TABLE OF CONTENTS

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Lund, April 2004

Mirco Negri

SUMMARY

The importance of E-commerce in the grocery and food retailing is growing and an increasing number of home delivery solutions are being studied. Some observers predict that the consumers will use e-commerce and home delivery services more and more in the future. However, these developments are affected by a number of problems, many of which are not completely understood. This thesis particularly focuses on the environmental effects of b2c e-commerce, and especially on the potential impacts on pollution that can be associated with home delivery practices.

This thesis aims to compare the environmental impacts of traditional shopping (with a large majority of people using private cars) with a scenario characterized by e-commerce shopping and home delivery. The evaluation is done based on the simulation and analysis of vehicle emissions of CO_2, NOx and particles in the atmosphere. The main research questions are as follows:

- *Can the development and implementation of b2c e-commerce (associated with home delivery solutions) benefit the environment, especially concerning vehicle emissions?*

- *Under which conditions and with which practical solutions are the environmental impacts of e-commerce more beneficial?*

In addressing these questions a system approach has been used with the purpose of both explaining and understanding the phenomenon. Secondary data has been collected from the literature with a qualitative approach, while the primary data has been obtained by means of case study research (conducted with the support of Lund University, Department of Packaging Logistics) about the emissions of home delivery services in the city of Lund (Sweden).

The results of the calculations show that, the environmental effects of e-commerce home delivery can be beneficial (i.e. causing a substantial reduction in the emissions of CO_2, NOx and particles), on condition that a vast number of consumers do e-commerce instead of traditional shopping.

The problem is that most customers order by Internet only a limited number of goods (and especially dry, heavy or “boring” products), but still make car trips to buy the majority of the products they need. In other words, e-commerce can be an additional modality to the traditional shopping, and not a substitute for that. In this case the environmental impacts of e-commerce may be not beneficial, because the emissions of the home delivery vehicles must be summed with the emissions of the cars that go to the store.

This is the reason why there may be the need for public policies for traffic limitation, or “environment-friendly” logistic structures to support the development of e-commerce, so that to the new technology can develop with environmental sustainability.

SOMMARIO

L'importanza dell' e-commerce nel settore della distribuzione alimentare sta aumentando e si stanno studiando un gran numero di soluzioni per la consegna a domicilio. Alcuni studiosi prevedono che il numero di consumatori che sfruttano l'e-commerce e dunque la consegna a domicilio crescerà sempre di più in futuro. Tuttavia, questi sviluppi sono affetti da una serie di problemi, molti dei quali non ancora compresi a fondo. Questa tesi si focalizza sugli effetti ambientali dell' e-commerce nel b2c, e in particolare sui potenziali impatti che le pratiche di consegna a domicilio possono avere in termini inquinamento ambientale.

La mia tesi compara gli impatti ambientali dello shopping tradizionale (dove la maggioranza dei consumatori usa l'automobile privata) con uno scenario caratterizzato da e-commerce e consegna a domicilio. La valutazione è fatta sulla base di simulazioni e analisi delle emissioni di CO_2, NOx e particelle nell' atmosfera da parte di veicoli. Le principali domande a cui la tesi prova a rispondere sono:

- *Può lo sviluppo e l' implementazione dell' e-commerce nel b2c (associato alla consegna a domicilio) avere effetti positivi sull'ambiente, specialmente in riferimento alle emissioni di veicoli?*

- *Sotto quali condizioni e con quali soluzioni pratiche gli effetti dell' e-commerce sull'ambiente sono più benefici?*

Per rispondere a queste domande verrà usato un approccio sistemico, allo scopo di spiegare e comprendere allo stesso tempo il fenomeno. Dati secondari sono stati raccolti dalla letteratura con un approccio qualitativo, mentre i dati primari sono stati ottenuti da un caso studio sulle emissioni nella consegna a domicilio, sviluppato a Lund (Svezia) in collaborazione con il Department of Packaging Logistics dell'Università di Lund.

I risultati dei calcoli rivelano che gli impatti ambientali dell' e-commerce possono essere benefici (causando una sostanziale riduzione delle emissioni di CO_2, NOx e particelle), ma a condizione che un vasto numero di consumatori usi l'e-commerce invece dell'acquisto tradizionale.

Il problema è che la maggior parte dei consumatori ordina in Internet solo un numero limitato di prodotti (specialmente prodotti secchi, pesanti o "noiosi"), ma continua ad andare con i propri mezzi al supermercato per comprare la maggior parte della merce. In altre parole l'e-commerce può essere una modalità aggiuntiva allo shopping tradizionale, ma non lo sostitutisce del tutto. In questo caso però gli effetti sull'ambiente possono essere tutt'altro che positivi, perché le emissioni dei veicoli nella consegna a domicilio vanno sommate alle emissioni delle automobili che vanno al supermercato per gli acquisti tradizionali.

Può esservi di conseguenza la necessità di politiche pubbliche di limitazione del traffico, o di infrastrutture logistiche adeguate che supportino lo sviluppo dell' e-commerce perché sia possibile che le nuove tecnologie si sviluppino nel rispetto dell' ambiente.

1 INTRODUCTION

This chapter describes the thesis background and purposes, trying to define the focus and limitations of this work. There is also a description of the area where the study has been done. Also, definitions of some important terms used in the thesis are listed at the beginning of the chapter.

1.1 Background

Internet and e-commerce are re-shaping and transforming the way in which the distribution of marketable goods is organized. The concept of e-business began to grow in 1994, with the introduction of the Internet to the public. In Sweden, current forecasts made by manufacturers and retailers show that home shopping in the near future will represent 5-10% of total grocery turnover[1]. In ready money it represents about SEK 9 to 18 billion, because the total grocery sales in Sweden was of SEK 188 billion in 2002.[2]

A secondary but important effect of e-commerce concerns traffic. It is common opinion that home delivery services for online groceries could play a critical role in reducing car use for food shopping, as they release the customer from carrying home what they buy. The problem is that today's home shopping examples still represent experimentation of state-of-the-art information technology. In recent years, most of the major supermarket retailers all over the world (especially in UK and US) have been involved in a number of home shopping experiments. An enormous diversity of schemes has been introduced over the years, based on different technologies, targeted to different social groups of consumers, and implemented for different reasons. Some online projects failed, whilst others are still expanding. Generally, there was a decline in profitability of sole e-business companies, and the result is that most of the online food shopping solutions today is predominantly locally organized. Most involve groceries being picked and packed at an existing supermarket and local deport, and the service is usually offered over a fairly compact area. This is also the situation in Lund, the Swedish city where this study was conducted. As a matter of fact, one of the most serious problems of online grocery is home delivery, and this has also a deep impact on costs. In fact, theoretically speaking, it would be even possible to sell groceries on the Internet for a cheaper price but with the same margins of traditional shops.[3] But in order to achieve this goal, the logistic solution becomes critical, both between the producer and the retailer (e.g. the supply chain), and between the retailer and the consumer – which in this case recalls the problem of home deliveries.

Clearly, today it is still unlikely that home delivery services will replace all other forms of goods transport, but however they will play an increasingly important role in the future, with the expansion of b2b e-commerce. Today, all the most successful examples

[1] Annika Olsson, working paper: Home Shopping, Lund 1997
[2] Statistics Sweden Value added tax statistics
[3] Carlheim-Gyllenskiöld and Rangefelt, Matomera, Department of Desigh Sciences, Lund University, 2002

of online selling companies (including well known brands such as Amazon and Dell) currently make very extensive use of home distribution.
This can have a number of important effects in the society. Beside the direct economic consequences, there could also be other social benefits, as service can improve options for those having problems getting to the shops, like elderly or disabled, or those living in remote areas.[4] Also, some observers, argue that home delivery services could be a good environmental solution, as they help to release people from carrying what they buy, and encourage them to shop by alternative means, thus potentially reducing car traffic. Instead, others are concerned that e-commerce is likely to reinforce longstanding trends of transport growth, rather than breaking them. Generally speaking, E-commerce and IT affect the environment in terms of vehicle miles, related emissions and energy consumption, by speeding up the time and decreasing the size of the orders transported. However, in order to have beneficial effects the overall environmental impacts of home delivery services should be lower than traditional grocery shopping. Whether e-commerce contributes to a more efficient distribution system or not very much depends on the particular circumstances, such as consumer habits, delivery modes and population density in a specific area.
Although e-commerce applications are expected to become more and more common, there is lack of knowledge about the effects of e-business and about the aspects mentioned above. In my thesis, I'll try to analyze which impacts could have this expected growth in the use of home delivery solutions on the environment. In order to understand how a particular distribution system for online shopping is effective and environmental friendly, a number of relevant variables and key factors must be considered. After this, it is essential to design an integrated model of the system in which all these variables and key factors are included. The next step is the calculation and the analysis using the model like a tool.

1.2 Terminology: e-commerce

In this section a number of relevant definitions is given of the terms and concepts that are central in the analysis conducted here: e-commerce and e-business.
There are lots of definitions of electronic commerce. The first definition that I show reflects the observation that e-commerce is more than just a tool for optimizing goods flows:

1) "It is a basic element of a newly emerging 'sphere of circulation', the system of information, finance and goods flows that is both a fundament and an outcome of the network economy".[5]

The second and third definitions are suggested by OECD (Organization for Economic Co-operation and Development), and give eitherer a narrower or a broader definition of the term focusing on its crucial aspect, i.e. electronic transactions:

[4] Sally Cairns, Home delivery of shopping: the environmental consequences, working paper 1999
[5] Castells, 1985, 1996

2) Narrow definition. *"An electronic transaction is the sale or purchase of goods or services, whether between businesses, households, individuals, governments, and other public or private organizations, conducted over the Internet. "*.

3) Broad definition. "*An electronic transaction is the sale or purchase of goods or services, whether between businesses, households, individuals, governments, and other public or private organizations, conducted over computer-mediated networks. The goods and services are ordered over these networks, but the payments and the ultimate delivery of the good or service may be conducted on or off-line"*. [6]

The forth definition is suggested by the so called government bill of IT in Sweden and can be translated into English like follows:

4) "All situations where parties exchange business information via different forms of telecommunication and where at least one party has an economical interest in the communication".[7]

E-BUSINESS: "*business processes, commercial activities, or other economic tasks conducted over the Internet or computer-mediated networks (Intranet, etc.)"*.[8]

Some of the definitions are too general for the purpose of this thesis, or they considered unessential aspects.This thesis focuses on grocery shopping and e-commerce performed by Internet, so I prefer to restrict the definition of the term e-commerce to the essential aspect of "consumer goods sold online" and delivered by means of traditional distribution channels.

1.3 Problem definition

My research focus is the study of the environmental impacts of e-commerce in the grocery sector. This subject was studied with reference to a specific situation, that is the analysis of the current situation in Lund and the possible future scenarios in relation to the development of e-commerce and home delivery schemes. The extent to which e-commerce contributes to changes in logistics and retail distribution processes (and especially how it may affect transportation and the environment) is still debatable.
Certainly, the most important factor is the rate of e-commerce adoption by users. We said before that probably in the near future home shopping will represent a significant market share, in Sweden as well as in other countries. Consequently, studies about how the development of home delivery services may impact the environment are of great interest today.

[6] Carlheim-Gyllenskiöld and Rangefelt, Matomera, Department of Desigh Sciences, Lund University, 2002
[7] Carlheim-Gyllenskiöld and Rangefelt, Matomera, Department of Desigh Sciences, Lund University, 2002
[8] Klaus Fichter, 2003, E-commerce: sorting out the Environmental Consequences, Journal of Industrial Ecology, vol 3, num. 2

Home delivery is a quite complex process that may require:[9]

- access to the customer's home;
    - the customer must be present to take delivery (attended solution), or the delivery is deposited in a storage box (unattended solution);
    - a procedure for legally proving that the merchandise has been transferred from the carrier to the customer;
- a means of returning goods to the supplier in the event of a problem;
- a country-wide service;
- very short delivery times;
- delivery of very small packages;
- a method of secure payment;

For companies that already had a traditional business and provided a home delivery service, e-commerce was initially just an add-on. Sometimes this last link of the chain has been outsourced to specialised carriers. These services may seem to be unprofitable in the short term, but they can be important in building up a strategic client base from which highly useful commercial data on customers' buying habits could be extracted. With regard to the subject of the study conducted here, some observers think that home delivery services for groceries could play an important role in reducing car use for food shopping, but there aren't enough studies to prove this positive impact on the environment. Others are concerned that home shopping schemes could be detrimental to the environment, as they could generate large numbers of extra van trips.
The research questions this thesis aims to answer are:

- Will development and implementation of home delivery solutions benefit the environment, especially concerning vehicle emissions?

- Under which conditions and with which home delivery solution are the environmental impacts of e-commerce positive?

1.4 Focus and limitation

Transportation is essential for the functioning of modern societies. A well-developed transport system will favor the development of the economy and will also allow people a greater choice of location for work, trade, living, shopping etc.
My thesis will evaluate how the growth of e-commerce in the grocery industry will influence transportation and consequently the emissions by vehicles. The sector's contribution to air pollution was reduced substantially across Europe but transport also contributes to cause several environmental (and health) problems, particularly climate change, acidification, local air pollution, noise, land take, and the fragmentation and disruption of natural habitats. E-commerce activity could impact considerably in these problems, due to the indirect influence of home delivery service in transport.E-commerce

[9] OECD, Organization for Economic Co-operation and Development, discussions on the impact of e-commerce on transport, 2001

is a broad field including several applications and businesses, and this can cause many different effects on the environment. That's why first of all I will define clearly the focus and the limitation of my work (also see fig. 1).

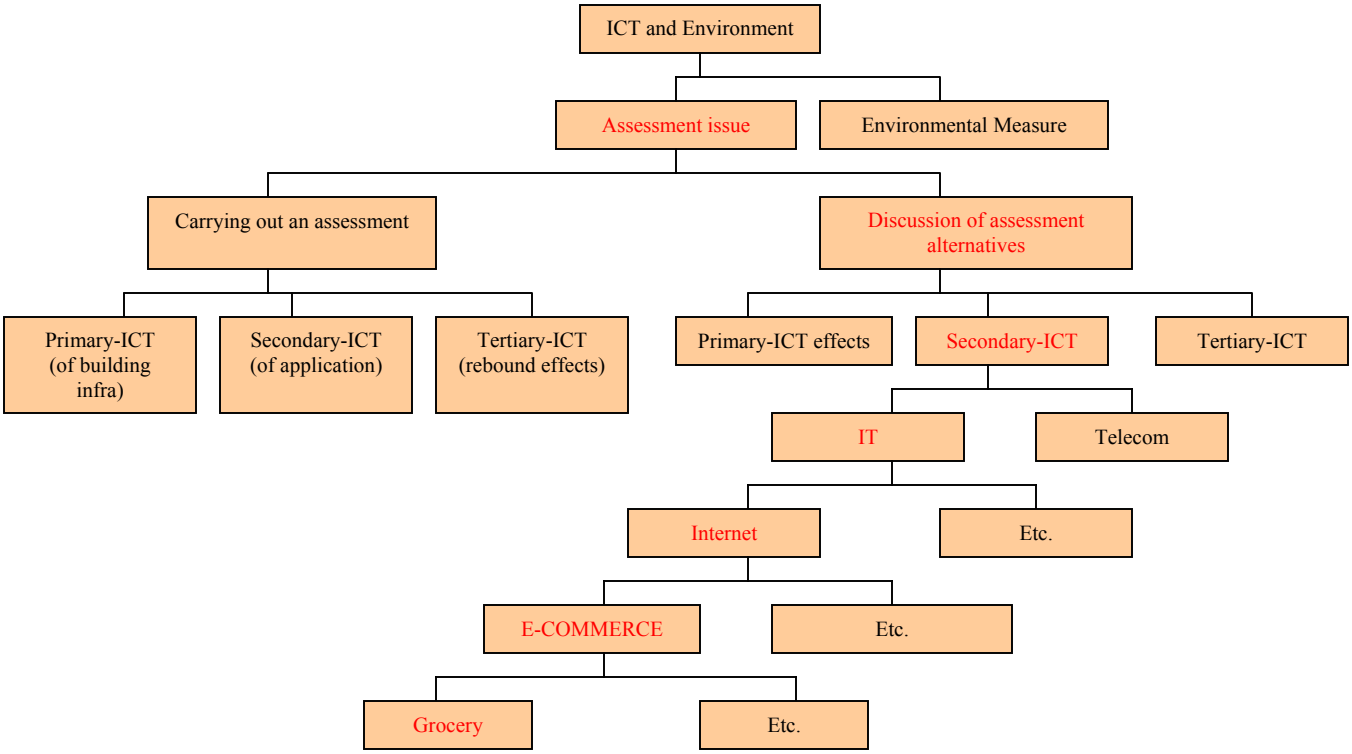


Figure 1: Thesis demarcations and focus[10]

[10] Sajed M. Abukhader, The Environmental Implications of Electronic Commerce – The Assessment Approach Problem, Department of Design Sciences, Sweden 2003

1.4.1 E-Commerce in the broader context of ICT[11]

E-commerce position

First I will define my work focus underlining the position of e-commerce in the broad field of ICT (Information and Communication Technology).

The term "IT" (Information Technology) is included in a larger term, which is "ICT" (ICT = IT + Telecom). This context includes the hardware and the software that run them and can be considered the equipment part of the "ICT". The application part of "ICT" is for example teleconferencing, teleworking, etc.

"Internet" is just one "ICT". We can consider personal computers and software like the equipment of "Internet", while the applications are for example information retrieval, mailing, trading, chatting, etc.

"E-commerce" (electronic commerce) is a phenomenon that is generally associated to the Internet, although we can find e-commerce applications like "EDI" (Electronic Data Interchange) or others that do not necessarily use the Net..

Food and non-food[12]

My work focusses on e-commerce for the grocery industry. So, the next step is to underline the differences between the food home shopping services and the home services for non-food goods. According to Sally Cairns (1999), three important environmental factors that differentiate these two business can be identified:

1) For non-food goods, the van trip is rarely likely to replace a dedicated car trip, while this is often true for the grocery shopping. Usually people go out solely to do their main food shop, while most people do not go out just to buy for example one CD or one t-shirt.
2) Home shopping companies for non-food goods often operate from more centralised, picking-and-packing centers. In this way, individual car trips to a shopping centre will potentially be replaced by much longer van trips.
3) TV selling, Internet selling and catalogue sales are all seen as an increasingly European with global opportunity. This "global selling" requires a far more sophisticated distribution system with interactions between international retailers and national distribution networks. Clearly, in these circumstances, home delivery could constitute an "environmental disaster", because of the large increase in the amount of long distance van travel, without necessarily reducing individual car travel for shopping. This scenario could interest the non-food goods, while I think it can't influence the grocery distribution system.

[11] Sajed M. Abukhader, The Environmental Implications of Electronic Commerce – The Assessment Approach Problem, Department of Design Sciences, Sweden 2003

[12] Sally Cairns, Home delivery of shopping: the environmental consequences, working paper 1999

It is thus important to underline that this thesis analyses a specific form of e-commerce (online grocery), which implies big differences in implementation and impacts on the environment compared with the other forms of e-business.

B2B and B2C[13]

As is well knows, the term e-commerce can refer to the exchange of information and the transactions between different firms (so called business-to-business electronic commerce or B2B), or between firms and consumers (B2C) relations).

In B2B the Internet functions are deemed to offer a number of advantages. For instance, the supplier receives orders with a substantially higher degree of reliability and often predictability. Business customers can accelerate the entire ordering process, receive delivery faster, and are able to follow the status of their order on-line. In addition, greater market transparency (offers, prices) can result, and changes can easily be processed within a fraction of the time required before. Today, the majority of e-commerce applications regard B2B transactions, while for B2C relationships, the degree of change required appears more difficult to implement, because it involves the traditional customer behaviors. Today, according to OECD research, about 70-85% of all electronic commerce transactions refer to B2B exchanges[14].

In any case, my study focusses on B2C-related e-commerce, that is significantly less important in terms of number and value of operations today, but it could become critical for the economy (and also the environment) in the near future. In particular, this thesis focusses on the emissions by vehicles involved in home delivery services, so it considers only the relation between retailer and customer (B2C) and not the others (B2B). In addition, most innovations induced by e-commerce refer to the "front-end" part of the system, which comprises the customer-related activities, such as order, receiving, sales and marketing. The so-called "back-end" regards the processing and shipment of the ordered good. This is the central aspect took in consideration in the analysis conducted here.

1.4.2 Environmental impacts

In the previous paragraph, I underlined that my thesis analyses the home delivery service (B2C relation) in the food sector. In this paragraph, I want to make clearer which environmental aspects are taken into consideration. We said that e-commerce influences transport, and transport is a significant source of emissions of acidifying pollutants, eutrophying compounds, ozone precursors and particulate matter[15]. Beyond transportation, the food distribution system is important in GHG emissions also from many other perspectives, such as land use and energy consumption[16]. Road transport is

[13] Markus Hesse, Shipping news: the implications of electronic commerce for logistics and freight transport, June 2002, Berlin, Germany

[14] OECD, 2000

[15] European Environment Agency, Europe's environment report 2003, Transport

[16] Siikavirta, Punakivi, Kärkkäinen and Linnanen, Effects of E-commerce on Greenhouse Gas Emissions, Finland 2003

also mayor cause of noise nuisance, especially in the urban zones. In big lines, we can distinguish three main categories of environmental effects of e-commerce:[17]

1) *Fist-order effects*. E-commerce presupposes the availability of an ICT infrastructure. The production and use of ICT infrastructure cause material flows, use of substances, and lead to energy consumption and electronic waste.

2) *Second-order effects*. E-commerce is transforming economic processes and markets. E-markets, virtual business networks, and the digitalization of products and services entail environmental consequences, for example, for resource productivity, transportation, and land use. These are the main aspects that are analysed in my thesis, especially referring to logistics. Previous studies show that the effect of e-commerce on logistics may be either beneficial or damaging for the environment, depending on several parameters. My study is focalised on the direct effects of electronic grocery on traffic, which might be of greater significance with regard to overall environmental impacts.

3) *Third-order effects*. E-commerce may cause structural changes in the economy and affect lifestyles and consumption patterns, which, in turn, indirectly affect the environment. If the rate of efficiency increase is lower than the growth rate of consumption, we have the so-called rebound effect. The rebound effects of ICT and e-commerce is a major challenge for national and international environmental politics.

The overall environmental effects of e-commerce cannot yet be predicted, but it is obvious that the Internet economy is not and will not be "weightless economy". My thesis takes in consideration a little aspect of the bigger field of e-commerce and a little aspect of the environmental effects of it. However, this work is intended to be a starting point to understand the development of e-commerce from a perspective that includes environmental sustainability.

1.5 Scope of the thesis

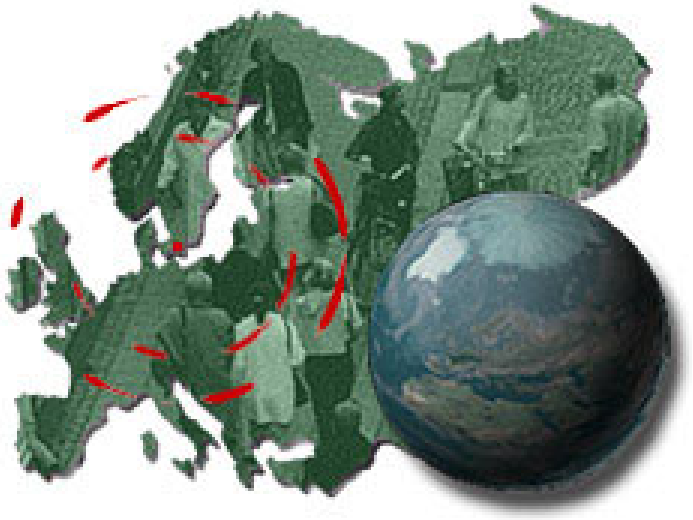
In these years much research has been done about the effects that e-commerce could have on the emissions. The results are contrasting. Some studies say that e-shopping causes a reduction of traffic because people can buy groceries from the Internet without using the car; others state that e-commerce will cause an environmental disaster. Probably, the best way to study this subject is to start from the beginning, i.e. supposing that e-commerce does not exist at all, and estimate the effects of its introduction. Firstly, the idea is thus to calculate the emissions of CO_2, NOx and particles for the case of traditional shopping, i.e. when the people go to the store by their private cars. The place where this study is conducted is Lund, an important city in the south of Sweden. The following step is to analyse the actual situation of e-commerce development in Lund and to calculate the

[17] Klaus Fichter, E-Commerce: Sorting Out the Environmental Consequences, 2003

emissions of the grocery distribution system considering the current share of e-commerce users. Then a comparison is possible between the traditional shopping and the new e-commerce schemes, to understand if and in what circumstances the effects can be beneficial for the environment. The last step is to draw possible future scenario by changing factors and variables.
In this way it becomes possible to understand, thanks to actual data, if the implementation of home delivery service will be environmental friendly or not, which are the better delivery solutions and under which conditions e-commerce can be beneficial in an environmental point of view.

1.6 Lund presentation[18]

My study is done in Lund, the twelfth largest municipality in Sweden, centrally situated in the "Öresund" region, in the southern part of the country. The city is built on a medieval network of streets and bears a cultural-historical identity provided by its old buildings and surroundings, and is famous in the world like an important university centre.



Lund covers 447.2 km^2, of which 22.9 km^2 is densely populated. The population is of 100 402 residents and the age group 20-29 (21%) is remarkably higher than the national average (13%), due largely to the students at the university. 130 nationalities are represented among the residents, thanks especially to the high number of foreign students. The average age of the population is 37 years while in all of Sweden is 40 years. The level of people education is very high: 58% of Lund's population between the ages of 25 and 64 have a university education. The total for Sweden as a whole is 29%.

The working part of the population between 20 and 64 years of age is quite low (64.3%) because of the large age group 20-29 of people that study.

These particular characteristics make Lund a bit special compared with a normal city, and different purchase habits could be analysed because of the higher number of young residents. Anyway in my calculations I will not consider this aspect, and I will assume the buying patterns of people in Lund as the "normal" ones for any city in south of Sweden.

The high level of education makes this zone positive for the development of e-commerce activities because people are supposed to have more confidence with the use of the computer and Internet. That's why two important groceries of Lund have decided to start this business and to offer to the customer this service. The two important e-commerce players are ICA Vildgåsen and ICA Malmborgs Clemenstorget, both situated in the highest densely populated zone of the city. Anyway the share of e-

[18] www.lund.se

commerce users in Lund today is very low (about 1%)[19] and groceries considered it only a marginal business compared to the traditional shopping. In 1999 there was an attempt to create a "pure" e-commerce activity in this zone. Matomera was unique in Sweden in its concept of selling groceries only on the Internet with no supporting physical store using a dedicated warehouse especially designed for this purpose. The company ended in 2001 because of the low volume of affairs.[20] The city of Lund is a fertile ground for a host of new ideas focusing on the environment. The UN plan of action for long-term sustainable development, Agenda 21, is regarded as the utmost seriousness in Lund. Lund's own Agenda 21 has first and foremost endeavoured to reduce the use of fossil fuels (coal, oil, peat, fossil gas), thereby reducing environmentally damaging carbon dioxide emission. Since the largest source of this emission in Lund is from vehicles used for transport, work has begun on LundaMaTs, an environmentally adjusted transportation system.

[19] Stefan Holst interview, ICA Malmborgs director, 2004
[20] Matomera, Carlheim-Gyllenskiöld and Rangefelt, Department of Design Sciences, Lund University, 2002

2 METHODOLOGY

There are many ways to approach a research problem. This chapter presents my views of methodological issues and describes the research process of my study.

2.1 Research Approach

I will refer directly to the works of Abnor and Bjerke, that describe three main methodology approaches in a range from subjective to objective study. According to these authors, the explanatory and understanding knowledge can be achieved through *Analytical*, *Systems* or *Actor* approaches.[21] The *Analytical* approach is considered to be the most objective – explaining phenomena –, the *Systems* approach has the purpose of both explaining and understanding a phenomenon, while the *Actor* approach is considered to be the most subjective, focusing on understanding phenomena.[22] My thesis is carried out from a *Systems* perspective due to the characteristics of the issue investigated. This is due to the fact that it's a clearly defined system, where individual variables are very dependent on each other. The *Systems* approach is also very well suited for analysing logistics[23], which is an important subject of my thesis. Based on this, this appears to be the most suitable approach for the issue at hand.
The fundamental thought in the *Systems* approach is that reality has to be studied as a system[24]. A general definition of system is:

"*Something that due to its separate elements reciprocal action and structure has a certain function. This will mean that the system as a whole has different characteristics, from the separate elements characteristics*"[25]

Combined together, the elements of a system create synergy effects. If the system is not studied as a whole, these effects can't be seen.[26]

In my thesis I considered the home delivery service as a system in a complex environment, I tried to identify the different components of the system and the interaction between them, as suggested in the *Systems* approach definitions[27] (see also paragraph 2.2.4). A system approach means that one must understand and take into consideration the context of the research.

Having said that, research on a system can be done in either a *quantitative* or in a *qualitative* way.
Q*uantitative* research seeks to find and understand an overall picture of a research problem, through for example a survey sent to a statistically correct selection group.

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[21] Bjerke, 1981, No. 8
[22] Claes Wallin, Contract packaging and its implications for the supply chain, Thesis work, Department of Design Sciences, Lund 2003
[23] Lambert et al, 1998, p. 9-10
[24] Bjerke 1981, No. 8, p. 7
[25] Wallen, 1996, p. 28
[26] Arbnor, Bjerke, 1997, p. 64-70
[27] Wallen G. (1993), Lund

Q*ualitative* research is another approach; for instance the researcher is interested in trying to understand how the environment reacts changing some variables, and this is analysed by means of qualitative observations. A deep understanding of the structure of the problem and the nature of causal relations can be achieved, although quantitative relations are not explored.

In summary, this thesis is based on a *Systems* approach with an initial *qualitative* research. The collection of data, by literature studies, case-studies and interviews, has been made using a *qualitative* approach to find the factors that influence the system and the relations between them. The analysis involves a complex system of several connected variables (*Systems* approach). A second step consists on the development of a mathematical model based on *quantitative* relations. Computer simulations on a mathematical model have been then made to predict data about emissions associated with home delivery service in the city of Lund.

2.2 Collection of data

Collection of data has been made through literature studies, case-studies and interviews. Generally, we can classify data into two categories[28]: *primary* data is information directly collected by the researcher for the purpose of the study. *Secondary* data is information collected by others for different purposes, but still used in the work. In my thesis, *primary* data are data collected through interviews or coming from simulations and calculations. *Secondary* data are data collected from previous studies in the literature.

2.2.1 Literature studies

With regard to this, different kinds of information sources are used. The literature studies have been found mainly at the Lund University libraries and at the Division of Packaging Logistics in Lund. These information sources give a great variety of different literature needed for the outcome of the thesis. The research has been focused on four different areas (key-words):

1) E-commerce;
2) Environmental impacts;
3) Online grocery;
4) Home delivery service;

The literature study includes previous studies, such as thesis and reports, websites, articles, statistics, and was made in order to achieve understanding of the four different areas, and to find useful models to use in the thesis. The research was made in various

[28] Karin Samuelsson, Thesis work, Packaging logistics at Schenker, 2003

databases[29] and mixing the four key-words, so that to compare the information from different sources and to obtain a broader perspective of the problem.

2.2.2 Interviews

The model (based on an Excel spreadsheet) and the calculations are based mainly on data collected from the Internet about Lund, and on the interview with Stefan Holst, the ICA Malmborgs director. This supermarket is located in the center of Lund and offers home delivery service to the customers. The interview was done to obtain specific information in the area of home delivery in Lund and to obtain some opinions about the future of e-commerce in Lund. Questions were categorized in two big areas: the technical questions and the general questions (the questionnaire is shown in appendix 9.6).
Other information was obtained from different people, especially in the field of the environment and the emissions. Another interview was done to Fredrik Orremo (author of the thesis: "It, mat och miljo"; Department of Design Sciences, Lund University) to develop the Excel model used to evaluate the emissions of the different home delivery solutions. The interviews were made in person.

2.2.3 Case-studies

Previous case-studies about e-commerce were in order to understand the most important factors that influence the home delivery systems. For example, the case of Matomera (a "pure" e-commerce player in the south of Sweden[30]) was very important to understand the logistic implications of e-commerce. It is worth to note that Matomera stopped the activity in March 2001, because of the low volume of customers. Anyway the study of this and other real cases allowed to focus the problem and to identify the most important variables involved and the relations between them.

2.2.4 System modeling and computer simulation

The system considered in this study is the e-grocery system in the city of Lund (Sweden), with an emphasis on the emissions due to the home delivery service. The study was done using an Excel model that compares vehicle emissions of traditional shopping (mainly done by car) with the emissions deriving from e-commerce shopping.[31] Knowledge collected from previous literature shows that certain factors influence more than others the environmental impacts of home delivery service. These aspects were taken under

[29] ELIN (Electronic Library Information Navigator), provided by Lund University Libraries, Head Office.
[30] Matomera, Carlheim-Gyllenskiöld and Rangefelt, Department of Design Sciences, Lund University, 2002

[31] Orremo & Wallin, It mat och miljo; Division of Packaging Logistics, Department of Design Sciences, Lund University 1999

special consideration and were used as a starting point of this analysis. The following picture shows the most important factors considered in the Excel model, and its structure:

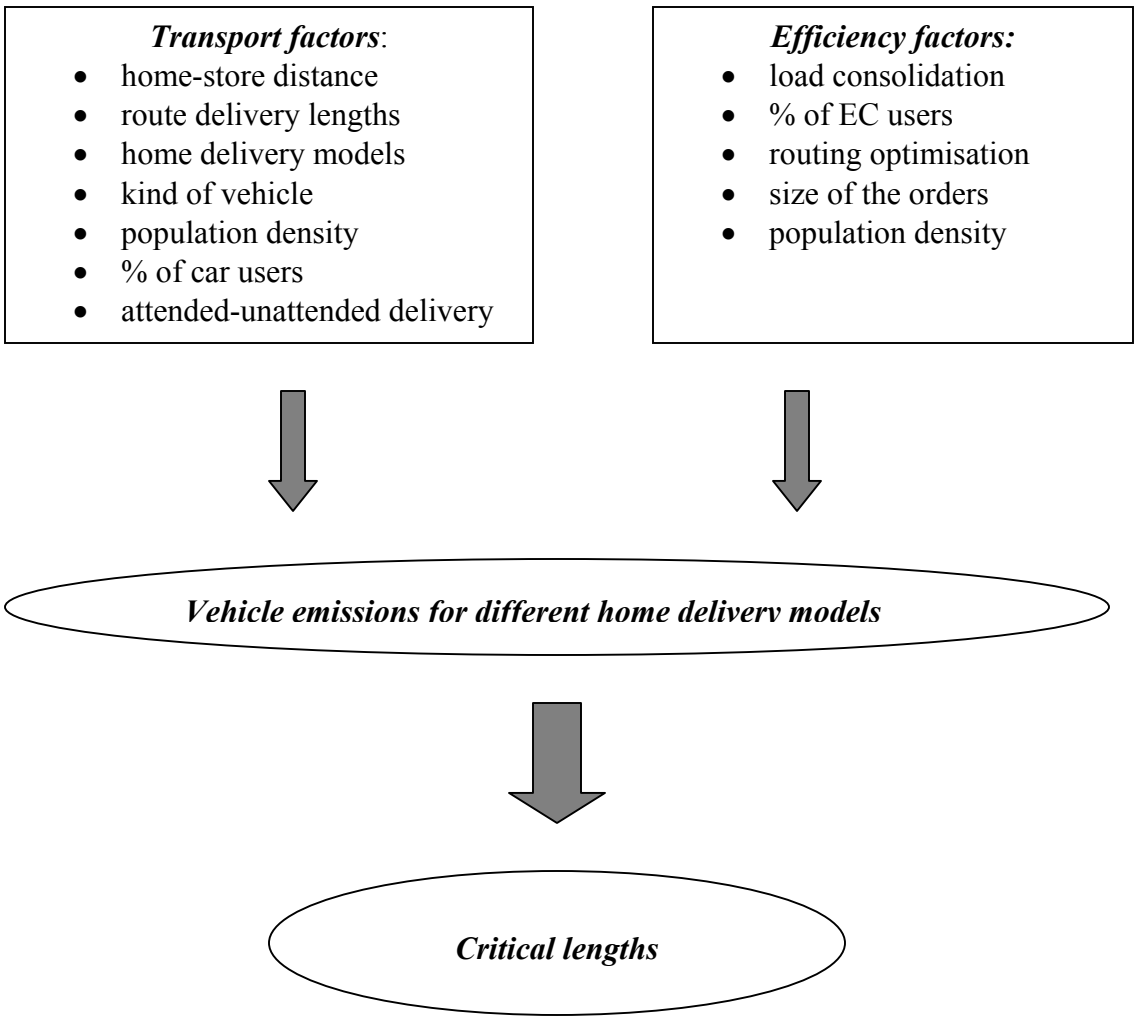

Figure 2: Structure and factors of the Excel model

The scope of the Excel model is to obtain primary data about the vehicle emissions of the traditional shopping and the emissions of the e-commerce system. The model permits also to make a comparison between these two shopping solutions, so that to obtain the critical lengths. A critical length indicates how long the van or truck distribution route could be before the delivery route effluents more emissions than the corresponding traditional shopping.

2.3 Research Process

Figure 3 illustrates the work process, to make a comprehensible picture of the course of action of this study.

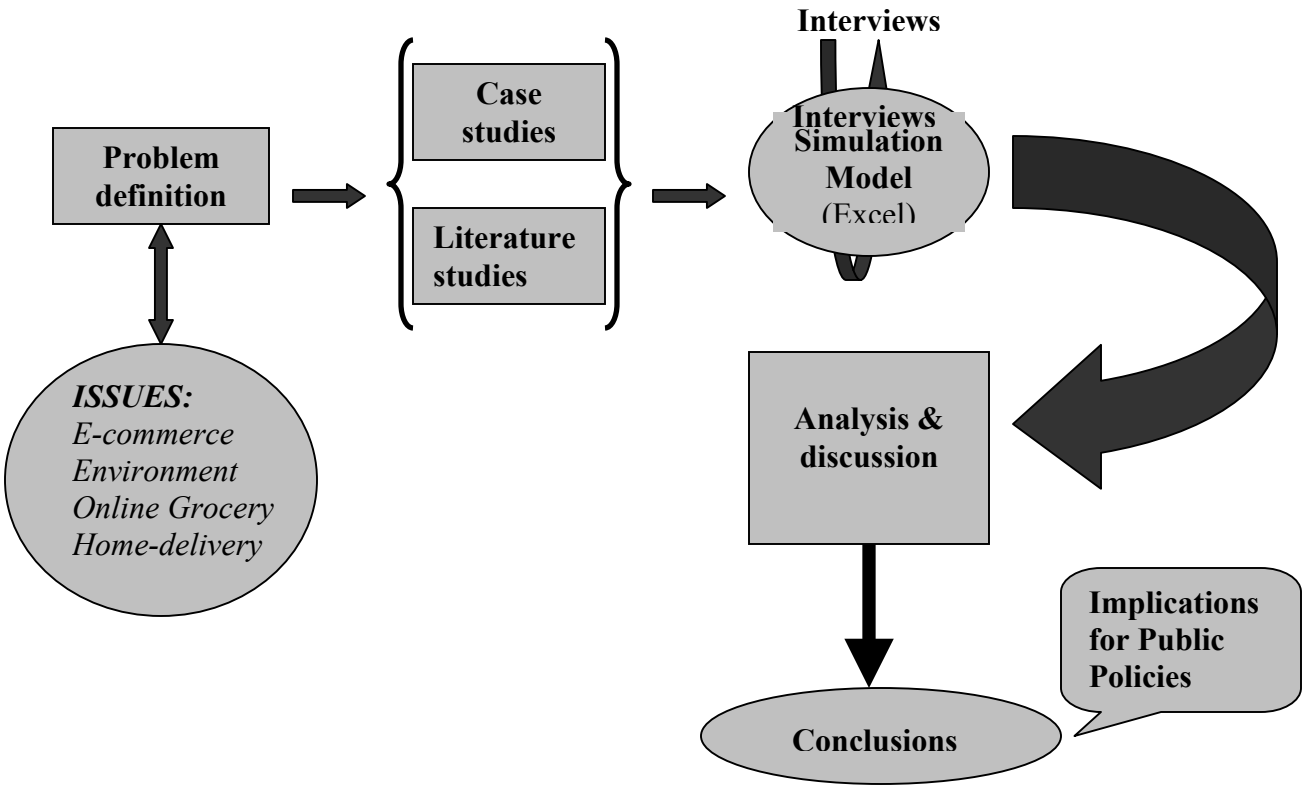

Figure 3: The thesis approach

The research problem was first formulated, by mixing together the four different areas of study. To get an overall knowledge of the problem to be investigated, research of literature and documents were done, as described above. Based this general knowledge, the case study in Lund and the simulation Excel model was with the help of the secondary data collected from interviews. Thanks to the model a collection of primary data was obtained. The analysis and discussion was made to debate primary and secondary data and make valuable conclusions.

Personal viewpoints by the author have built, been taken into consideration and, on the basis of the conclusions, a brief discussion on implications for public policies is proposed.

3 DISTRIBUTION SYSTEMS

During the last 10 years a consolidation and concentration process is going on in the food & grocery sector in all the major countries with a strengthening of the large wholesalers'.[32]
The same process characterises Sweden, where the grocery wholesaler market is today controlled by three major companies: Ica, Coop and Axfood. Ica is without doubts the market leader with the 37.2% of market share, followed by Coop (18.2%) and Axfood (16.8%) who represent roughly the same market share (see fig. 4).

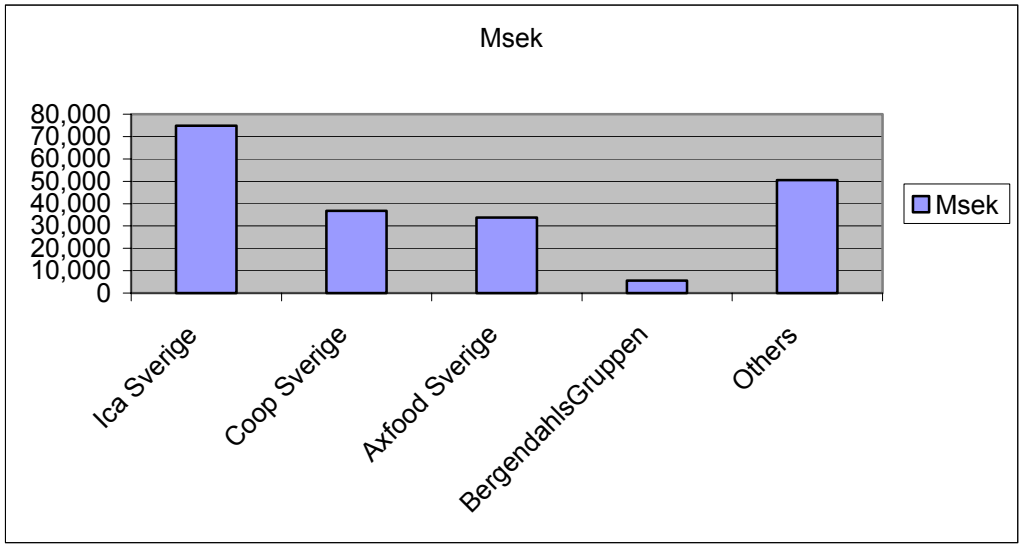

Figure 4: Swedish grocery wholesaler market[33]

This trend is also connected to the applications of information and communication technology (ICT) that are developing in the grocery sector and are adopted by the most important sector's actors. The ICT adoption is the first step toward an informative standardization that concurs for an efficient and integrated management of information flows, but in most cases these sistems are difficult and expensive to implement. For this reason, only the big and consolidate companies can exploit these technologies.

[32] Ettore Bolisani: La grande distribuzione alimentare on-line, 2004
[33] Supermarket (Swedish magazine): www.forlaget.ica.se

3.1 On-line distribution models

The Internet diffusion is opening new markets and scenarios for the grocery industry. Selling on-line is often seen as a "perfect" solution for the increasingly frantic rush characterising the consumers' activities in the post-industrial economies. Thanks to e-commerce, the customer has the opportunity to buy goods using the computer at home, saving both time and car trips. Clearly, the functions of picking and delivering, that are usually done by the customers themselves in the traditional shopping, have to be arranged by the e-retailer. One of the most significant obstacles for the growth of e-commerce in general and the e-grocery business in particular is the lack of a suitable logistic solution for home delivery.[34] In my thesis, I intend to analyse some logistic solutions for home delivery, in order to compare them with the traditional purchase in an environmental point of view.
It is firs useful to classify the categories of online retailers. According to Bolisani (2004), we can classify on-line retailers in two categories:

a) Warehouse direct delivery (or *virtual reseller*): this is an e-grocer that has its own warehouses to stock the goods to be delivered once ordered by customers (fig. 5). In some cases this can be a service storage, but more often it is a traditional store that is also used as point of delivery for electronic orders.

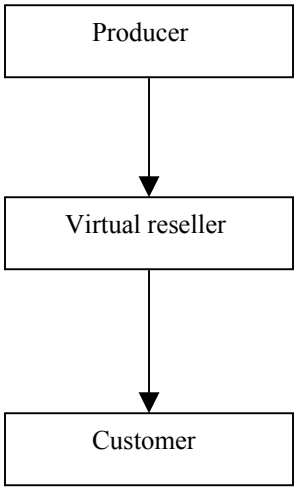

Figure 5: the virtual reseller supply chain

b) Third-party store-based delivery (or *virtual mall*): this operator sells on-line goods on behalf of others, i.e. never becoming the physical owner of the products sold. These operators are middlemen that present the offerings of different suppliers, collect the orders, and transmit them to the sellers' Web systems (pure mall). In other cases they could even buy goods from the suppliers when ordered by the customer, and deliver it

[34] Punakivi and Saranen: Identifying the success factors in e-grocery home delivery, 2001

directly to the homes (real virtual mall). Goods can come from manufacturers, or other traditional stores (supermarkets, etc.). In both cases the agreements with the suppliers (producers) or with the stores are critical. In fact, the sellers should permit the use their warehouses and point of sales as storage for the deliveries, and in turn have the chance to activate their network presence through to the mall platform.

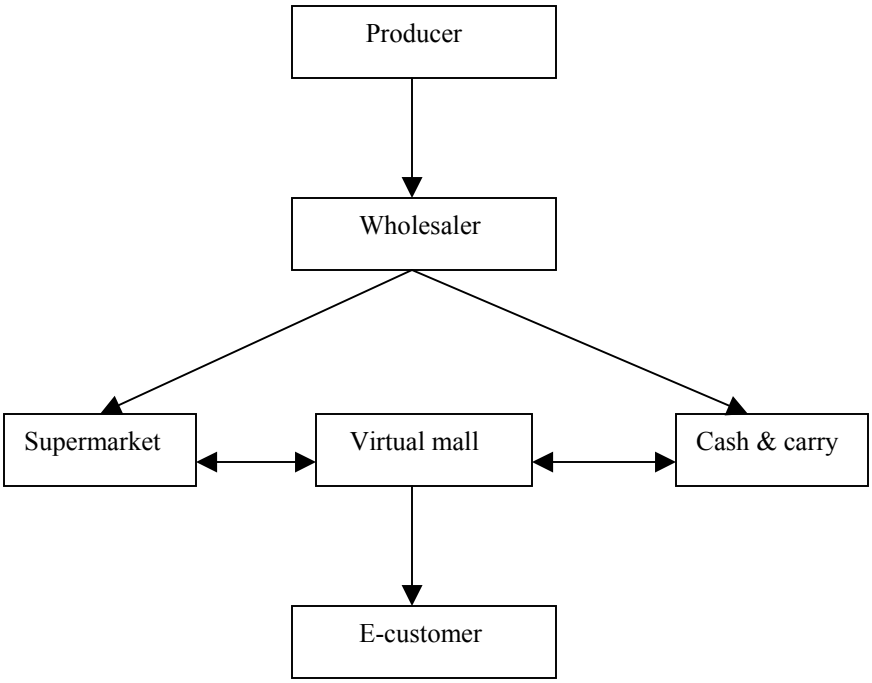

Figure 6: a virtual mall solution[35]

Most of the actual big distribution e-player fall into the category of virtual reseller, while the virtual mall category is not very effective and it has little success.
According to the literature and existing case-studies, companies with existing infrastructure ("traditional food retailers") tend to use their stores and warehouses (at least at start up) to enter in the new e-grocery market.[36] When sales volumes are sufficiently large, they can decide to create a totally new direct channel (i.e. dedicated distribution centers). Today many Swedish e-commerce solutions in the grocery sector adopt the in-store model, i.e. picking and packing the goods in their conventional stores. This approach minimize the initial investment and can be set up.

[35] Vesa Kämäräinen: The reception box impact on home delivery efficiency in the e-grocery business, 2001
[36] Rene´ B.M. de Koster: Distribution structures for food home shopping, 2002

We can also classify the operators in accordance with another criterion: the "pure Internet player" is the operator born exclusively in an e-commerce context, while the "incumbent" operator is the traditional company with part of the activities online. Until 2001 there was a substantial equal division into these two categories but today, with the collapse of most of the "pure Internet players", there are much more "incumbent" operators. Ring and Tigert (2001) assert that there are a number of significant factors causing the collapse of the "pure players". First, they have failed in achieving a competitive advantage over the traditional food retailers on those dimensions that drive the consumer store/channel choice process. Secondly, they have failed in developing profitable business models; and, thirdly, they have dramatically overestimated the size of the market for grocery shopping from the home.[37]
By analyzing the situation of e-grocery in Lund, the same trend can be found, and the two existing firms use part of their pre-existing facilities for the e-commerce activity (i.e. the "incumbent" model). Having said that, in my thesis I will attempt to compare the environmental impacts (in terms of emissions of vans and trucks) of different home delivery solutions with the corresponding traditional shopping (emissions of customers' car trips). The most important assumption is that delivery vehicles act as a straightforward substitute for car trips. The question is what happens if the consumers only switch part of their ("boring") purchases into e-commerce and keep shopping the rest of their purchases in the traditional way. In this case the delivery vehicle emissions associated with e-commerce must be added to the traditional car trips of the customers, with a negative overall consequence for the environment. Unfortunately, according with Stefan Hölst, director of the Ica Malmborgs Clemenstorget in Lund, the current trend seems exactly that of people using e-commerce just to order the big, heavy or "boring" goods, while they continue to go to the traditional store for buying the other products. In this way, the delivery of on-line-ordered products to the household does not eliminate customers' shopping trips, and e-commerce is likely to reinforce the longstanding trend of transport growth, rather than reducing it. In any case, I will make a comparison considering different scenarios, so that to clarify if and under what conditions e-commerce could have beneficial effects for traffic reduction, and identify the best home delivery solution from an environmental point of view.

3.2 Distribution channels

Corporate logistics is usually divided into three functions: supply, production and distribution. Many firms are now following a more integrated approach, which emerged as a result of the upcoming demand for flexibility.[38] In fact, time has become critical in value creation, and the introduction of new information and communication technologies could help the firms. My research work focusses on the application of these technologies on e-grocery distribution solutions and on their environmental impacts.

[37] Anckar, Walden and Felassi: Creating customer value in online grocery shopping, 2002
[38] Markus Hesse, Shipping news: the implications of EC for logistics and freight transport, june 2002

3.2.1 Standard approach

As mentioned, the Swedish market for groceries consists of three big actors ICA, Coop and Axfood which together control more than 70 percent of the grocery market.[39] Before the advent of e-commerce, the supply chain was more or less identical for the majority of the grocery stores.[40] There were normally two links between the manufacturer and the consumer. The links were the wholesaler and the retail store.[41] Due to the fact that the final transportation is traditionally responsibility of the consumer, the costs of distribution in retail industry are associated to the physical flow to the store.[42]
The supply flow within Swedish grocery retailing is shown in fig. 7:

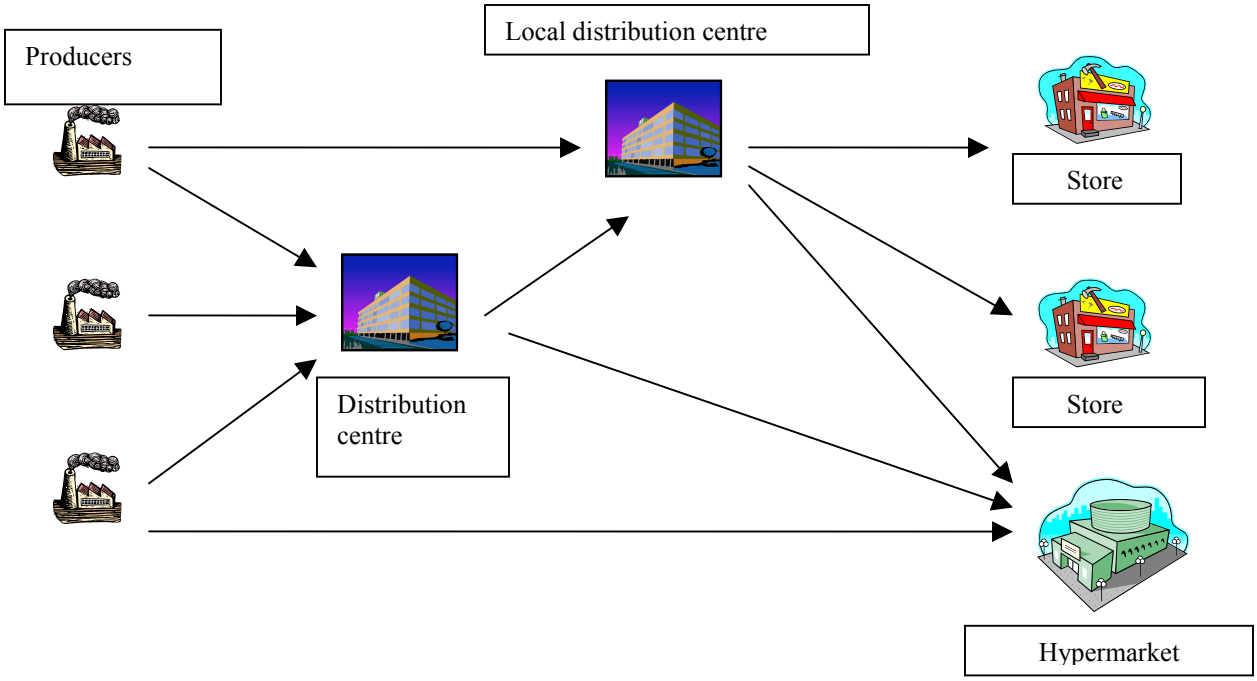

Figure 7:The supply flow within Swedish grocery retailing.[43]

The goods come from many producers and go to the local distribution centers, and then directly to the hypermarket. In figure 7 there is a difference between "distribution

[39] Supermarket Nbr. 6-7, published by ICA 1999
[40] Orremo and Wallin: IT, mat och miljö, Department of Packaging Logistics, Lund Institute of Technology, Lund, 1999
[41] Annika Olsson, Home Shopping: cost and function analysis of a future grocery distribution system, Thesis work, 1997
[42] Carlheim-Gyllenskiöld and Rangefelt: Matomera, Department of Packaging Logistics, Lund Institute of Technology, Lund, 2002
[43] Orremo and Wallin: IT, mat och miljö, Department of Packaging Logistics, Lund Institute of Technology, Lund, 1999

centres" and "local distribution centres". The local distribution center stores goods and to distribute it to the points of sale. The distribution center collects the goods from different producers and then, in a consolidated way, distribute it to the local distribution center or to the stores directly. From which center the stores get their supply depends on the size of the store.[44] The final step is the transport from the store to the customers' home. Traditionally this activity is performed by the customers themselves, after buying the goods from the store.
However, this traditional way of distribution for groceries might endure transformations in the future.

3.2.2 New approaches

With the advent of e-commerce, the activities that are carried out by the customer today, i.e. grocery assembly and home delivery, must be done by the retailer, which adds new components to the retail price. E-customers can buy the goods from their computer at home, and this can impact on the structure of the supply chain for groceries (see fig. 8). The most radical change can be the direct connection between consumers and producers: one e-commerce solution in fact can be the producers that offer their goods directly to the consumers through the Internet, and bypass all the traditional supply chain steps. In this case, highly bundled shipments to retailers are substituted with single shipments to each end consumer, and that means that the producers will have to completely reconfigure their established logistic systems, from consolidated shipments to small packages which have to be shipped directly to the customer. This phenomenon is called disintermediation. The most important reason for this phenomenon is the fact that each stage in the chain adds costs in the form of handling, shipping, profits and transaction costs.[45] A producer offering direct home delivery might retain the profits deriving from elimination of intermediaries, but at the same time it should be evaluated whether or not these additional profits compensate the additional costs implied by direct home delivery.[46] Apart from the costs, this can also have potential effects on the environment.
The different possibilities are summarized in figure 8:

[44] Carlheim-Gyllenskiöld and Rangefelt: Matomera, Department of Packaging Logistics, Lund Institute of Technology, Lund, 2002
[45] Benjamin and Wigand, 1995
[46] Delfmann, Albers and Gehring, The impact of EC on logistic service providers, 2002

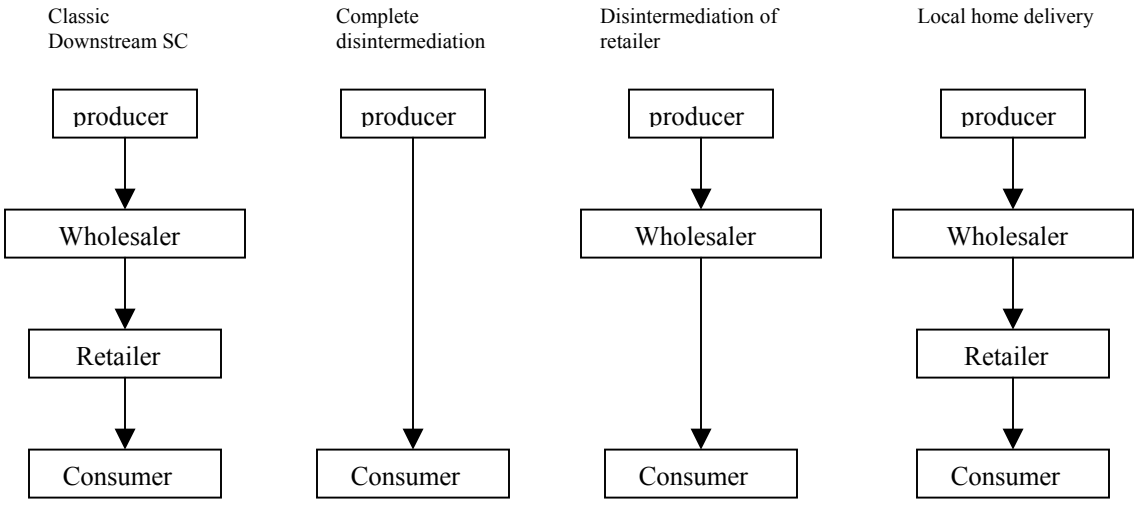

Figure 8: Forms of supply chain disintermediation

Fig. 8 shows that the classic supply chain is usually composed by four step: producer, wholesaler, retailer and consumer. The disintermediation phenomenon can generate the elimination of wholesaler and retailer (complete disintermediation), or the elimination only of the retailer (disintermediation of retailer). The last alternative is when e-commerce doesn't cause substantial changes in the structure of the supply chain (local home delivery).

One effect of disintermediation is that the total physical space of warehouses may be reduced, with consequent less use of land resources. It should be considered, however, that intermediaries not only cause costs, but can also add valuable services. For instance, every link in a supply chain works as an intermediate warehouse. Low warehouse levels lower the total costs, but also a system's ability to absorb variation peaks. Therefore, the competitive advantage of home distribution can not only rest on a cost reduction but should also be able to add value to the groceries and the customers. The home shopping system could have a competitive advantage by giving the customer real value-added products.[47] In short, the complete disintermediation is only a possible scenario (and not the most likely), while other situations are possible (see fig. 8). Current data show opposite cases, and in general the idea of a "death of middlemen" has been exaggerated.[48] There are various reasons for this. Beyond a reason for this is the geographical dispersion of producers, with consequent problem of geographical coverage of delivery service. Established distributors can therefore have advantages compared to other actors.
In addition to this, a recent trend is the increasing competitiveness of the so called "click-and-mortar" companies in online markets. They combine on-line sales and ordering systems with the traditional distribution at their store.[49]

[47] Annika Olsson, Home Shopping: cost and function analysis of a future grocery distribution system, Thesis work, 1997
[48] The Lehman-Brothers, 1999
[49] Markus Hesse, Shipping news: the implications of EC for logistics and freight transport, 2002

The environmental problem, as we saw, arises from the fact that the new online distribution channel does not completely replace the traditional logistics system, but it adds to it. This primarily happens in core, dense urban areas, where new economy and e-commerce firms are generally located. In these areas it is clearly impossible to use railway and waterway (that are less intensive in energy consumption and emissions) to deliver goods to the consumers homes, and the truck or van solution is used.
So it is important to analyze, beside the kind of disintermediation occurring in the supply chain, the structure of shipments introduced and designed to comply with the requirements of e-commerce. Also, sometimes firms are not able to develop and manage this logistic structure on their own, and decide for a co-operative strategy, which may result in strategic alliances with carriers or service providers.[50] Such outsourcing strategy implies a reduction of the personnel and other assets, that are remitted to others in the supply chain. However, since in any e-commerce solution a very critical activity is represented by the home delivery process implemented, the specific possible solutions have to be singled out first.

3.3 Home-delivery models[51]

Home delivery of groceries was not a very popular service among customers. In the past A reason for this was the time-consuming and expensive ordering process of the previous solutions (such as mail or TV shopping); in recent years, the Internet-based solutions have solved most of these problems related to the order transmission process.[52]
In any case, the issue of physical delivery of the goods to the customers' homes remains important. Four different home-delivery models can be singled out, that are the most used today (see e.g. the case-studies found in literature). In all these models, the e-grocer is a traditional supermarket that uses the pre-existing facilities, just to offer one more service to the customers (this is the situation in Lund, for instance).
In this case, e-customers are a share of the total number of customers of the store.

[50] Delfmann, Albers and Gehring: The impact of EC on logistics service providers, 2002
[51] Orremo and Wallin, Department of Desigh Sciences, Lund University, thesis work: IT, mat och miljö, 1999
[52] Vesa Kämäräinen: The reception box impact on home delivery efficiency in the e-grocery business, 2001

3.3.1 Model 1

In this solution the e-grocer delivers the goods by van (<3.5ton) and the customer must be at home in a pre-specified 2 hours time-window. This is the most popular delivery model today, and is used by Lund's operators too (see fig. 9). Each van contains up to 25 orders (this is also the value considered in the simulations conducted here). .

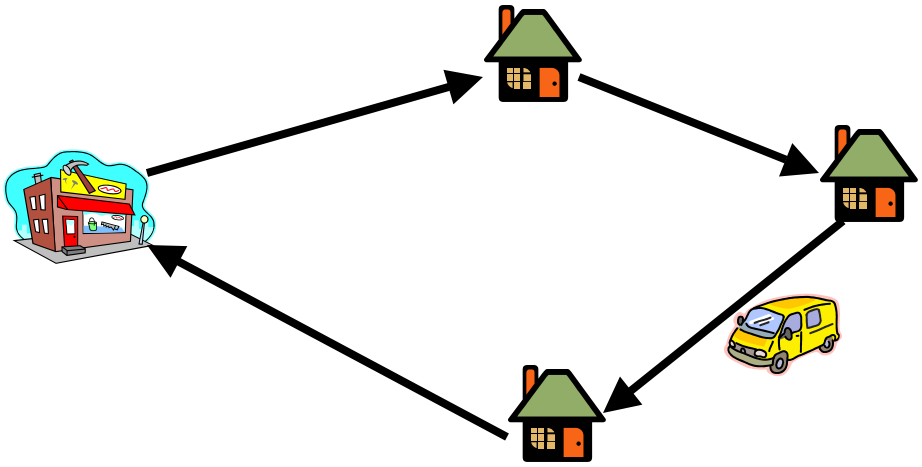

Figure 9: model 1, home delivery by van

3.3.2 Model 2

In this model the delivery is carried by larger trucks (3.5-16ton) directly to the working sites instead of homes of the customer. The reason is that at a working site more customers are available, and thus larger trucks with more loading space can be used.
Each truck contains an average of 120 orders (with a full utilization of the space). I'll sum these trucks emissions with the cars emissions of the workers that go to work by car and do e-purchases. I did that because it's more probable that workers go to work by car knowing that they have to take home the goods.

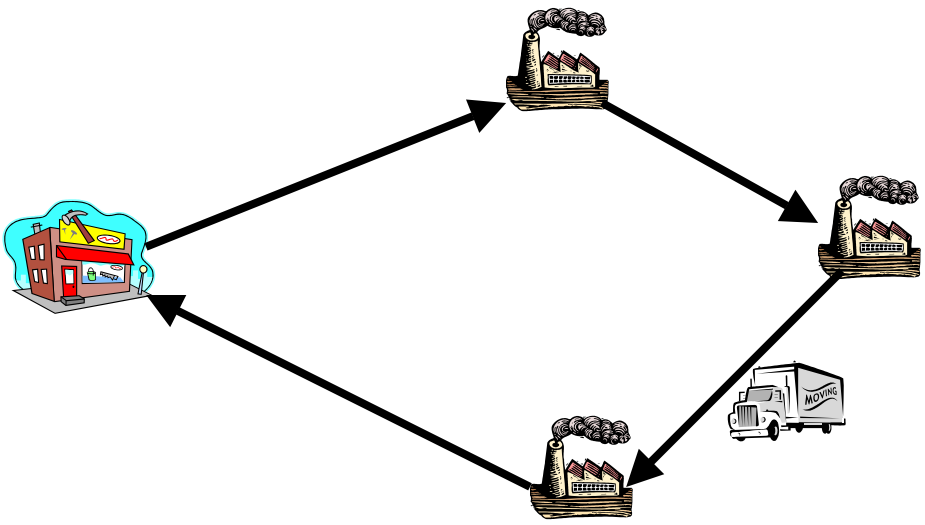

Figure 10: model 2, delivery to working sites

3.3.3 Model 3

In this solution the orders are delivered to specific pick-up points, where the customers collect the goods. The pick-up point can be a gas station, an area with multistory buildings, or similar (see fig. 11). Again, because of the high number of customers converging to each pick-up point, a large truck (3.5-16ton) can be used for the deliveries, with an average of 120 orders per truck. In addition, an average distance between home and pick-up point of 8 kilometers can be assumed; with reference to the environmental impact, truck emissions should be added with car emissions of the people that should go to collect the goods to the pick-up points by car (it is supposed that 100% of the customers go there by car). For small villages in the countryside, a local store can replace a pick-up point, but this case was not considered here.

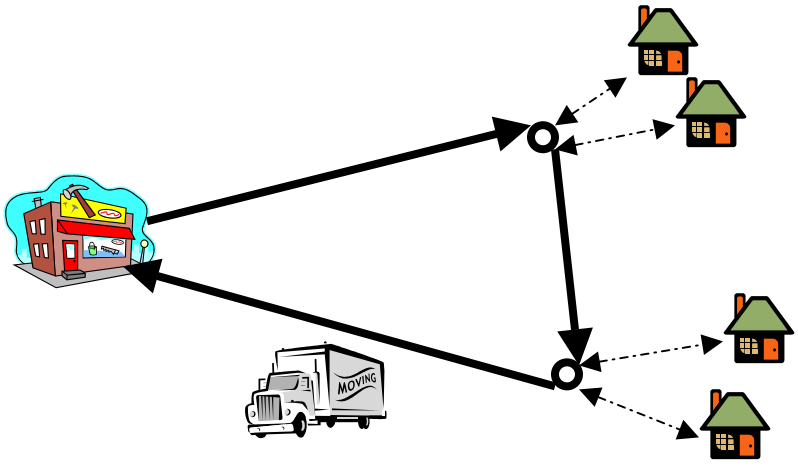

Figure 11: Model 3, delivery to pick-up points

3.3.4 Model 4

The profitability and efficiency of the e-commerce system depends on the volume of orders. In order to increase this volume, the delivery area needs to get bigger. A potential way to made it possible is the use of this model of home delivery.
Trucks(3.5-16ton) deliver to spreading points where the orders are shattered to smaller delivery vans(<3.5ton) that deliver to the customers home (see fig. 12).

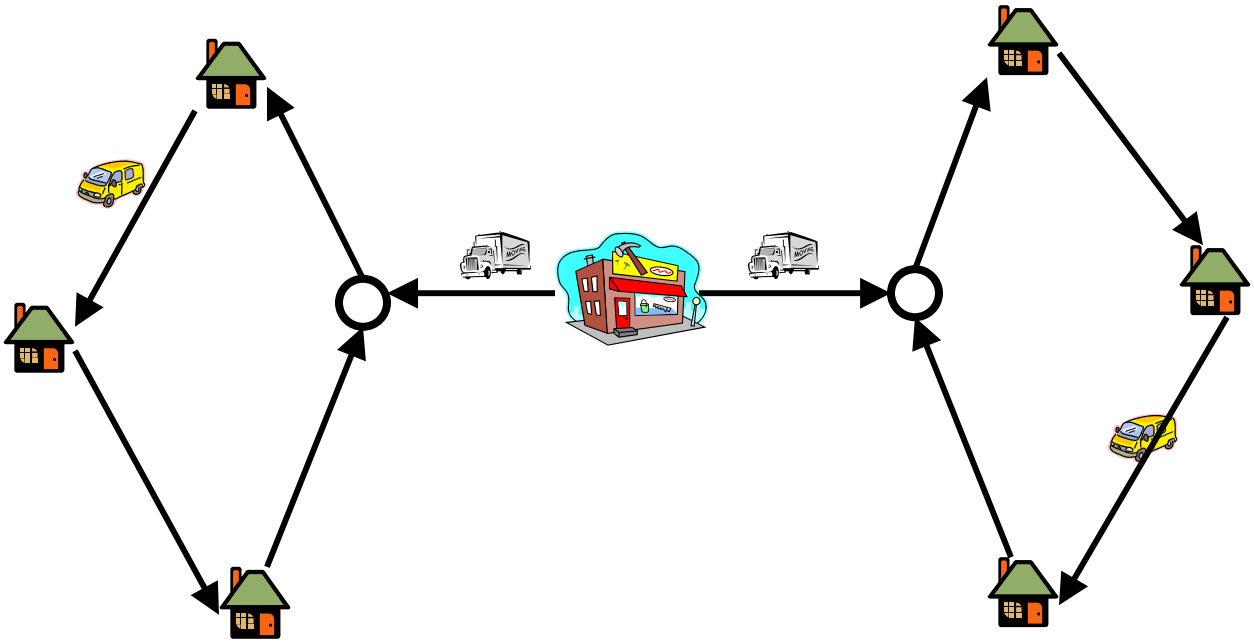

Figure 12: model 4. delivery to spreading points

3.4 Network optimization (environmental point of view)

There are lots of levers that can be used to reduce the environmental effects of e-Commerce and to optimize the sales network. In the following section, I tried to analyze some of these.

3.4.1 Routes planning

The routes optimization for trucks and vans can reduce vehicle miles, fuel consumption, and consequently the emissions. A way could be the installation of devices in trucks and vans that signal to drivers when they need to update their routes, thanks to information technologies. The Swedish freight company ASG, using these system, have reduced fuel consumption by 5-10%; computerized route planning could lead to further reductions of about 5% in kilometers driven.[53]
Another way of improvement could be the integration of the primary and secondary distribution activities in order to reduce empty running. Tesco (one of the Britain's leading food retailers) introduced two initiatives in this sense:

a) Supplier Collection
   Through the introduction of a Supplier Collection Scheme, primary and secondary return journeys have been removed from the transport chain (although the deviation mileage must be deducted when evaluating the net mileage saving). In addition, a number of secondary distribution vehicles must be used to consolidate and return the packaging and store delivery cages required for secondary distribution.

b) Onward Supply Schemes
   Onward Supply Schemes utilize the supplier resources and are organized so as to make use of vehicles designed for primary distribution in a secondary distribution role.

Trailer conversions were also needed by Tesco for both Supplier Collection and Onward Supply Schemes, for instance in the case of multi-temperature vehicles and vehicle ambient conversion, to carry pallets and store cages as properly as possible. Through this integration Tesco has substantially reduced the empty running mileage and consequently the vehicle emissions.[54]

3.4.2 Warehousing

Warehousing (in terms of "keeping certain commodities ready for quick shipment") is becoming increasingly important, as the economy is more and more demand-side oriented, and it is now one of the most dynamic categories of land use.

[53] Streeter, 1998
[54] Department of the Environment Transport and the Regions (UK), Best Practice Programme, Energy savings from integrated logistics management, Tesco plc

Warehouses exist because companies are unable to predict demand, and need to provide a buffer that accommodates spikes and lulls in the sales process. Ecommerce tools, which enable the instant sharing of data among trading partners, dramatically improve this ability to predict demand[55] and encompass more distribution and less warehousing space. However, most existing buildings do not fit into the advanced technological requirements of automated warehouse operation, and new buildings for Ecommerce contribute to further land consumption. In any case automated warehouses are subjected to large economies of scale and require a high capacity utilization. Currently, because of the low number of Ecommerce users, the prevalent trend is toward decentralization, with a development of land demand for distribution and storage purpose.

3.4.3 Vehicle use

Transportation is that part of the logistics process that has the greatest impact on the environment, and with the advent of Ecommerce this is becoming more and more important. In Sweden there are national environmental targets to reduce the emissions per roll-off container by using particular vehicles or alternative fuels.

ICA (the biggest player in the Swedish food industry, and an important Ecommerce player as well) is constantly working in this sense, both for environmental and financial reasons. Many ICA vehicles can be packed on two levels (double-decker lorries) and use bio-diesel (the definition of bio-diesel is environmental Class 1 diesel with 2% RME, that is a 100% bio-fuel). The impact on the environment is further reduced by ICA's demands on vehicle fuels, tires, car maintenance products and driving styles (the drivers are gradually being trained in "economical driving"). Several warehousing units are also lined up to train their drivers in this field.[56]

In all Europe the possibility of using vans that use alternative fuels (such as natural gas, biogas and ethanol) is increasing, and new developments in hydrogen fuel cell technology are expected in the next years. Moreover, hybrid technologies such as diesel-electric vehicles, and cleaner lower-sulpher forms of petrol and diesel fuel are being more widely adopted. Exhaust filters and catalytic converters are also important to reduce pollution. [57] Another kind of environmental impact of transportation is the noise pollution, that could be reduced with the diffusion of quieter vans, like hybrid-electric vehicles. Very interesting is also the use of alternative types of vehicles, like the delivery of goods by bikes and walking couriers in the cities or the transport of goods by rail. But these initiatives can be adopted only in specific circumstances, and may require regulations at national or local levels (e.g. providing incentives for change).

[55] Elsevier, Shipping news (June 2002)
[56] ICA report 2002
[57] Sally Cairns, TSU Working paper, April 1999

3.4.4 Last mile logistics

The goods reception mode is one of the key issues for the operational efficiency of home deliveries, but at the same time is one of the major problems of e-business. Food is perishable, severe quality and safety regulation have to be met, and margins in the food business are usually small. Also, the requirements of customers are high: food has to be in time to be cooked, not too expensive, quality must be good, and selection from a full assortment must be possible.[58]
In general, there are three different alternatives for receiving the groceries after an order by Internet:[59]

1) *In-store pick-up*: customers pick up groceries from the local supermarket or a warehouse, so the e-grocer only offers picking services. Shopping is easier, but pick-up from the store does not eliminate the customers' problems completely, because they still have to travel to and from the store.[60] That's why this alternative will be considered in my model as a "traditional way" to purchase.

2) *Attended delivery*: the shopkeeper or a third party delivers groceries to a given place where the customer accepts the delivery choosing a specific time window. The delivery time window represents how long the customer has to stay at home waiting for the delivery, so in many cases the delivery hours are limited to late afternoons and evenings. A broader time window allows better vehicle routing optimization, but customer service suffers, as customers need to attend and await the deliveries for a longer time.[61]
   The more the customer is allowed to control the home delivery service and select the delivery time window, the higher the costs and mileage. This causes more working hours for the staff, and has an immediate and considerable effect on the total cost of the home delivery service.[62]
   Here, a two hours delivery window for the attended delivery will be considered, because this is the average result found from literature and interviews.

[58] Rene´B.M. de Koster, Distribution structures for food home shopping, 2002
[59] Ettore Bolisani, La grande distribuzione alimentare on-line, 2003
[60] Vesa Kämäräinen, The reception box impact on home delivery efficiency, 2001
[61] Punakivi, Yrjölä and Holmström, Solving the last mile issue, 2001
[62] Punakivi and Saranen, Identifying the success factors in e-grocery home delivery, 2001

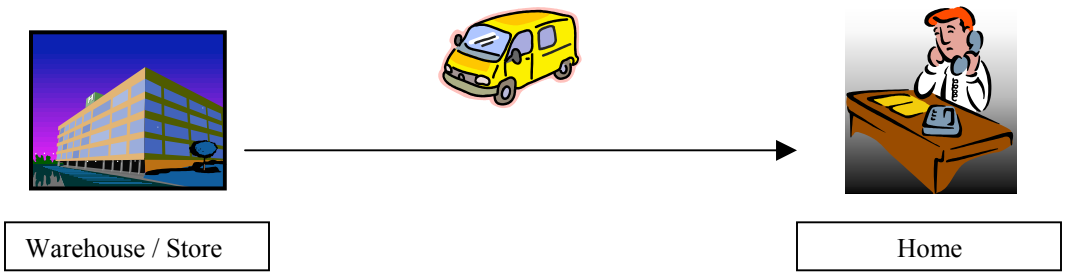

Figure 13: The attended delivery

3) *Unattended delivery*: in this case the delivery time window equals the delivery hours. The two main approaches to unattended delivery are:

   a) The reception box: in this concept every household has its own reception box, which is a refrigerated, customer-specific box installed in garage or home yard.

Figure 14 A reception box solution (Homeport)

   b) The delivery box: in this solution an insulated secured box is delivered to the customer and attached securely in a locking device bolted on the building wall. The empty boxes are collected on the day following the delivery, or even later.

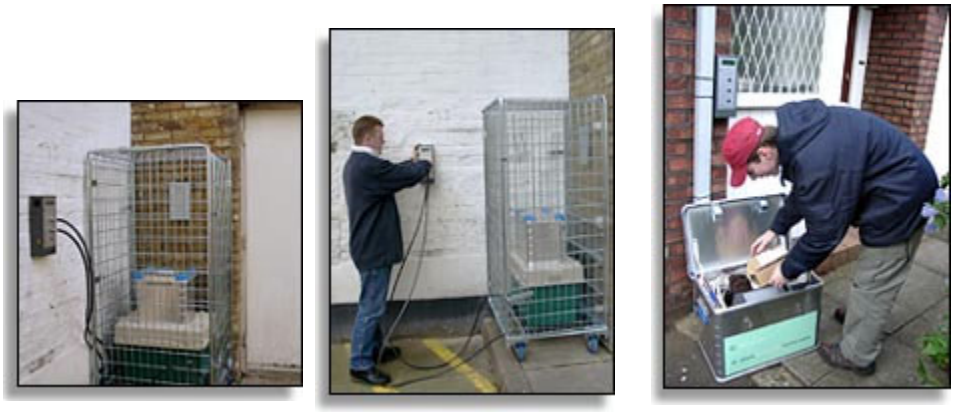

Figure 15 Some delivery box solutions (Homeport)

Using unattended delivery, customers become independent from the delivery timetable because they do not need to be at home to receive the goods. Some initiatives have though been taken to arrange these facilities while building new houses and blocks of flats. For the customers, these ways of receiving the groceries are the most convenient ones, due to the option of being at home or not, no waiting time to spend, and closeness to the collecting point.[63]

The reception boxes enable considerable cost savings in the e-grocer's home delivery operations, but the investments involved are high for the customers. An operating concept based on reception boxes leads to a low growth rate of online sales, because the installation of the boxes for new customers is costly and slow. The delivery box solution potentially enables a faster growth rate and higher flexibility, because of the lower investment required per customer. The drawback is the additional cost of collecting the empty boxes. In the attended delivery, no investment in reception technology is required. This is why attended delivery is the most common modality today, and the only one used by the Ecommerce players in Lund. Also, it offers the opportunity of a face-to-face service with customer, which could be a very useful way to collect feedbacks and to improve the service. Research into last mile e-grocery logistics has shown that unattended reception leads to significant savings in operational costs by allowing optimized routing, higher capacity utilization, and even more capacity load in picking operations.[64] Based on this analysis, an average value (40%) of savings in the delivery routes (km) was considered for the unattended solution, without considering the different logistics performance between reception box and delivery box.

[63] Carlheim-Gyllenskiöld and Rangefelt, Matomera, 2002

[64] Punakivi and Tanskanen, Increasing the cost efficiency of e-fulfilment using shared reception boxes, 2002

3.4.5 Load consolidation

Consolidating loads for delivery (i.e. to minimize empty or part-full running of vehicles is vital to minimize the environmental impacts of services). A company could decide to outsource the delivery to third party operators, but more often they do it by themselves. A way to rationalize transportation could be, as we said before, the use of vehicles that can be packed on two levels (double-decker lorries)[65] or the use of temperature-controlled vehicles that can operate as multi-compartment vans.[66]

Also, there are ways in which companies can help to influence the patterns of customer demand for greater efficiency in the distribution structure. One possibility is to specify different prices for different delivery times, in order to induce the choice of less used time windows by the customers. There are examples of important delivery organizations (like CERT group) that, by operating in a more consolidated way, reduced the number of journeys of more than 50%.[67] However, there seems to be general agreement that, as home delivery develops and unless the case of one company reaching a monopolistic position, the reduction in average parcel size and the increase in the number of delivery destinations will increase the benefits of "co-operative delivery arrangements" between companies.[68] Today, there are a lot of stores that are offering e-commerce as an additional service to their customers, and it is difficult for these stores to get enough orders to fill a delivery van, or to achieve load optimization when vans are empty.

This aspect of home delivery will be of critical importance for the environment, when and if there will be more Ecommerce users.

3.4.6 Sales Returns

Another critical aspect for the environmental implication of home delivery regards the returns of unsatisfactory goods, or returns because the customer is not at home. The unattended delivery solutions does cause this problem, that could instead be significant for the attended solution. Minimizing returns will help to minimize the traffic that home delivery service generates and consequently the emissions, and can bring benefits to the business.

Two possible solutions are:

a) Pre-call to customer: The customer is called before the van is sent out to ensure of the delivery.

b) Call centers for product information: The customer can get more information on products before placing an order to ensure the goods are exactly what they are looking for.

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[65] ICA report 2002

[66] Department of the Environment Transport and the Regions (UK), Best Practice Programme, Energy savings from integrated logistics management, Tesco plc

[67] Lainas, 1998

[68] Sally Cairns, Home delivery of shopping: the environmental consequences, april 1999

Today returns are a relatively small feature of grocery delivery; so they were not considered in the application of the model.

4 CONSUMERS BEHAVIORS

4.1 Information Technology

The most important aspect for studying the development of e-commerce in the society is to understand how new technology is used and what influence it has on the consumers' activity.

SIKA report (August 1998) shows the result of a survey on people's access to and use of information technology in its different forms. Among nations, in these years Internet penetration is highest in Sweden (69% of population), and the United States are in sixth position (with nearly 59%), and Japan is 21st (44%).[69]

Access to various types of communications equipment is high in Sweden, both at workplaces or schools, and at home. Over 75% of the working population have access to a computer at their place of work as shown in the figure below (fig. 16).

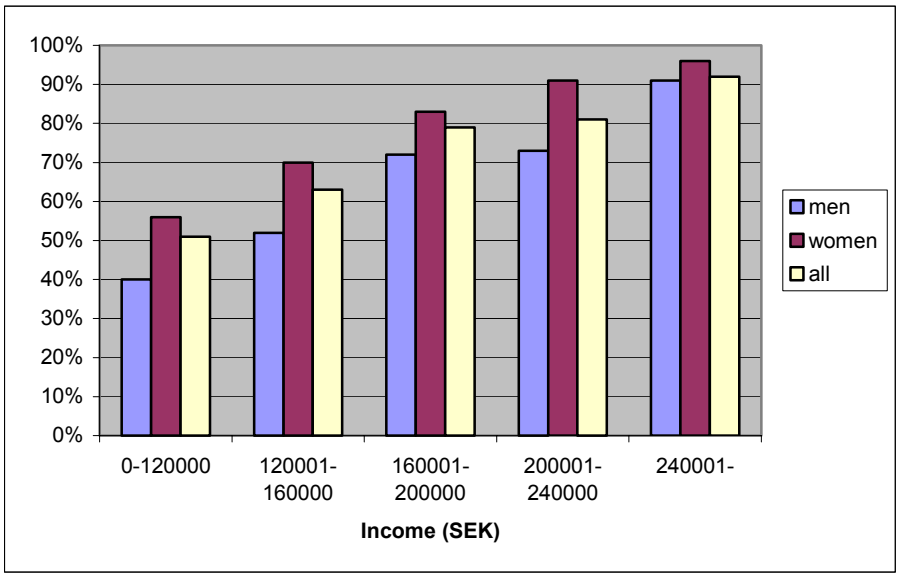

Figure16: People access to a computer at work in Sweden[70]

Access to computers and other equipment at work is generally linked to the income level. An explanation for this is the duties associated with the high–income positions often imply greater use of communication.

We can also compare people's access to a computer between different groups as shown in figure 17:

[69] Report: Industan Times, October 2003, Tokyo
[70] SIKA Report 1998

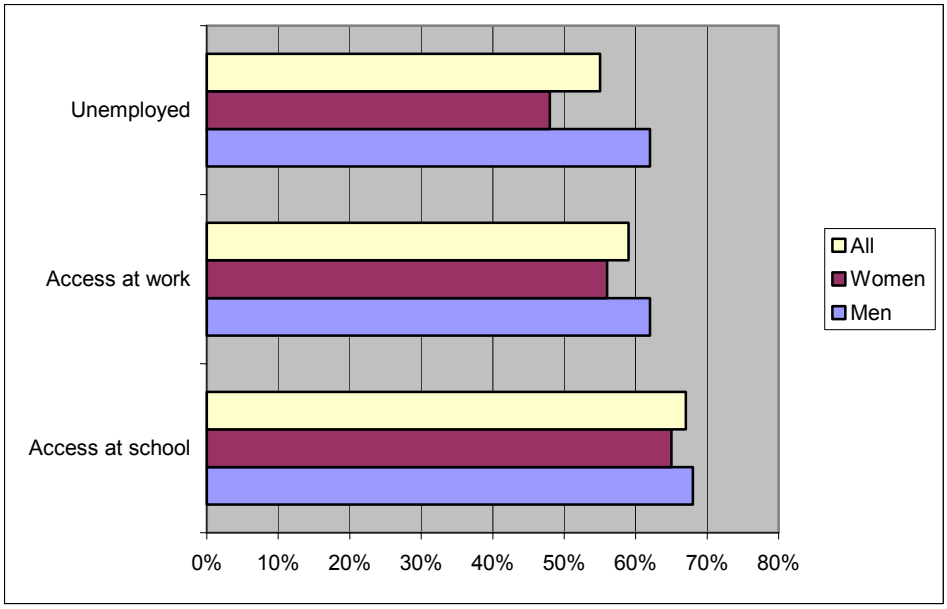

Figure17: People's access to a computer, comparison between different groups in Sweden.[71]

Due to its high percentage of people that have access to the Internet, Sweden is a country that potentially may have the higher development and diffusion of e-commerce in the future.

4.2 Trips to and from shop

During 2001 the Swedes made close to 5 billion journeys, of which 55 per cent were made by car. On average, each person aged 6-84 years made 1.7 journeys per day. People traveled 132 billion kilometers in all, which is equivalent to 44 kilometers per person and day, of which 29 kilometers by car.[72]

A specific research was done in 1998 by the Swedish Institute for Transport and Communication Analysis (SIKA) about trips to and from groceries in Sweden. The analysis was done for each region of the country because of the great demographic and territorial differences. A map of Sweden with is shown in the follow picture (fig.19); fig. 18 shows how the regions where grouped in SIKA analysis.

[71] SIKA Report 1998
[72] SIKA RES 2001, Statistiska centralbyrån

R-region	Zone
R1	Stockholms
R2	Uppsala
	Södermanlands
	Östergötlands
	Örebro
	Västmanlands
R3	Jönköpings
	Kronobergs
	Kalmar
	Gotlands
R4	Blekinge
	Skåne
R5	Hallands
	Göteborg
	Älvsborgs
	Skarborgs
R6	Värmlands
	Dalarnas
	Gävleborgs
R7	Västernorrlands
	Jämtlands
R8	Västerbottens
	Norrbottens

Figure 18: R-regions of Sweden

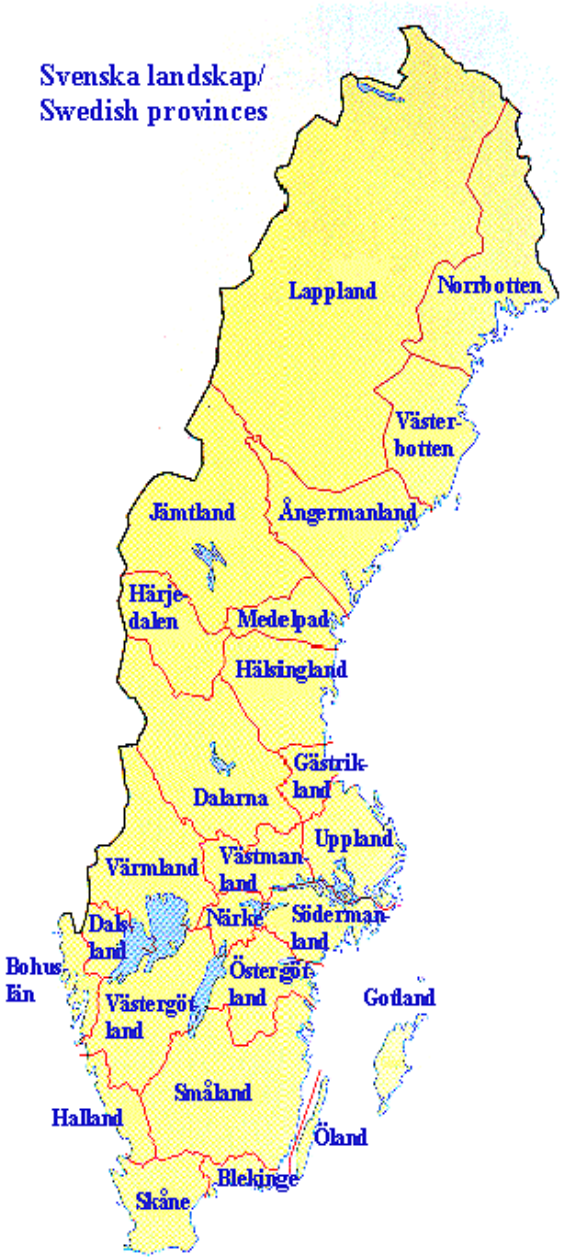

Figure 19: map of Sweden

In my analysis, the data referring to R4-region were used for calculations, because such data refer to the area of Lund. The results of this research also show the average distance to groceries in each region of Sweden (fig. 20).

R-region	Car	Other	car(%)
R1	8.85	2.74	51%
R2	8.52	1.67	57%
R3	7.14	1.11	63%
R4	8.54	2.2	58%
R5	7.67	1.76	60%
R6	6.54	1.62	66%
R7	5.72	0.9	65%
R8	7.29	2.08	71%

Figure 20: Average distance driven (km) to go to groceries in each R-region of Sweden[73]

Another data that is useful for the calculations conducted here is the average distance from home to work every day. Sika RES 2001 has studied this aspect of Swedish people behaviours with the results shown in the following picture (fig. 21):

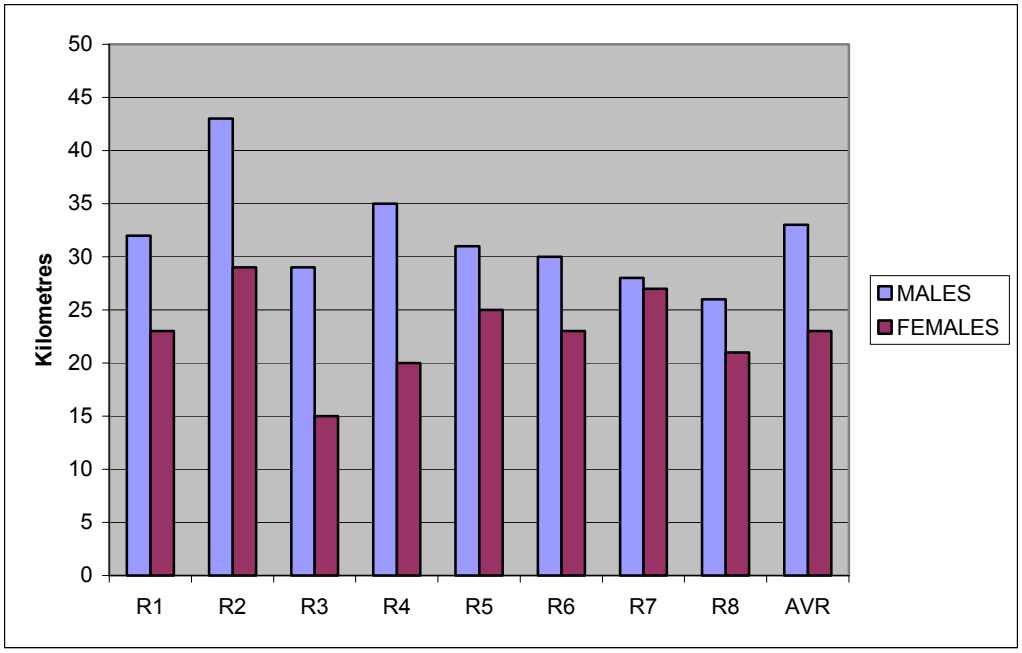

Figure 21: average distance home-work for each region per person in Sweden[74]

I will consider in my calculation the average value (between males and females) in the R4-region. The result is that the average distance home-work in the zone of Lund is 30 km.

[73] SIKA Rapport 1994 SCB
[74] SIKA RES 2001

4.3 Buying patterns

There is much research about buying patterns of Swedes at the supermarket, and about the average amount of money that they spend buying groceries in a traditional way or by e-commerce. Here, the data obtained by a direct interview with Stefan Holst, director of the Malmborgs supermarket in Lund, was used. This data refer to the Lund's population habits and are shown in the following picture:

Purchase	Amount (SEK)
Traditional	125
E-commerce	650

Figure 22: Average amount of a purchase in Lund's grocery

The e-purchase is usually bigger than the traditional one, and the customers often buy by Internet only the "boring" or heavy goods while they continue to go to the store for buying the other goods. This is a big problem from an environmental point of view, because in this case the e-delivery trips by vans or trucks must be added to the customer trips for the purchase of "no-boring" goods.

5 EMISSIONS

The dramatic increase in transport demand, and in particular road transport, makes this sector a major contributor to several health and environmental problems in Europe. The most important environmental impacts of transport are climate change (greenhouse gas), loss of biodiversity due to habitat disruption, and effects on human health (air pollution, accidents, and noise).[75] E-commerce and IT are interrelated components of the structural change in distribution. They affect the environment in terms of vehicle use, related emission and energy consumption, by speeding up the time and increasing the geographic area of transport operations.

The following diagram shows the actual modal shares freight transport in Western Europe:

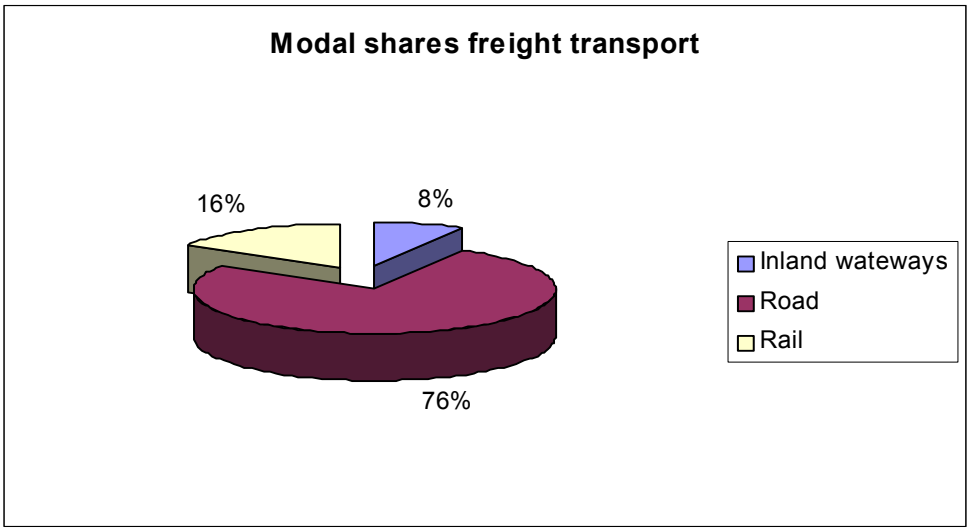

Figure 23: Western Europe's modal shares freight transport[76]

Rail freight and inland waterway systems (more friendly for the environment than the road-system) cannot cope with the demand for flexibility as well as with the decreasing size of the truckloads. By all indicators, in Europe the widening gap between truck and non-highway modes in domestic freight service will continue to increase.[77]

[75] European Environment Agency: Europe's Environment report, 2003

[76] European Environment Agency, 'Environment for Europe' Ministerial Conference being held under the auspices of the UN Economic Commission for Europe in Kiev, Ukraine on 21-23 May 2003

[77] Markus Hesse, Shipping news: the implications of EC for logistics and frieght transport, 2002

5.1 Emissions categories

In my thesis, I focused my attention only on the effects of e-commerce on conventional air pollution, and in particular on emissions of NOx, CO_2 and particulates by road transport vehicles. In this part of my work, I will analyse the current situation and the health and environmental effects of each of these emission categories.

5.1.1 Carbon Dioxide

Carbon dioxide (CO_2) emissions from transport contribute to the anthropogenic greenhouse effect. Global warming resulting from increased levels of greenhouse gas (GHG) emissions has only recently been recognized as a major threat. CO_2 is the most significant greenhouse gas; it contributes for about 80% of total EU greenhouse gas emissions. Literature studies show that IT and e-commerce can help to reduce GHG emissions in the food production and consumption system, but possible negative effects were also identified.[78] I have focalized my model on e-grocery shopping home delivery service, because of its direct and indirect potential effects on GHG emissions in the food production and consumption system.
Total EU carbon dioxide emissions in 1998 were similar to those in 1990. Emissions fell between 1990 and 1994, mainly because of relatively slow economic growth, increase in energy efficiency, and switch from coal to natural gas. Emissions then increased by 3% between 1994 and 1998 (fig. 24).

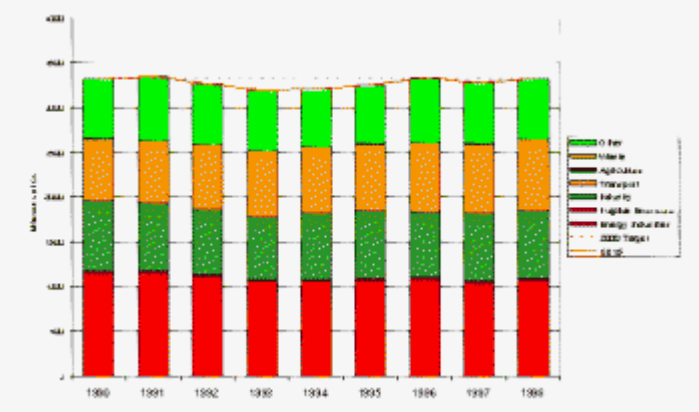

Figure 24: Total EU carbon dioxide emissions[79]

The EU (Kyoto Protocol) target for 2008-2012 is a reduction of 8% below 1990 levels for the basket of six gases, including carbon dioxide.

[78] Siikavirta, Punakivi, Kärkkäinen and Linnanen: Effects of EC on Greenhouse Gas Emissions, 2003
[79] European Environment Agency, indicator: carbon dioxide emissions 2001

The problem is the upward trend in CO_2 emissions from transport, largely due to growing traffic volumes, while there has been very little change in average energy use per vehicle kilometer.

Figure 25: Total EU15 transport greenhouse gas emissions 1990-2000[80]

In the future, policies such as the voluntary agreements within the car industry are expected to bring energy use down.

5.1.2 Nitrogen Oxides

Nitrogen oxides are air pollutants that contribute to the destruction of forests and are also irritant gases with oxidizing characteristics that can lead to an increase in respiratory diseases.[81]

Emissions of nitrogen oxide (NOx) contribute to the acidification of the environment and can, under certain conditions, contribute to the generation of ozone, a characteristic it shares with volatile organic compounds (VOCs).

In EU emissions of NOx increased steadily during the 1980s with approximately 20% due to increasing road traffic. From 1991 to 1998 NOx emissions have decreased by 20% in EU Member States mainly due to the introduction of three-way catalysts on new passenger cars.[82] Without these measures, nitrogen oxide emissions by traffic in the EU would have been 50% higher in 1998.

[80] European Environment Agency, report on greenhouse gas emissions refer transport only, 2002
[81] Umwelt Bundes Amt: Future diesel, July 2003 (www.europa.ue)
[82] European Environment Agency: National and central estimates for air emissions from road transport, Copenhagen 2002

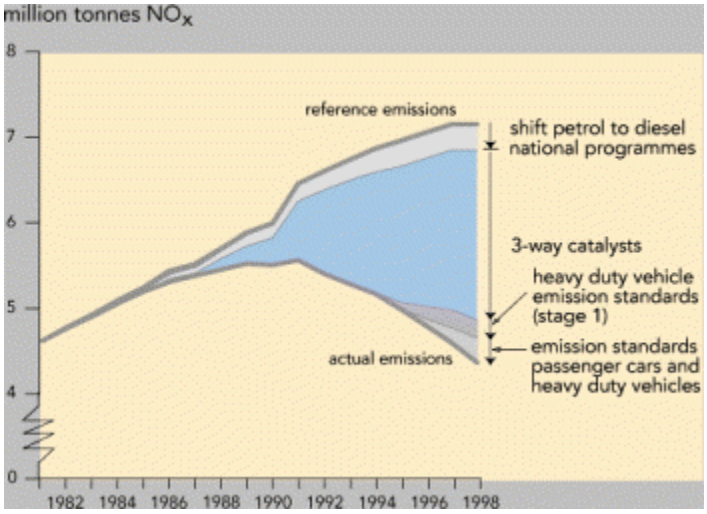

Figure 26: NOx emissions from road transport in EU[83]

The implementation of stringent measures through the 1999 directives, on the other hand, is expected to significantly reduce NOx emissions from 2000 onwards.

[83] European Environment Agency: Transport emissions of air pollutants, 2001

5.1.3 Particulates

Breathing in fine particles (PM10s) can increase the frequency of lung problems and even trigger premature death. Apart from being directly emitted into the atmosphere, PM10s are also created from precursors such as nitrogen oxides, sulphur dioxide and ammonia.

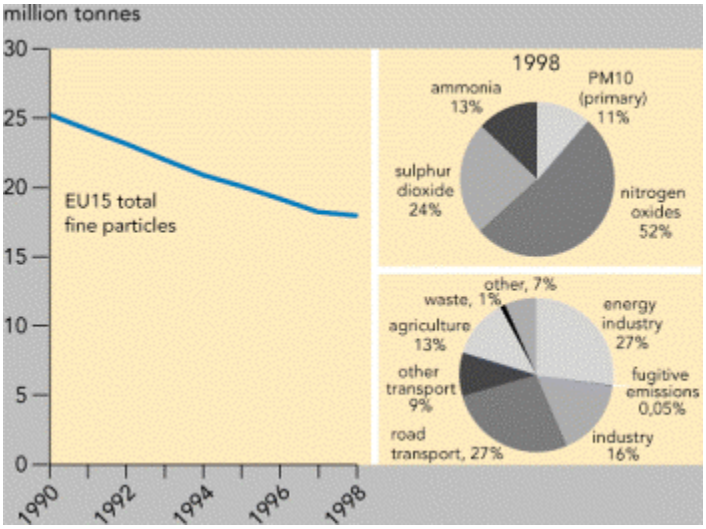

Figure 27: Emissions of fine particulates (PM10), EU15[84]

The 29% drop observed to date therefore stems from reduction in both direct emissions and in emissions of these precursors. The reduction is mainly due to two factors:

a) Energy producers switching from coal-fired to natural gas-fired power plants and introducing abatement technologies.

b) The increasing penetration of catalytic converters in road vehicles

Particulate emissions are therefore expected to continue falling as vehicle technologies improve and the energy sector becomes less polluting

[84] European Environment Agency: Emission of particulates, EU15, 2001

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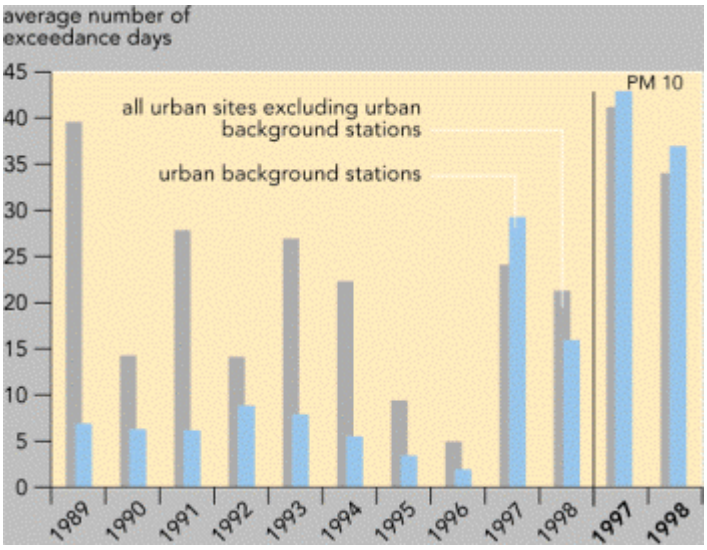

Figure 28: Exposure to fine particles above EU threshold values[85]

Suspended particles have not been monitored consistently over the years and monitoring PM10 has only begun recently. While this does emphasise the need for consistent PM10 monitoring across Europe in the future, the data show that a large fraction of Europe's population is exposed to particulates at levels above those recommended for their health.

[85] European Environment Agency: Are Europeans less exposed to particulate? (2001)

5.2 Emissions data[86]

With regard to road transport, there is a lot of data concerning emissions and energy use. Most data are based on documented emission values from test results in laboratory environments. I decided to use data from NTM (Network for Transport and the Environment) because its emissions data was compiled by a group of manufacturers and transport companies that are expert at lorries. The information shown refers to the transport work in grams per ton-km for all lorries. This data were used as an indicator of the environmental impact of a certain quantity of freight over a known route. The compilation relates to circumstances for transport by lorry within Sweden, and the data constitute a summary of the current situation.
The size classes of lorry that I'll consider are:

Vehicle classes	Total weight	Payload (ton)	Approx. length (m)
Van	3.5	1.4	5.5
Light lorry	3.5-16	1.5-8.5	9

Figure 29: Size classes of transport vehicle

All emission values are presented as gram emissions per kilometer but this value depends on many factors. The most important factor is the kind of road: there are enormous differences in emissions data between driving in a low densely populated zone (countryside road) and driving in a city zone as shown in the following tables (fig. 30 and fig 31).

Low densely populated zone	HC g/km	CO g/km	NOx g/km	CO_2 kg/km	Partiklar g/km	SO2 g/km
Car	0.689	3.75	0.74	0.18	0.0137	0.0044
Van (<3,5ton)	0.716	4.75	1.23	0.24	0.0584	0.0065
Bus	0.491	1.21	5.37	0.59	0.1731	0.0189
Light lorry (3,5-16ton)	0.672	1.37	4.97	0.55	0.3042	0.0179
Heavy lorry (>16ton)	0.35	1.25	10.88	1.09	0.1761	0.0344
Motorbike	4.189	19.97	0.27	0.15	0.0889	0.0038

Figure 30: vehicle emissions for countryside zone driving (NTM)

[86] NTM (Network for Transport and the Environment): environmental data 2000

City	HC g/km	CO g/km	NOx g/km	CO_2 kg/km	Partiklar g/km	SO2 g/km
Car	2.6	12.74	0.78	0.28	0.03	0.007
Van (<3,5ton)	2.54	14.08	1.33	0.34	0.1	0.01
Bus	0.76	2.09	9.85	1.1	0.146	0.034
Light lorry (3,5-16ton)	1.02	2.17	7.5	0.51	0.242	0.016
Heavy lorry (>16ton)	0.64	2.19	15.92	1.26	0.239	0.04
Motorbike	6.5	20.3	0.28	0.15	0.092	0.004

Figure 31: vehicle emissions for city zone driving (NTM)

Another parameter that influences the emissions is fuel consumption, which varies widely depending on the type of transport, roads, driving styles etc. The driver's style of driving can affect consumption up to 100%. Loading factor, correct service and maintenance are crucial too. Combustion produces carbon dioxide (CO_2), the quantity of which is determined by the carbon content of the fuel (see table following), that is why the fuel quality is also an important factor in an environmental point of view.

CO_2 emitted per litre fuel	CO_2 (kg/litre)
Environmental Class (EC) 3 (standard fuel)	2,7
Environmental Class (EC) 1	2,6

Figure 32: CO_2 emitted per litre fuel (NTM)

Fuel of environmental class 1 is the most common fuel in Sweden (more than 90% of sales, while the remainder is environmental class 3.
Compared with standard fuel, emissions of carbon dioxide fall from 2.7 to 2.6 kg per litre of fuel and particles falls by 15-30%.
Taking in consideration all these factors, the emission data used in my calculation are the following (fig. 33):

Average values	HC g/km	CO g/km	NOx g/km	CO_2 kg/km	Partiklar g/km	SO2 g/km
Car	1.38	7	0.75	0.21	0.02	0.005
Van (<3,5ton)	1.37	8.11	1.27	0.28	0.073	0.008
Bus	0.6	1.58	7.24	0.8	0.162	0.025
Light lorry (3,5-16ton)	0.76	1.58	5.64	0.54	0.288	0.017
Heavy lorry (>16ton)	0.39	1.39	11.62	1.12	0.185	0.035
Motorbike	5.1	20.08	0.28	0.15	0.09	0.004

Figure 33: Emissions average values (NTM).

6 CALCULATION MODEL

Until today, not many surveys have been conducted about the environmental impacts of e-commerce. The model is intended to be a starting point for future research, to assess the environmental impacts of the home-delivery shopping system and clarify the trade-off between the distance traveled by customers if they transport their own shopping home by car, and the equivalent distance driven by a fleet of vans or trucks to deliver the same number of shopping loads. This is a complex problem because the trade-off depends on a lot of parameters, some of which were analysed here. The model was adapted from a previous work of Claes Wallin and Fredrik Orremo.[87]

6.1 Parameters

Turnover of grocery industry (TOTp)

This is the total turnover of the grocery sector in one year in Lund. I calculated it using the data from Statistic Sweden center about retail trade with mostly food (shown in the following table):

Retail sales statistics

Domestic turnover in millions of SEK, excl. VAT

Business	2000	2001	2002
Retail trade with mostly food	170,738	178,599	188,790

Figure 34: Total domestic turnover food in Sweden[88]

I did the proportion between turnover and population, by comparing Sweden and Lund, to arrive at the total turnover in the city of Lund. This is not a perfect way to calculate it, because the population of Lund is composed by lots of students (about 30%) that have usually particular purchase habits. In any case, this aspect was not considered, since it is quite hard to quantify, and probably this does not influence the findings.

[87] Orremo & Wallin: IT, mat och miljo, thesis work 1999, Department of Design Sciences, Lund University, Sweden

[88] Statistics Sweden Center

Average amount of each purchase (STp, ECp)
I use the data obtained by the interview to Stefan Holst, ICA Malmborgs director, that gave me his statistics about the average amount of traditional purchases and e-purchases in his grocery of Lund.

Average distance home-store by car (d1)
Thanks to SIKA Report 1994 SCB I obtained the average distance home-grocery by car in the zone of Lund. This data is not updated because not further research were done about this.

Route length of a van (rv), Route length of a truck (rt)
The average route lengths of a van and a truck in Lund are difficult to quantify because are influenced by lots of factors. Estimates were obtained from Stefan Holst's interview.

Average distance home-work in km (hw)
I obtained this data from SIKA RES 2001, where the average distance home-work per person for each zone of Sweden is calculated.

Average distance home-pick up point in km (hp)
I supposed that the average distance home-pick up point in Lund is 8 km.

Percentage of traditional purchases done by car (ppc)
SIKA Report 1998 shows that 55% of trips in Sweden are done by car. I used this data as the percentage of traditional purchases done by car in Lund.

Current percentage of e-customer (ECu)
The actual percentage of e-commerce users in Lund is about 1%.[89]
I analyzed the current situation first, and after that some possible different scenarios.

Percentage of workers in Lund (wor)
The percentage of workers in Lund (2002, group 20-64 years) is 68.3%.[90] The low figure is depending on the great number of students (not working) in the age group 20-29 years.

Percentage of people that go by car to pick-up points (ccp)
I supposed that all the e-customers go to the pick-up points by car, because this is still the most convenient way to take and carry the goods.

[89] Stefan Holst interview, ICA Malmborgs director, Lund, 2004
[90] Bengt-Åke Leijon, www.lund.se

Percentage of people that don't go to work by car (pwc)
The percentage of people that don't go to work by car in Sweden is 57%.[91] (source: last census in Sweden, 1990)

Average number of orders for each van (C2) and truck (C3)
Taking in account the kind of vehicle and in accordance to the estimates provided by Stefan Holst, the average number of orders loads in each van is 25 and in each truck is 120.

Emission data of cars (E1), vans (E2) and trucks (E3)
The emissions of car, vans and trucks used are the data of NTM (Network for Transport and the Environment) and are shown in paragraph 7 of the thesis.

Routing optimized (ra) or no-optimized (rb)
I considered the use (ra) or the not-use (rb) of devices on trucks and vans for the optimization of the delivery routes. A reduction of 10% in km was estimated in case of routing optimization.[92]

Attended home delivery (da) or unattended home delivery (db)
There are great differences in delivery efficiency between attended and unattended delivery (paragraph 3.4.4). However, today in Lund only the attended solution is used; after the first calculation, the possible unattended delivery is also considered (sensitive analysis): based on a literature survey, 40% of savings were estimated in delivery routes (km) when the unattended solution is applied.

Percentage of returns (ret)
This parameter is not significant in Lund, and was not considered in my calculations. In any case, this factor can be easily introduced in the model.

[91] www.lund.se
[92] Sally Cairns, Home delivery of shopping: the environmental consequences, April 1999

6.2 Formulas

The basic idea in this work is to evaluate the environmental impacts of e-commerce by quantifying the emissions associated with the different models of home delivery, and by comparing the results with the emissions of the traditional way of purchase, i.e. when the customer goes to the store. The following formula summarises this principle (1):

$$(1) \qquad \begin{cases} Etot = Etr + Ee \\ Eo - Etot = Ediff \end{cases}$$

Where Eo: car total emissions with no home delivery (i.e. the customers go to the store - mainly by car).

Etot: the total emissions in case of e-commerce, due to the sum of car emissions (percentage of traditional purchases) plus the van or truck emissions (percentage of e-purchases).

Ediff: permits the evaluation and indicates whether e-commerce reduces the total emissions ($Ediff>0$) or increases it ($Ediff<0$).

Etr: car emissions of the percentage of traditional purchases in presence of an alternative e-commerce service.

Ee: van and truck emissions (depends by the model of home delivery) due to the e-purchases (and home deliveries).

With this comparison between the emissions of the "old" way of purchasing (Eo) and the emissions of the "new" e-solutions (Etot) we can evaluate if e-commerce is beneficial for the environment, and which is the most environmental friendly model of home delivery. $Ediff = 0$ means that the use of e-commerce does not make differences for the environment in terms of emissions.

6.3 Calculations

In order to make an evaluation of the environmental consequences in terms of emissions for the 4 models of home delivery (paragraph 3.3), the elements and parameters used for the evaluation are listed as follow:

- Application context: Region of Lund, Sweden (paragraph 3.5)
- 25 orders for each van delivery (<3,5ton)
- 120 orders for each truck delivery (3,5-16ton)
- Distance home-grocery 8,54 km
- 58% of traditional purchases made by car
- Traditional order size is 125 SEK
- E-commerce order size is 650 SEK
- Emission data for cars, vans and trucks from NTM (Network for Transport and the Environment)
- Attended delivery solution
- Percentage of returns: 0%

The average travel length of a delivery van or truck is not known statistically, but estimates made by an expert (Stefan Holst) indicate 20 km for vans and 80 km for trucks. The calculation concerns the current situation in Lund, where the percentage of e-commerce users is about 1%[93]. After that, other hypothetical situations were evaluate, and compared through a sensitive analysis of some parameters.

6.3.1 Emissions associated to traditional purchase

The first step is to quantify the total emissions of the traditional way of purchasing, where customers go to groceries by themselves to collect the goods. The results were compared to the emissions of the different home delivery models.
This first calculation was thus made without considering the presence of e-commerce; the results are shown in the following picture (fig. 35):

Total car emissions	CO_2 (ton)	NOx (kg)	Particles (kg)
Traditional solution	16,75	59,83	1,59

Figure 35: Total car emissions for traditional purchases

[93] Stefan Holst interview, director of ICA Malmborgs in Lund, 2004

The total turnover of the grocery industry in Lund was divided for the average size of traditional purchase (125 SEK) to find the total number of customers. The percentage of customers that use car to go to the store is 58%[94].

6.3.2 EC Purchases

The next step is to calculate the total emissions for the different home delivery models and to compare them with the traditional scheme. The maximum length of the distribution route that causes more emissions than the corresponding traditional shopping is calculated. This length is called *critical length*.
When the delivery van or truck exceeds the critical length, the environmental implication in terms of emissions increases. If the delivery route is shorter than the critical length, it means that the home delivery model is more environmental friendly than the traditional shopping and there will be a reduction in effluents.

Delivery model 1
The total emissions and the critical length for the model 1 (3.3.1) are shown in the following picture (fig. 36):

Model 1			
	CO_2	Nox	Particles
Emissions (kg)	16591	59	1,58
Van critical length (km)	458	361	167

Figure 36: Emissions and critical lengths for model 1

The results show that the critical lengths are quite long compared with the travel length estimated for a typical delivery route van in Lund (20 km). This means that the environmental consequence is beneficial by adopting this model of home delivery, as the impact on the environment decreases.

[94] SIKA Report 1998

Delivery model 2
The results for model 2 (see 3.3.2) are as follows (fig. 37):

Model 2	CO_2	NOx	Particles
Emissions (kg)	16651	60	1,59
Truck critical length (km)	1380	472	132

Figure 37: Emissions and critical lengths for model 2

The results tell us that this solution is positive for the environment especially for CO_2 and NOx emissions, because the critical lengths are very long. The critical length for particles is not so long, but in any case it is longer that the average travel length of a delivery route truck in Lund zone (80 km). I considered an average distance home-place of work of 30 km[95] and a percentage of 43% of people going to work by car[96]. However, to take the goods to the working places might increase the percentage of workers that use the car to go to work, because they have to carry home the shopping. Consequently, the figure calculated may not represent exactly the reality, and the critical length for this model is probably overestimated.

Delivery model 3
The total emissions and the critical length for model 3 (see 3.3.3) are shown in the following picture (fig. 38):

Model 3	CO_2	NOx	Particles
Emissions (kg)	16629	59	1,59
Truck critical length (km)	398	152	91
Distance to pick-up-place (km)	23	19	15

Figure 38: Emissions, critical length and distance to pick-up-place for model 3

To calculate the truck critical length, the average distance home-pick up place was estimated to be 8 km, and all the e-customers were assumed to go to the pick-up-place by car, because this is the most convenient way. The results are beneficial for the environment, because the truck critical lengths are longer than the delivery route (80 km)

[95] SIKA RES 2001
[96] www.lund.se

especially for CO_2 emissions (398 km) and for NOx emissions (152 km). The critical length for particles is 91 km, only a bit longer than the standard reference.
I calculated the distance to pick-up-place considering the truck delivery length 80 km long, and the results show that the distances obtained are longer than the standard one (8 km). This means that this model of home delivery is more environmental friendly than the traditional way of shopping.

Delivery model 4
The results for model 4 (see 3.3.4) are shown in the following picture (fig. 39):

Model 4			
	CO_2	NOx	Particles
Emissions (kg)	16598	59	1,58
Van critical length (km)	426	287	179
Truck critical length (km)	1090	368	102

Figure 39: Emissions, van and truck critical length for model 4

I supposed a delivery route truck of 80 km to calculate the van critical length, and the results are positive for the environment. This is due to the fact that the van critical length for CO_2, NOx and Particles are longer than the standard van delivery route (20 km).
To calculate the truck critical length, I supposed a truck delivery route of 20 km; the results are positive as well, because the truck critical lengths are longer than the standard one (80 km).
Consequently, this home delivery model, in which trucks deliver to spreading points where the orders are shattered to smaller delivery vans to the homes, is more environmental friendly than the traditional shopping.

Summary

In this analysis I compared the emissions in the traditional way of purchasing, where customers go to groceries by themselves to collect the goods (paragraph 6.3.1), with the emissions of shopping using four different home delivery solutions (paragraph 6.3.2). The comparison was done using a "critical" parameter called *critical length*, which indicates the maximum length of the distribution route such that the e-commerce solution results in less emission than the corresponding traditional shopping. We said that an average van delivery route in Lund is about 20 km long, while a truck delivery route is about 80 km long. It means that if the critical length of the home delivery model is longer than the average delivery route, the environmental impact of e-commerce is positive. The figure below reassumes the results:

TRADITIONAL SHOPPING

Car emissions	CO_2 (ton)	NOx (kg)	Particles (kg)
Traditional solution	16,75	59,83	1,59

E-COMMERCE

Model 1	CO_2	NOx	Particles	
Emissions (kg)	16591	59	1,58	← POSITIVE
Van critical length (km)	705	555	257	
Model 2				
Emissions (kg)	16651	60	1,59	← POSITIVE
Truck critical length (km)	1800	615	145	
Model 3				
Emissions (kg)	16629	59	1,59	← POSITIVE
Truck critical length (km)	411	165	104	
Distance to pick-up place (km)	36	33	28	
Model 4				
Emissions (kg)	16598	59	1,58	← POSITIVE
Van critical length (km)	411	578	289	
Truck critical length (km)	36	481	192	

We may conclude from this analysis that all the four home delivery models have positive impacts on the emissions of CO_2, NOx and particles in the atmosphere, because in all the models the delivery route is shorter than the critical lengths (for vans or trucks).
However, we have to underline that we obtained these results under very strict conditions and heavy assumptions, and a slight difference in the parameters can cause big changes in the results.

6.4 Sensitivity analysis

For that reason, the next step of the analysis was to produce future possible scenarios by changing the values of some critical parameters:

6.4.1 Share of EC users

The most important parameter is the percentage of e-commerce users. Today, in Lund's zone, e-commerce represents just a marginal market with about 1% of share, and some groceries offer the home delivery only as an additional service to the customers. The emissions for the for different home delivery models where re-calculated by assuming online percentages of 15, 30 and 50 of the total grocery turnover in Lund. Again, the results are compared with the emissions of the traditional shopping (E0). The horizontal line (E0) indicates the emissions without considering e-commerce while the other lines represent the emissions for different percentage of e-commerce users. The analysis was conducted only for model 1 and model 2.

Delivery model 1

The results for model 1 are shown in the following pictures (fig. 40):

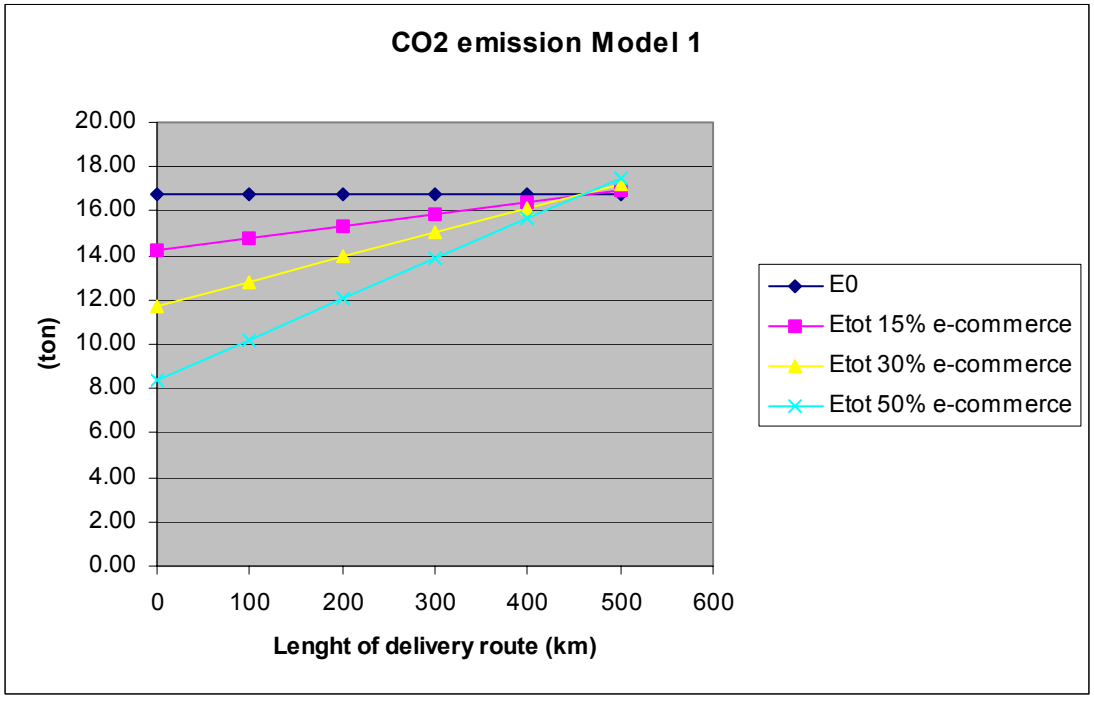

Figure 40: CO_2 emissions for Model 1

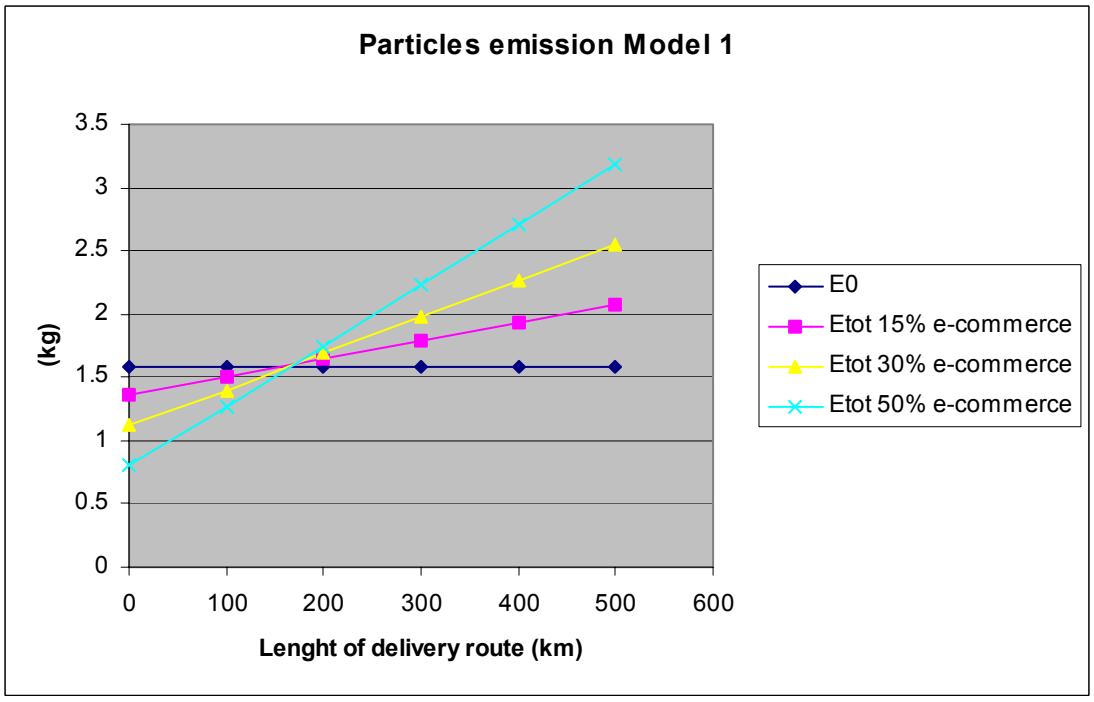

Figure 41: Particles emissions for Model 1

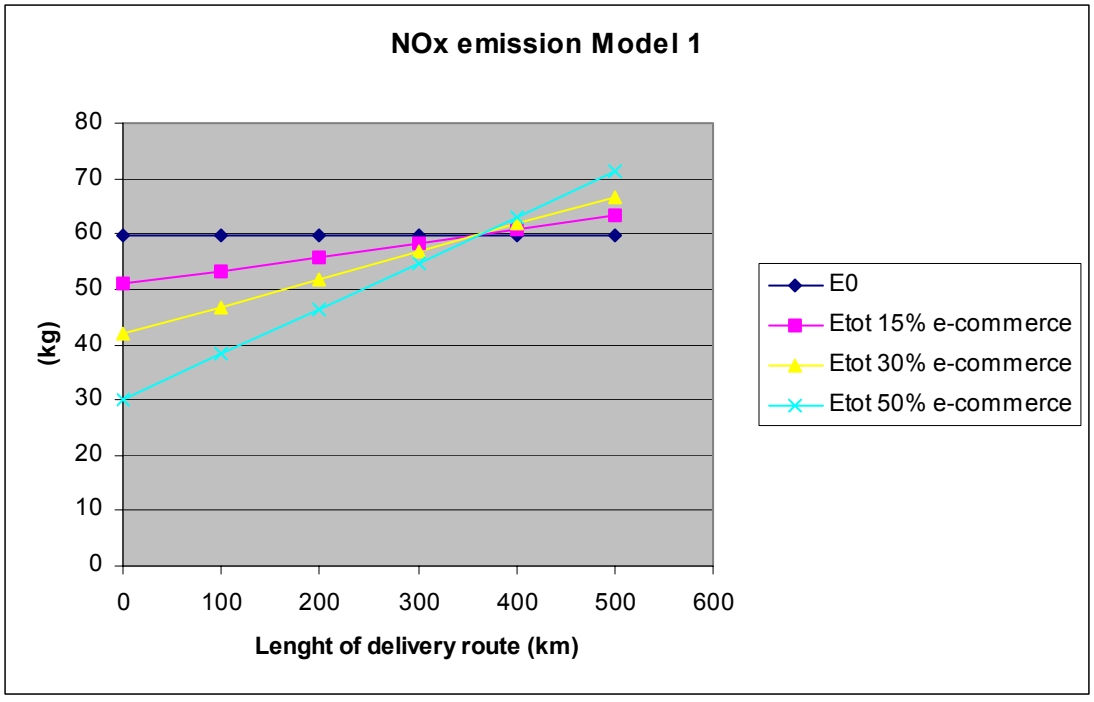

Figure 42: NOx emissions for Model 1

The results show the course of emissions assuming that the share of e-commerce users is 15, 30 or 50 percent of total turnover. The horizontal blue lines are the emissions when all the groceries are transported through the traditional supply chain, when the consumers themselves travel to the stores.
The other 3 lines show the course of the emissions when 15, 30 and 50 percent of the groceries are acquired through home shopping, depending on the length of the route that the delivery van travels in km. This length depends on a lot of factors but especially on the size of the area where the deliveries are made. According to Stefan Holst (director of ICA Malmborgs in Lund) this length route for vans can be assumed to be 20-30 km in Lund. We can see from the graphs that the areas corresponding to these values are those where the effects of the e-commerce for the environment are positive. This is due to the fact that in these areas the amount of emissions of CO_2, NOx and particles for the e-solution are lower than the traditional shopping ones.
In each graph, there is a point (superimposition of the lines) where the emissions for the delivery van are equal to the emissions of the traditional shopping (horizontal line). This means that when the delivery route exceeds this point, the emissions for the delivery van will be greater than that of traditional way of purchase.
For CO_2 emissions for example, the point is about 450 km and this means that when the van delivery route exceeds 450 km, the CO_2 emissions for the delivery van will be greater than that of traditional shopping. However, this is impossible in practice, because, as we said, a normal van delivery route is about 20-30 km long in Lund.
Based on this analysis, we can conclude that, under the described conditions, the home delivery model 1 solution permits a considerable reduction in the emissions compared with the traditional way of shopping, and this reduction is higher with the grown of e-commerce share.

Delivery model 2

The results for model 2, where a truck is conducting the delivery, are shown in the following graphs:

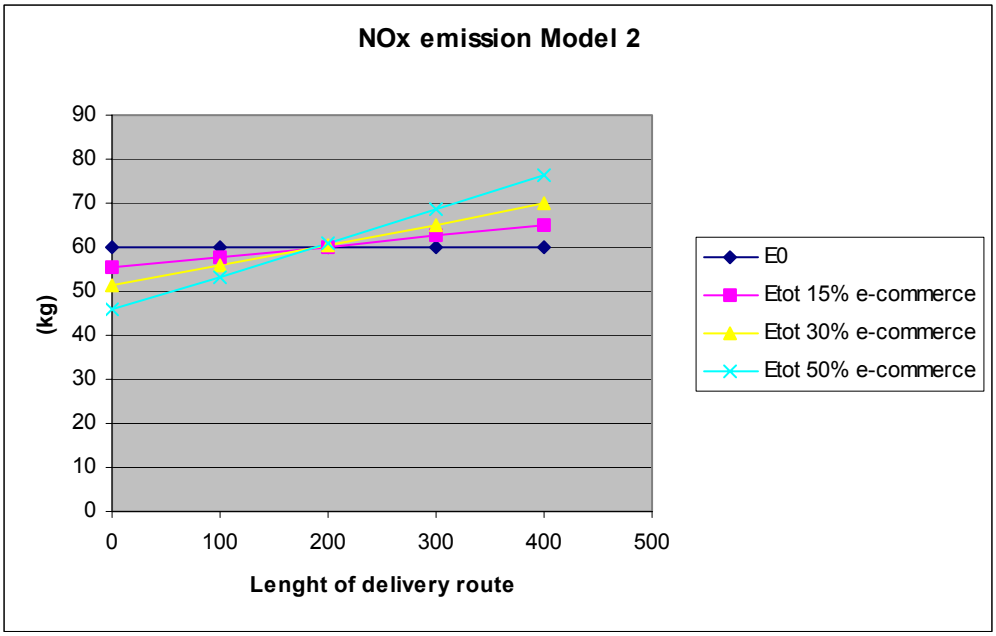

Figure 43: NOx emission for Model 2

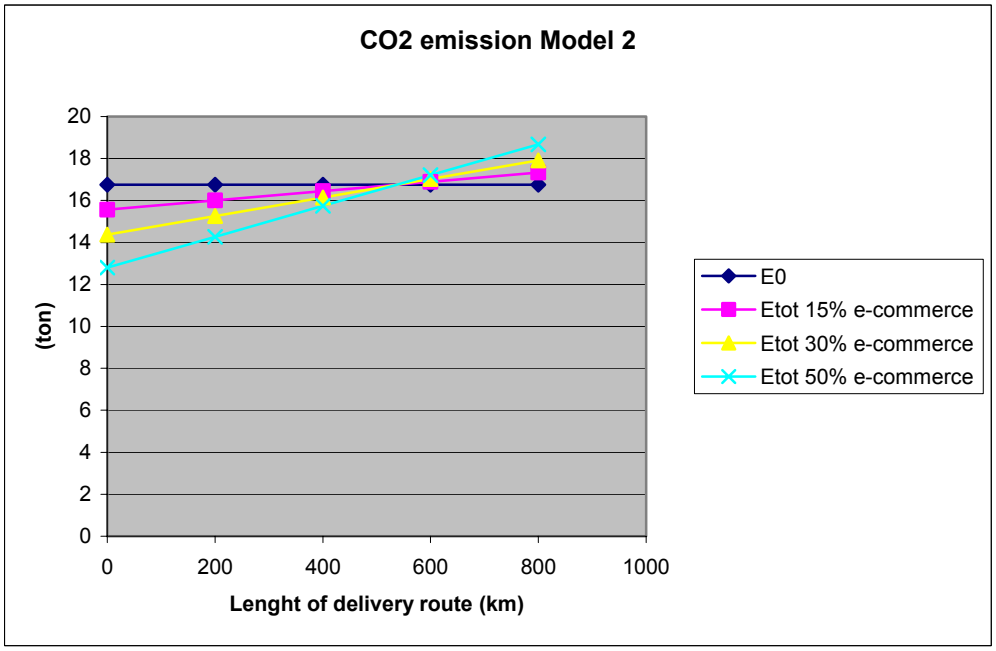

Figure 44: CO_2 emission for Model 2

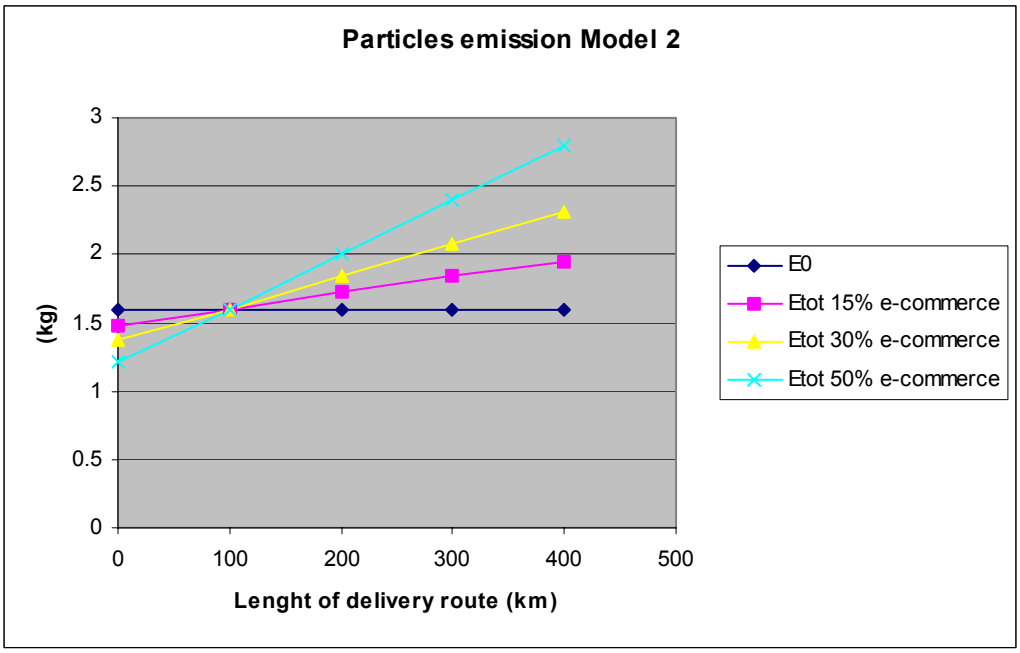

Figure 45: Particles emission for Model 2

The horizontal line represents the course of emissions for traditional shopping, that of course is constant if the length of truck delivery route is changing.
According with Stefan Holst, we'll consider the average truck delivery length in the zone of Lund of about 80 km. For CO_2 emissions, the point of superimposition of the lines coincides with a delivery route of about 550 km. It means that the impact of this home delivery model could be really positive for CO_2 emissions because it is impossible that a delivery truck route is longer than 550 km. For NOx emissions the results are positive as well, because the point of superimposition of the lines is at about 200 km.
As concerns particles, the graph shows that when the delivery route exceeds 110 km, the emissions for the delivery truck will be greater than that of traditional way of purchase.
In short, we can conclude that in case of model 2, like model 1, an increasing of the share of e-commerce users causes a sensible reduction in the emissions of CO_2, NOx and particles in the atmosphere.

6.4.2 Fill rate

Another very important parameter to consider and to test is the number of orders for each van. Especially today, when there are several stores that offer e-commerce services to their customers, the delivery vehicles are often not full. We saw in the first calculation that assuming a quite full utilization of trucks and vans (first calculation) the results are positive for the environment, because a development of home delivery solutions causes a

decrease of the emissions. The problem is that the volume of e-commerce users is often too low to cover the expense of the home delivery system, and this is also the cause of failure for many e-commerce players and especially "pure Internet players" (par 3.1). A Swedish example is Matomera, an e-grocery system developed in the zone of Lund that started in 1998 and ended in 2001 because of the low volume of customers.[97]
In this analysis I assumed a 10% of share for e-commerce users, and I varied the load consolidation of vans to see the weight of this parameter for the environmental effects of e-commerce. The analysis was done only for model 1 because this is the model used today in Lund and the most important in general.
The emissions were compared assuming that each van contains respectively 5, 10 and 25 orders. In the graphs below (fig. 46, fig. 47 and fig. 48) the CO_2, NOx and particles emissions can be seen as a function of the length of the delivery route.

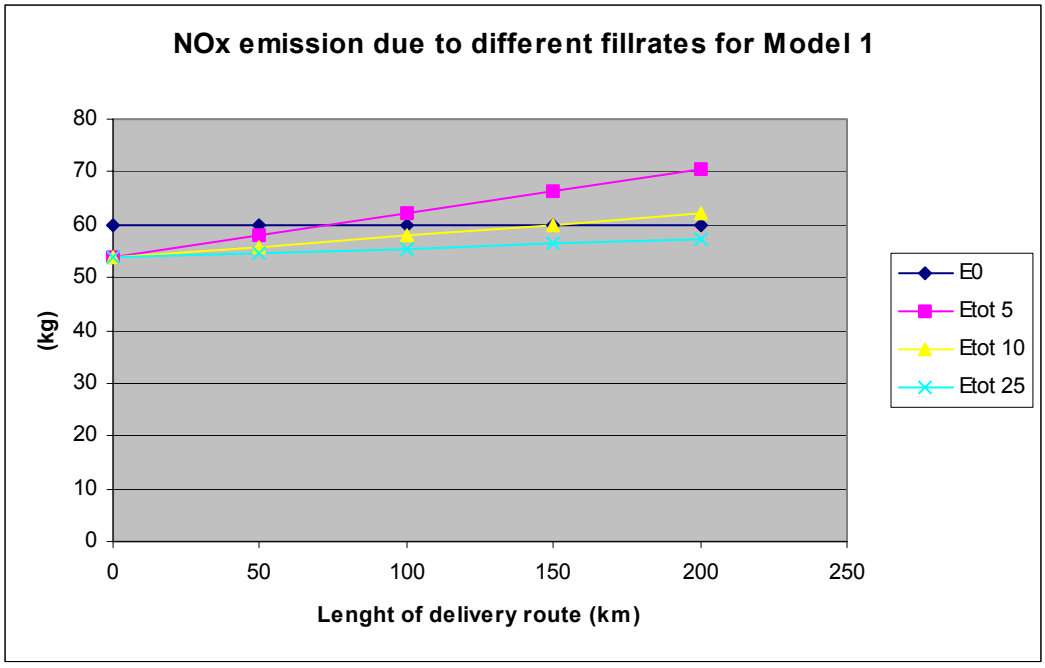

Figure 47: NOx emission due to different fillrates and route lengths for model 1

[97] Matomera: Carlheim, Gyllenskiöld and Rangefelt, Department of Desigh Sciences, Lund University

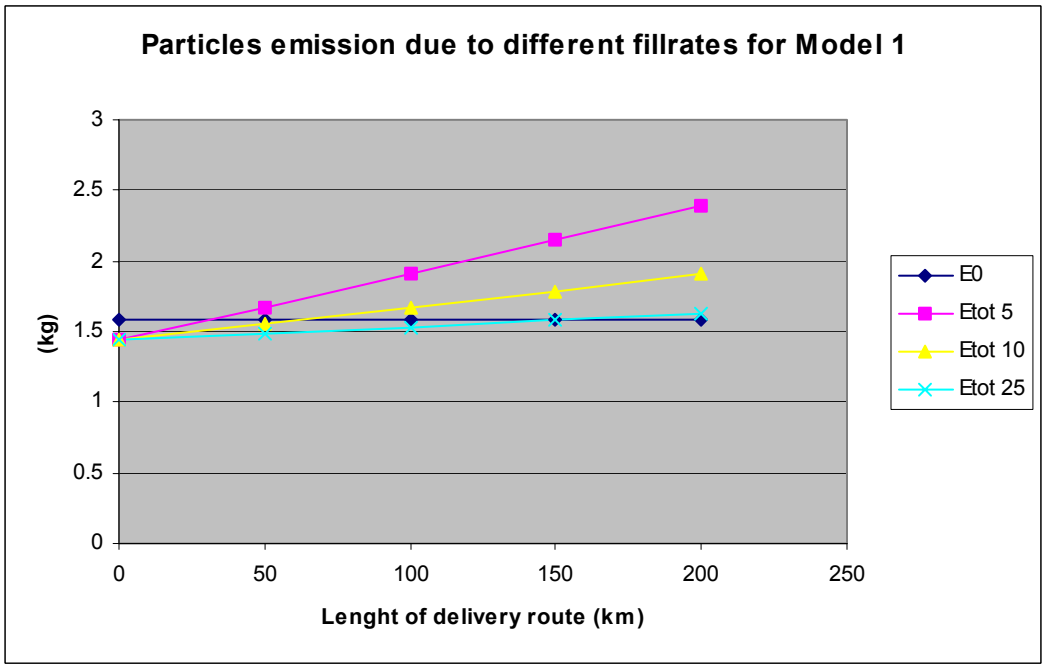

Figure 48: Particles emission due to different fillrates and route lengths for model 1

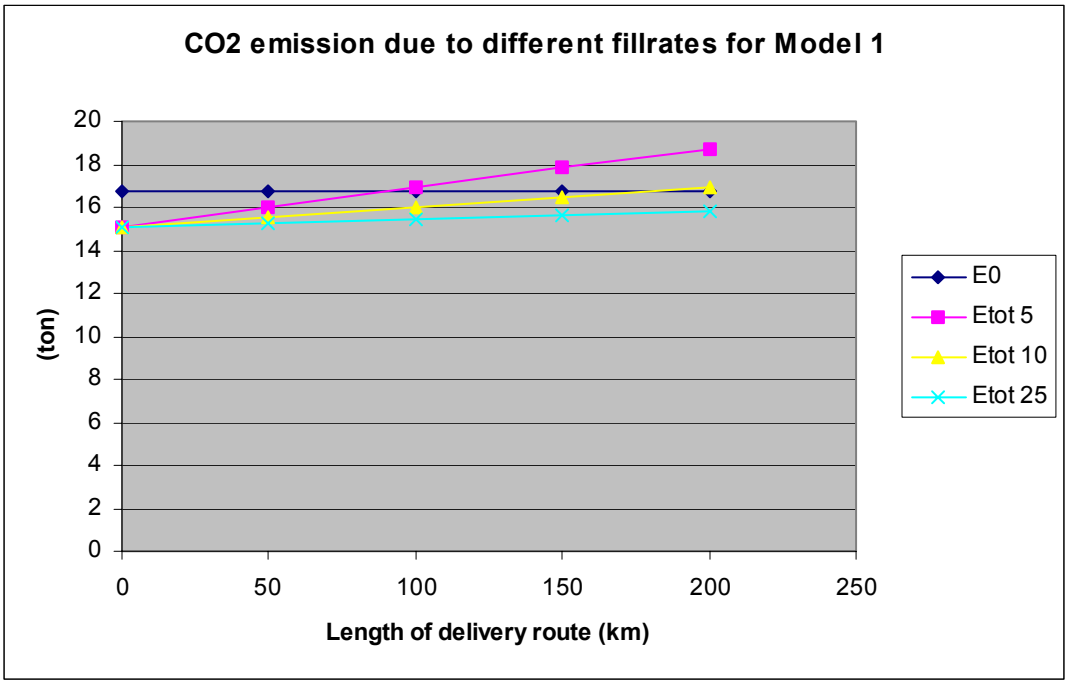

Figure 49: CO_2 emission due to different fillrates and route lengths for model 1

The blue horizontal lines (E0) represent the emissions without e-commerce with which we compare the other lines that represent the emissions considering 5, 10 and 25 orders

for each van. Where the tilted lines are up the blue line (we'll call the point of intersection *critical length*), the emissions of the e-commerce solution are higher than which ones of the traditional shopping. We can see from the graphs that the critical length decreases very much when the number of orders in the van fall to 5, especially for the particles where the critical length is about 25 km. If there are 10 orders in the van (yellow line), the critical length for particles increases to about 55 km. With reference to CO_2 emission, the critical route is of 80 km when 5 orders are delivered by each van. In any case, we can notice that if the vans are not full, the environmental impacts of the home delivery model are significant, especially when compared with the first calculations. It is easy to conclude that with a small number of customers it is more likely that the customers are spread over a larger delivery area, with consequent increase of the delivery routes. Under these conditions, it is likely that the critical length becomes shorter than the real delivery route, and that the environmental impacts of e-commerce turn to be not beneficial.
The growing number of the customers served by e-commerce causes a decrease in time and distance to drive for each delivery, because they are more likely to live closely together and consequently the delivery routes are shorter.
For this reason the number of customers and the consequent fill rate of vans and trucks are very important parameters: they are fundamental for the economical results of the e-players, but at the same time they are important for the environmental evaluation of the e-commerce activity. In some respects, one can conclude that a single "monopolistic" player, that can be more efficient in economic terms, is also more beneficial for the environment compared to a situation with a large number of competitors. But clearly, a monopolistic structure may not be positive for the consumers, that have less choice and probably higher prices. Consequently, a sort of dilemma arises.

6.4.3 Attended-unattended delivery

In this paragraph I analyse how could be the situation in Lund if the unattended delivery is used instead of the current attended solution. As we saw in paragraph 3.4.4, the unattended home delivery makes customers independent from the delivery timetable, because they do not need to be at home to receive the goods. The two solutions analysed are the reception box and the delivery box. In both these solutions great savings in time and kilometers result, compared with the attended delivery. According to the literature, many studies on last-mile logistic and the average value reduction in the van kilometers was of about 40 percent when the unattended delivery is used compared with the attended one. That is the value that I used in my calculation, together with a share of e-commerce users of 10 percent. The results (for model 1) are shown as follows (figures 50, 51 and 52):

	CO_2	NOx	Particles
Total emission (kg)	16753	59.83	1.6

Figure 50: Emissions for traditional shopping

	CO_2	NOx	Particles
Total emission (kg)	15151	54.18	1.46
Critical length (km)	458	361	167

Figure 51: Emissions and critical lengths for model 1 with attended delivery

	CO_2	NOx	Particles
Total emission (kg)	15122	54.05	1.45
Critical length (km)	763	601	279

Figure 52: Emissions and critical lengths for model 1 with unattended delivery

The results show big difference between the distinct solutions; the unattended delivery is more environmental friendly than the attended one. However, the higher investments needed for delivery boxes or reception boxes must be justified only by higher volumes of online orders, and by more consolidated relationship between the customers and the e-grocer. For this reason, only a major increase in the number of e-customers and a consolidation of this business can make the unattended delivery attractive to the operators, since this can generate considerable savings for both traffic and emissions compared to both the traditional shopping and the attended solution.

6.4.4 Coexistence of e-commerce with traditional purchased

In my first calculation, I considered (according with Lund ICA's director) that the purchase at the traditional store was smaller (125 SEK) than the purchase in the e-commerce store (650 SEK). In this situation it is easy to think that e-customers use home delivery just as the bigger "heavy" purchase, or to buy the "boring" goods while they continue to go to the traditional store for the other goods. This has a major consequence in the calculations. As a matter of fact, so far I assumed a total substitution of the car trips of the customers to the groceries, with van trips of the home delivery service. But if e-customers use home delivery just for a part of the purchases continuing to go to the store as well (which, as mentioned, is a more realistic assumption), the van emissions must be

summed to the car emissions. In this case, it is easy to demonstrate that the environmental effects are not beneficial for the environment (fig. 53 and fig. 54). In this simulation the 10% of e-commerce users was assumed.

	CO_2	NOx	
Total emission (kg)	12091	56	1.14

Figure 53: Emissions for traditional shopping

	CO_2	NOx	Particles
Total emission (kg)	12227	57	1.32

Figure 54: Emissions and critical lengths for model 1 summing car and van emissions

In my last simulation I made the assumption that the customer have the same average of online purchase and of traditional shopping (125 SEK). The purpose is to understand the effects of e-commerce if this way of shopping is used as a complete substitute of the traditional shopping. I'll compare the critical lengths in this situation varying the distance to supermarket in km. The results for model 1 for each emission category are showed in the following graphs:

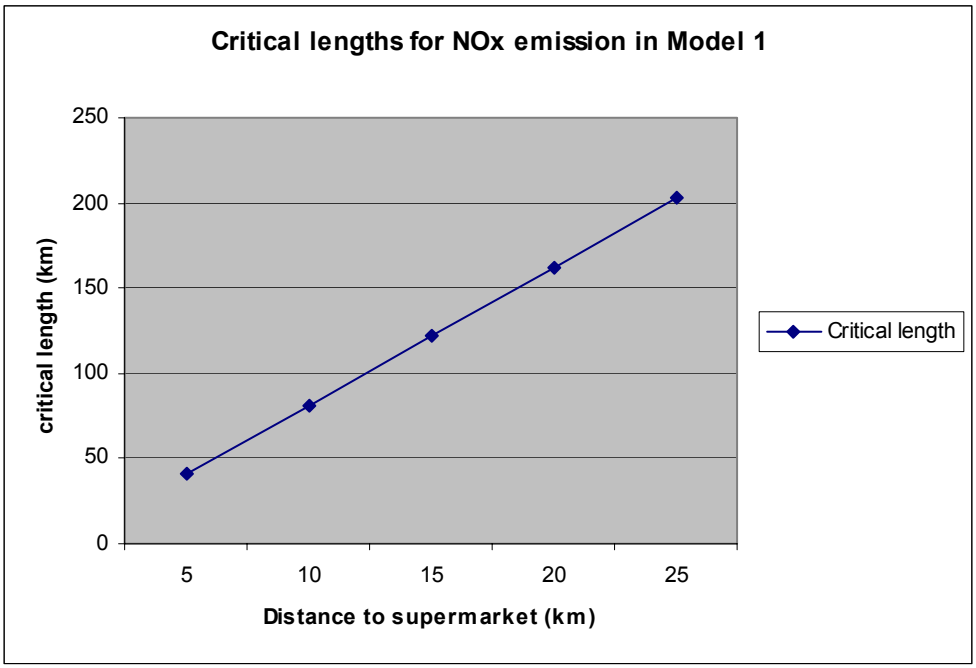

Figure 55: Critical length in function of distance to stores for NOx in model 1

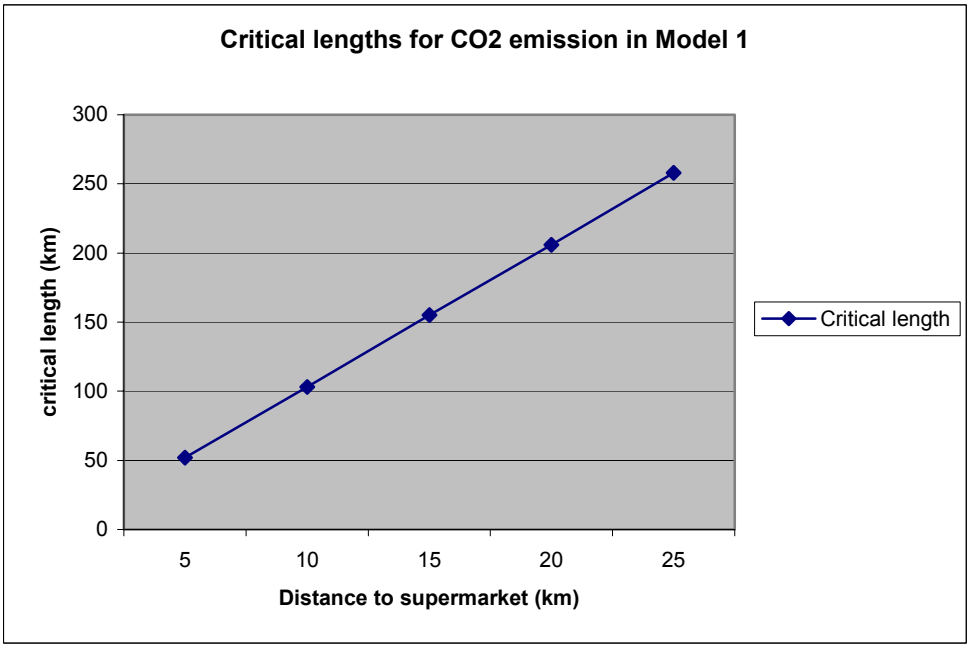

Figure 56: Critical length in function of distance to stores for CO_2 in model 1

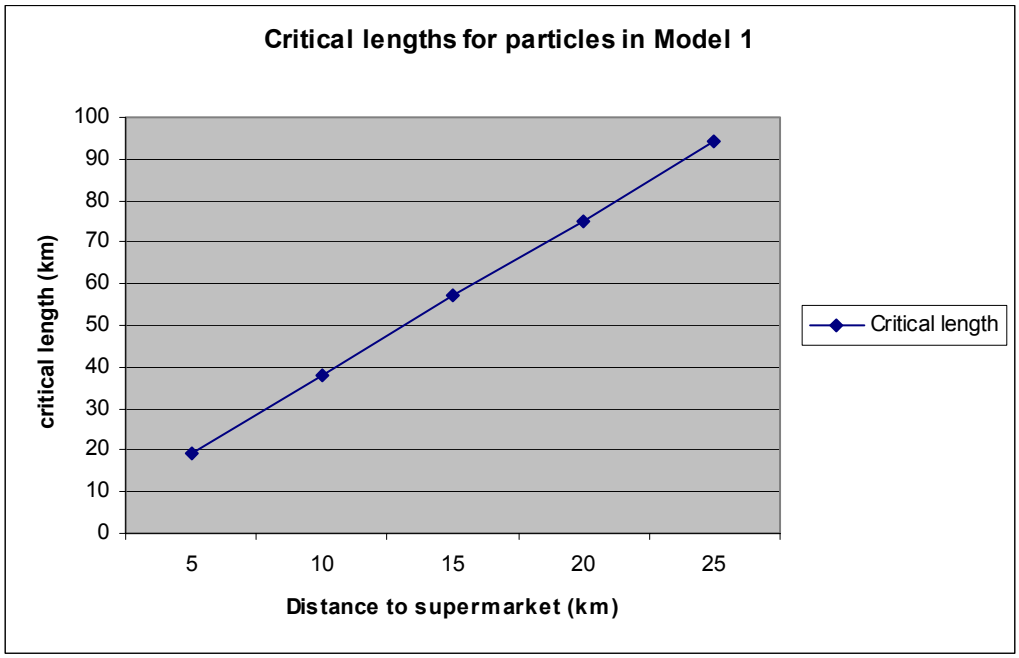

Figure 57: Critical length in function of distance to stores for particles in model 1

We can see from the graphs that increasing the distance home-store there is an increase of the critical lengths. It means that if the supermarket is further away the delivery van can be longer without increasing the environmental effects.
The average distance from the supermarket in Lund's zone is 8.54 km. For that distance the corresponding values of the critical lengths are quite high compared with the average delivery van length in Lund (about 20 km).
It means that, also under the condition of equal purchase amount between traditional shopping and e-shopping, the environmental impacts of e-commerce is positive.

7 CONCLUSIONS

7.1 Discussion of the results

The advent of e-commerce is causing big changes in the food distribution industry. These changes have many environmental implication and I tried to understand the environmental impacts of four different home delivery solutions compared with the traditional shopping.
The results of my calculations show that, under the right conditions, the environmental impacts of e-commerce home delivery can be positive, causing a substantial reduction in the emissions of CO_2, NOx and particles. My study is done in the zone of Lund, a densely populated area in the south of the Sweden. The case-study of Lund is just an example, but we could see this case in a more general perspective . This is possible because most of the problems connected with the home delivery service (b2c), such as the point-to point delivery, are also present in the other situations. The mayor factors that I considered responsible for the performance of distribution are the distance home-store, the delivery route lengths of vans and trucks, the average purchases amount for traditional shopping and e-commerce shopping, the load consolidation and the percentage of e-commerce users. After the first basic calculation, I modified some factors (sensitive analysis) in order to see the impacts of e-commerce for different possible scenarios. Particularly beneficial for both the efficiency and the environment is the adoption of unattended home delivery (reception box or delivery box) instead of the actual used attended delivery solution; but this solution is also more difficult for the firms. In any case, my calculations (especially the sensitive analysis) also show that e-commerce can have either positive or negative environmental impacts depending on the context of application.

In particular, the results are beneficial for the environment ONLY under very "strong" assumptions. Some of these are:

1) a complete substitution of the traditional car trips of the e-commerce users with the delivery van and truck trips.
2) the value of an average online purchase (650 SEK) is higher than in traditional purchase (125 SEK)[98]
3) each delivery van contains 25 orders and each delivery truck contains 120 orders

I consider these assumptions "strong" because some of these are far to be true with consequently worst real implications for the environment.
For example, as concerns the first assumption, my research shows that most customers order by Internet dry, heavy or "boring" products, but they still make a car trip to buy fresh goods, which means that in my calculation the home delivery trips must be summed with the traditional trips instead of substitute it. In this case (and unfortunately this is the actual situation), the environmental implication may be dramatic.
Delivery services are also likely to be used by non-car owners, who may previously have done their shopping without using a vehicle. This will also generate extra-motorized travel, although the availability of home delivery may influence longer terms decision

[98] Interview to Stefan Holst, ICA Malmborgs grocery, Lund, 2004

about car purchase. Some people have expressed concerns that reduced car use for food shopping may means more car use for other journey purposes.[99] That is because shopping is often seen as a social event, increasingly being mixed with leisure or other activities. I can say, after my study, that the new technologies are far from changing the social practices and the daily routine of the customers. It is hard to think that they will buy fresh food like meat or vegetables by the Internet, because for these products it is important for the customer to see and "touch" the goods. That's why it is critical for the e-commerce sellers to have a good reputation, to offer high quality products, to build stable relations with customers, to reach the maximum satisfaction of the buyer. Especially for "fresh" goods, for an e-commerce player, this is not granted, because in this business it is very difficult to find new customers and very easy to lose the old customers.

In short:
Positive effects for the environment are possible only by assuming a total substitution of car trips with van and truck trips for e-commerce delivery services, but in general this is not true. E-customers use home delivery just for a part of the purchases, and continuing to go to the stores with their cars, with negative effects on the environment because the delivery trips must be summed with the traditional car trips.

Other important findings can be highlighted. Firstly, a cost-efficient home delivery service can be organized in different ways, and I analyzed four different home delivery solutions. Model 1 is the today's way of home delivery (in Lund and in other cities around the world), and is more convenient for high density urban areas. Model 2 could be much more beneficial for the environment, but is more difficult to apply, because it needs major changes in customer behaviors.
Model 3 is likely to support efficient home distribution in more dispersed areas, thanks to the use of pick-up points where the customer can take the goods.
In addition, there are other parameters that influence the results. The population density and the optimized logistic, both an expression of high degree of consumer participation and high load factor, are the most important factors to reach positive environmental results. We have also to take into consideration the extremely low margins in grocery industry and the fact that most advanced delivery models (like those offered by Webvan - US, Peapod – US, Matomera - Sweden) just failed in the past. Today's trend is that of a business that combines Internet platforms on the "front end" (customer order) with neighbourhood stores for optimized distribution on the "back end".[100] For instance, in Lund e-commerce is considered only one additional service that the traditional groceries offer to their customer, and the e-facilities are implemented on the pre-existing traditional structure. Again, this is another reason for the coexistence of online with traditional selling schemes, which, as I said before, can have dramatic results for the environment.

[99] Sally Cains, Home delivery of shopping: the environmental consequences, April 1999
[100] Markus Hesse, Shipping news: the implications of electronic commerce for logistics and freight transport, 2002

It may be argued that the challenge in the future is to ensure that people are provided with a more attractive alternative than the car. The change of the customer behaviors is necessary, but this clearly needs additional specific regulations. That emphasizes the need for a more integrated transport policy, with the final target of a world where the customer find over the Internet their goods, and receive them directly at home without the necessity to take the car. The e-sellers must also offer high quality products especially for fresh goods to build a good reputation and the web-sites must be user-friendly as much as possible and offer a vast variety of products.
In this way, e-commerce could potentially give a substantial contribution to the environment, with significant emissions reduction, in the context of policies to discourage car use and to develop the exploitation of information technology.
In short, there are various important factors for the arrangement of an environmental friendly home delivery service. These include:

- policies to discourage the car use
- increasing use of alternative fuels or special vehicles (less emissions)
- optimization of the home delivery routing
- adoption of unattended solutions
- efficient load consolidation of vans and trucks
- prices that encourage bigger orders

Put in this way, the problem is very complicated. On the one hand, we showed that it is not possible to "let the market be free of rules", because this could cause negative effects on the environment. The firms take care of their costs, and the customers seek the most comfortable way for their shopping, and this may not be the best solution for the environment.

The introduction of additional rules may however have negative impacts on the food industry. It generates additional costs for the firms, that could prefer to leave this business. It also requires changes of customer behaviors (for example in the use of the car or in the food shopping) that could be not accepted by customers. That's why the introduction of additional rules to put the e-commerce in an environmental friendly way could cause the failure of the system.

E-commerce is a new business, that's why is very important to place right bases in order to favor a good development in an environmental point of view for the future. Anyway the problem is complicated because lots of factors are involved in the system and it generates lots of effects[101].
The most important problem related to emissions is the increasing number of road vehicles on urban roads has been a long-term trend and currently freight traffic accounts for 15 to 20 percent of all vehicles movement in urban areas. E-commerce is based on home-delivery, which may lead to less consolidated deliveries and thus more freight traffic. We saw that under the right conditions the environmental impacts of e-commerce

[101] In Appendix 9.7: what the European Union is doing in this way is analysed.

home delivery could be positive. The implications will depend on whether groceries can consolidate their deliveries, thereby improving vehicle load factors and reducing the number of car trips, and on whether the governments can favor this process.
Urban areas have to be accessible, without congestion, which implies the introduction of a policy to discourage non-essential traffic (private cars), shifting it to other models and encouraging high added value traffic (freight).[102]
Road pricing is an option that would encourage commercial traffic by reducing private car trips through charges for road infrastructure use. Pricing can also contribute to better use of existing infrastructure instead of systematically expanding infrastructure.
The key of the problem is to find a balance between people demand of affordable mobility and the growing threats to the environment and human health, developing policies that integrate environmental and other sustainability concerns into transport decision-making and related policies. The traditional approach of environmental regulation, such a setting vehicle and fuel standard, has resulted in significant improvements, as we said before. But much of the gain is rapidly being outweighed by growing transport volumes, particularly private car transport, and by the introduction of heavier and more powerful vehicles. Clearly, major efforts are needed to reduce the linkage between transport and economic growth. As suggested by European Environment Agency, this requires a change in policy from the mainly supply-oriented transport policies of recent decades (focused on road transport infrastructure and car supply) towards more integrated demand-side policies designed to improve accessibility.[103] It is only in this context that we should consider IT and Ecommerce as technologies that can provide positive effects for the environment.

[102] OECD (Organization for Economic Co-operation and Development, Summary of discussions of the joint OECD/ECMT seminar on the impact of e-commerce on transport, 2001
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9 APPENDIXES

9.1 Basic equations to calculate environmental impacts

The equations were taken from a previous thesis of Claes Wallin and Fredrik Orremo.[104] In the table below are shown all the parameters considered in the calculations:

List of parameters	
TOTp	Turnover of total grocery in Lund for one year (in SEK)
STp	Average purchase for traditional shopping in Lund (SEK)
ECp	Average purchase for e-commerce in Lund (SEK)
d1	Distance home-grocery in Lund (km)
rv	Route delivery length of a van in Lund zone (km)
rt	Route delivery length of a truck in Lund zone (km)
hw	Average distance home-work in Lund (km)
hp	Average distance home-PUP (pick-up-place) in Lund (km)
ppc	Percentage of purchase by car in traditional shopping
C2	Number of orders for each van
C3	Number of orders for each truck
Ecu	Percentage of e-commerce users
wor	Percentage of workers in Lund
ccp	Percentage of people that go by car to PUP
pwc	Percentage of people that don't go to work by car
E1	Car emissions (g/km)
E2	Van emissions (g/km)
E3	Truck emissions (g/km)

Coefficient of efficiency (EFF)

It takes in consideration and quantify the degree of optimization of the home delivery service. It considers a reduction of 10 percent in km for the delivery route if special devices are used to optimize the delivery scheduling and a reduction of 40 percent in km if unattended delivery is used.

Car emissions for traditional shopping without e-commerce

The car emissions for the traditional shopping without considering the existence of e-commerce (Ecu=0) are calculated as follow:

$$Eo = \frac{TOTp \times ppc}{STp} \times E1 \times d1$$

[104] Orremo & Wallin: IT, mat och miljo, Thesis Work 1999, Department of Design Sciences, Lund University, Sweden

Car emissions for traditional shopping considering e-commerce
Total turnover (TOTp) is divided for the average purchase in traditional shopping (STp) and multiplied for the percentage of traditional shoppers (1-Ecu) to obtain the number of e-commerce buyers. This result is multiplied for the percentage of people that use car to shop (pwc), for the emissions of each car (E1) and for the average distance home-grocery (d1) to obtain the final result.

$$Etr = \frac{TOTp \times ppc \times (1 - Ecu)}{STp} \times E1 \times d1$$

Car emissions to go to work
Total turnover (TOTp) is multiplied for percentage of e-commerce users (Ecu) and for percentage of people that go to work by car (1-pwc) and divided for the average purchase for e-shoppers (Ecp) to find the number of workers that use e-commerce.
The result is multiplied for car emissions (E1) and for the average distance home-work (hw).

$$Ewc = \frac{TOTp \times Ecu \times (1 - pwc)}{ECp} \times E1 \times hw$$

Car emissions to go to PUP (pick-up-place)
Total turnover (TOTp) is divided for the average e-purchase (Ecp) and multiplied for the percentage of e-buyers (Ecu) and the percentage of people that go to PUP by car (ccp) to obtain the number of e-commerce users that go by car to PUP. This data is multiplied for car emissions (E1) and for the average distance home-PUP (hp).

$$Ep = \frac{TOTp \times Ecu \times ccp}{ECp} \times E1 \times hp$$

Van emissions

The total turnover (TOTp) is multiplied for the percentage of e-commerce users (Ecu) and divided for average e-purchase (Ecp) and the number of orders for each van (C2). This result is multiplied for van emissions, route delivery van for Lund's zone (rv) and for the coefficient of efficiency (EFF).

$$Ve = \frac{TOTp \times Ecu}{ECp \times C2} \times rv \times E2 \times EFF$$

Truck emissions

Total turnover (TOTp) is multiplied for the percentage of e-commerce users (Ecu) and divided for the number of orders for each truck (C3) and the average e-purchase in SEK (Ecp). This data is multiplied for the truck delivery route and for the truck emissions.

$$Te = \frac{TOTp \times Ecu}{C3 \times ECp} \times rt \times E3$$

9.2 Equation Model 1

To evaluate the environmental impacts of model 1 we compare the emissions for traditional shopping without e-commerce (Eo) with the emissions for shopping considering e-commerce (Etot).
We obtain Etot summing the van emissions of the home delivery (Ve) with the car emissions of the people to go to the store in a traditional way (Etr).

$$Eo = \frac{TOTp \times ppc}{STp} \times E1 \times d1$$

$$Etot = \frac{TOTp \times ppc \times (1 - Ecu)}{STp} \times E1 \times d1 + \frac{TOTp \times Ecu}{ECp \times C2} \times rv \times E2 \times EFF$$

Placing Etot = Eo we obtain:

$$rv(critical) = d1 \times \frac{ECp \times ppc \times E1 \times C2}{STp \times E2 \times EFF}$$

9.3 Equation Model 2

For model 2 I compared the emissions for traditional shopping without e-commerce (Eo) with the emissions of the shopping using the model 2 solution (Etot).
In this case Etot is due to the sum of the emissions for the traditional shoppers (Etr) plus the truck emissions for the home delivery (Te) plus the car emissions of workers that use e-commerce and that go to work by car (Ewc).

$$Eo = \frac{TOTp \times ppc}{STp} \times E1 \times d1$$

$$Etot = \frac{TOTp \times ppc \times (1 - Ecu)}{STp} \times E1 \times d1 + \frac{TOTp \times Ecu}{ECp \times C3} \times rt \times E3 + \frac{TOTp \times Ecu \times (1 - pwc)}{ECp} \times E1 \times hw$$

Placing Eo = Etot we obtain:

$$rt(critical) = d1 \times \frac{ECp \times C3 \times ppc \times wor \times E1}{STp \times E3} - hw \times \frac{C3 \times E1 \times (1 - pwc)}{E3}$$

9.4 Equation Model 3

For model 3 the comparison between Eo and Etot, as in the precedent models, permits to obtain the truck critical route (rt(critical)).
Etot is due to the sum of emissions for traditional shopping plus the truck emissions to delivery to the PUP (Te) plus the car emissions of customers that go by car to take the goods to the PUP (Ep).

$$Eo = \frac{TOTp \times ppc}{STp} \times E1 \times d1$$

$$Etot = \frac{TOTp \times ppc \times (1 - Ecu)}{STp} \times E1 \times d1 + \frac{TOTp \times Ecu}{ECp \times C3} \times rt \times E3 + \frac{TOTp \times Ecu \times ccp}{ECp} \times E1 \times hp$$

Placing Eo = Etot we obtain:

$$rt(critical) = d1 \times \frac{ECp \times ppc}{STp \times ccp} - hp \times \frac{ccp \times E1 \times C3}{E3}$$

$$hp(critical) = d1 \times \frac{ECp \times ppc}{STp \times ccp} - rt \times \frac{E3}{ccp \times E1 \times C3}$$

9.5 Equation Model 4

For Model 4 the comparison between Eo and Etot permits to obtain both vans critical length and trucks critical length fixing respective the truck delivery route length (rt) and the van delivery route length (rv). Etot is obtained summing the car emissions for the traditional shopping (Etr) plus the truck emissions to delivery to the spreading points (Te) plus the van emissions for the home delivery (Ve).

$$Eo = \frac{TOTp \times ppc}{STp} \times E1 \times d1$$

$$Etot = \frac{TOTp \times ppc \times (1 - Ecu)}{STp} \times E1 \times d1 + \frac{TOTp \times Ecu}{ECp \times C2} \times rv \times E2 \times EFF + \frac{TOTp \times Ecu}{C3 \times ECp} \times rt \times E3$$

Placing Eo = Etot and fixing respective rt and rv we obtain:

$$rv(critical) = \frac{d1 \times E1 \times ppc \times ECp \times C2}{STp \times E2 \times EFF} - \frac{rt \times E3 \times C2}{E2 \times C3 \times EFF}$$

$$rt(critical) = d1 \times \frac{E1 \times ppc \times C3 \times ECp}{STp \times E3} - rv \times \frac{E2 \times C3 \times EFF}{C2 \times E3}$$

9.6 Questionnaires and check lists for the interview to

Stefan Holst (ICA Malmborg director)

Technical questions

1) Which is the percentage of e-commerce users in Lund?
2) Which is the home delivery model used by your store?
3) Which is the average size of the order for traditional shopping?
4) Which is the average size of the order for e-commerce?
5) How many orders do you delivery for each van?
6) How many orders do you delivery for each truck?
7) Do you use attended or unattended delivery?
8) Which is the average route length of a delivery van in Lund?
9) Which is the average route length of a delivery truck in Lund?
10) Which is your percentage of returns?

General questions

1) Do people that use e-commerce continue to go to the store for buying fresh or "boring" goods?

2) Do you think that e-commerce is only one more service of your grocery, or do you think that this modality will change the future consumer behaviors?

9.7. Policy implications and the actions of European Union

As we said before, an integrated transport policy is critical for the development of e-commerce in an environmental friendly way. This implies the need for governance at the highest levels, to make local policies efficient. In this Appendix I will mention what the European Union is doing in this way, and if the future projections are going in the right direction for the environment. Statistics from the European Environment Agency say that nitrogen oxide emissions from road transport in EU-15 Member States increased by about 20% from 1980 to 1990 and were then reduced, so that by 1998 they essentially returned to 1980 levels. The fact that the emissions did not continue to increase in line with traffic growth was mainly due to the introduction of three-way catalyst cars in the late 1980s and early 1990s and the introduction of emission standards for heavy-duty vehicles. Without these measures, NOx emissions by traffic would have been 50% higher in 1998.[105] This fact testifies the absolute importance of a strong and clear traffic policy at European level. In general, a substantial decrease in emissions of air pollutants has occurred, and is also forecasted up to 2010-20, while CO_2 emissions are projected to increase, largely due to increasing passenger car transport. The European countries differ in the extent to which the transport sector contributes to the CO_2 emissions. Some common features and conclusions concerning transport in the national strategies are:[106]

(1) The greenhouse gas emissions from transport increase.
(2) Current traffic growth is unsustainable – it is necessary to limit the growth.
(3) Need for change in lifestyle and driving behavior are a constant.
(4) Increased fuel efficiency of new cars is emphasized. EU common initiatives to develop railways and inland waterways.

As mentioned, such policies are also needed for gaining beneficial effects from the use of IT and Ecommerce. A guiding example for integrating environmental and sustainability issues in innovation planning in the IT and e-commerce sector is the road-map project "Sustainable Information and Communication Technologies" (NIK)[107] initiated by the German parliament. The objective of NIK is to link development toward the information society with the concept of sustainability. NIK is not only aimed at developing consensus in industry forecast and sustainability goals, but is also intended to stimulate initiatives and to set up business networks that commonly plan and implement process, product and service innovations.[108]
Also, in the EU Climate change program (European Commission, 2000) a number of transport related measures are proposed:[109]

a) Transport pricing and economic instruments

[105] European Environment Agency, National and central estimates for air emissions from road transport, Technical report, Copenhagen 2002
[106] Lars Westermark, Integrate the envieonmental dimension – Visions for transport, Swedish Environmental Protection Agency, 2001
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b) Fiscal framework as a part on the strategy on CO_2 and cars
c) Extension of the Enhanced vehicle concept to passenger cars and light duty vehicles
d) European campaign for more fuel-efficient driving behavior
e) Revision of transport policy (rail, road freight, modal-shift, maritime, aviation)
f) Sustainable mobility and intermodality
g) Satellite navigation systems (Galileo)

In general the role of EU in supporting the national strategies is to provide a smooth working market throughout the union. Harmonize taxes and charges, promote liberation of railways, emission regulations and develop environmentally enhanced vehicle concept, apply exchange of experiences and best practices are some of the most important aspects that must be taken in consideration.
The EU is thus making efforts in this direction, and these general guidelines should be individually implemented by each country. E-commerce is a young business but it's in constant growth. European countries have to implement an environmental friendly logistical structure to support this development, in the way to integrate as much as possible the economic growth with the environmental sustainability.