuel
will be done more correctly.

Transparency

Accuracy will also help the company to establish transparency. Being able to track the location
and trace the products’ transportation route, will help the company to show their clients how
their products are exactly transported, what time their transportation needs and, of course, how
much CO₂ emissions were exhausted during the transportation. Transparency will also help the
company to install more efficient and effective processes. Since the software provides user with
a map, the company will be able to see also alternative routes for the transportation. Thus, Alwex
Transport AB will be able to choose between the fastest or shortest routes.

Higher Customer Service

As mentioned in the interview with Peter Hildingsson, the manager for information systems,
quality and environmental issues, nowadays customers demand for more information. They want
to know where their products are coming from, how they were produced and transported and which impact they have on the environment (Hildingsson, 11.03.2011) and (New, 2011, 77). Therefore, the company was searching for a method that allows the calculation and allocation of CO₂ emissions. Thus, giving the customer the total information about the distribution way, the amount of CO₂ emissions it caused, allows the company to higher its customer service and, thus, to increase the loyalty of its current customers and even to allure new ones.

The fact that the new method allows even customers tracing transportation routes, the company can invite the customers to participate in transport planning of their own products. This means that the company can even let decide the customers whether their products should be transported on the shortest, fastest or less fuel consuming way (i.e. avoiding highways for lowering the fuel consumption). Thus, the company’s customers from the food sector, such as ICA can actively work on lowering the CO₂ emissions burden of their products and, thus, get their ecological products more attractive for the end customers. This would cope with the company’s slogan: “Ditt naturliga val på vägen” (Your natural choice on the way).

**Sustainable and Environmental Friendly**

In 2010, Alwex Transport AB published its sustainability report. The company’s aim is to communicate to customers its policy and procedures of sustainability and environmental friendly practices. Therefore, it follows the accounting standards of the Global Reporting Initiative (GRI) as already mentioned on page 5. Nowadays, the company is certified by GRI Report with a level of C. The company’s aim is to improve its processes and being certified for the level C plus. By following the GRI Report, the company wants to present its contribution to the environment and society. Which, on other hand, affects its image positively and, thus, can also allure new clients (Hildingsson, 11.03.2011).

The GRI Report asks the company to take responsibility of society and environment. Therefore, a company’s disclosure of its energy consumption and other environmental harmful or consuming procedures is asked by the GRI Report (GRI, 2008, 5).
The new CO₂ calculation and allocation method, allows the company not only calculating the exact amount of CO₂ emissions caused by the respective transportation, but also has the effect that it reports effectively less CO₂ emissions than the method used currently by Alwex Transport AB. Thus, the new method is not only economically precise, but positions also the company in a more environmental friendly light since the company produces effectively less CO₂ emissions than calculated, i.e. estimated, before. This, of course, is also closely related to the customer service. Thus, reporting the true amount of CO₂ emissions, i.e. a lower amount, will satisfy the customers.

5.4 Requirements and recommendations using the new method

It was illustrated that the current method for CO₂ calculations at Alwex Transport AB causes a distortion of information since the tariff zone model is used for both: to calculate the prices as well as the transportation distances traveled. In order to achieve an accurate CO₂ calculation, it is in general recommended not to use the price list, i.e. the tariff zones listed above in table 4-5, for calculating the CO₂ emissions. The company, on other hand, should continue using the price list only for setting prices. Thus, a distinction between the calculation of distances and prices has to be done in order to achieve an accurate and precise calculation and allocation of CO₂ emissions.

Implementing the new method as the standard calculation and allocation method for CO₂ emissions has also its drawbacks. Even though the new method is regarded as simple and economical, i.e. easy to understand and handle with and no high investments are need, the company will have to invest the factor time in order to calculate and allocate the CO₂ emissions. The method used by now at Alwex Transport AB can be seen as less time consuming since calculations were estimated. Due to the fact, that the distribution routes vary very often and even daily, Alwex Transport AB has to reckon with more time consuming calculations using the new method. In 2010, the company reported 888.414.611 SEK as revenues before tax. 99,45 % of those revenues had to cover the company’s transportation costs: 883.539.177 SEK. Thus, it can be seen how low the company’s profit margins are. This means, that the company cannot invest in sophisticated calculation tools that allow, on one hand, precise calculations and allocation of
CO₂ emissions but, on other hand, require high investments. Since Peter Hildingsson is the only responsible for the company’s environmental issues, this would mean, that he has to do the calculations by himself (see also page 48). An alternative would be to hire an employee or create a part-time workplace in order to get accurate and precise calculations and allocations of CO₂ emissions. The consideration of this recommendation depends certainly on the need in time. Therefore, it is recommended to test for a certain period the time consumption of the CO₂ calculations and allocations and then to decide which investments should be done. According to the company’s sustainability report from 2010, Alwex Transport AB spent 31.360.195 SEK for salaries (Alwex Hållbarhetsredovisning, 2010, 13). With a staff of 77 workers it can be assumed that the company paid in average 407.275 SEK per worker for 2009. Thus, a test period for decision making whether it has to be invested in a new workplace is recommended.

The arguments listed above and justified by the calculations, lead the author to the conclusion that the new method is recommended to Alwex Transport AB in order to calculate and allocate CO₂ emissions accurately, precisely and simply – as demanded by the company.
6 Conclusion

The last chapter of the Thesis is dedicated to conclude the outcomes and answer briefly on the research questions.

The increasing awareness of customers vis-à-vis environmental issues demands the companies to respond to the needs such as environmental friendly manufacturing and transportation of products. In a global world where information flow is fast and the products’ life-cycles are becoming shorter customers want to know exactly where and how their products were produced, transported and which pollution they caused during their life-cycle. Thus, transparency, sustainability and environmental friendly products and processes are to be seen as competitive edges.

Therefore, companies seek more and more to communicate to customers that they are able to respond to their environmental friendly needs. Companies use certifications such as ISO 14001 and sustainability reports from the Global Reporting Initiatives in order to communicate their goodwill vis-à-vis environmental friendly activities. These certifications, in turn, attract new customers and increase their loyalty towards the company. Thus, greening the supply chain becomes more and more important for companies in order to avoid environmental harmful activities such as exaggerated CO₂ emissions. Processes that help to control CO₂ emissions through precise and accurate calculations are more and more required. This is also highlighted by the fact that customers ask for clear information about how much CO₂ emissions their products produce during their production and transportation. Due to the fact, that the demand for CO₂ allocation on products is a new phenomenon, researchers cannot base their calculations on general and widely used methods. Thus, companies have only a limited access to accurate and precise methods which help them to calculate CO₂ emissions and allocate them on products.

Furthermore, restrictions such as the firm’s financial situation, tacit knowledge and the lack of human resources, which are the characteristics for small and medium-sized companies, limit the companies to use high developed and sophisticated methods for CO₂ emissions calculations and allocation.
In this thesis, the problem of CO₂ emissions calculation and allocation on products or locations of the medium-sized Swedish transportation company Alwex Transport AB served as an example to face the problem discussed above. The company faces small profit margins and a lack of human resources. The manager, Peter Hildingsson, is responsible for several activities in the company: IT systems, quality and environmental issues. Thus, CO₂ emissions are calculated very simply with the help of estimations and through averages. The distances between the main terminal in Växjö and the destination points throughout south Sweden are calculated by estimations based on tariff zones. The company divides its operational area within Sweden in different tariff zones. The tariff zones vary from each other and are based on the distances from the terminal in Växjö. The further a destination point is the higher the number of the tariff zone and the higher the price for the transportation. The fact, that the company uses averages and the price list (both based on tariff zones) for calculating CO₂ emissions leads to information distortion, since the calculation method does not base on the effective total distance traveled. Furthermore, the allocation of CO₂ emissions could only be carried out by estimations, no calculations. Thus, the company’s managers ask deservedly:

“How can the company Alwex Transport AB allocate correctly the CO₂ emissions to the respective product/location which were effectively caused during the product’s transportation?”

This research question was answered by the authors attempt to find an appropriate method for the CO₂ emissions calculation and allocation. The term appropriate method stood for a method which is simple to use and still helps the company to calculate and allocate the CO₂ emissions precisely and accurate.

The new method presented in the chapter above bases the CO₂ calculations on the Internet software Google Maps which runs on GPS, is cost free and available on Internet. The allocation of CO₂ emission was easily calculated in four steps (pages 65-66).

Thus, the first research question is to be answered that the company Alwex Transport AB is able to allocate correctly the CO₂ emissions to the respective product/location by using the new method introduced above. This, method bases its calculations on the effective total distance
traveled. Furthermore, the software provides the user with accurate and precise calculations of
distances between the terminal and the destination points. Thus, estimations and the usage of
imprecise averages become obsolete.

By applying the new calculation method the second research question can be answered as well

**Which framework should be chosen? The easiest, the less costly or the most precise?**

Due to the company’s size and business, financial, structural, behavioral and strategic restrictions
a method is needed which can be handled easily, does not need specific and time consuming
instructions and simultaneously provides the company with precise and accurate CO₂ emissions
calculations. Therefore, a cost free and on the Internet available route planning program was
chosen as the base for the calculations of CO₂ emissions. The program has also the advantage
that it calculates the transport route according to the sweep method. Thus, the new method for
calculating and allocating CO₂ emissions can be considered as a suitable method, i.e. a
framework was found which is easy to handle, causes low costs, is precise and conforms to the
company’s the restrictions listed above.

Even though, the new method has also its drawbacks which were discussed in the previous
chapter, the author concludes that the application of the new method would provide the company
with more advantages than disadvantages compared to the old method. Even though the
company would face to new customer requirements such as the allocation of CO₂ emissions on
weight or volume, the new method’s principle can still be used. The company would have only
to change the basis of CO₂ calculations, i.e. to use ton kilometers. Thus, the allocation method
can be used flexibly.

Furthermore, it was stated that the company could face to the possibility that customers will ask
for full truck loads deliveries in order to decrease their products’ CO₂ emissions. This would, in
turn, force the company to change its transport planning system and switch from the sweep
method to the direct transportation of goods which could, in turn, require the company to be
more flexible but also help to reduce the total CO₂ emissions. This flexibility will require
possessing a higher number of vehicles that in turn would affect the company’s costs negatively.
Thus, further calculations by the company are required in order to decide which transportation
method should be used widely. Further observations and calculations would also allow the company to cluster its destination points with the help of the new method. This, in turn, will allow the company to implement new tariff zones that are more accurate and precise for the calculation of CO$_2$ emissions. Other advantages illustrated and discussed above such as simplicity, accuracy, transparency, higher sustainability and more environmental friendly processes are considered to affect the customer service positively and directly.

The balancing of advantages and disadvantages of the new method leads to the conclusion that the new method should be tested for a short period. If the test turns out to be successful, i.e. the new method is suitable and contributes add value, the implementation should be started. Consequently, it was suggested that the company invests in the creation of a new workplace dedicated to the calculation and allocation of CO$_2$ emissions since the scientific literature forecasts an increase in the importance of CO$_2$ emissions calculations and allocations. This will allow the company to respond the customers’ needs and to keep its promise to give the customer a natural and environmental friendly choice: “Ditt naturliga val på vägen”
VII. Sources


IFEU, Institut Für Energie- und Umweltforschung Heidelberg GmbH (2000), Wissenschaftlicher Grundlagenbericht zur Mobilität-Bilanz und zum Softwaretool Reisen um die Welt in Deutschland, WWF-Deutschland, Heidelberg.


VIII. Appendix

The interview was carried out on the 11th of March 2011 during three hours and was held with open questions in order to allow a discussion and to gather information as much as possible. Due to the respondent’s demand, the answers will not be published literarily. Consequently, only the questions asked during the interview will be illustrated below. For further information, the respondent referred to the company’s annually report of sustainability according to the Global Reporting Initiative (Alwex Transport AB – Hållbarhetsredovisning 2010) which can be downloaded on the company’s web page: http://www.alwex.se/System/FileArchive/224/File_24106.pdf

The Interview was carried out on the 11th of March 2011 from 13:00 o’clock till 16:00 o’clock. The respondent was Peter Hildingsson the Manager at Alwex Transport AB responsible for environmental issues, quality and the company’s IT.

1. Question: Please describe the company’s structure and its core business.
2. Question: What is your position in this company and which duties do you have?
3. Question: Which services beside your core business ask your customers for?
4. Question: How big is your vehicle fleet and of what kind of vehicles does it consist?
5. Question: How many customers do you have?
6. Question: What are you most important customers?
7. Question: What are your company’s responsibilities towards the customers and the society?
8. Question: Which challenges do you see for your company in the future?
9. Question: How do you communicate your customers that your company is environmental friendly?
10. Question: Which certifications are helpful for your company to communicate your environmental friendly policy?

11. Question: Why do you have to calculate CO₂ emissions?

12. Question: How do you think will affect a precise calculation and allocation method of CO₂ emissions the company’s success?

13. Question: What is your route planning method and why did you choose this specific method?

14. Question: How do you calculate the distances between the main terminal in Växjö and the single destination points?

15. Question: How do you calculate the CO₂ emissions?

16. Question: Why do you calculate them by using this method? Which are the company’s restrictions that obliged you to choose this method?

17. Question: Where do you get the Emission Factor and statistical data from to calculate the CO₂ emissions?

18. Question: Why do you use estimations and averages for the calculations?

19. Question: What do you expect from the new method?

20. Question: What should be the new method, the most simple, accurate and precise one or the less costly?