Comparing alternative home delivery models for e-grocery business

Mikko Punakivi

Dissertation for the degree of Doctor of Science in Technology to be presented with due permission for public examination and debate in auditorium Luna at Helsinki University of Technology, Department of Industrial Engineering and Management, Finland on the 7th of June, 2003 at 12 o'clock noon.

Abstract

Recently, last mile logistics has been identified as one of the most important factors in developing consumer direct business concepts. Research and experience have revealed that the goods reception mode is one of the key factors when developing cost-efficient home delivery operations. This dissertation identifies, models, and analyses existing and emerging e-grocery home delivery operation models. The cost levels of various home delivery models offering attended and unattended reception are compared, and their feasibility evaluated using real point-of-sale data and a vehicle routing tool. The cost level of home delivery service is also compared to the current costs of a household customer visiting a supermarket using his/her own car. In addition, the environmental effects of the different home delivery models are analysed.

According to the results, home delivery transportation costs using the shared reception box concept are 55-66% lower than those of the current standard home delivery model with attended reception and 2-hour delivery time windows. This cost reduction alone justifies the two-to-five-year payback period of the investment required, even if there is only a fairly small number of deliveries per day. Compared similarly, using customer-specific reception boxes in home delivery operations leads to a cost reduction of 44-53%. Because of the high investments involved in customer-specific reception boxes, the payback period, based on the cost savings, is 6-13 years. This requires customer involvement in investment. These results show that the most cost-efficient e-grocery home delivery model is based on unattended reception, which enables the optimal routing and scheduling of delivery vehicles. It would also be the best solution when considering the environmental aspects. Usage of e-grocery home delivery services offers a notable potential for traffic reduction when compared to the situation in which customers visit the shop using their own cars. In the selected test area, the reduction would be between 54 and 93 per cent, depending on the home delivery model used. However, the total traffic reduction and reduction of traffic emissions depends greatly on the e-grocery market share in the future.

Keywords: electronic grocery shopping, home shopping, home delivery, last mile problem, transportation, home delivery costs, unattended reception, reception box, delivery box, shared reception box

Acknowledgements

First and foremost I would like to thank my supervisor Professor Kari Tanskanen and instructor Docent Jan Holmström for their time and valuable pieces of advice during the research and writing process. Especially professor Tanskanen offered his help and support during the critical "last mile" in this process. Additionally, I would like to thank the pre-examiners of this dissertation Professors Michael Browne and Aimo Inkiläinen. Their feedback has been valuable and the quality of the dissertation has been improved considerably based on their comments.

I would also like to take this opportunity to thank all my colleagues and other people that have helped me through this learning process. Since this dissertation is a binding story based on several individual articles, I owe a special thanks to my friends and co-authors: Kari Tanskanen, Jan Holmström, Hannu Yrjölä, Vesa Kämäräinen, Juha Saranen, Jaana Auramo, Anna Aminoff, Hanne Siikavirta, Mikko Kärkkäinen, and Lassi Linnainen. During the research work and also in spare time I have spent some unforgettable moments with you. Additionally, I wish to thank my parents, relatives and friends for their encouragement and support during the last four years.

Other contributors to this dissertation are of course the commercial partners in the Ecomlog research program providing business critical case data, experience, and advice during the work. I would like to thank all the commercial partners and Tekes - the national technology agency- for providing the financial foundation for the Ecomlog research program. I'm also very grateful to Kuorma-autoliikenteen Volvo Säätiö, Tekniikan edistämissäätiö, Henry Fordin Säätiö and the Doctoral Program in Industrial Engineering and Management for the financial support that enabled finalising this dissertation.

My warmest thanks I owe to the world's best wife Pia and my lovely daughter Ella for their supportive and understanding attitude towards my work and for offering me great moments in private life.

Espoo 15th May 2003

Mikko Punakivi

CONTENTS

List of Figures and Tables

Papers

Paper I	Auramo, J., Aminoff, A., **Punakivi, M.** (2002), "Research agenda for e-business logistics -based on professional opinions", *International Journal of Physical Distribution and Logistics Management, Vol.32, Iss.7, pp.513-531*.
Paper II	**Punakivi, M**. and Saranen, J. (2001), "Identifying the success factors in e-grocery home delivery " *International Journal of Retail and Distribution Management*, Vol. 29, Iss. 4, pp. 156-163.
Paper III	**Punakivi, M**., Yrjölä, H. and Holmström, J. (2001), "Solving the Last Mile Issue: Reception box or Delivery box" *International Journal of Physical Distribution and Logistics Management*, Vol. 31, Iss. 6, pp. 427-439
Paper IV	Siikavirta, H., **Punakivi, M**., Kärkkäinen, M. and Linnainen, L. (2003), "Effects of e-commerce on greenhouse gas emissions case: home delivery service", *Journal of Industrial Ecology, Vol.6, No. 2, pp.83-97*
Paper V	**Punakivi,** M. and Tanskanen, K. (2002), "Increasing the cost efficiency in e-fulfilment by using shared reception boxes", *International Journal of Retail and Distribution Management,* Vol.30, Iss. 10, pp.498-507.

Definitions

e-Grocery	An abbreviation of online grocery shopping, or electronic grocery shopping also referred to as EGS.
Home delivery model	Home delivery model is defined by the e-grocery service provider. Characteristics of the service offered include delivery hours, for example from 8 a.m. to 10 p.m. on weekdays. Additionally, if attended reception is used, there are delivery time windows, for example 2-hour time windows during the delivery hours.
Attended reception	Attended reception is the traditional home delivery model, where customers wait at home to receive the delivery. (see: Home delivery model)
Unattended reception	Using facilities enabling unattended reception, the customer is relieved of the need to receive the goods ordered. Unattended reception may be based on reception boxes, delivery boxes, shared reception boxes, or collection and delivery points (CDP).
Reception box:	The customer-specific reception box is equipped with a refrigerator-freezer unit, enabling compartments for frozen and chilled food. In the reception box there is also a room temperature compartment. The customer-specific reception box is installed, for example, in the customer's garage or the yard of their home.

Figure 1 Customer-specific reception box (Hollming).

Delivery box:	A delivery box is an insulated secured box that can be left on the customer's doorstep. In the best case, the delivery box is equipped with a secure docking mechanism. (See Figure 2)

Figure 2 Delivery box with a secure docking mechanism (Homeport, 2002).

Shared reception box

Shared reception box units may have various amounts of separate lockers, which may contain freezer, chilled, and room temperature compartments. The separate lockers have electronic locks with a changing opening code to enable shared usage of the lockers using a mobile phone. The shared reception box units may be placed, for example, in bus or underground stations, supermarket and office car parks, or apartment house cellars. In this dissertation delivery operations based on shared reception boxes are regarded as home delivery, although the location of the shared reception box unit is not necessarily at the customer's home.

Figure 3 Shared reception box unit (Hollming).

Collection and Delivery Point (CDP)

Kiosks, superstores, petrol stations and tobacconists are potential locations for use as CDPs. At the CDP the ordered goods can be stored until the customer is able to collect the delivery. A shared reception box unit may be referred to as an automated Collection and Delivery Point (CDP).

1 INTRODUCTION

1.1 Review of current e-grocery operations

The development of information technology and the utilisation of the Internet in ordering goods have made it possible to develop new business models and service concepts for consumers. One example of new service concepts and better customer convenience is consumer direct electronic grocery shopping (e-grocery) and home delivery service. In brief, electronic grocery shopping means ordering a basket of commodities over an electronic network (Internet, email). The home delivery of the ordered goods is then an additional service included to the service concept.

Thus, one major precondition for using the electronic grocery shopping service is the customers Internet access. However, that is not seen as a barrier since, for example, in the USA 57%, in Finland 45%, and in the UK 34% of the adult population are already Internet users (GER, 2001). What is seen as a barrier is the resistance of change and slow adoption of new ways of action in general. Developing and implementing new operating concepts, as well as using those new services, requires a willingness to change the current operating models. This willingness is required of consumers, retailers, and manufacturers, as well as of the various service providers in the supply chain.

Compared to traditional grocery shopping, e-grocery requires new operating models in the supply chain. In the traditional grocery supply chain, goods are delivered to the store and customers perform the picking and final delivery to the home. For an e-grocer the major cost drivers are picking, packing, and home delivery transportation (Lewis, 2000; @ Your Home, 2001). The challenges for an e-grocer are to achieve cost-efficient operating models and to provide more convenience to consumers.

The challenge in picking operations has been solved by using two alternative strategies. Picking operations can be carried out either by using the current store infrastructure or new dedicated distribution centres. The first strategy is called an intermediary model and the second, based on a distribution centre, a channel model (Dagher, 1998; Bartolotta, 1998; Heikkilä et al., 1998a; Holmström et al., 1999; Kämäräinen et al., 2001a). Traditional retailers have generally used the first strategy, in which e-grocery operations are based on current store infrastructure. The second strategy, based on distribution centres, has been used mainly by the new rival competitors, also known as "pure play" e-grocers.

Both of these strategies have their strengths and weaknesses. In the channel model, distribution centres may be located in an area that is not as expensive as the one where the traditional stores are located (Jaakola, 1999; Kämäräinen et al., 2001b). A distribution centre is typically designed to achieve efficient picking operations, whereas traditional stores are normally designed to display products to consumers (Peters, 2001; Yrjölä, 2001). Additionally, in the intermediary model the customers doing their shopping in the store slow down the picking work, whereas in distribution centres some of the picking work may even be automated (Reda, 1998; Kämäräinen et al., 2001b). Automation, however, requires high investment and, for it to be viable, high capacity utilisation and stable demand are also needed (Kämäräinen & Punakivi, 2001).

When using the intermediary model, where picking operations are based on the existing store infrastructure, the required investment is significantly smaller compared to using distribution centres. Compared to the channel model, the intermediary concept has three main strengths. Firstly, the risk of over investment is small. Secondly, customer acquisition is easier because of the fact that traditional retailers usually have a well-known brand on the market. Thirdly, the traditional retailer already has a well-established relationship to their suppliers.

Regardless of the strategy used in the picking operations, the goods have to be delivered to the customers. Home delivery operations, the second major cost driver, have become the Achilles heel of the e-grocery business. Daily grocery products are more demanding than other physical products like books or clothing, because the trade of grocery goods is tightly regulated and controlled in terms of preservation and the quality of the delivered goods. This is why dedicated delivery structure with temperature controlled storage and vehicles are needed. Various models of home delivery operations have been developed and are in use, including both attended and unattended reception. An overall classification of home delivery models follows:

1. Attended reception of the goods ordered at a location chosen by the customer (home, office) using delivery time windows defined by the service provider.

2. Unattended reception using a reception box concept. A reception box is a refrigerated, customer-specific locked reception box installed in the consumer's home yard or garage. (See Figure 1 on page 7)

3. Unattended reception using a delivery box concept. A delivery box is an insulated secured box that can be left on the customer's doorstep but which is returned to the retailer. Delivery boxes may be equipped with a docking mechanism that makes secure delivery possible. (See Figure 2 on page 8)

4. Unattended reception using shared reception box units, also known as automated Collection and Delivery Points (CDP). The shared reception box units have various amounts of separate lockers, each of which contains freezer, chilled, and room temperature compartments. The separate lockers also have electronic locks with a changing opening code to make possible shared usage of the lockers using a mobile phone. The shared reception box units may be placed, for example, in bus or underground stations, office and supermarket car parks, apartment house cellars, or wherever the retailer believes it to be convenient for consumers. (See Figure 3 on page 8)

To illustrate the importance of the home delivery model selected, let us look at a few case examples where different home delivery models are used. The first case example is Webvan, probably the best-known "pure play" e-grocer, which launched its e-grocery business in June 1999. To reach market dominance, Webvan offered its customers home delivery with attended reception and delivery time windows of 30 minutes. Furthermore, the service was free of charge for orders above $50. In spite of that, Webvan was unable to create sufficient delivery density to reach economically viable home delivery operations. Low customer density, attended reception, and short delivery time windows together resulted in extremely high delivery costs. In November 2000 Webvan started to charge $4.95 for deliveries worth less than $75 (Austria Farmer, 2000). In December 2000 Webvan tried to decrease its home delivery costs by cutting down its service level to 60-minute delivery time windows (Webvan, 2001). Then, in May 2001, Webvan again raised its delivery charges from $4.95 to $9.95 for orders under $75, and imposed a new fee of $4.95 for orders between $75 and $100, leaving free delivery only for orders over $100 (Sandoval, 2001a). Even rationalising and pricing its home delivery service was not enough to prevent Webvan from running out of money as a result of an unexpected drop-off in incoming orders when delivery fees were introduced (Austria Farmer & Sandoval, 2001; Reinhardt, 2001). Finally, Webvan ceased its operations in July 2001 (Sandoval, 2001b).

Another example of an e-grocer offering home delivery and attended reception is Matomera (owned by Bergendahls Gruppen), which operated in Malmö, Sweden from 1998 to March 2001 (Johnsson, 1999; Matomera, 2001; Borgström, 1998). The distribution centre based picking operations were manual but efficient. The problematic issue with the Matomera e-grocery service was its home delivery operation. The service area selected was too large, being of a 30-kilometre radius around Malmö, leading to huge amounts of kilometres being driven, thus destroying the business' profitability. This large service area was selected to attract as many customers as possible. Although only three 2-hour delivery time windows were offered to the customers, the low customer density led to a high home delivery cost per order. According to a Matomera press release on 26.3.2001, the e-grocery operations were closed down as a consequence of small market demand (Matomera, 2001).

Streamline.com was the first e-grocer offering unattended reception by installing refrigerated reception boxes in the customer's garage (Bartolotta, 1998). Streamline launched its e-grocery business as early as 1993 and commenced Internet ordering in 1997. As early as 1997, around 75% of the orders were being placed over the Internet (Feare, 1999). The idea was to offer well-off suburban families a convenient grocery service that also included value-added services such as dry cleaning, film processing, UPS package pick-up, and Vendor Managed Inventory (Dagher, 1998; Feare, 1999;

Småros & Holmström, 2000; Småros et al., 2001). Additionally, the service concept, based on unattended reception, made possible the achievement of a high repetitive purchasing rate, customer loyalty, stable demand, and notable efficiency gains in home delivery operations compared to attended reception (Lardner, 1998). Streamline offered its reception box and home delivery service once a week for $30 a month; additionally, an entrance fee of $39 was charged when first subscribing to the service (Dagher, 1998; Feare, 1999). However, in 2000 Streamline had to close its business because it was unable to reach the necessary critical sales volume (Nasdaq, 2000; Junnakar, 2000). Another problem that it encountered was weak negotiation and purchasing power with its suppliers. Streamline's operations in the Chicago and Washington D.C. areas were acquired by Peapod.com in September 2000 (Peapod, 2000), and in November 2000 Streamline closed down the rest of its business (Junnakar, 2001).

Streamline's experience, however, shows that offering unattended reception could bring benefits to the e-grocer, home delivery service provider, and to the customers. At the moment the standard home delivery service concept offered by the worlds leading e-grocers, Tesco.com and Peapod.com, is attended reception with 2-hour delivery time windows. Tesco.com was started in 1996 and is currently the world's biggest e-grocer with annual online sales of £356 million (approximately 535 million euro) in 2002. Tesco.com relies on store based picking operations and carries out more than 3.7 million home deliveries per year in the UK market. The home delivery operations are based on attended reception and 2-hour delivery time windows. The cost of the last mile home delivery operations not including picking was some 7% of Tesco.com sales (Reinhardt, 2001; Jones, 2001). Peapod.com was founded in 1989 and since August 2001 is totally owned by Royal Ahold. Peapod.com is currently the second largest e-grocer in the world and biggest in the USA operating in 5 metropolitan areas there. In the picking operations Peapod relies on both warehouses and supermarkets depending on the market size. In the home delivery operations, providing both attended reception with 2-hour delivery time window and unattended reception, Peapod uses about 600 delivery vehicles. The average order size was worth of USD 135 in the year 2002. Additionally, according to Van Gelder (2002a) Peapod.com operations are profitable in 4 out of 5 markets and the company has achieved an annual growth rate of 35 per cent.

To develop operational efficiency and customer service, also Tesco has plans for unattended reception and like noted Peapod is already offering unattended deliveries (Tesco, 2001; Bentham, 2001; Peapod, 2001). In fact according to Van Gelder (2002a) some 35 per cent of Peapods customers in Washington and 10 per cent of the customers in Chicago use unattended reception today. Service offers with a delivery box concept have also been started in the UK, for example by the Food Ferry and Sainsbury's (Homeport, 2002). Consignia, the former Post Office organisation, has also launched trials of five different solutions to the question of unattended deliveries in the UK (Rowlands, 2001a). Additionally, major white goods manufacturers such as Siemens in Holland and Electrolux in the UK have projects in which facilities for unattended reception are being tested (Bearbox, 2001; Siemens, 2001).

However, there are still many unsolved problems concerning customer-specific unattended reception concepts. Facilities require high investment and, at the same time, the utilisation rate is very low. One of the solutions that has been suggested and is also supported by policy makers is the usage of shared reception boxes (Browne et al., 2001; Rowlands, 2001b). The assumption is that, using shared reception boxes, the utilisation rate of the facilities would be higher than in the case of customer-specific reception facilities.

One of the earliest shared reception box pilot projects was introduced in 2000 by the GIB Group in greater Brussels, Belgium (GIB, 2001). GIB had 18 trucks specially designed to act as pickup points for grocery shopping baskets ordered online. Every day the 18 trucks were loaded with up to 45 orders each and driven to selected pickup points to intercept the consumer on their way home from work. The trucks stayed at the pickup point for five hours, from 4 p.m. until 9 p.m. (Ring & Tigert, 2001). Unfortunately, the business model did not work, presumably as a result of the high level of investment and inefficient usage of the trucks. Recently, shared reception box units for receiving grocery products have been introduced, for example by Hollming Ltd in Finland and Boxcar Systems Inc. in the USA (Hollming, 2001; Boxcar, 2001). Pilot experiments with these shared reception boxes have also been started. Additionally, Consignia in the UK already has a pilot project in which shared reception box units or "boxbanks" from Bybox are used for parcel deliveries (Rowlands, 2001a).

To summarise, although many e-grocery home delivery models have been launched and are emerging, knowledge of the success factors has remained hidden. Due to lack of research, the potential savings, for example, of using unattended reception are not yet known or publicly available. However, customer demand for unattended reception already exists. According to Lewis (2001), 40 per cent of active or potential European online grocery shoppers would be interested in unattended deliveries. Additionally, according to a Finnish market research company, Gallup Web, 45-50 per cent of Finnish Internet users are interested in using unattended reception for groceries purchased online. In particular, active Internet users and Internet users living in the countryside are very interested in unattended reception (Gallup Web, 2001). Another factor supporting the research focusing on developing e-grocery home delivery is the forecast market growth. According to Verdict Research (Rowlands, 2001b), online grocery shopping will be one of the fastest-growing businesses on the Internet in coming years. Between 1999 and 2000 the online grocery market grew by nearly 200 per cent and the average growth rate forecast for the next five years is 64 per cent (Jupiter, 2001). In 2001 the market share of online groceries was only 0.3-0.7 per cent in the UK (Finch, 2001; @ Your Home, 2001), 0.22 per cent in the USA (IDC, 2000; Van der Laan, 2000), and 0.1 per cent in Finland (Päivittäistavarakauppa, 2001). However, online shopping may represent as much as 2 to 15 per cent of grocery volume in the USA by the year 2006 (Peapod, 2001; Jupiter, 2001). In Europe, it has been estimated that online shopping will account for from 2.5 up to even more than 20 per cent of the grocery market by 2005-2010 (Lewis, 2000; Powell, 2000; @ Your Home, 2001; Finch, 2001; O'Neill, 2001; Heiskanen, 2000; Tuunainen, 1999; Heikkilä et al. 1998b). Currently, after the e-commerce hype, the growth estimates tend to be closer to 3-10 per cent by 2005-2010 on both continents.

Estimates presented vary significantly from one another. However, the grocery market is so vast, currently approximately 500 billion euro in the USA, 140 billion euro in the UK, and around 10.5 billion euro in Finland, that even development according to the most conservative estimates would create substantial business.

1.2 Research objectives and research scope

As already shown in the Introduction, home delivery has become a major problem in the e-grocery business. Furthermore, this problem is not going to disappear as the online grocery market grows in the future. Therefore, the objective of this dissertation is to identify existing and emerging home delivery operations models in the e-grocery business. A second objective is to analyse and compare the cost efficiency of the alternative solutions in home delivery operations by modelling. The modelling work, analysing and comparing the cost levels of various home delivery models, is based on real traditional grocery shopping point-of-sale data. In the modelling, the cost levels of home delivery operations are also compared to the current costs of a household customer visiting a supermarket using their own car. In addition to the cost efficiency analysis, a further objective is to analyse the environmental effects of the alternative home delivery models. Giving guidelines for developing feasible and economically and environmentally sustainable home delivery services is seen as the final objective. The aim of the research is to formulate answers to the following research questions:

- *What are the cost levels of the identified e-grocery home delivery models?*
  - *What is the impact of alternative goods reception modes on home delivery cost-efficiency?*
  - *What are the costs of home delivery models compared to "self-service", where a household customer visits a supermarket using their own car?*
- *In which situations is each alternative home delivery model feasible?*
- *Can the operational cost savings in home delivery transportation justify the required investments in unattended reception?*
- *What are the possible environmental effects of the alternative home delivery models?*
  - *What is the impact on the mileage driven in urban traffic?*
  - *What is the effect on greenhouse gas emissions?*

The focus of this dissertation is home delivery operations in the e-grocery business. A great business potential is seen there because grocery shopping is the largest business in retailing. Consumers buy grocery products regularly and frequently and thus groceries make up the greatest constant material flow to household customers, regardless of the time of year. Additionally, there is no need to test or see the supposedly well-known products before ordering them. This is why grocery products are also seen very suitable for e-commerce. Thus, here the grocery products are seen as basic home delivery material flow into which other product groups, such as books, CDs, laundry etc., may be included in the future, increasing the service level and customer convenience. The research work for this dissertation was conducted in Finland. The central reasons for focusing the research on the Finnish e-grocery business were the availability of proper data for research purposes and of the expertise of the Finnish grocery and transportation businesses.

1.3 Research environment

This dissertation is a part of the Ecomlog research programme, started in April 1999 and carried out by the TAI Research Centre at the Helsinki University of Technology, Finland. The programme was a three-year e-commerce initiative funded by Tekes - the national technology agency - and leading Finnish companies in telecommunications, logistics, retailing, and packaged consumer goods (Appendix I).

The Ecomlog research programme co-ordinated three subprojects addressing different challenges facing companies in a changing supply chain environment. This dissertation was produced within the Intertrade project, which aimed to create competitive logistics solutions for e-business and especially for electronic grocery shopping in Finland. The principal company partners in the Intertrade project were S-Group, Norpe, Valio, Panimoliitto, and Trading House Hansel.

In the Intertrade project the initial problem definition and planning was carried out mainly by Hannu Yrjölä, starting in 1997 and resulting in the commencement of the actual Ecomlog research programme in April 1999. Yrjölä & Tanskanen (1999) and Yrjölä et al. (2000) were published soon after starting the Intertrade project, providing guidelines for the research work.

The main research question in the Intertrade project, *What is the effective supply chain for e-grocery business?*, was formulated on the basis of the definition of the problem area and current state analysis of the problem area. Then the relevant research topics were identified and selected for research. The *home delivery system*, including analysis of various service models and the effects of attended vs. unattended reception, was seen as an important research topic. Another important topic to be analysed was the *order assembly system*, including comparing the picking operations in a dedicated DC and store and the analysis of appropriate level of automation in the picking operations. A third area of interest was the possible *impacts on upstream operations* in the grocery supply chain, including analysis from the first-tier supplier's point of view.

Hannu Yrjölä took the research responsibility of studying the main research question. However, since the main question was found to be very complex and includes several essential sub-questions, the research work was carried out as a joint effort. During the research process the research responsibilities were divided in the following way:

1. *What is the impact of alternative goods reception modes on the effectiveness of home delivery?* (main responsibility: Mikko Punakivi)
2. *What is the impact of alternative order assembly systems on the effectiveness of the e-grocery supply chain?* (main responsibility: Vesa Kämäräinen)
3. *What are the implications of changing from conventional shopping to EGS for the grocers' first-tier suppliers?* (main responsibility: Hannu Yrjölä)

In the main research phase these topics were then analysed partly by the authors working together and partly individually. Regardless of dividing the research work in to parts co-operation between the researchers was emphasised bearing in mind that every action in a supply chain affects many others. During the research work the chief emphasis was placed on topics 1 and 2, since greater development potential was identified there. During the research process, several more specific questions were revealed and selected for further research conducted both individually and in co-operation. The research questions and focus areas of the researchers in the Intertrade project are presented in detail in Appendix II. The research results of Yrjölä and Kämäräinen are briefly covered next.

The dissertation by Yrjölä (2003) concentrates on finding out under which conditions e-grocery business could be cost competitive compared to conventional grocery retailing. The main hypothesis of the dissertation is that "e-grocery with home delivery can be more efficient than supermarket retailing handling a similar volume of sales".

According to Yrjölä, the e-grocery business should be seen as an assembly industry producing shopping baskets. Instead, the e-grocery business has typically been conducted as a supermarket copied into an electronic form, that is, it is seen only as an opportunity to buy products. Yrjölä states that the starting point of operational design should be the real needs of a household, and take into account the possibility of adding new services for the customers.

According to Yrjölä (2003), the most important research finding of his dissertation is that the operational costs of a Local Distribution Centre can be lower than those of a supermarket.

According to Yrjölä's analysis, store-based order picking is less expensive than using a specialised distribution centre when turnover is less than one million euros per year. A turnover of more than 3 million euros means that a dedicated distribution centre appears to be more efficient than store-based picking. However, the distribution centre must be purpose-built for shopping basket assembly with a reasonably stable workload to avoid unnecessary high resource allocation to be able to cope with demand peaks.

Yrjölä (2003) introduces additionally a hybrid model that combines distribution centre and store-based picking as an opportunity to create gradual low-risk growth in the e-grocery business. In the hybrid model, supermarkets are redesigned by dividing the floor space into to Local Distribution Centre and supermarket areas. This is how order picking and home deliveries can be carried out more effectively than in a conventional supermarket.

One of the important characteristics of the hybrid model is that grocery products in a supermarket are initially divided into three categories based on sales volume. Products in class A are high volume goods that are not stored in the supermarket but can be ordered directly to the Local Distribution Centre from the producers. The orders can be made according to the customer's online orders. Class B products have some inventory in the supermarket, and the picking operations may be manual or automated depending on the sales volume. The products in class C are low volume goods that use the supermarket as an inventory, and picking is done manually from the supermarket shelves.

Yrjölä (2003) also focuses on the efficiency of home delivery operations. According to Yrjölä's research findings, it seems that efficient home delivery can be achieved even with a moderate market share.

Largely based on the early research work done in co-operation with Punakivi and Saranen (Punakivi & Saranen, 2001), he concludes that unattended reception is very important for the overall cost structure of the supply chain. According to Yrjölä, there seems to be a possibility of achieving real economy of scale in home delivery, but not with the service models used by the early e-grocers. If the consumer is free to decide the delivery time, the production cost of the service will be high, even with high customer density. This is also proven in the research work done by Laseter et al. (2000). With service models that give flexibility in route planning and optimisation, for example home delivery based on unattended reception, the service can be provided more efficiently.

However, the investments that home delivery based on unattended reception requires are only discussed briefly in Yrjölä's dissertation. He suggests that household customers themselves could make the investment in the long run. This requires that the facility enabling unattended reception be seen as additional refrigerator-freezer for the household, not only for the purpose of receiving goods ordered online.

Another important research finding in Yrjölä (2003) is that costs in the middle and upstream of the supply chain will not increase as a result of changing supermarkets to Local Distribution Centres. Some investments in better and more detailed order handling and fulfilment in some food industries, such as breweries, is required. However, there are many positive aspects, for instance increased demand predictability and cost reductions in deliveries, which will more than offset the negative aspects.

On the basis of earlier research findings, the main research finding in Yrjölä (2003) is that electronic grocery shopping with home delivery service can be made cheaper to operate than supermarket retailing handling a similar volume of sales.

Yrjölä, however, states that this requires a restructuring of the supply chain and consumer co-operation. Successful operations require customer loyalty, forward planning, and delivery times optimised by the service provider rather than dictated by the customer on impulse. According to Yrjölä's analysis, a local distribution centre-based home delivery service with annual sales of more than 200.000 euros per square kilometre seems to have the potential to become more cost-effective than running supermarkets. This sales volume can be achieved with 25 four-person households per square kilometre with 90 per cent loyalty. Based on his research results, Yrjölä states that new efficiency indicators, such as sales per distribution centre and sales per square kilometre, are needed to measure the efficiency of the e-grocery business. According to Yrjölä the most useful factor is sales per square kilometre.

Based on the research results, some conclusions are made in Yrjölä's dissertation. According to Yrjölä, e-grocery retailing is a very local business, and store-based picking is a good alternative if fast roll-out with a low level of investment is required. A distribution centre-based operation is potentially much more efficient, but it is slower to implement and needs more investment. Whatever service model is chosen, it should first be made to work in a relatively compact geographical area and only then copied to new areas.

Concurrent with Yrjölä's research work, Kämäräinen, one of the researchers in the Ecomlog programme, has published results supporting the research work in this dissertation. The licentiate thesis by Kämäräinen (2002) is based on the research work from the pre-understanding phase and on early results published up to the spring of 2001. Kämäräinen (2002) concentrates on identifying the biggest logistical challenges when developing operations for the e-grocery supply chain and describes some basic principles of how to develop cost-efficient supply chain solutions.

The work in progress dissertation by Kämäräinen (2003) is enlarged on the basis of the licentiate thesis. According to Kämäräinen (2003) improving overall logistical efficiency can be seen as one of the most important steps towards profitability in e-grocery. Therefore, he aims at understanding e-grocery business system implementation from the logistics point of view.

The main objective in Kämäräinen (2003) is to study how best to implement e-grocery business so that e-grocers can make their business profitable. A second objective selected in his dissertation is to identify, model, and evaluate different logistical solutions that can be used in the e-grocery business system. Solutions for achieving better picking efficiency are presented and modelled. Special attention is paid to investments in picking automation. Different solutions and revenue models of unattended reception are identified and examined. The potentials of the revenue models are evaluated with modelling and concrete examples. The last objective is to find out cost-effective combinations of solutions in different market situations to enable successful e-grocery business implementation.

According to the results in Kämäräinen (2003), cost-savings in picking cannot be realised with automation if demand and capacity utilisation varies too much. Automation, however, can be a remarkable solution when trying to increase the picking efficiency in the distribution centre. The problem is how to make the investment on the right level while customer demand is still low and may vary a lot. To realise cost savings, high and stable capacity utilisation must be achieved. Therefore, Kämäräinen suggests that the focus should be more on creating a flexible distribution centre and use of manual solutions with labour instead of automation.

Another research finding partly based on Punakivi & Tanskanen (2002) and the co-operation of Kämäräinen and Punakivi (Kämäräinen & Punakivi, 2002; Kämäräinen & Punakivi, 2003) suggests that operations models based on shared reception boxes have the best potential to become profitable among the solutions offering unattended reception.

Investments required in the reception facilities are high, and if the e-grocer or customer makes the investments, it is likely that access to the reception boxes would be limited. Therefore, according to Kämäräinen, the most likely investor for the reception facility is a third party operator who could offer receiving facilities for both

B2C and B2B customers, keeping the service open for many retailers and transportation service providers. According to Kämäräinen, in this way it is also possible to offer the services with a reasonable service fee. Additionally, Kämäräinen states that capacity utilisation is a crucial factor and must be high enough for the service to become profitable.

Thirdly, Kämäräinen (2003) focuses on analysing how the order of implementing solution components affects the success of e-grocery supply chain investment. First, Kämäräinen has identified that the possible investment targets are investments in new customer services, investments in reception facilities, and investments in the distribution centre.

According to Kämäräinen's results, the order of implementing solution components has a strong impact on the success of e-grocery supply chain investment. All the solutions have some impact on the other solutions, which should be taken into account when implementing an e-grocery supply chain. Kämäräinen concludes that while the goal should be the creation of a wide and loyal customer base in a dense service area, investments should be started from the reception facilities or value-added services. In spite of the high investments required, customer specific reception boxes are seen as a good way to reach a loyal customer base. In the case of pure play e-grocers, the distribution centre has been the most obvious alternative of the investment possibilities. However, this implementation strategy has been too expensive for most of the pure e-grocers, and it has often led to failure in the e-grocery business.

Based on the research results, Kämäräinen makes some conclusions. According to Kämäräinen, it is more important to take into account the flexibility and usability of individual solutions in different market situations than the maximum performance of an individual solution. Additionally, solutions and implementation strategies chosen depend heavily on the targets of the service. If e-grocery business is established only to support traditional grocery retailing, the starting point is entirely different to the starting point of pure play e-grocers.

1.4 Outline of the Dissertation

This dissertation consists of five individual articles and this binding story. In the first chapter, the background to the dissertation, research objectives, research questions, the scope of the research, and the research environment are introduced and described. In Chapter 2 a literature study of the accumulated theoretical knowledge (body of knowledge) relevant to this work is covered and discussed. Chapter 3 presents the hypotheses of this dissertation and gives an overview of the separate papers that are used to answer the hypotheses. The research methodology in this dissertation are presented in Chapter 4. In Chapter 5 the research results are analysed and conclusions considering the hypotheses are drawn. Chapter 6 then evaluates the contribution, relevance, validity, and reliability of the results of this dissertation, and raises some themes for further research.

2 LITERATURE REVIEW

This literature study starts with a brief introduction of logistics and supply chain management. Since the focus area in this dissertation is developing cost-efficient home delivery operations for an e-grocery business, the second and third sections of the literature study covers more thoroughly both the traditional grocery supply chain and the e-grocery supply chain. In the fourth section the basic principles of modelling in logistics decision-making are covered. The fifth section then covers the basic characteristics of home delivery operations and focuses on the vehicle routing problem. In the final section also the possible effects of home delivery on traffic and the environment are covered.

2.1 Logistics and supply chain management

In the early 1950s the management of logistics was still quite an unexplored area in business life. Companies had concentrated on transportation and inventory activities having the main focus on transportation (Ballou, 1999; Bowersox et al., 1999). During the 1950s the great potential of integrated logistics was discovered and total cost concept developed (Lewis et al.,1956). The main finding was that the lowest total cost might not be achieved by pursuing the lowest achievable cost in each individual logistics function. In order to reduce total costs, it was now seen possible to spend more on one function, such as selecting air transportation, in order to reduce the costs of other functions, such as inventory holding.

Recently, the Council of Logistics Management defined logistics as follows (Bowersox et al., 1999): "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements."

Another commonly used definition of logistics has been presented by Christopher (1998): "Logistics is the process of strategically managing the procurement, movement of storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost efficient fulfilment of orders."

The challenge currently facing logistics managers is to integrate the performance of the different logistical functional activities in the whole supply chain. The supply chain typically consists of raw material suppliers, production facilities, warehouses, distribution centres, transportation services, and customers (Seppälä, 1997). The interacting functional elements of various supply chains form a logistics network, as shown in Figure 4.

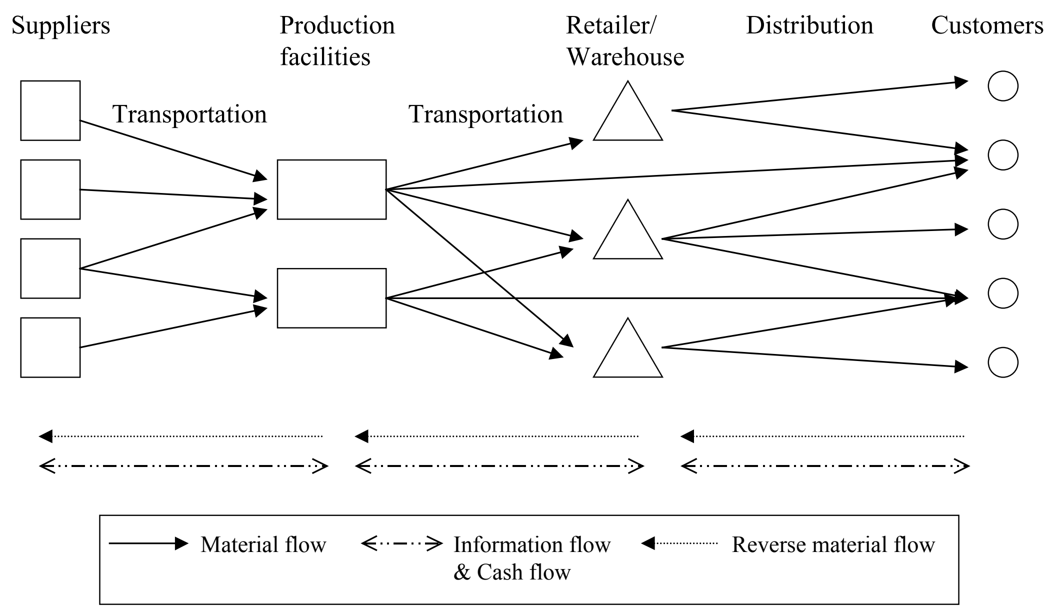

Figure 4 Logistics network.

A single company is not generally able to control its entire supply chain from raw material source to the points of final consumption. For practical purposes, single companies usually have a narrower scope, controlling the immediate physical supply and physical distribution (Ballou, 1999).

This is why managing the whole supply chain is generally seen as a broader concept than managing logistics. Supply chain management (SCM) focuses more on the management of sourcing, manufacturing, and delivery systems, while logistics has traditionally focused on the operational principles of these systems.

Bowersox et al. (1999) see supply chain management (SCM) as a collaborative-based strategy to link interorganisational business operations to achieve a shared market opportunity. The activities associated with logistics are included in this definition.

Similarly, according to Christopher (1998), supply chain management is the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole.

Nowadays, the development of cost-efficient operations is still seen as one of the main objectives of both logistics and supply chain management. High service level, flexibility, customer satisfaction, and profit performance are also seen as very important.

The importance of the logistics operations for a typical commercial enterprise can be illustrated by the fact that 10-25 per cent of every sales dollar is spent on logistics (Bowersox et al., 1999). For example, in Finnish companies the cost of logistics is, on average, 10.2 per cent of sales (Kanerva & Purola, 2001). According to Ballou (1999), transportation and warehousing usually represent the most important single elements in logistics costs for most companies.

However, through developing logistical operations models and the supply chain structure, improvements can be achieved. According to Seppälä (1997), the size of a logistics network, the number of echelons in the network, and the number of facilities in each echelon have a strong impact on logistics costs. Additionally, according to Inkiläinen (1998) the level of centralisation and usage of postponement are strategic decisions affecting both cost-efficiency and responsiveness of the distribution systems. Typically the major trade-offs are the level and the cost of customer service. To summarise, by developing new logistical operations models and changing the structure of the logistic network costs may be decreased and the service level raised.

2.2 *Traditional grocery supply chain*

2.2.1 Traditional grocery supply chain structure

Just as in the general example of logistical networks (Figure 4) in the previous chapter, the grocery supply chain serves as the link between manufacturers and the end customer in the grocery business. The supply chain partners perform a variety of logistical functions as a part of that link, including warehousing, transportation, sales, marketing, order taking, customer service, and merchandising. Figure 5 illustrates a simplified structure of the traditional grocery supply chain. Here, the supply chain is viewed as supplying finished products from the manufacturer's plants to the grocery stores. The consumers are the final part of this supply chain being responsible for the picking of the goods in the store and transporting the goods home from the store.

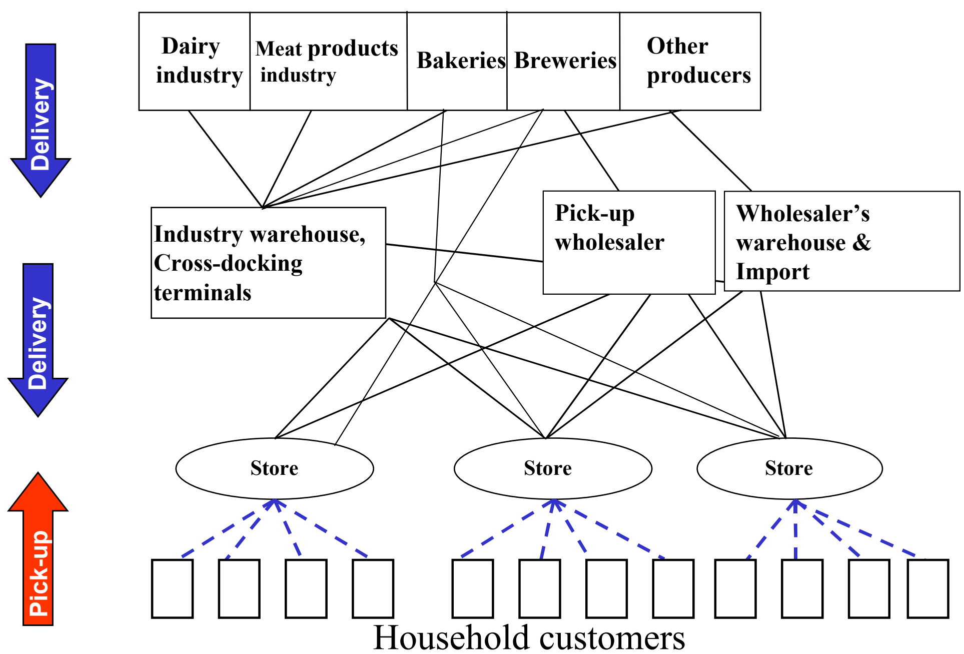

Figure 5 Traditional grocery supply chain structure (Yrjölä, 2001).

The exchange, as well as the storage of products, takes place in various parts of the traditional grocery supply chain. For example, retail stores may purchase from all levels of supply, ranging from farmers to wholesalers (Bowersox et al, 1996). The orders are typically generated in the store and warehousing levels based on demand for the products. The finished goods are then transported from the manufacturer's plants to the wholesaler or retailer's warehouse, where the shipment is stored. In the traditional grocery supply chain the warehousing level then fulfils the retail orders. In practice, because of door-to-door service requirements, flexible operating hours, the need to move small shipments, and short distances, the transportation of grocery products is carried out using trucks (Magee et al., 1985; Lambert & Stock, 1993; Lambert et al., 1998).

Pressure to improve physical distribution effectiveness and customer service has led to alternative distribution channels. For example, grocery product manufacturers have set up multiple systems, under pressure from major chain stores, with the traditional wholesale channel being supplemented by direct distribution to chain stores and chain distribution centres (Magee et al., 1985). Direct-to-store delivery is typical in food and beverage distribution, for example, in the brewery or dairy industries (Bonning et al., 1998).

Additionally, for example in Finland, the brewery industry is committed to common recyclable and reusable packing standards (bottles and cans) and this policy is supported by the society in the form of taxation. Using packages other than those approved in the common recycling system leads to an environmental tax of FIM 4 (0.67 euro) per litre. Consumers are committed to the system as well and return the packages to the supermarkets. According to Panimoliitto (2002) the return rate of the packages is 97-98 per cent for bottles and 84 per cent for cans. From the supermarkets the breweries collect the empty packages for reuse as a part of the direct distribution channel.

2.2.2 Development trends in the traditional grocery supply chain

As described in the above, the traditional grocery supply chain involves the management and control of the flows of information, products, and resources from manufacturers to consumers and in some instances, back to the manufacturers.

For retailers, the goal in traditional grocery supply chain operations is to satisfy the consumers' desire for product availability. Similarly, pressure is put on all retailers to offer the consumer the best price and to reduce the costs associated with distribution. As retailers expand their product ranges, the complexities of the supply chains increase. However, by constantly developing the operations models in the grocery supply chain, retailers seek to achieve the customer service goal and at the same time reduce the overall cost level of the operations. Some of the key objectives are achievement of improved on time delivery, accuracy, inventory reduction, and reduction of distribution costs, which consist of warehouse costs 46.8%, transport costs 40.7%, system costs 3.4% and other costs 9.0% (IGD, 1999; IGD, 2001).

The recent development in retail logistics has been widely reviewed in the UK. Fernie et al. (2000) identified major stages in the development of grocery retail logistics in the UK. the first stage was supplier control (pre-1980), the second one was centralisation stage (1981-1989), the third stage was just-in-time or Quick Response between 1990 and 1995, and the current stage is the relationship stage from 1996 onwards. Additionally, during these development stages, six trends in retail logistics have been identified by McKinnon (1996). These trends are briefly described in the following (McKinnon, 1996):

1. **Retailers have been increasing their control over secondary distribution** from warehouses to the stores. The retailer's distribution centre can order and receive bulk loads from suppliers. The distribution centre also acts as a central stockholding point and consolidates the deliveries to retail outlets. It can be claimed that retailers have taken over the traditional wholesaler function, though supplying only their own chain stores. Benefits such as bulk discounts from suppliers, inventory reductions due to centralised warehousing, cheaper storage space, quick offloading of consolidated deliveries, more frequent and rapid delivery of supplies, expansion of product range, and conversion of retail floor space from storage to sales display area have been achieved (McKinnon, 1990). This has also enabled more efficient central processing of orders and invoices. However, the logistical operations are now more dependent on IT, particularly the integrated stock replenishment systems that control the movement and storage of the products.

2. **Restructuring of retailers' logistical systems** has been implemented to reduce inventory and generally to improve the efficiency of the operations. Examples of this are development of "composite distribution", centralisation of slower

moving stock, and establishing common stock rooms for non-food retailers to reduce the backstore-room inventory. Composite distribution is a system in which different product groups, requiring varying degrees of temperature control, are channelled through the same distribution centre and delivered with the same vehicle.

3. **Adoption of Quick Response,** again with the aim of cutting inventory levels. This involves applying just-in-time principles to grocery logistics, that is, reducing order lead-times and providing more frequent delivery of smaller consignments, both between suppliers and distribution centre and between distribution centre and stores. The benefits achieved are increased rate of stock-turn and inventory reductions. The adoption of quick response has also involved the use of "cross-docking", whereby the goods are received, resorted according to the retail stores, and despatched often within a few hours rather than stored in the distribution centre. Quick response has been made possible through the use of EPOS (Electronic Point Of Sale) information and EDI (Electronic Data Interchange) in ordering the goods. The drawback of using quick response is the increase in inbound deliveries and backdoor congestion in the distribution centres as well as poorer utilisation of suppliers' vehicle capacity due to reduction in average consignment size.

4. **Rationalisation of primary distribution.** Partly because of quick response pressures and partly as a response to more intense competition, retailers have additionally been extending their control upstream from the distribution centre. Nominated carriers have been selected to undertake consolidation of inbound supplies. This carrier collects the goods from the suppliers or have the suppliers deliver the goods to their nominated warehouse. In most cases, the carrier then distributes the consolidated loads to the retailers' distribution centres. Additionally, timetabling of inbound deliveries in the distribution centre has been applied to overcome the problems associated with increased numbers of deliveries. To improve the utilisation of their logistical assets, retailers are also trying to integrate their secondary and primary distribution operations. It has become common practice for retailers' vehicles to collect goods from suppliers' premises on the return journey from stores. It was also noticed that there is a

need for software tools to plan and manage these more complex cross-shipment networks.

5. **Collaboration in the supply chain:** Today, many retailers collaborate closely with suppliers to maximise the efficiency of the retail supply chain as a whole. Supply Chain Management (SCM) and Efficient Consumer Response (ECR) provide a management framework within which retailers and suppliers can more effectively co-ordinate their activities. SCM is well established in manufacturing industry, for example in the automotive and electronics industries, and is similarly becoming more common in retailing. ECR has become widely adopted in retailing to describe the development of new open relationships and the exchange of information between retailers and suppliers working together. Three key elements in an ECR programme are category management, operations improvement, and enabling technologies. The aim is to optimise assortment, promotions, and product introductions and to automate store ordering, enabling continuous replenishment, cross-docking, and synchronised production. By adopting the ECR principles, the flow of products through the supply chain could be "smoothed" and inventory levels again reduced. Recently, CPFR (Collaborative Forecasting and Replenishment), a new approach to improving the overall supply chain performance in retailing, has emerged in retailing. According to CPFR.org (2002), CPFR includes a set of business processes that entities in a supply chain can use for collaboration on a number of buyer/seller functions. By integrating demand and supply side processes, CPFR improves efficiencies, increase sales, and reduces fixed assets, working capital, and inventory for the entire supply chain while satisfying consumer needs.

6. **Increasing return flow of packaging material and handling equipment for recycling/reuse.** An increasing proportion of transit packaging, mainly of cardboard and plastic, is being returned by retailers for recycling and reuse. Cardboard boxes are being replaced by reusable trays. This is increasing the return flow of packaging waste and handling equipment back along the supply chain. Retailers are involved in developing reverse logistics for three reasons. Most are doing it primarily to make money. It also helps retailers in creating a favourable environmental image to consumers. Thirdly, retailers are coming

under stronger legislative pressure to reduce the amount of packaging materials entering the waste stream.

McKinnon (1996) also notices that the consumer direct channel, namely home shopping, may increase sharply in the next 10-15 years, creating logistical challenges. According to his analysis, four logistical problems with home shopping would need to be addressed: order picking, home reception, return flow, and channel structure. Packaged groceries and household consumables present the greatest order picking problems because of their diverse handling characteristics. In home delivery, the reception of the goods is seen as the major problem. There is a conflict between the customer's wish for personal freedom and the delivery company's desire for flexibility in the routing and scheduling of vehicles. Return flow of the products is also seen as a potential problem an average of 20 per cent of mail orders are returned. However, in the grocery sector this is not seen as an acute problem. The distribution channel structure is seen as the fourth problem area. The growth of home shopping would probably require development of a new logistics infrastructure or reallocation of logistical responsibilities among the channel members. Since this dissertation is focused on developing e-grocery home delivery operations, this topic is discussed in more detail in Chapter 2.5.

2.2.3 The grocery market in Finland

Development in the Finnish grocery retail market has been somewhat similar to that described above, although market size is notably smaller than in the UK (Päivittäistavarakauppa, 2001). As in the UK, in Finland the grocery retail market has undergone notable structural changes during the past three decades (Heiskanen et al., 2001). The general trend has been the concentration of grocery retailing followed by a reduction in the number of retail outlets. Until the 1970's, the number of grocery stores increased, and in 1978 the number of the grocery stores was 9,398. Currently, it is only 3,555. However, including specialist shops, market halls, kiosks, and petrol station shops offering grocery products, the number of outlets was 4,165 in the year 2001 (Päivittäistavarakauppa, 2001; AC Nielsen, 2002). Additionally, the general trend in Finnish grocery retailing has been towards larger grocery stores and concentration of the stores in the population centres (Yli-Kovero, 2002). Since 1980, the number of grocery stores has decreased by more than half, 60 per cent of small grocery shops have disappeared, and larger stores have been established (Raijas, 2000a). The number of grocery stores continues to decrease, and retailing is concentrated in a few chains and in super- and hypermarkets built outside densely populated areas.

In Finland, the grocery market was 10,514 million euro in the year 2001 (AC Nielsen, 2002). Clear signs of concentration in the grocery markets are that approximately 30 per cent of the stores make around 81 per cent of the total sales. Additionally, the 199 largest grocery stores make more than 37 per cent of total sales, and the 491 largest stores make over 56 per cent of total grocery sales in Finland (ACNielsen, 2002).

Chain formation has also been a current trend. It is more cost efficient to purchase in consolidated volumes, operate the wholesaling and distribution, and manage the assortments in the stores throughout the entire centralised chain. The two dominant purchasing, wholesaling and distribution organisations in the market are Kesko for the stores of K-Group and Inex Partners Oy for the stores of S-Group and Tradeka. In Finland, grocery retailing market is dominated by a few chains. These are K-Group, S-Group, Tradeka, and Spar. Wihuri and Stockmann are the biggest companies classified in the group of others. The market shares of the major chains in Finland in 2001 are shown in Figure 6.

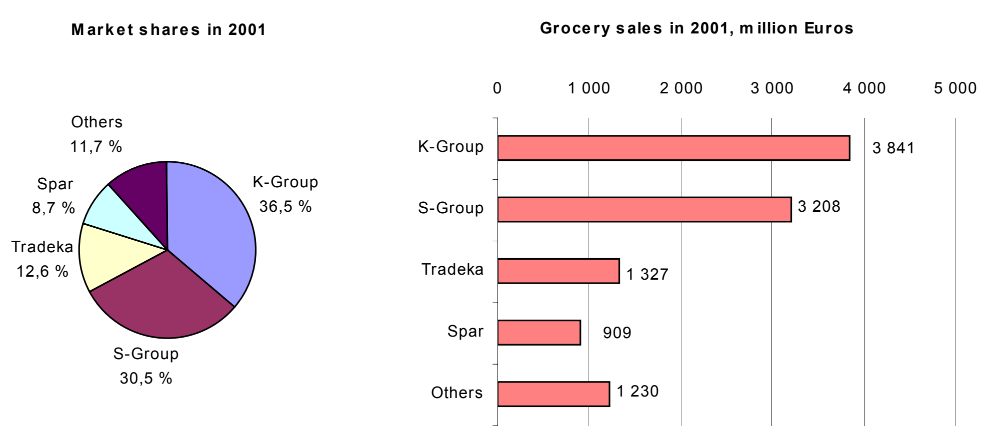

Figure 6 Market shares of grocery sales in Finland (AC Nielsen, 2002)

As a result of the described development in grocery retailing in Finland, for example, the logistics costs of the distribution of goods to the fewer number of stores has decreased, self-service in the large grocery stores has increased, and thus prices have decreased. However, nowadays consumers need to travel longer distances to get to the store, and transport costs related to grocery shopping have increased (Heiskanen et al., 2001). Additionally, the larger grocery stores are often not easily accessible to consumers without a car. The development is reflected in the store selection criteria of the consumers. Currently, distance to the store is the most important selection criterion for 52 per cent of the consumers (Päivittäistavarakauppa, 2001). This, has led to increasing sales in small convenience stores such as kiosks and petrol stations shops, where the prices are not at all at the supermarket level.

2.2.4 The consumer in the traditional grocery supply chain

In the traditional grocery supply chain, the final exchange takes place in the grocery stores or supermarkets, where the consumers select and buy the products. After picking and purchasing, the consumers carry out do-it-yourself packing and home delivery work.

Though there have been considerable structural changes in grocery retailing as described earlier, consumers' shopping habits have not yet changed significantly. In the future, the traditional grocery supply chain will face challenges based on changing consumer demand. In Finland, for example, the number of households is increasing and the average size of a household is decreasing (Heiskanen et al., 2001). Additionally, the proportion of ageing or elderly people in the population is increasing. According to Statistics Finland (2001), in 2010 17% and in 2020 some 23% of the population in Finland will be over 65 years of age. Additionally, the increasing number of people using the Internet, expanding knowledge about online services, and increasing confidence in online shopping (GER, 2001) can be seen as factors accelerating customer demand for new services in grocery retailing.

The current shopping habits of Finnish consumers are briefly covered in the following. In 2001, the yearly average amount of grocery purchases in Finland was

FIM 11,900 (2,001 euro) per capita (Päivittäistavarakauppa, 2001). Additionally, Finns do grocery shopping frequently and buy relatively small purchases at any one time. According to studies in Finland (Granfelt et al., 1995; Raijas, 1994; Pylvänäinen, 1996; Spåre & Pulkkinen, 1997: Päivittäistavarakauppa, 2001), households visit grocery stores 3.4 to 5.0 times a week, depending on their place of residence and the type of grocery store used. The average was 4.3 times a week in 1996 and 4.04 times a week in 2001 (Spåre & Pulkkinen, 1997; Päivittäistavarakauppa, 2001). Although the number of visits has constantly been declining, it is still reasonably high when compared, for example, to US consumers, who make only 2.2 to 2.3 visits to supermarkets a week (Priluck, 2001; Mendelson, 2001).

It has also been found that US consumers make two types of trips: regular trips on a weekly basis and quick trips to pick up additional items (Priluck, 2001). Similarly, in Finland time spent per shopping trip was, on average, 48 minutes on weekdays and 58 minutes at weekends (Spåre & Pulkkinen, 1997). Additionally, of the shopping trips in Finland, a total of 57 per cent was spent in cars driving the average 3.5-kilometre one way journey to the store and back (Granfelt et al., 1995).

In summary, according to Raijas (2000b), from the consumer's viewpoint, traditional grocery shopping can be described as rational routine action. It is also obligatory and regular. Some customers see grocery shopping as a burden, and want to do it as quickly as possible, sacrificing as little time and effort as possible. Additionally, the majority of consumers' shopping expenditure is associated with the shopping trip, and during the last decade consumers' costs of shopping has increased. Reasons for this include structural changes in retailing, longer shopping trips, and increased car use, all of which have created the demand for developing electronic grocery shopping and home delivery services.

2.3 e-Grocery supply chain

2.3.1 e-Grocery supply chain structure

In the e-grocery business the supply chain structure looks much like the traditional grocery supply chain structure (Figure 5). However, in Figure 7 the direction of the last arrow on the left is now turned around, illustrating the extension of the supply chain, through the home delivery of goods, to the place of consumption. The additional operations to be performed by an e-grocer are picking, packing, and home delivery of the goods (Reda, 1998; Ring & Tigert, 2001; Carneal, 2001). In order to be viable and to attract consumers, this new structure must be more efficient than the current one. It is also required that the consumers realise the cost of doing the shopping trip on a self-service basis (Bartolotta, 1998). Most consumers would consider the cost of a trip to the shops by car as the cost of the petrol and parking fees. However, what is typically not taken into account is the maintenance cost of the car and the "opportunity cost" of their spare time (Lewis, 2001).

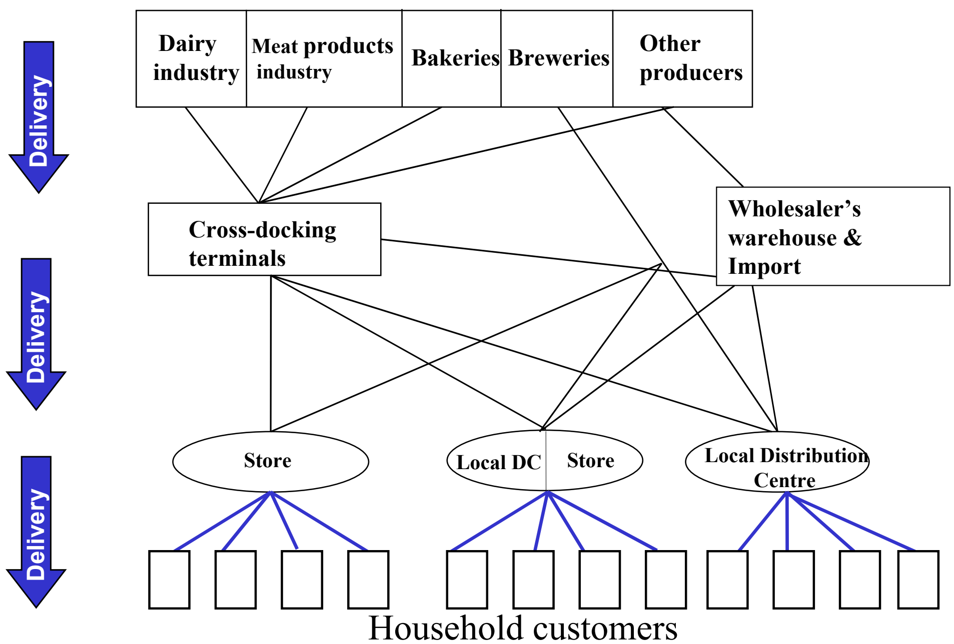

Figure 7 simplified structure of the e-grocery supply chain (Yrjölä, 2001).

The challenge for an e-grocer is to produce cost-efficient picking, packing, and home delivery operations providing consumers with greater convenience. Typically, the challenge in the picking operations has been solved by using two alternative strategies. Either the picking operation has been performed in an existing store or a new dedicated distribution centre has been built. The first strategy is known as an intermediary model and the second, based on a distribution centre, a channel model (Dagher, 1998; Bartolotta, 1998; Heikkilä et al., 1998b; Holmström et al., 1999; Kämäräinen et al., 2001a). Traditional retailers have generally used the first strategy, in which e-grocery operations are based on current store infrastructure. The second strategy, based on distribution centres, has been used mainly by the new rival competitors who are also known as "pure play" e-grocers. Jaakola (1999) and Yrjölä (2001) suggest a third strategy for performing the picking operations. The idea is that a traditional store could be partly transformed into a local distribution centre serving an e-grocery picking operation. Also the alternative picking strategies are shown in Figure 7.

2.3.2 e-Grocery operations

The first online grocer, Grocery Express, was founded in San Francisco in 1981. It offered home delivery of grocery products ordered via an on-line service with a simple user interface in addition to phone and fax. Grocery Express was eventually closed down because of logistical challenges and inability to build scale (Mendelson, 2001). After the fast market growth from mid 1990's to the end of 1990's, many new players with different operations models, such as Webvan, Streamline, Homegrocer, Peapod, and Groceryworks have either collapsed or been acquired by traditional retailers. However, successful and profitable operations models such as Tesco's, started in 1996 based on picking from existing stores, have been developed and today Tesco.com is the world's biggest e-grocer with sales of £356 million or 535 million euros in 2002 (Reinhardt, 2001; Reynolds, 2002). Currently, other big players are Peapod (120 million euro in 2001), Safeway (65 million euro in 2001), Sainsbury's (65 million euro in 2001), Asda Wal-Mart (60 million euro in 2001), Iceland (50 million euro in 2001), and Carrefour (50 million euro in 2001) (Van Gelder 2002a).

The market share of online grocery shopping is tiny at the moment, only 0.3-0.7 per cent in the UK (Finch, 2001; @ Your Home, 2001), 0.22 per cent in the USA (IDC, 2000; Van der Laan, 2000), and 0.1 per cent in Finland (Päivittäistavarakauppa, 2001). However, the growth estimates for e-grocery business tend to range from 3 to 10 per cent of the grocery market by 2005-2010, in both the USA and Europe. Thus, it is worth trying to learn from the mistakes made by the early e-grocers.

During the biggest hype of e-commerce in the years 1999 to 2000, the pure play e-grocers in particular invested heavily in dedicated distribution centres to make possible efficient picking and packing operations. Webvan, for example, invested around $35 million in each of its fully automated distribution facilities (Himelstein, 1999; Sandoval, 2000b, Perman, 2000). Because of lower than expected growth in customer demand, low capacity utilisation, and high investments, this structure soon proved highly unprofitable. Currently, the major e-grocers rely on their traditional stores when considering their picking operations. For example, Tesco.com uses 250 of its 690 stores for e-grocery picking operations, covering 91% of the population in the UK (Reinhardt, 2001; Jones, 2001; Knichel, 2001).

Regardless of the strategy used in e-grocery picking operations, the goods must be delivered to the customer. Because of the nature of grocery products, the picking and home delivery operations must be performed locally. According to John Caltigerone, former logistics director for Peapod, online grocers forgot that they must home deliver the products to the customers. Instead of their betting on fulfilling high customer demand based on estimates suggesting rapid growth, the process should have been started smaller and then enlarged once the business could support the costs (Carneal, 2001; Tanskanen et al., 2002). Similarly, according to Van der Laan (2000), success in online food retailing depends on two factors, market potential and distribution costs, which are interdependent.

Currently, the cost of picking and home delivery operations in the Tesco.com e-grocery supply chain is approximately 14 per cent of sales, divided evenly between both operations (Reinhardt, 2001). Tesco.com performs its picking operations in traditional stores, and offers home delivery with attended reception and 2-hour delivery time windows. The delivery fee charged is USD 7.26 (£5) per order. The average purchase from Tesco.com in 2001 was around USD 123, more than three times a typical supermarket purchase of USD 35 in Tesco store. For Webvan, the cost of picking and home delivery operations was as much as 26 per cent of sales, and the average shopping basket size was USD 114 (Reinhardt, 2001). At that time, Webvan executed its picking operations in fully automated distribution centres, and offered free home delivery with attended reception and 1-hour delivery time windows. Additionally, as already described in the introduction, Streamline offered reception boxes for their customers in order to offer a convenient unattended reception service for the customer and to operate home delivery cost-effectively[1]. According to Lardner (1998), Streamline also succeeded in its attempt to please customers and reach, on average, 10 deliveries an hour, while others in the field at that time were struggling to reach three deliveries an hour. However, in November 2000 Streamline had to close down its business because of lower than expected market growth (Nasdaq, 2000; Junnakar, 2000).

As in the USA and elsewhere in Europe, in Finland e-grocery shopping is still in its infancy. At the moment, the customer base for the e-grocery businesses consists mainly of busy well-off families with children, as well as elderly and disabled people (Tuunainen, 1999; Raijas, 2000b; Anckar et al., 2002). In Finland, the e-grocery market share was only around 0.1 per cent in 2000, and the value of an e-grocery shopping basket was, on average, 85 euro (Päivittäistavarakauppa, 2001; Raijas, 2000b). In 2000, there were around 20 e-grocers in Finland, but the amount has since decreased. Currently, e-grocery services in Finland are provided by a handful of service providers in different cities. Most e-grocers operate next to a traditional supermarket, and the home delivery transportation is usually an additional service provided using outsourced service providers. Ruokavarasto, providing e-grocery services in eight cities in southern Finland based on the Ruokavarasto stores, is the largest Finnish e-grocer at the moment. Ruokarasti operates based on store picking and outsourced home delivery in Kuopio and Ykköshalli, and K-Supermarket Hertta operate in the Helsinki metropolitan area. The latter two also operate based on traditional store picking and outsourced home delivery service. Currently, only two operators, Nettimarket in Turku and Ruokanet in the Helsinki metropolitan area, use wholesaler warehouses for their picking operations.

The delivery time windows for attended reception are normally one to three hours (Ykköshalli, 2003; Ruokanet, 2003; Ruokavarasto, 2003; Ruokarasti, 2003; Hertta, 2003; Nettimarket, 2003). In addition, S-Group had a two-year e-grocery pilot operation, launched in June 2000 in co-operation with the Ecomlog research group,

[1] Hoover et al. (2001) refer to Streamline's concept based on customer-specific unattended reception as a "we service your home" grocery business model.

offering e-grocery services and a home delivery model in which the groceries were delivered to locked reception boxes located in customers' yards (Huhtakangas, 2000; SOK, 2001). Currently, Ruokavarasto has taken over the S-Groups pilot operation and continues developing the e-grocery service models offering both attended and unattended reception options.

2.3.3 Motivations for e-grocery

From the consumer's point of view, electronic grocery shopping is a new attractive service model providing help in everyday life for many consumers. The premise of the consumer direct channel is for the consumer to be able to order groceries and other products from home, and have them delivered to the door. This appeals particularly to people with little time or desire to shop and those unable to leave the home (Bartolotta, 1998; Hoyt, 2001).

Based on longitudinal data collected in three studies in 1998, 1999, and 2001, Morganosky & Cude (2002) describe the typical e-grocery customer to be younger that 45 years of age, female, and a college graduate. Additionally, customer households typically include children and two adults and the annual household income is USD 70,000 or more. This type of customer profile is also identified as the typical online grocery shopper in earlier research (Lardner, 1998; Ingram, 1999).

According to Raijas (2000) and Morganosky & Cude (2000 and 2002), the customer's main motivations for using e-grocery services are convenience, time saving, and avoiding the work involved in picking and home delivery. Additionally, a significant proportion of customers (15%) cited physical or constraint issues as their primary reason for online shopping.

Nowadays, the customers are also buying the same product groups online as in traditional grocery stores. According to Morganosky & Cude (2002) in their most recent study 80 per cent of customers were willing to buy any grocery item online, whereas in their first study in 1998 only 48 per cent responded this way. Additionally, e-grocery customers particularly appreciate being able to buy packaged and heavy goods such as beverages (Raijas, 2000b). These product groups are also the easiest to preserve in the e-grocery supply chain all the way from picking to home delivery.

From the retailer's point of view the consumer direct market seems tempting. Retailers believe that electronic grocery shopping will form a significant part of the future market, and high customer service levels are an essential element for satisfying customer requirements (Lewis, 2000). In contrast with the e-commerce hype in 1999 to 2000, nowadays the consumers using the online shopping services are not price sensitive. This is because the main motivation for using online services is convenience and time savings or physical/constraint issues. According to Anckar et al. (2002), online shoppers are willing to pay a slightly higher price than in the traditional stores or alternatively a delivery fee, as shown by Tesco.com (Reinhardt, 2001) in order to have the convenience benefits. However, many operational questions are still unanswered from the service provider's point of view.

According to Bartolotta (1998), the ability of a pure play online grocer to deliver higher net profits rests on the fact that it is more efficient than the traditional retail channel. Using warehouses for picking the orders, enabling the elimination of retail stores in, high priced locations was seen as a means to reduce cost levels. Cost reductions could also be achieved by reducing labour costs and inventory levels. Furthermore, bundling of non-traditional services such as Streamline was seen as a driver to attract new customers and increase the average gross margins. Additionally, this type of wholesale or warehouse based operations model (channel model) offered the possibility to new competitors to enter the retailing market. However, at least the first pure play online grocers have failed as the examples of Webvan, Streamline, and Matomera show. This implies that the operations models and service offerings provided still needs to be developed, and the appropriate customer groups must be better defined in the future.

From the traditional retailer's point of view, entering the consumer direct channel is additionally seen as a possibility. Initially, the main motivation of traditional retailers for entering the market, however, was to respond to the pure play e-grocers' offerings. At the moment Tesco, for example, sees online grocery as a way to build and expand its relationship with the customers (Hoyt, 2001). Since the frequency of ordering groceries is higher than with other products, the online grocery shoppers could be offered other product groups a side increasing the total sales. If the picking operations were to be based on using the existing store infrastructure, higher resource utilisation of the existing assets would be achieved (Knichel, 2001). Efficiency of this operations model would became a problem only with higher customer demand and demand peaks (Reinhardt, 2001; Kämäräinen & Punakivi, 2002). If most customers order via e-grocery only once a week, this accumulates the deliveries to demand peaks. These peaks are usually on Fridays and Saturdays, as with a traditional grocery business. This reduces operational efficiency and so increases costs (Kämäräinen & Punakivi 2002).

Additionally, it was seen that by offering online grocery shopping, the retailer could enlarge the geographic service area covered, while taking the transportation restriction into account (Kyyrö, 2000). By offering better customer service, the retailer could also gain higher market share through extra sales from both new customers due to higher reach and by winning competitors customers. Here, a risk of cannibalisation of the existing business was identified (Hoyt, 2001). Since the grocery business is highly local because of transportation costs, many of the "new" online customers would in fact be established, regular customers who actually become less profitable for the retailer when shopping electronically (Anckar et al., 2002). Tesco, however, reported that one-third of its online customers had never shopped in Tesco stores, and that 25 per cent of the online sales come from new customers and 25 per cent from increasing spend (Knichel, 2001; Hoyt, 2001).

From society's point of view, there is also motivation for supporting the development of e-grocery services. Creation of online grocery shopping services with home delivery would support offering better and/or lower cost services to disabled and elderly people living at home (Tuunainen, 1999). Another social aspect related to the creation of e-commerce services is the question of coverage. Are the people living in deprived urban environments or in rural areas excluded from e-commerce services and what are the logistical solutions in those areas (Reynolds, 2000; Lewis, 2000)? An additional aspect is environmental sustainability. What is the capability of e-grocery and other e-commerce sectors with home delivery to affect the increase of overall traffic levels, congestion, and the level of traffic emissions? The overall impact on traffic levels depends upon the balance between total distance travelled by home delivery vans and the impact that this has upon customer travel behaviour (Reynolds, 2000; Lewis, 2000). As this topic is one of the focus areas in this dissertation, it is covered in more detail in Chapter 2.5.4.

In brief, the development of more efficient operations models supporting the consumer direct channel is seen an important topic from many points of view, thereby strengthening the motivation for this dissertation.

2.4 Modelling in logistics decision-making

Since the focus in this dissertation is modelling existing and emerging home delivery models in the e-grocery business, a brief introduction to modelling in logistics decision-making and a more thorough description of the home delivery business are presented next.

Currently, modelling is an important part of logistics analysis, planning, and decision-making. Today, logistics networks, and often also individual supply chains, are highly complex. However, the logistical decisions and operational models selected directly affect the profitability both of the individual company and the whole supply chain. One major complicating factor in logistics decision-making is the high amount of data available concerning the various logistics functions. Trying to find better operations models is not easy and that is where computer models are used (Powers, 1989).

The facility or process of interest is usually called a system and in order to study it a set of assumptions often has to be made about how it works (Law & Kelton, 2000). These assumptions, usually mathematical or logical relationships, constitute a model that is used to gain a better understanding of how the system of interest behaves (Law & Kelton, 2000).

Analysing logistical problems involves the organisation of the available data into meaningful information in the form of alternative solutions. Making decisions based on the analysis is then simply a matter of choosing from among the alternatives to get the best outcome. The more alternatives there are and the more complete the analysis, the better the chances of selecting the right solution (Powers, 1989).

According to the classification used by, for example, Powers (1989) and Mentzer (1989), there are three modelling techniques in logistics decision-making: optimisation, heuristics, and simulation. More recently, Seppälä (1996) too has divided the modelling techniques similarly and, additionally, includes simple spreadsheet models. Law & Kelton (2000), however, due to their focus on simulation, divide the mathematical models into analytical models and simulation. According to Law & Kelton (2000), if the model is simple enough, it may be possible to work with its relationships and quantities to get an exact analytical solution. However, highly complex systems often lead to too-complex mathematical models, precluding analytical solutions (Law & Kelton, 2000).

According to Bowersox & Closs (1989), the division used by Law & Kelton (2000) is common in practice and practitioners then group heuristic and simulation models as one methodology, whereas analytical modelling is seen as equal to optimisation. In the following paragraphs the characteristics of the three modelling techniques in logistics decision-making are briefly presented.

In its simplest form, optimisation merely means that no better answer exists to a given mathematical problem (Powers, 1989). The mathematical problem may be very complex, consisting of thousands of variables and equations. An example of such a complex mathematical problem would be a logistics network (Powers, 1989). According to Mentzer (1989), optimisation is the best approach if it will work; however, it is the largest user of computer capacity and the most restrictive in assumptions, and is unable to deal with the uncertainty of logistics operations. When compared to heuristics, the primary difference is the degree of mathematical precision (Bowersox & Closs, 1989).

Heuristics are rules of thumb or common sense solution approaches (Powers, 1989) that direct the solution approach toward the best solution but do not guarantee that it will be found. The idea is to find a satisfactory rather than an optimal solution, but in a fraction of the computational time required, for example, in an optimisation approach (Ballou, 1989). Ballou (1989) describes good heuristics as being frequently the result of common sense procedures that work effectively. Heuristics may be based on concepts, principles, and theories that relate to a specific problem, or they may result from observing the form of optimised solutions and imitating them (Ballou, 1989). Heuristics are typically used in truck routing and scheduling, warehouse location problems, and designing the layout of items in a warehouse (Ballou, 1989). According to Mentzer (1989), heuristics also suffers from an abstraction from reality, especially uncertainty, but not to the same degree as optimisation. Typical of heuristics are lower computer resource needs and less restrictive assumptions leading to only satisfactory, rather than optimal, answers to a given problem (Mentzer, 1989).

Simulation can be described as building an experimental model of a system, usually in great detail, and then evaluating alternatives that are fully specific to the model in a series of test runs (Powers, 1989). According to Law & Kelton (2000), in simulations a computer is used to evaluate a model numerically, and data is gathered in order to estimate the desired true characteristics of the model. Examples of suitable targets for simulation are conveyor systems in a factory or queuing and inventory systems (Law & Kelton, 2000). Additionally, channel structure and facility location analyses, as well as evaluating trade-offs between costs and service level, are also typical (Bowersox & Closs, 1989). According to Bowersox & Closs (1989), simulation will seek merely "better" as opposed to "optimal" solutions to the problems analysed. Additionally, the distinguishing feature of simulation is its capability to include dynamic and stochastic situations, i.e. the model may evolve over time and involve at least some random input components, providing the most realistic analysis of the problem (Lehtonen J-M, 1999).

According to Mentzer (1989), each of these techniques is viable in solving particular logistics problems. However, in order to make intelligent analysis and decisions, matching the specific problem to the right approach seems appropriate. Additionally, the different modelling techniques are often used in combination (Bowersox & Closs, 1989).

Usage of modelling techniques in logistics decision making has become more and more common. In the 1990s especially the spreadsheet packages begin to play major role in modelling and solving management science problems (Lawrence & Pasternack, 2002). Today enterprise requirements planning software (ERP) typically includes also logistics modelling tools. For example, the worlds leading ERP-software, SAP R/3, include optional modelling packages from CAPS Logistics (CAPS, 2002).

In this dissertation the home delivery operations are modelled using CAPS RoutePro, a commercially available vehicle routing tool from CAPS Logistics. Thus, the modelling technique selected in this dissertation for modelling home delivery operations is heuristics. The heuristic algorithm used was developed by CAPS Logistics. The functionality of the Route Pro vehicle routing tool and the selected routing algorithm is explained thoroughly in Chapter *4*.

2.5 Backgrounds for modelling home delivery operations

2.5.1 General

Home shopping is the provision of goods directly by a company to a customer in response to an order. The order could have been generated in a number of ways: general catalogues, direct catalogues etc., but the essence of mail order is provision - the final point of the logistics network being the customer's home. (Brady & Harrison, 1990)

As stated in the above definition the development of consumer direct markets has created a fundamental change in the design of retail supply chains, from store-centric to customer-centric. Typically, retail supply chains were designed to move products efficiently from many vendors to a finite number of stores. Theoretically, a consumer direct supply chain allows shipment from any place to any customer (Bonning et al., 1998). However, in practice the final home delivery of the products is very much a local business (Carneal, 2001). Regardless of the product group, the basic principles of achieving success in the home delivery business depend on the same fundamental characteristics as in cost-efficient transportation generally.

In transportation economy of scale refers to the fact that the transportation cost per unit of weight decreases when the size of the shipment increases. As an example, truckload (TL) shipments utilising the entire vehicle's capacity cost less per pound than less-than-truckload (LTL) shipments utilising only a portion of the vehicle's capacity. The economies of scale exist because fixed expenses associated with moving a load can be spread over the load's weight (Bowersox et. al, 1996).

The fixed expenses, which do not vary with shipment volume, include terminal facilities, transport equipment, administrative costs such as taking the order, time for positioning the vehicle for loading or unloading, and invoicing. The variable costs usually include fuel and labour, equipment maintenance, handling, and loading and unloading (Ballou, 1999; Bowersox et. al, 1996).

Over the past few decades a serious problem was found in small-shipment transportation. For a common carrier it was difficult to provide a reasonably priced small-shipment service because of the significant overhead costs associated with terminal and line-haul services. This offered a market entrance opportunity for new companies offering a specialised small-shipment service or parcel service. Today, parcel delivery services represent an important part of transportation infrastructure (Bowersox et. al, 1996). Examples of parcel delivery service providers of this type are UPS (United Parcel Service Inc.), FedEx (Federal Express Corporation), DHL, and TNT.

2.5.2 Home delivery market

The growth of home delivery markets has been strong. According to the Retail Logistics Task Force report @ Your Home (2001), for example, the UK internal market for express delivery services in 1998 was 660 million small packages and had a value of £1554 million. Of the packages delivered, around 60 per cent were business-to-consumer (B2C) deliveries. In the B2C sector parcel services have increased, primarily to support the fast-growing area of non-store retailing, based on catalogue or mail ordering of merchandise and subsequent home delivery. This consumer direct channel has recently been expanding rapidly, along with mail-order sales growth and the growth of e-commerce. For example, in the UK the value of the total home delivery market is likely to rise by 83 per cent, from £18.3 billion in 2000 to £34.5 billion by 2005 (Rowlands, 2001b; @ Your Home, 2001). Additionally, Forrester (Brooksher, 1999) estimates that along with the growth in online sales, the number of residential deliveries in the USA will exceed 2.1 billion by 2003.

In Finland the Post, national postal service provider, is the leading distribution channel for mail order business, e-business, and companies' postal services. The Post delivers around 25 million packages (less than 35 kg) yearly of which some 50 per cent is B2C deliveries. The Post has strong market share in Finland covering around two thirds of the parcel market. The Post is strong especially in delivering B2C mail order parcels and aims for increasing its share of B2B parcel market as well. It is estimated that the economic downturn in 2001-2002 has decreased the total parcel volume slightly in Finland (Lassila, 2000; Posti, 2002).

2.5.3 Key elements in home delivery

In the home delivery business, consolidating many small shipments into the same truckload enables cost efficiency to be reached. According to Lee and Whang (2001), the cost of delivery is justified only if there is a high concentration of orders from customers located in close proximity or if the value of the order is large enough. However, the consolidation of several orders also raises the problem of how to reach cost-efficient delivery operations. In selecting their operating strategy, the service providers have to consider the following elements affecting to the cost-efficiency of home delivery (Van der Laan, 2000; Laseter et al., 2000; Reinhardt, 2001; Browne, 2001):

- size of the service area,
- order frequency,
- number of companies offering home deliveries,
- market penetration of home shopping,
- the higher the average order size the better,
- delivery charges,
- customer density,

    - the average distance from the warehouse or store to the customers,
    - the average distance between customers,
- vehicle routing according to the promised delivery time windows,
- the stop time at customers' locations,
- the loading and unloading time,
- handling efficiency,
- cost per hour,
- vehicle fill rate, and
- capital investment.

However, the paradox in developing home delivery operations is that as online shopping markets increase, the likelihood of the customers being at home to receive the delivery seems to decrease. According to the Retail Logistics Task Force report @ Your Home (2001), as many as 60 per cent of home deliveries may fail due to the absence of the customer from the home, causing increased costs to the distributor and inconvenience to the customer. One of the solutions presented to solve the problem in the home delivery business is unattended reception of orders (McKinnon, 1996; Reda, 1998; Lardner, 1998; Lewis, 2001). This would allow a wide delivery time window, a better possibility of optimising vehicle routing, and maximum utilisation of transportation equipment, as well as of the personnel involved. Furthermore, the level of customer convenience would increase significantly, as the customers would be totally independent of the delivery timetable.

2.5.4 Vehicle routing

Reaching cost-efficient e-grocery home delivery operations is challenging, for example, due to constantly-changing customer locations, failed deliveries because customers are not at home, rush hours, multiple delivery vans, parking restrictions, and tight delivery time windows promised to the customers (Reda, 1998; Lardner, 1998). Vehicle routing problems, as in e-grocery home delivery operations, typically arise in situations where vehicles must travel to a variety of locations to deliver or pick up goods or provide services. Generally, the goal in solving vehicle routing problems is to achieve minimal total operating costs based on a high rate of deliveries per hour and high vehicle fill rate. However, at the same time the aim is to fulfil the service offering promised to the customer. Good solutions to routing problems can be found by applying the following 8 principles (Ballou, 1999):

1. load trucks with stop volumes that are in the closest proximity to each other,
2. stops on different days should be arranged to produce tight clusters or service areas,
3. build routes beginning with the farthest stop from the depot,
4. the sequence of stops on a truck route should form a teardrop pattern, so that no paths of the route cross,
5. the most efficient routes are built using the largest vehicles available,
6. pickups should be mixed into the delivery routes rather than assigned to the end of routes,
7. a stop that is greatly removed from a route cluster is a good candidate for an alternative means of delivery, and
8. narrow stop time window restrictions should be avoided.

These types of guideline principle are the result of long research and development work both in practice and theory. However, in the e-grocery home delivery business the deliveries are made in suburban and urban areas hindering, for example, the possibility to use large vehicles. Additionally, the service models selected by the e-grocers has typically led to a situation with a narrow delivery time windows, like described in the introduction and literature review. However, the principles presented by Ballou (1999) are seen very useful in this dissertation and are based on wide body of knowledge in vehicle routing briefly described in the following.

Optimal solutions for vehicle routing problems have been studied intensively and one of the most widely studied and best-known routing problems is the Travelling Salesman Problem (TSP) (Lawler et al., 1985; Onal et al., 1996). TSP is a problem in which a number of cities have to be visited by a salesman who must return to the same starting point; each city must be visited exactly once and the aim is to minimise the total distance travelled (Perttunen, 1995). The Vehicle Routing Problem (VRP) is an extension of TSP. According to Solomon (1987), in VRP the problem is to design a set of minimum-cost vehicle routes for a fleet of vehicles from a central depot to a set of customers (cities, stores, warehouses etc.) with known demand. The routes must be designed so that each customer is served exactly once by one vehicle and taking into account the fact that the total demand of all points on the route does not exceed the vehicle capacity (Desrochers et al., 1992; Bräysy, 2001). Routing and scheduling problems are typically NP-hard problems, for which no polynomially-bounded algorithm has yet been found, meaning that solving these problems optimally suffers from an exponential growth in computational burden with problem size (Bräysy, 2001). In other words NP-hard problems are difficult because there is no algorithm that will solve them swiftly and optimally. Instead, all possible solutions have to be tried to find out which produces the best result.

The e-grocery home delivery problem has the characteristics of a Vehicle Routing Problem with Time Windows (VRPTW). In VRPTW added complexity is involved, when compared to VRP (Desrochers et al., 1992). In VRPTW every customer may select a time window, the earliest and the latest time within which the customer should be served (Desrochers et al., 1992). The objective is to minimise both distances travelled and the total duration of routes, in addition to the number of routes, which is often the primary criterion. Additional complexities in VRPTW are the length-of-route constraint arising from depot time windows and the cost of waiting time if the vehicle comes to a customer location too early (Solomon & Desrosiers, 1988; Bräysy, 2001).

Vehicle routing problems with time windows have recently been investigated intensively by a number of operations researchers (for example Golden & Assad, 1986; Solomon, 1987; Solomon et al., 1988; Desrosiers et al. 1988; Desrochers et al., 1988; Bodin, 1990; Desrochers et al., 1992; Desrosiers et al., 1995; Bramel & Simchi-Levi, 1996; Bräysy, 2001). However, the vehicle routing problems have been studied widely since as long ago as the late fifties. Danzig and Ramser (1959) described a practical problem concerned with delivering petrol to filling stations. According to Fisher (1995), this was the first formulation of the general vehicle routing problem. Soon after that, Clark and Wright (1964) presented probably the best-known route-building heuristic, the Clark and Wright savings method, beginning with a solution in which every customer is supplied individually by a separate vehicle. By combining any two of these single customer routes, one less vehicle is needed and costs would be reduced. A few years later, Pullen and Webb (1967) developed a heuristic-based system for scheduling van drivers' duty schedules for the bulk conveyance of mail in the Central London area in order to reduce idle and empty-running time between jobs. At the same time, Knight and Hofer (1968) presented a case study of a contract transport company where a heuristic manual system was developed to increase the utilisation of its 40 vehicles in the London area. In this case study the service time windows of individual customers were also taken into consideration. Since the simple heuristics of the 1960s and 1970s, the development of better vehicle routing methods has continued constantly. For example, mathematical programming-based heuristics have been applied. Additionally, exact optimisation algorithms and artificial intelligence techniques have been developed (Fisher, 1995).

Recently, in the context of developing last mile physical distribution operations, vehicle routing tools have been used, for example, in research on city logistics focusing on co-operation between various freight forwarders delivering goods to the shops in the inner city (Taniguchi & Van Der Heijden, 2000). Studies have also been carried out analysing the effects of unattended reception in the e-grocery home delivery business. Kallio et al. (2000) used a spreadsheet model, Kämäräinen et al. (2001a) used a vehicle routing tool in a one vehicle environment, Punakivi & Saranen (2001), Punakivi et al. (2001), and Punakivi & Tanskanen (2002) used a vehicle routing tool in a multi-vehicle environment with real point-of-sale data. In these analyses, the usage of unattended reception actually relaxes the time window constraint and in this way enables more optimal vehicle routing. Additionally, analysis of grocery home delivery operations has been conducted that takes into consideration the environmental effects of home delivery services (Cairns, 1998; Cairns, 1999). This theme is covered in greater depth in the next chapter.

2.5.5 The possible effects of home delivery services on road traffic

As stated earlier, home shopping is currently becoming more general both in Europe and the USA. Various associated home delivery models have been developed and are still in the process of development. However, knowledge of the possible effects of consumer direct selling and home delivery services on road traffic and the environment is still fairly sparse. It is challenging to make specific estimates or analyses, since the future market demand for this type of service is unknown at the moment.

On the one hand it is argued that home delivery services are an environmental solution, as they release people from carrying what they buy and encourage them to make their shopping trips using public transport services, thus potentially reducing car traffic and dependence on cars. Additionally, home delivery services could bring social benefits, such as new service options for elderly or disabled people who have trouble getting to the shops themselves (Tuunainen, 1999; Heikkilä et al, 1999). Shoppers may also be able to fulfil their needs in a single trip, eliminating the need for a separate trip from the main weekly trip (Lewis, 2000). On the other hand it is argued that home delivery services may cause an environmental disaster, due to increasing road freight traffic in population centres while customers still make additional shopping trips using their cars, for example to buy fresh food or visit different retail outlets. Additionally, delivery services are also likely to be used by non-car owners, who may have previously done the shopping without using a vehicle, thus generating a net increase in traffic (Cairns, 1999; @ Your Home, 2001). Political decision-makers are, however, in favour of developing new services that offer the potential to reduce overall road traffic and traffic emissions, lessen the need for travelling, and reduce car dependence in everyday activities (Cairns, 1997; Department of Environment, Transport & the Regions, 1998; @ Your Home, 2001; EU, 2002; Nuutinen, 2002; YTV, 2001). Currently, for example, the Department for Transport, Local Government and the Regions in the UK is committed to the commissioning of new research in the home delivery sector, dealing with issues such as operational transportation efficiency and the environmental impacts of increasing home shopping (DTLR, 2002).

A supportive attitude from policymakers and strong development in the area has encouraged analysis focusing on the environmental issues connected with home delivery services. However, only a few studies covering information relevant to this focus area have been published. Interviews dealing with service provider experiences and customer questionnaires have been reported, covering associated changes in customers' shopping and travelling behaviour (Cairns, 1996; Cairns, 1999; Tacken, 1990; Knichel, 2001). Additionally, Cairns (1997) built a hypothetical home delivery models using Geographical Information System TransCAD and analysed the trade-off between car trips and home delivery service, taking into consideration the distance driven. Cairns (1997) showed that even with a relatively small number of customers and vans which can only carry 8 loads of shopping each, 70-80 per cent of vehicle kilometres could be saved if customers no longer travelled to the shops by car, but had their shopping delivered from the same store by a fleet of delivery vans instead. In practice, the traffic reduction would increase still further if customers were concentrated in particular locations such as specific housing estates or along bus routes (Cairns, 1997). Generally, this result implies that there would still be a traffic reduction if 7 out of 10 customers continued to use their cars for shopping trips along with using the home delivery service. However, it was noted in Cairns (1999) that the 70-80 per cent mileage savings would only apply to the customers using the home delivery services. Based on estimates that the maximum usage of the e-grocery and home delivery services would be 10-20 per cent of all customers, the traffic reduction at a local store resulting from the replacement of car trips by van trips could be in the range of 7-16 per cent (Cairns, 1999).

Additionally, on the basis of recent reports, home shopping and home delivery services are likely to change customers' shopping and travelling behaviour. According to Knichel (2001) and Reinhardt (2001), the average shopping basket ordered from Tesco.com is USD 123. This is nearly four times more valuable than the average shopping basket, USD 34, sold in a Tesco store. This implies that the customers shopping online and using home delivery services tend to buy more and shop less often so as to get the most out of the delivery charge. Furthermore, according to Cairns (1999), 61 per cent of the home delivery customers of The Food Ferry, an independent e-grocery service provider operating in London, are the owners of at least one car. Of the car owners, 74 per cent were nowadays using their cars less because of shopping with The Food Ferry. In a similar customer questionnaire (Tacken, 1990), 70 per cent of the home delivery customers of James Telesuper in Amstelveen in the Netherlands believed that the service saved them time. Two-thirds of the customers were the owners of at least one car. When asked how their means of travel for shopping had changed, 28 per cent of the customers estimated that they travelled less by car, 23 per cent said that they walked more often, and 14 per cent travelled more by bike.

To evaluate the road traffic reduction potential offered by home delivery services in the focus area of this dissertation, the following general analysis considering the overall road traffic in Finland and in the Helsinki metropolitan area is given next.

The amount of overall road traffic both in Finland and in the metropolitan area of Helsinki can roughly be divided into two main categories: 15 per cent is the transportation of goods and 85 per cent is passenger traffic and professional business traffic (Mäkelä, 1999; Nummenpää & Ollikainen, 1999; YTV, 2001). The yearly road traffic in Finland is presented in Figure 8 in terms of distance driven.

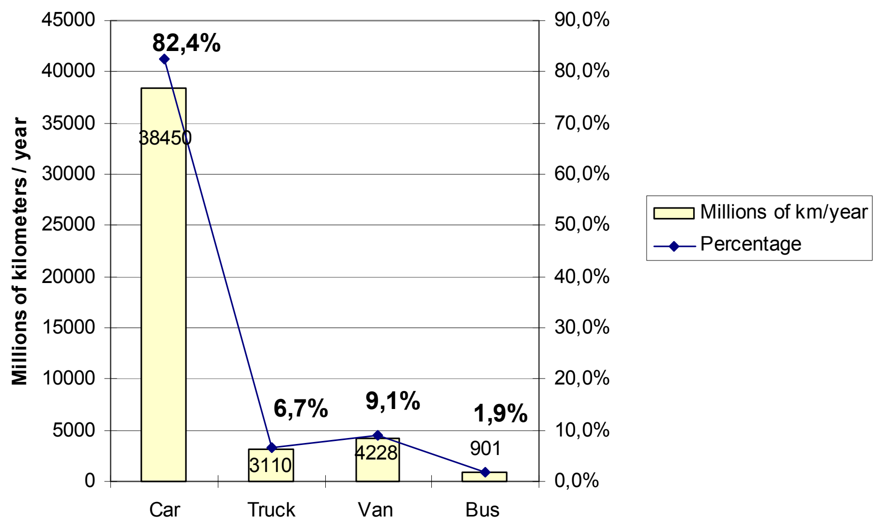

Figure 8 Road traffic in Finland 2000 (VTT, 2002).

The share of passenger traffic is divided into subcategories including all transport modes, such as travel by car, bus, train, aircraft, on foot, and by bike. In Finland and in the Helsinki metropolitan area the passenger traffic is mainly (66 per cent) by car (Pastinen, 1999). Based on the results of Pastinen (1999), excluding personal business trips and travelling to work or school, it can be estimated that the share of the distance driven of trips for the purchase of daily goods is around 12 per cent of the overall road traffic. This 12 per cent can be regarded as the maximum potential for traffic reduction by means of home delivery services. However, in reality the size of the traffic reduction depends especially on the market share of home shopping and associated home delivery services in the future.

3 RESEARCH HYPOTHESES

3.1 Hypotheses

Based on the earlier chapters describing the background, research objectives, research questions, and the focus area of this dissertation, the following three hypotheses are formulated:

Hypothesis 1:	*Home delivery operations are significantly more cost-efficient based on unattended reception than based on attended reception.*

The answer to Hypothesis 1 will show the impact of unattended reception on the operational home delivery cost structure.

Hypothesis 2:	*The most cost-efficient home delivery model offering unattended reception is based on shared reception boxes.*

To answer Hypothesis 2, a comparison of home delivery cost structures using three models enabling unattended reception is conducted (see definitions on page 7). Additionally, the payback periods for the investments in unattended reception facilities are analysed on the basis of the potential cost savings in home delivery operations.

Hypothesis 3:	*Home delivery services reduce traffic and GHG emissions compared to the situation, in which customers make shopping trips using their own cars.*

The answer to Hypothesis 3 presents new knowledge concerning the traffic reduction potential and the possible environmental effects of different e-grocery home delivery models.

3.2 Overview of the separate papers

In this section the dissertation papers are identified, using their titles and publication references. The identification is followed by a brief introduction to each of the papers. Finally, an overview of the hypotheses and the interconnections between the separate articles and the hypotheses is shown.

Paper I	Auramo, J., Aminoff, A., Punakivi, M. (2002), "Research agenda for e-business logistics -based on professional opinions", *International Journal of Physical Distribution and Logistics Management, Vol.32, Iss.7, pp.513-531*.
Paper II	Punakivi, M. and Saranen, J. (2001), "Identifying the success factors in e-grocery home delivery " *International Journal of Retail and Distribution Management*, Vol. 29, Iss. 4, pp. 156-163.
Paper III	Punakivi, M., Yrjölä, H. and Holmström, J. (2001), "Solving the Last Mile Issue: Reception box or Delivery box" *International Journal of Physical Distribution and Logistics Management*, Vol. 31, Iss. 6, pp. 427-439
Paper IV	Siikavirta, H., Punakivi, M., Kärkkäinen, M. and Linnainen, L. (2003), "Effects of e-commerce on greenhouse gas emissions case: home delivery service", *Journal of Industrial Ecology, Vol.6, No. 2, pp.83-97*
Paper V	Punakivi, M. and Tanskanen, K. (2002), "Increasing the cost efficiency in e-fulfilment by using shared reception boxes", *International Journal of Retail and Distribution Management,* Vol.30, Iss. 10, pp.498-507.

Paper I defines the most important research and development questions related to the logistics of electronic business. In this article the requirements of e-business on the national logistics infrastructure were found to be one of the focus research areas. According to the study, integrated supply network structure with suitable visibility and usage of real-time data transfer is another area of great importance. According to the results, the R&D of new logistics service concepts such as home delivery should also be promoted, as well as there being a need for research on the effects and possibilities of using new product data management and product identification methods.

Paper II compares the cost levels of various home delivery models and the current costs when customers do the shopping trip using a car. Additionally, the first results of unattended reception compared to attended reception are obtained. Finally, identifying the cost factors in home delivery operations gives guidelines for the future development of e-grocery home delivery services.

Paper III extends the analysis started in Paper II, concentrating on studying the models offering customer-specific unattended reception. In Paper III two possibilities for unattended deliveries, the reception box concept and the delivery box concept, are analysed. According to the study, the reception box concept results in more effective home delivery transportation and the delivery box concept in a smaller investment to achieve unattended reception. The cost savings in transportation when comparing unattended and attended reception are analysed using a vehicle routing tool. Then the payback periods of investments in facilities enabling unattended reception are calculated on the basis of the operational cost savings.

In Paper IV a literature review of the effects of e-commerce on various parts of the demand-supply chain was carried out. The literature study revealed many possibilities for e-commerce to reduce GHG emissions in the food production and consumption system. Some possibly negative effects were also identified. The e-grocery home delivery service was chosen as the subject of a case study because of its potential for reducing road traffic and GHG emissions in the food production and consumption system. In this case study the same results as in Paper II were analysed from the viewpoint of environmental effects, that is mileage and greenhouse gas emissions produced.

Paper V continues the work started in Papers II & III and complements the knowledge of cost savings related to unattended reception. In this paper the shared reception box concept is identified and compared to the models offering customer-specific unattended reception and to attended reception. This article also analyses the payback period for investment in shared reception box units in the current business environment.

The interdependence of the separate articles and the hypotheses in this dissertation is shown in Table 1.

Table 1 Relations of the separate articles and the hypothesis.

Hypothesis	***Articles***
Hypothesis 1: *Using unattended reception, cost-efficient home delivery operations can be created and significant cost savings can be reached compared to operating models based on attended reception.*	Paper II "Identifying the success factors in e-grocery home delivery" Paper V "Increasing the cost efficiency in e-fulfilment by using shared reception boxes"
Hypothesis 2: *The most cost-efficient home delivery model offering unattended reception is based on shared reception boxes.*	Paper III "Solving the Last Mile Issue: Reception box or Delivery box" Paper V "Increasing the cost efficiency in e-fulfilment by using shared reception boxes"
Hypothesis 3: *Home delivery services reduce traffic and GHG emissions compared to the situation, in which customers make shopping trips using their own cars.*	Paper IV "Effects of e-commerce on greenhouse gas emissions case: home delivery service"

4 RESEARCH METHODOLOGY

In the following chapters the research methodology is presented. First, the research approach is introduced and then the research process, data and the modelling tool used are described.

4.1 Research approach

Research in industrial engineering and management is positioned within applied sciences aiming at practical results applicable in industry (Olkkonen, 1994; Eloranta, 2000). According to Niiniluoto (1993), applied sciences, falling between basic science and technology (engineering), produce new knowledge intended to be useful for the specific purpose of increasing the effectiveness of some human activity. Hence, the results can be evaluated both based on the new information and practical usefulness of this knowledge. Additionally, Näsi (1980) argues that the results of applied science, supporting decision making, can be evaluated based on applicability, usability, practicability, and feasibility.

Depending on the research problem selected, the available information, the level of available information, and the final results the research aims at, several research approaches may be used. The research approach to be selected in this dissertation should provide means to answer the practical research questions formulated in chapter 1.2. Additionally, it should enable reaching the final objective of creating new knowledge and practical recommendations for developing feasible, economically and environmentally sustainable home delivery services.

At the time the research work was started in 1999, there were practically no historical data nor established operations models in the e-grocery home delivery business. The operations models were just created and introduced by the service providers according to the expected customer demand. Thus, when selecting the research approach and research methods, the operations were still in a development phase and under constant change.

For example, it seemed impossible to reach a large enough sample size to arrive at generally valid and reliable results by using a nomothetical research approach and survey methods with detailed questionnaires. Because of the highly competitive market conditions and growth expectations, the e-grocers' willingness to open up and publish the cost structure of their core operations seemed unrealistic. Furthermore, the differences in the e-grocer's service area characteristics and, for example, labour cost levels were seen as factors hindering equal comparison of different home delivery operations models offered by different service providers. For the same reasons, an action oriented approach and case study method based on real-life observations or measurements and interviews also seemed unrealistic. Additionally, when the research was started, the major e-grocers typically rejected requests for visits or interviews or e-mail questionnaires hindering the applicability of both the survey and case study methods.

Moreover, one important issue discovered when first studying the available service offerings was that not all the identified operational home delivery models were used yet by the service providers. This eliminated completely the possibility of getting part of the information required in answering the practical research questions formulated.

Answering the practical research questions, providing new knowledge and recommendations was seen as normative goal-directed problem solving task. Thus, the conceptual approach with theoretical and descriptive characteristics was not selected. Based on the above reasoning, the constructive research approach was selected in this dissertation.

Additionally, modelling appeared the most feasible research method, offering the possibility of analysing all the home delivery models in equal experimental conditions. Interviews and literature based case studies was selected to be used as supporting research methods increasing the validity of the modelling work.

In the Figure 9 the constructive research approach is presented in a framework (Kasanen et al., 1993) that classifies different research approaches according to their main emphases on two axes, theoretical-empirical and descriptive-normative.

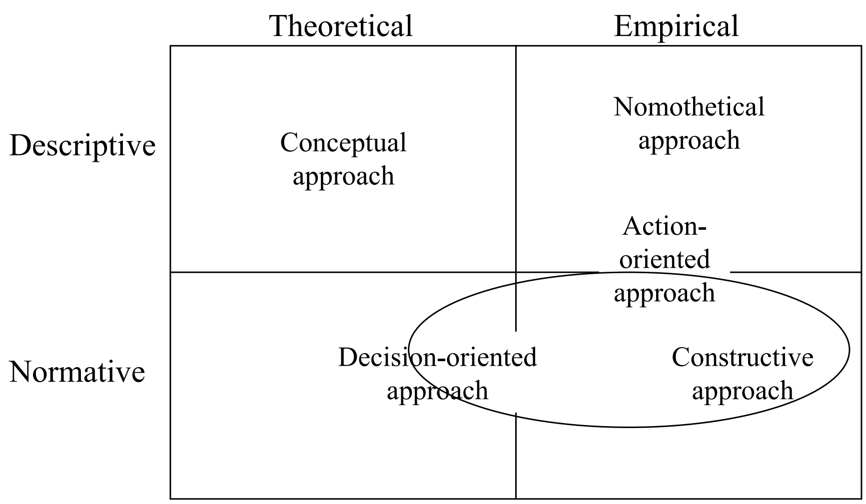

Figure 9 Positioning of the Constructive approach (Kasanen et al., 1993)

In this classification, a constructive approach is seen to have similar characteristics to action oriented and decision oriented (management science oriented) approaches. Between action oriented and constructive approaches, the common features emerge mainly in the empirical phase of the studies in which the case method is usually applied. According to Eisenhardt (1989), the case study is especially appropriate to explain and understand new topic areas. The action oriented approach, however, does not aim at creating managerial constructions (Kasanen et al., 1993). The decision oriented approach (management science oriented) typically uses the method of deduction (logical reasoning), and involves building mathematical models of complex business situations, using spreadsheets and/or other software programs to gain insight into the business situation, and communicating the resulting insights and recommendations (Lawrence & Pasternack, 2002 ; Kasanen et al., 1993). According to Kasanen et al., (1993), the main difference is the fact that the constructive approach always entails an attempt to demonstrate explicitly the practical usability of the constructed solution.

In brief, the constructive approach is defined as a goal-directed managerial problem solving activity through the construction of models, diagrams, plans, organisations, etc. Constructive research is also normative and innovative by its nature. As Figure 10 illustrates, an essential part of the constructive research approach is to tie the problem and its solution to accumulated theoretical knowledge (body of knowledge).

In addition, the constructive research approach requires that the practical usability of the construction be demonstrated. (Kasanen et al., 1993)

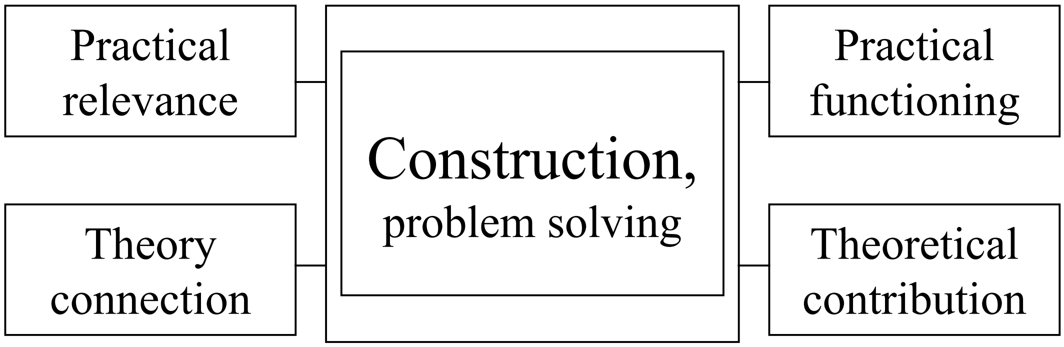

Figure 10 Elements of Constructive Research (Kasanen et al., 1993).

Additionally, Kasanen et al. (1993) have characterised the constructive approach by dividing the research process into the following six phases.

1. Find a practically relevant problem which also has research potential
2. Obtain a general and comprehensive understanding of the topic
3. Innovate, that is, construct a solution idea
4. Demonstrate that the solution works
5. Show the theoretical connections and the research contribution of the solution concept
6. Examine the scope of applicability of the solution.

These phases are also used in this dissertation and the research process is described in the next chapter. Additionally, for examining and demonstrating the practical usability of the construction, Kasanen et al. (1993) have suggested market tests of three different levels. These market tests are presented in the following:

- Weak market test, which requires that the construction is in use somewhere,
- Semi-strong market test, which requires that the construction has become widely adopted by companies, and
- Strong market test, which requires that the companies applying the construction have systematically produced better financial results than those not using it.

Kasanen et al. (1993) note that even the weak market test is relatively strict, and it is probably not often that a tentative construction is able to pass it. Thus, it is usual that several attempts must be made.

As described earlier in chapter 1.1 and in chapter 2.3.2, applications of different types of the identified home delivery models have already been used by some e-grocers. Thus, in this dissertation it is seen that the weak market test has already been taken by companies offering e-grocery services in various geographical areas. To ease passing semi-strong and strong market tests in the future, however, more information seems to be needed. In order to provide new and objective information as a result of this dissertation, the testing of various home delivery models was done using modelling. In this way, the comparison could be made in equal conditions for all the identified home delivery models. Additionally, the modelling results were compared with relevant real-life information from a practical e-grocery pilot operation. Thus, the pilot operation was used for validating the modelling settings and the research results. A detailed description of the research process is provided in the following chapter.

4.2 Research process and data

The research process in this dissertation follows the six steps of the constructive approach described above. In the following, the research process and data used are described.

Find a practically relevant problem with research potential

As described in the introduction of this dissertation, the home delivery service model is a potential problem area in the supposedly rapidly growing e-grocery business. The problems encountered by early e-grocers reveal that this problem area has significant research potential and notable impact on developing the e-grocery business. It was also obvious that this problem area belonged to the research area of logistics as it covers developing various transportation service solutions for the consumer direct channel.

Obtain a general and comprehensive understanding of the topic

Already in early research, developing home delivery operations in an e-grocery business was found to be a more complex issue than initially appeared. Comparing, for example, the distance driven by the customers if they transport their shopping home by car to the distance driven by a fleet of home delivery vans delivering the same shopping seems simple. However, the trade-off depends on many factors, including the nature of the road network, the number and location of customers, van capacity, the number of delivery vans required, the time period within which the shopping must be delivered from when the order is placed, the delivery time window, and the reception mode. Because of the complexity of the problem area and lack of suitable data, in earlier research work, for example that of Cairns (1997), only some of these constraints were taken into account.

Innovate, that is, construct a solution idea

Analysing the existing and emerging home delivery models required first identification of possible solutions to the home delivery problem, which is seen as the construction in this dissertation.

The possible home delivery operations models were identified from literature, newspapers, interviews with e-grocers' management in magazine articles, and especially by analysing the e-grocers' home delivery service offerings that existed at that time. Additionally, when starting the research in 1999, we succeeded in organising an interview with, and evaluation of, the established Matomera e-grocery operation in Sweden (Johnsson, 1999). Interviews at Inex Partners Oy, which is one of the two dominant purchasing and distribution organisations in the Finnish grocery retailing market, was also organised to understand better the characteristics of grocery distribution (Harju, 1999; Ojala, 1999). Additionally, interviews at Harwall Oyj, the biggest brewery in Finland (Matikainen, 1999), and Valio Oy, the biggest dairy products manufacturer in Finland (Hilden, 1999), were organised to understand the direct distribution operations model. Furthermore, interviews of transportation service providers' representatives were organised to reveal the characteristics of home delivery operations in the Helsinki metropolitan area (Lehtonen, 1999; Holtari, 2000; Henriksson, 2000; Danska, 2001). The home delivery models to be analysed in this dissertation were then selected on the basis of the information collected.

Demonstrate that the solution works -analysis and testing

Demonstration of the identified service solutions in the e-grocery home delivery business was to be made by means of analyses and comparisons based on modelling. It was noticed that not all the possible home delivery models were yet in use. Consequently, modelling appeared the most feasible research method because it offers the possibility of analysing all the home delivery models in equal experimental conditions. The main settings for the modelling work were created together with Juha Saranen (Paper II) on the basis of the information collected.

However, most important from the modelling point of view was the availability of real point-of-sales data from S-Group, covering detailed information about customers' grocery shopping. The exact receipt information from one week in October 1999 was collected from five of S-Group's supermarkets, including 81,139 receipts, henceforth referred to as orders. These data include, for example, items, quantities, volumes (litres), supermarket, date and shopping time, and the prices of shopping baskets. Customers' street addresses were obtained from their loyalty cards. However, the customers remained anonymous in order to keep their identities confidential.

The data selected for the modelling work were limited in two ways. First, the order size taken into account was limited to shopping baskets that exceeded 25 euro. Smaller purchases were not considered feasible for home delivery service modelling. The second limitation to the data was the customer's place of residence, which had to be within the boundaries of the selected test area (135 km^2) that was considered reasonable for deliveries from one location. The test area covered part of the Helsinki metropolitan area in Finland, and was defined using the postal codes of the area. A list of these postal codes and a map of the area can be seen in Appendix III. The number of inhabitants in the test area is approximately 202,000, and the number of households is about 89,000 (Statistics Finland, 1998). Given these limitations, the research data included 1,639 shopping baskets belonging to 1,450 anonymous household customers, slightly more than 1.6 per cent of the households in the area.

From the modelling point of view, the most important elements in this point-of-sales data were shopping time, customers' place of shopping, and customers' addresses.

Limitations to vehicle capacity utilisation were determined by the delivery time windows, shopping basket volume, and the number of orders. Later in Paper V, after the validation of the results, number of orders and delivery time windows were selected as the limiting factors (see Appendix III).

Using this real shopping data and customers' street address information, the e-grocery home delivery models were modelled using the CAPS RoutePro vehicle routing tool (see Chapter 4.3). Additionally, the situation in which the customers do the shopping trip using their own cars, was modelled. Papers II, III, and IV were then written based on these first modelling results, forming the basis for the practical e-grocery pilot operation.

The e-grocery pilot operation, in which around 50 household customers used an online grocery shopping service based on the reception box concept, was launched in June 2000 by S-Group and Hollming Ltd in co-operation with the Ecomlog research group. In this dissertation, the two-year pilot operation was used to verify the research results achieved.

Show the theoretical connections and the research contribution of the solution concept

The theoretical connections and the research contribution are demonstrated in both the individual articles and this binding story. Of the individual articles, Papers II, III, and IV were written based on the first modelling results, forming the basis for the e-grocery pilot operation in the selected test area. Comparing the original analysis and the verification results obtained during the practical pilot operation led to more reliable settings in the model (described in Appendix III). Furthermore, a need for more specific analysis and comparisons of various possible ways to offer home delivery and unattended reception emerged. Paper V was then written based on these complementary results.

Examine the scope of applicability of the solution.

The scope of applicability of the various home delivery models and the results attained are discussed in both the individual articles (Papers II-V) and the Results and Discussion chapters of this binding story.

4.3 Modelling tool used

The modelling work in this dissertation was performed using a commercial vehicle routing tool, RoutePro (6.4.1) from CAPS Logistics Inc (CAPS, 2002). The modelling work can thus be described as static and deterministic, that is, the modelling is a representation of a particular time, and the components such as costs and data are known with certainty (Lehtonen J-M, 1999). Additionally, spreadsheet programs were used in data processing and analysing the cost structures of the home delivery models.

With over 20 years of experience, CAPS is a leading provider in decision support software. The products are used in a wide range of industries, such as Chemical, Food and Beverage, 3PL Providers, and Transportation. CAPS RoutePro product features include, for example, an unlimited number of depots, sites, orders, vehicles, routes, and time windows in the routing. Vehicle types, order types, and site types and their specific characteristics may be defined by the user. Additionally, RoutePro uses digital road maps in the vehicle routing. This make possible taking into consideration, for example, different road characteristics like speed limits and rush hours for different road types. Finally, also the presentation of the results is progressive. The routing results are visualised on the map and illustrated in graphics showing, for example, under/over utilised routes.

It soon became obvious that the RoutePro vehicle routing tool was suitable for the purposes of this research. Additionally, it was available to be used. When starting the modelling work a two phased selection process was used for choosing the routing algorithm. First the descriptions of the various algorithms available in CAPS RoutePro software were studied using the users' manual. Based on the manual two algorithms, namely Tree-algorithm and Nearest neighbour-algorithm, were selected as suitable candidates for this type of modelling work. In the second phase of the selection process these two algorithms were tested in the selected geographical area. The difference between the calculation results of Nearest neighbour-algorithm and the Tree-algorithm were small, but the Tree-algorithm was slightly better in optimising the routes in the selected area. Additionally, according to the advice of the

CAPS representative (Lindholm, 2000) and the operating instructions (CAPS, 1998), the Tree-algorithm is more suitable for modelling home deliveries that originate from, and are destined for, a single depot in a suburban and urban area.

The Tree-algorithm builds routes one at a time and tries to build a full truckload with one vehicle before using another vehicle. The highest priority order will start a route. The site that starts the route is called the seed location. The algorithm grows the route by adding the unrouted candidate order whose summed distance to the seed location and the depot is the smallest. The orders can be pure pickups, pure deliveries, or a mixture of pickups and deliveries (CAPS, 1998). The Tree-algorithm used was developed by CAPS Logistics but seems to bear similarities to the successful Solomon (1987) insertion heuristic I1.

Other possible vehicle routing tools that could have been used in this dissertation are, for example, RouteView Pro (Genimap, 2002; InfoTech, 2002). However, it was noticed that reaching the objective of this dissertation did not require the use of more than one vehicle routing tool. The focus was to analyse the differences among the possible operations models in the e-grocery home delivery business. Even if the absolute numerical outcomes of the tests had been slightly different using another vehicle routing tool or another routing algorithm, the relative differences and relations of the analysed home delivery models would have been the same.

4.4 Discussion of the research approach selected

Constructive research approach selected in this dissertation is seen to have similarities with two probable more generally known research approaches or frameworks in logistics research.

Firstly similarities are found with Forrester's (1961) experimental approach, used for research into the management of industrial systems. Forrester (1961) describes the experimental approach as one of building experimental models of companies or industries to determine the influences of organisation and management policy. Although his methods are quantitative and result in a mathematical representation of the business system, the philosophy, objectives, and approaches are more like those of the practising manager. In practice, this approach consists of first identifying a problem area in the business and then setting up a computer model of the conditions describing the problem area. Different management decisions, operations models, and market assumptions can then be tested with the computer model to determine their effects on the company's success and increase the understanding of the business system.

The second one is the logistics research framework presented by Mentzer & Kahn (1995). According to this framework, good research in the field of logistics includes an appropriate literature study and sufficient real-life observations to provide evidence of the importance of the research, proceeds to theory development and testing, and finally presents conclusions consistent with the theoretical basis as regards reliability and validity. Additionally, good research provides an adequate insight into the future research and managerial implications of the effort (Mentzer & Kahn, 1995).

5 REVIEW OF THE RESULTS

In this section the results of this dissertation are presented. To a large extent the results have already been published in the separate articles. Here, the findings of the five separate articles are collected and summarised according to the hypothesis outlined in Chapter 3. In the introduction the findings most relevant to the focus area of this dissertation published in Paper I (Auramo et al., 2002) are briefly covered. Then the cost levels of the various home delivery models, differences between unattended and attended reception, and payback periods for the required investments in unattended reception are examined. On this basis the most economically and operationally efficient home delivery model is identified. This is followed by an analysis of the possible effects of home delivery on traffic and the environment. Validation of the research results is presented during the review as well as in the Discussion in chapter 6.

5.1 Introduction

The development of e-business has already imposed increased quality requirements on logistics services and on logistics infrastructure as a whole and will continue to do so. It is seen as important to be able to fully utilise existing resources and to provide various service levels according to customer requirements. On the basis of the results in Paper I, the requirements e-business imposes on the national logistics infrastructure were found to be one of the focus research areas. Additionally, an integrated supply network structure with suitable visibility and usage of real-time data transfer was another area of great importance. Research into, and the development of, new logistics service concepts, as well as research into the effects and possibilities of using new product data management and product identification methods, were to be promoted as well.

According to the professional opinions reported in Paper I, it is presumed that material flows will become narrower but more frequent in the B2B e-business environment. This is due to increased information flow and the optimising of inventory levels in the different parts of the logistical network. Material flows to individual consumers in the B2C sector will follow the same tendency when more and more goods are transported directly to households. Unless the products are immaterial, management of physical distribution was seen as one of the most important R&D topics, regardless of the customer segment. According to the results published in Paper I, the development of e-business will especially increase the importance of delivery accuracy, delivery frequency, and delivery lead time. This applies to logistics operations both in the B2B and B2C segments. Additionally, when developing home delivery operations in the B2C e-business environment, some country-specific challenges came up. Some of those are, for example, local infrastructure, the geographical distribution of the end customers, and consumers' shopping habits and service requirements.

The results published in Paper I were used as supportive information providing the confidence that developing efficient home delivery operations in the B2C e-business environment is important.

5.2 Cost analysis of the operational home delivery models

The first of the hypotheses in this dissertation claims that *home delivery operations are significantly more cost-efficient based on unattended reception than based on attended reception*. Paper II (Punakivi & Saranen, 2001) presents results valid to this hypothesis, and additionally Papers III (Punakivi et al., 2001) and V (Punakivi & Tanskanen, 2002) present evidence that confirms this hypothesis.

5.2.1 Home delivery costs compared to the current situation

According to the results in Paper II, the more options the customer is allowed when selecting the delivery time windows, the greater is the number of vehicles needed, the amount of working hours, and the total distance driven. All these, added together, have a considerable effect on the costs of the home delivery operation.

In Paper II the point-of-sale grocery shopping data collected was used in the constructive modelling of various home delivery models and current operations in which customers do the shopping trip using their own cars. Details of the modelling work are described in Appendices III and IV. The results presented in Figure 11 show that an e-grocery home delivery service can actually be cheaper compared to the current costs of a household customer visiting a supermarket. However, for the service providers the main issue of this analysis is the cost level comparison of various home delivery models.

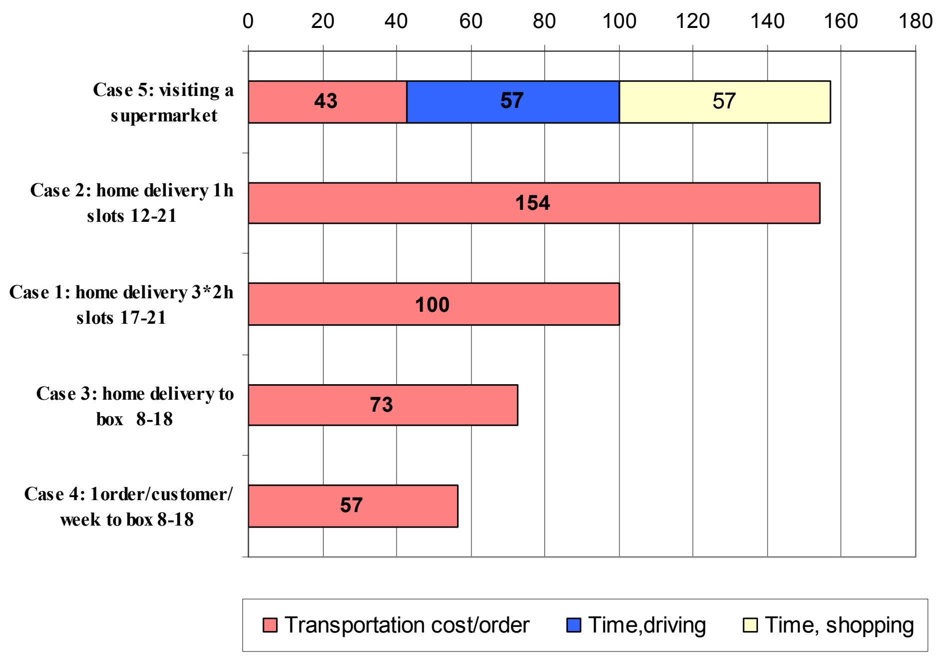

Figure 11 The indexed transportation costs of various home delivery models (Punakivi & Saranen, 2001).

Figure 11 shows the cost levels of different e-grocery home delivery models compared to the current cost of the customers visiting a supermarket (Case 5), presented at the top. The current "self-service" price is indexed to be the reference bar in the figure. The index (100) includes the costs of using the customer's own car and the spare time used for driving but not the time used for doing the shopping. The costs of driving back and forth to the store are calculated using an average cost multiplier of 0.15 euro/km, including the costs of petrol, insurance, tyres, servicing, and repairs (Aromaa, 1999; Aromaa, 2001). According to this modelling, as well as other studies in Finland, the average one-way distance to the grocery shop is 3.5 km (Granfelt et al., 1995), validating the first element in the reference bar. The cost of the spare time used is calculated using a estimate cost of 3.36 euro/h, which is in line with the value placed on leisure time by the Ministry of Transport and Communications Finland when assessing investments in the road network. The average driving and shopping time, 50 min/shopping trip, is here divided half-and-half between shopping and driving (Raijas, 1994).

According to Paper II, when an e-grocery home delivery service provider offers a one-hour delivery time window (Case 2) the delivery costs are 54 per cent higher than in Index 100, covering the cost of driving the car and using spare time for driving. The cost level obtained for Case 2 in the analysis has been confirmed as being correct by a Finnish e-grocery shopkeeper (Kyyrö, 2000).

Limiting the delivery time window to three 2-hour delivery slots (Case 1) enables better route optimisation and scheduling, leading to a significant (54 per cent) cost reduction compared to Case 2. With this operating model, the cost is the same as in "self-service" (Case 5). From the service provider's point of view, this operating model is cost-efficient, but significant cost reductions can still be found by using unattended reception, eliminating the tight time window constraint.

Unattended reception (Cases 3-4) and wide (8 a.m.-6. p.m.) delivery time windows enable efficient home delivery operations. Case 4 describes the best attainable situation, where the orders are sorted by postal code and divided evenly among six delivery days in a week. In Case 3 the orders are delivered on the original shopping date. According to the analysis, the cost level of Case 3 will be 28 per cent below the cost level of "self-service". In Case 4 the cost level drops dramatically, by 43 per cent, below the cost level of "self-service". In real life, this kind of situation could be reached only by an effective service area clustering and pricing policy.

The key factors in these results are the density of stops along the route and the possibility of route and schedule optimisation. To demonstrate this, the average distance driven per order and the number of deliveries per hour in each of the cases are shown in Figure 12. Analysing Figure 12, it can be noticed that the cost efficiency of a home delivery model is based on decreased average mileage per order and a simultaneously increased number of stops per hour.

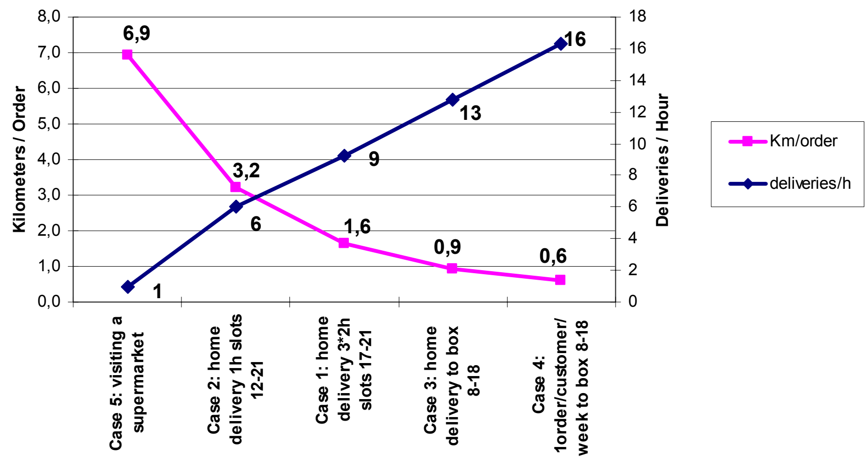

Figure 12 Average distance driven per order and number of deliveries per hour using different home delivery models (Punakivi & Saranen, 2001).

5.2.2 Costs of attended vs. unattended reception in home delivery

As covered in the previous chapter, the operational cost level of home delivery models using unattended reception is notably lower compared to the models using attended reception with tight time windows. During the analysis, the question of how mixing attended and unattended stops would affect cost efficiency arose as a possible way of reaching cost-efficient home delivery operations.

The further analysis in Paper II, focusing on mixed attended and unattended receptions (Case 6), was performed using the point-of-sale data from one day, including 462 orders. Attended receptions were described using "customer-chosen" 1-hour delivery time windows, which were chosen according to the real shopping time between 8 a.m. and 6 p.m. Unattended receptions were described using an open delivery time window between 8 a.m. and 6 p.m. During the analysis the amount of attended receptions was gradually increased.

Figure 13 shows the number of vehicles needed to deliver the orders and the indexed average time per stop for evaluating the cost effects.

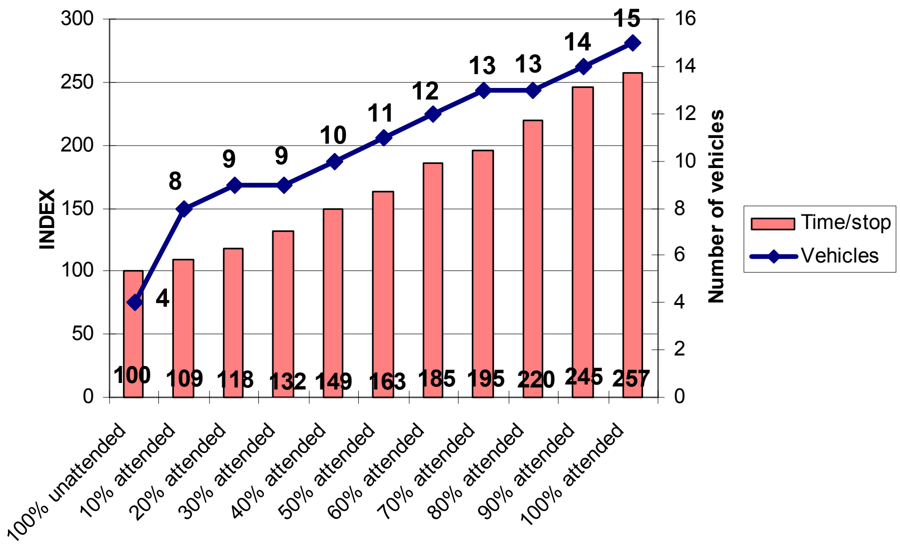

Figure 13 The average working time per stop and the number of vehicles needed (Punakivi & Saranen, 2001).

Generally the results in Figure 13 demonstrate a significant growth in the variable cost level when attended reception is used. The most important observation was that the number of vehicles needed increases rapidly if attended and unattended deliveries are mixed. Already 10% of attended deliveries along the route will double the number of vehicles needed, when compared to totally unattended home deliveries. After that increasing the number of attended stops, however, seems to affect more smoothly.

According to these results, the average cost per attended stop (100% attended) is 2.57 times higher than in the case of an unattended stop (100% unattended), meaning an additional cost of 157 per cent. For the service providers currently offering one-hour delivery time windows, the possible cost savings would be as great as **61 per cent**. The reason for this is simply that with one-hour delivery time windows the delivery vehicle needs to drive back and forth in the delivery area to meet the promised delivery time windows.

5.2.3 Validating the cost analysis of the home delivery models

To validate the results obtained using the modelling settings presented in Appendices III and IV, a further analysis was conducted in Paper V, in which three models offering unattended reception were analysed and compared to a model with attended reception. In Paper V, the same test area and point-of-sale data as in Papers II and III were used. However, the modelling settings were slightly changed, for example, by restricting the van capacity from 60 orders per route to 40 orders per route and using updated delivery time window promises. The settings in the analysis in Paper V are shown in Appendices III and V.

Regardless of the slight setting changes, the results in Paper V are in line with the earlier results in Papers II and III. When using the *reception box concept* or *delivery box concept A* (pick-up of the delivery box at the next delivery time), savings in costs as great as **44-53 per cent** can be reached when compared to the current standard model with attended reception and two-hour delivery time windows. Furthermore, the cost saving using the *shared reception box concept* is even higher. The cost saving using this model is as much as **55-66 per cent**. However, the *delivery box concept B*, where the pick-up of the boxes is carried out separately on the day after delivery, results in double the amount of stops. This weakens the operational efficiency of this model to the level of attended reception. In reality, the extra number of stops also represents a threat of two-times-higher costs than in other customer-specific models, if the drop-off time increases. Figure 14 shows the results of the cost analysis of home delivery models in Paper V.

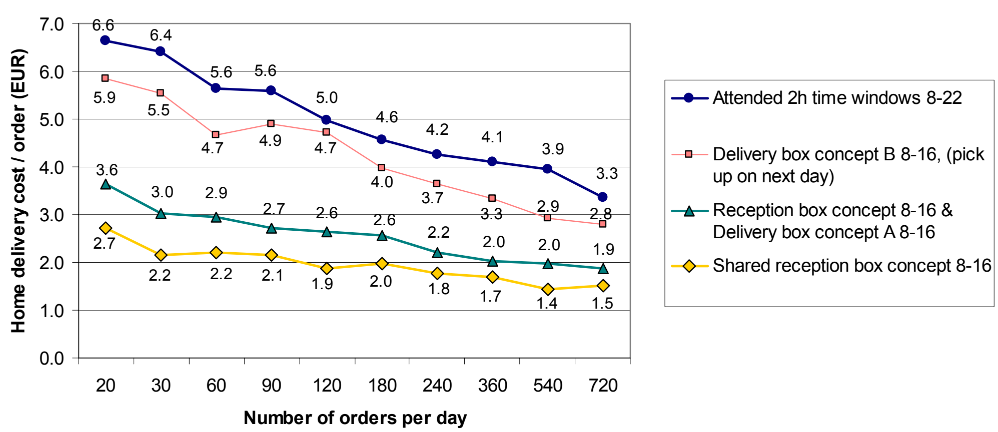

Figure 14 The operational cost levels of home delivery models (26 euro/h) (Punakivi & Tanskanen, 2002).

The cost driver behind the results shown in Figure 14 is the number of deliveries per hour. In Figure 15 the deliveries-per-hour performance of the home delivery models is shown.

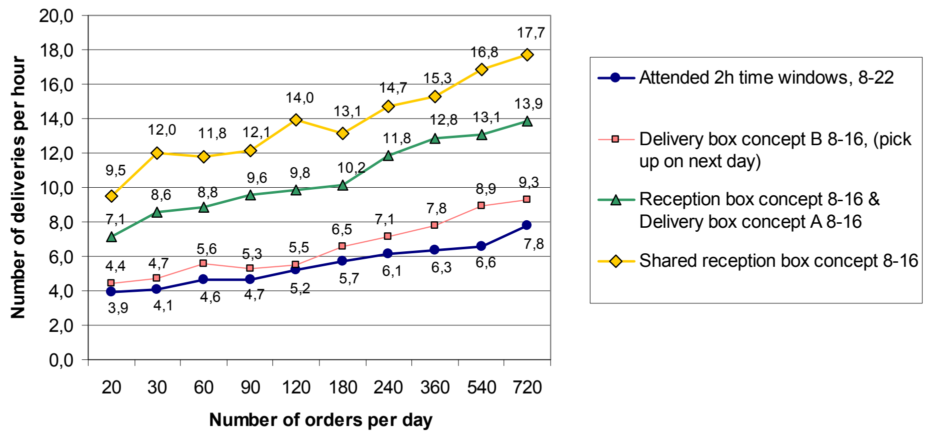

Figure 15 The deliveries-per-hour performance of the home delivery models.

For validating these results of the modelling work, some real-world references are considered. According to Lardner (1998), using the reception box concept, Streamline reached a performance level of 10 deliveries per hour, while others in the field, offering one-hour delivery time windows, were struggling to reach 3 deliveries an hour. Ykköshalli, operating in the Helsinki metropolitan area in Finland, has reached 5 deliveries per hour using one-hour delivery time windows (Kyyrö, 2000). Additionally, according to Homeport (2002), Sainsbury's have reached 18 deliveries in 3 hours or 6 deliveries per hour in London, using the delivery box concept. According to this real-life information, the modelling is valid; however, the performance levels of the service providers were not published with information detailing the sales levels or number of orders per day. Furthermore, the situation is affected by the characteristics of the local road network, the time needed to find a parking place, and the rush hours. This is why the e-grocery pilot operation (SOK, 2001), in which around 50 household customers were using an online grocery shopping service and the reception box concept in the test area selected for this modelling, is used for better validation of the results.

This was conducted by measuring the efficiency of the home delivery operations in two separate home delivery rounds. Afterwards, imitations of these two rounds were completed using the vehicle routing tool. In reality the deliveries-per-hour performance on a route consisting of 24 customer orders to refrigerated reception boxes was 7.3, whereas 6.3 was suggested by the modelling. This test was carried out on October 5th 2001 in very good weather conditions, well before the rush hour, which made this good result possible. The second test was carried out on November 23rd in 2001, right after the first snowfall and in poor weather conditions, but again before the rush hour. In the second test the deliveries-per-hour performance on a route consisting of 22 customer orders to refrigerated reception boxes was 6.6, whereas 7.2 was suggested by the modelling. Figure 16 shows the modelled route in the second test, with 22 customer orders.

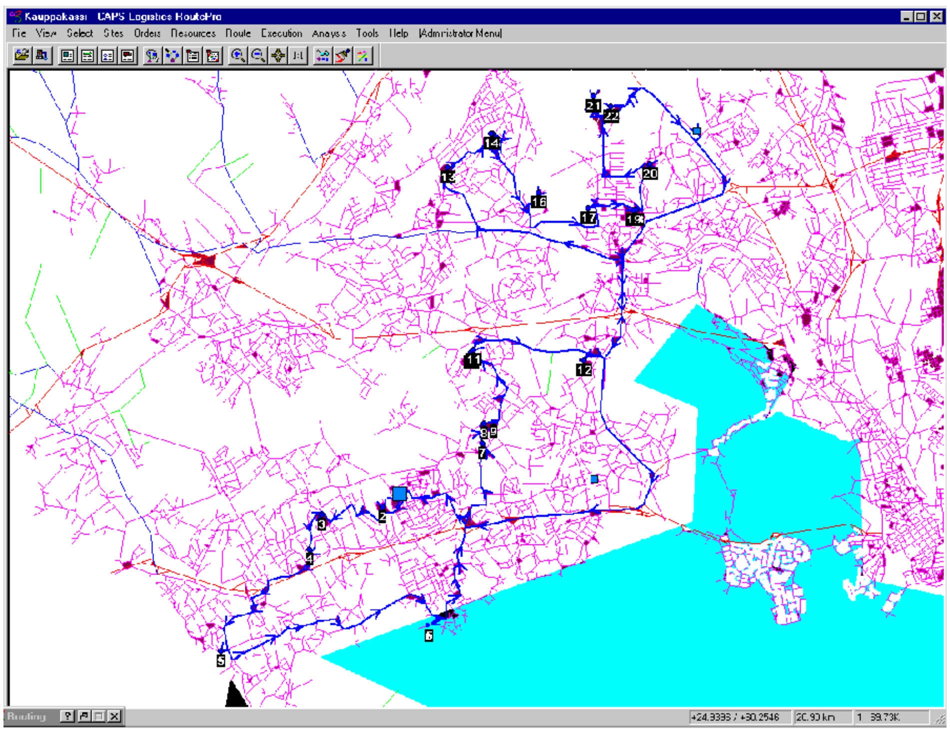

Figure 16 Screen shot picture of the route of the second test, with 22 customer orders.

The error between reality and the modelling results is probably due to the traffic situation, the driver's good knowledge of the local road network, and the weather conditions. Although the scale of the pilot operation is fairly small, the results of this verification effort add the reliability and practical utility of the modelling work and the results based on that.

To summarise, Hypothesis 1: *Home delivery operations are significantly more cost-efficient based on unattended reception than based on attended reception,* is confirmed since potential cost savings of 44-66 per cent can be considered significant. Furthermore, it is important to notice that in these analyses, the drop-off time was the same (2 minutes) for all the home delivery models analysed. It is likely that in a real situation attended reception includes some customer service and takes more time than unattended reception. This would make the cost advantage of unattended reception even greater than shown in these results. Additionally, in these analyses the home delivery cost driver was considered to be the actual working time needed per delivery, whereas in real life there would be an additional fixed price per vehicle needed. This would further increase the cost-saving potential of models offering unattended reception, enabling fewer vehicles to serve the customers. However, one of the major obstacles seen in implementing a home delivery service based on unattended reception is the investment involved in the reception facility. In the following chapter the investments involved in the facilities for unattended reception are considered.

5.3 Economical feasibility of unattended reception concepts

The second hypothesis claims that *The most cost-efficient home delivery model offering unattended reception is based on shared reception boxes*. In answering this question, the investments involved in facilities for unattended reception must be taken into consideration, in addition to the operational cost savings covered in Chapter 5.2. Papers III (Punakivi et al., 2001) and V (Punakivi & Tanskanen, 2002) present results relevant to this hypothesis.

5.3.1 Analysing the customer-specific solutions for unattended reception

It is convenient for customers to have groceries delivered to a reception box or a secured movable delivery box near the door of their home. This allows customers to be independent of delivery time windows. For home delivery service providers unattended reception means the elimination of tight time windows and capacity problems resulting from uneven demand during daily working hours. Both the reception box and delivery box concepts shorten the delivery time at the door and eliminate the "not at home problem" or the cost of redelivery (Jones, 2000).

Although both the reception box and delivery box concepts make possible the benefit of unattended reception, there are several differences. The customer-specific reception box requires a location in the customer's garage or home yard and is equipped with a refrigerator-freezer, providing total independence of delivery time windows (SOK, 2001; Huhtakangas, 2000; The Times, 2000; Croft, 2000). Secured delivery boxes, however, are insulated and should ensure that frozen/chilled food remains frozen/chilled for 12 hours (Homeport, 2002). An open question is whether the delivery boxes function in the northern winter, that is, do the groceries freeze if a delivery box is left outside in minus 15°C (5°F)? However, the issue of finding the space required for customer-specific reception boxes in, for example, apartment buildings can be avoided using the delivery box concept. Normally, there is little space around buildings, especially in city centres. Reception boxes could be installed in cellars, but delivery boxes, such as Homeports (Homeport, 2002), could even be left on the pavement, securely attached to a locking device bolted into the building wall.

In Paper III the focus was on assessing the payback period of investments in facilities enabling unattended reception. This was carried out by examining what level of investment the cost savings in transportation justify from the home delivery service provider's point of view. The price of a reception box was assumed to be comparable to a normal refrigerator-freezer, i.e. 400-1000 euros. For a retailer the price of a secured delivery box system is between 80 and 170 euros, including £7 to £60 for a delivery box depending on the size, £9 for the cable, and £30 for the locking device (Homeport, 2002). Thus, the investment in the delivery box concept can be expected to be significantly lower than in the case of reception boxes, where the electronics, the refrigerator, and the freezer increase the costs.

To be well-grounded, the investments in unattended reception need to be recovered either by the savings achieved in home delivery operations or by service fees. The payback period analysis in Paper III was conducted on the basis of the cost difference between the attended and unattended home delivery models. The analysis was made in the selected test area in metropolitan Helsinki, using five different customer density levels ranging from 47 to 1639 orders per day. The details are described in Appendices III and VI.

Based on the results presented in Paper III, Figure 17 illustrates how the e-grocer or home delivery service provider recovers their investment in unattended reception when compared to the home delivery service with one-hour delivery time windows. An investment level of 200 euro per customer is recovered in approximately 2 years with the cost savings (not discounted) made possible by unattended reception. The payback time at an investment level of 1000 euro per reception box and the cost of installation would be 7-12 years. This means that the operational cost savings of the home delivery service will not cover the 1000 euro investment if the life cycle of the equipment is less than 7 years.

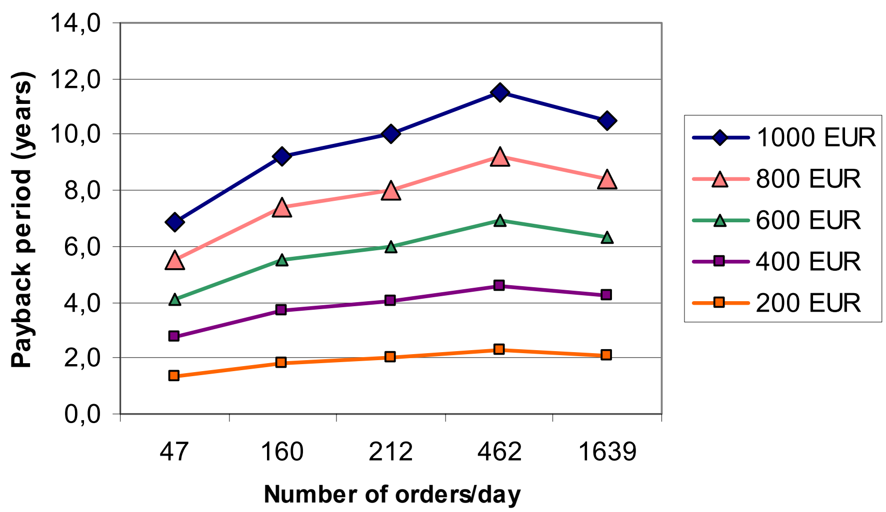

Figure 17 Payback period for the investment in unattended reception solutions compared to home delivery service with a one-hour delivery time window (Punakivi et al., 2001).

According to the results presented in Paper III, the payback period increases with a growing number of orders delivered per day in the same area. This is due to the fact that with an increasing density of stops a service with attended reception gains from the possibility of optimal routing and thus can be more cost-efficient. The result is that the cost difference between unattended and attended delivery decreases.

On the basis of the payback period analysis presented in Paper III, it is obvious that at least part of the investment in customer-specific reception boxes needs to be carried by the customer or possibly by employers. The payback time based on improvements in efficiency is simply too long from the e-grocer's or logistics service provider's perspective.

Compared to the reception box concept, the total investment in the delivery box concept is low, meaning a shorter payback time. But more importantly, when starting a home delivery service based on the delivery box concept, the switching cost per customer for unattended home delivery is low. This is due to the low cost (£30 or 50 euro) of installing a new locking device, compared to the high upfront investment and installation cost needed in the reception box concept. If the customer does not start using the service, only the locking device has been put there for nothing and the boxes can be used to serve other customers.

Along the insulation capability of the delivery boxes, one weakness of the *delivery box concept A* is that the delivery boxes must be stored by the customer until the next delivery. This also means that the delivery service provider has to invest in several delivery boxes per customer to be able to run the service. However, the number of delivery boxes needed would be smaller if the customers are ordering very frequently. The *delivery box concept B,* where the delivery boxes are collected separately during the next day from the original delivery, solves this problem but leads to very high operational transportation costs as shown in the Figure 14 in chapter 5.2.3.

From the e-grocer's or home delivery service provider's perspective, the delivery box concepts seems interesting, making possible the faster acquisition of new customers and a higher growth rate. However, from the customer's perspective, the reception box concept has advantages in that it offers total independence of delivery time windows and logistics service providers. Additionally, a refrigerated reception box preserves food supplies more reliably, and issues like the hygiene of the box are up to the customer.

5.3.2 Analysing the shared reception box concept

During the research process the idea of shared reception boxes emerged. Shared reception boxes could be used on a daily basis by several different customers, which would make possible the fast acquisition of new customers and high growth.

As in the previous chapter, the starting point for the payback period analysis in Paper V was the cost difference in operating efficiency of the home delivery models. The details of the modelling settings are in Appendices III and IV.

In Paper V the payback period analysis was based on the published price of a shared reception box unit with 24 separate lockers, representing the investment required per unit. Based on an interview with Hollming Ltd (Hollming, 2001) and published material from Boxcar Systems Inc. (Boxcar, 2001), the price of a unit of this kind is around 42,000 euro.

In the payback period analysis for 24-locker shared reception box units, the number of deliveries per day ranges from 60 to 540 and the utilisation rate is 50% or 75%. A 100% utilisation would mean one delivery per locker per day. Additionally, the number of shared reception box units and the number of different unit locations increases step by step in the analysis from 5 to 10, then to 20, and finally to 30.

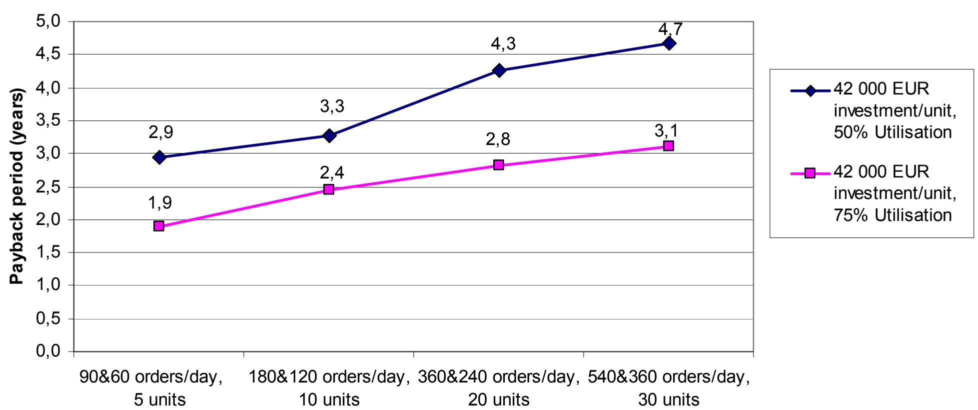

Figure 18 Payback period for a shared reception box unit with a capacity of 24 lockers (Punakivi & Tanskanen, 2002).

Figure 18 illustrates how the e-grocer or home delivery service provider recovers their investment in shared reception box units when compared to the standard home delivery service with 2-hour delivery time windows. With a 75% utilisation rate the payback time would be 2 to 3 years and with a utilisation level of 50% between 3 and 5 years (not discounted). This result encourages investing in shared reception box units rather than, for example, in specially designed vehicles, as in the GIB example (Ring & Tigert, 2001) described earlier.

For comparison to the results presented in Paper III, a payback period analysis for customer-specific reception boxes was made, based on the results in Paper V, using a price of 1,000 euro per unit. According to this confirmation analysis, the payback period for reception boxes is between 6 and 13 years, when the number of daily deliveries ranges from 20 to 720. According to this, the results presented in Paper III are in line with the results in Paper V.

As in Figure 17 and also in Figure 18, the payback period increases when there are more orders to be delivered per day. This is due to the reduced cost difference between the model with 2-hour delivery time windows and unattended reception. The reason for the reduced cost difference is based on the effects of economies of scale. With a higher number of orders, the density of the stops is also higher. With a higher stop density, home delivery operations are more cost-effective, regardless of the operating model.

To summarise, Hypothesis 2: *The most cost-efficient home delivery model offering unattended reception is based on shared reception boxes,* is confirmed. Additionally, in Paper V the analysis of the shared reception box concept was made using 50% and 75% unit utilisation rates. When a shared reception box is placed in a busy railway or underground station, as many as 2 or 3 orders per day per locker (a 200-300% utilisation rate) could be possible. Furthermore, as noted in answering Hypothesis 1, in this analysis the drop-off time for attended reception and unattended reception was 2 minutes, to enable proper comparison. In reality, the drop-off time using attended reception may be higher, whereas using the shared reception box concept it may turn out to be even shorter as a result of the scale benefits. However, the risk in the shared reception box concept is in unknown customer acceptance. At the moment it is unknown if consumers are willing to use a "halfway" home delivery model, which still requires collection of the goods and last mile transportation if the shared reception box unit is not installed in the apartment house cellar or on the office car park.

5.4 Effects of home delivery services on traffic and the environment

The third hypothesis in this dissertation claims that *Home delivery services reduce traffic and GHG emissions compared to the situation, in which customers make shopping trips using their own cars*. Paper IV (Siikavirta et al., 2003) presents results relevant to this hypothesis.

In Paper IV the same original results were used as in Paper II. However, in Paper IV the focus was placed on analysing the possible environmental effects of the home delivery models, whereas in Paper II only the cost levels were analysed. Thus the modelling settings were the same as in Paper II, presented in Appendices III and IV.

According to the results presented in Paper IV and Punakivi & Holmström (2001), all the home delivery service models are more environment-friendly than the situation, in which customers visit the store using their own cars. Figure 19 presents the average distance driven per order using various home delivery models and the situation in which household customers visit the store, driving back and forth with their own cars.

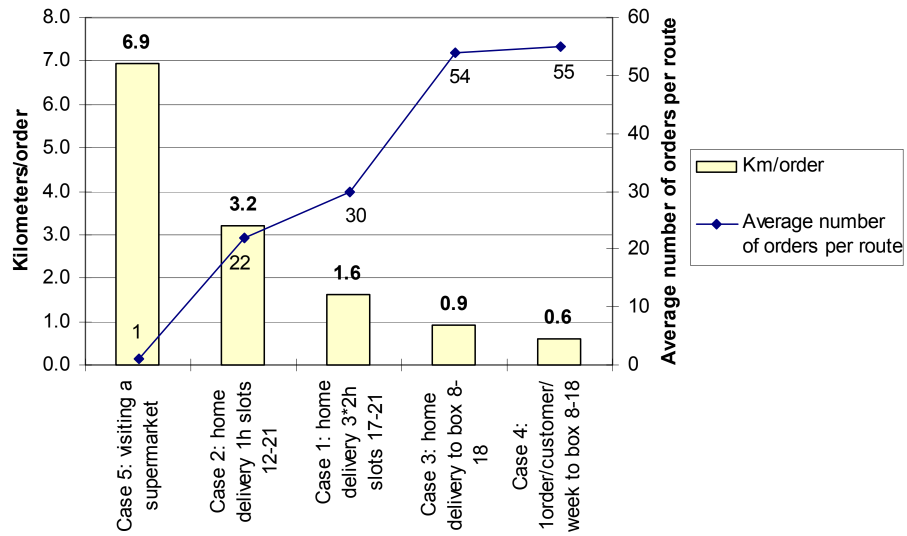

Figure 19 Average distance driven per order and average number of orders per route (Siikavirta et al., 2003).

According to Granfelt et al. (1995) in Finland the average one-way distance to the grocery store is 3.5 km. This information validates the modelling results since in Case 5, in which customers visit the store using their own cars, the average distance driven per shopping trip is 6.9 km (Figure 19).

When the e-grocery home delivery service provider offers one-hour delivery time windows (Case 2) the delivery vehicle needs to drive back and forth in the delivery area to meet the promised delivery time windows. Additionally, the delivery time windows significantly limit vehicle capacity utilisation, as can be seen in Figure 19. However, the distance driven per order in Case 2 is only 46 per cent of the distance driven in the situation (Case 5), where customers use their own cars.

Limiting the service time windows to three 2-hour delivery slots (Case 1) enables better route optimisation and capacity utilisation, leading to a significant reduction in the distance driven and resulting in only 24 per cent of the distance being driven compared with the situation in Case 5.

In Cases 3 and 4 unattended reception and an open (8 a.m.-6 p.m.) delivery time window enable the best possible optimisation of the routing and vehicle capacity utilisation. In Case 3 the orders are delivered on the original shopping date and the resulting distance driven is only 13 per cent of the distance driven in the situation in Case 5. Furthermore, Case 4 describes the best attainable situation, where the orders are sorted by postal code and divided evenly among all six delivery days of the week. According to the results in Case 4, the distance driven is only 7 per cent of the distance driven in the Case 5.

The distance driven, the types of vehicle, and the fuel used have a strong impact on traffic emissions. The possible effects have been calculated on the basis of the simulated distance driven in various home delivery models by using the emission factors for Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O), defined in LIISA 2000 software (VTT, 2001). In the calculations, the coefficients for cars equipped with catalytic converters are used. As for the home delivery vans, the coefficients for vans equipped with diesel engines are used. This is since in 1999 vans equipped with diesel engine produced approximately 86 per cent of the road mileage driven by vans in Finland (Mäkelä et al., 1996; Mäkelä, 1999). The emission factors used in the calculations are shown in Table 2.

Table 2 Emission factors (Siikavirta et al., 2003).

Vehicle	*CO_2/g/km*	*CH_4/g/km*	*N_2O/g/km*
Car, gasoline, cat.	159	0.014	0.03
Van, diesel	297	0.0015	0.008

IPCC (Intergovernmental Panel on Climate Change) factors 21 for CH_4 and 310 for N_2O were used for calculating the CO_2 equivalent emissions.

Table 3 Analysis results (Siikavirta et al., 2003).

Case	*Distance driven (km) per 1639 orders*	*Reduction in distance driven compared with Case 5*	*Vehicle type*	*GHG emissions , tCO2eq*	*GHG Reduction compared with Case 5*
1	2676	76.5%	Van, diesel	0.80	58.2%
2	5267	53.7%	Van, diesel	1.58	17.7%
3	1525	86.6%	Van, diesel	0.46	76.2%
4	822	92.8%	Van, diesel	0.25	87.2%
5	11365	0	Car, gasoline, cat.	1.92	0

The results presented in Table 3 show that a home delivery service creates a significant potential for traffic reduction when compared to the situation, in which customers visit the shop using their own cars. In the best possible case this reduction in the distance driven could be as much as 93 per cent (Case 4). However, depending on the home delivery model used the reduction would be somewhere between 54 and 93 per cent.

The results in Figure 19 and in Table 3 do not, however, cover the home delivery models based on using shared reception boxes or delivery boxes. Thus the traffic reduction potential associated in these service models was analysed during finalising this binding story. This additional analysis was conducted based on the original modelling results published in the Paper V. The additional results are presented in the Table 4.

Table 4 Reduction potentials in distance driven.

Home delivery model	***Reduction potential in distance driven***
Attended reception, 2h delivery time windows, delivery between 8-22	60 %
Delivery box concept B, delivery between 8-16, pick up of the delivery box on next day	80 %
Delivery box concept A, delivery between 8-16, pick up of the delivery box on next delivery	86 %
Reception box concept, delivery between 8-16	86 %
Shared reception box concept, delivery between 8-16	88 %

Compared to the results presented in in Figure 19 and in Table 3, only the results based on the shared reception box concept and delivery box concept B are new. The potential reduction in distance driven based on home delivery and attended reception is in line with the earlier results. This is also the case with the reduction potential based on the home delivery to reception boxes. Furthermore, delivery box concept A is comparable to reception box concept when the distance driven is considered. However, it was surprising according to this additional analysis that delivery box concept B also includes a reduction potential of 80 per cent, although two separate stops per order are conducted. In addition, the shared reception box concept seems particularly environment-friendly and includes a traffic reduction potential of 88 per cent.

However, the reduction potential included in the shared reception box concept is valid only if the shared reception box unit is located at customers' office or home car park, eliminating the shopping trip but increasing the delivery vehicle traffic. If the shared reception box units were located, for example, at the grocery shop car parks, there would be no shopping traffic reduction potential at all. In this case, the result would be an increased amount of traffic and a greater total distance driven as a result of the delivery vehicle trips. This, however, depends on the location of the store or distribution centre where the picking operations are performed.

In brief, these results indicating a traffic reduction potential of between 54 and 93 per cent are in line with earlier research. For example, Cairns (1997 and 1998) found a mileage reduction potential of 77 per cent. However, the results in this dissertation reveal the wide variations in the potential for reducing the distance driven by using different home delivery models, which have not been reported in earlier studies. Moreover, in Paper IV and in Punakivi & Holmström (2001), the reduction potential of traffic emissions was similarly analysed based on the potential reduction in traffic. In Paper IV, the analysis was concentrated on the effects on GHG emissions. According to the results shown in Table 3, the potential reduction in GHG emissions could be between 18 and 87 per cent compared to the situation (Case 5) in which cars are used.

Generalising these results is complicated since in reality, the results are highly dependent on local road networks, rush hours, and the vehicles used. However, putting the presented results into a more general form, we used our earlier estimate, that 12 per cent of the overall traffic is the maximum traffic reduction potential in Finland. Based on this assumption, with a 100 per cent e-grocery market share, the maximum attainable overall road traffic reduction potential in Finland would be between 6.5 and 11 per cent, depending on the home delivery model used. When using the current estimate for the market share of e-grocery, 10 per cent by 2005-2010, the attainable reduction potential would be between 0.65 and 1.1 per cent of overall road traffic in Finland.

The potential reduction of GHG emissions was similarly generalised. In Finland, the GHG emissions from road traffic were 11 million tons (Mt) in 1998, of which cars accounted for 6.3 Mt (KTM, 2001). In Paper IV, it was estimated that the current GHG emissions from grocery shopping travel are 1.1 Mt CO_2, which accounts for 1.4 percent of Finland's GHG emissions. Depending on the selected e-grocery home delivery model, a GHG emission reduction of 0.19-0.95 Mt CO_2 could be achieved in theory, which would reduce GHG emissions in Finland by approximately 0.3-1.3 per cent. However, again using the current estimate for the market share of e-grocery, 10 per cent by 2005-2010, the attainable reduction potential would be between 0.03-0.13 per cent.

Although these figures seem relatively small, the potential must be estimated alongside the expected traffic growth rates. For example, the Finnish Road Administration has estimated that the overall increase in traffic in Finland will be 38 per cent between 1997 and 2030. The growth rate is thus around one per cent a year. During the same period, the estimated overall increase in traffic in the Helsinki metropolitan area will be 50 per cent (FINRA, 2002). By supporting the development of e-grocery and home delivery services, the increase of traffic levels could at least slow down. Similarly, the potential of the e-grocery home delivery service to reduce the GHG emissions in Finland is small. In countries where the share of GHG emissions from the transportation sector are higher, the traffic reduction potential and GHG emission reduction potential of the e-grocery home delivery service can also be higher. The reduction potential of both traffic and GHG emissions depends on the size of the metropolitan area served, population density, and number of suitable market areas for e-grocery services in the country, that is, the market share of e-grocery services.

To summarise Hypothesis 3: *Home delivery services reduce traffic and GHG emissions compared to the situation, in which customers make shopping trips using their own cars*, can be answered positively. Based on the results, the traffic reduction potential is highly dependent on the selected home delivery model, varying between 54 and 93 per cent. The GHG emission reduction potential is directly dependent on the mileage reduction and varies from 18 to 87 per cent depending on the home delivery model.

Finally, according to this analysis, the potential over all road traffic reduction and reduction of GHG emissions from road traffic depends on both the home delivery model selected and, especially, the market share of home shopping in the future. Additionally, on the basis of earlier research (Cairns, 1999; Tacken, 1990), it may be assumed that customers using e-grocery and home delivery services would not use the increased amount of spare time they would have in such a way that would notably increase the need for using their cars. According to Cairns (1999), 61 per cent of the food home delivery customers of "The Food Ferry" are owners of at least one car, and 74 per cent of the car-owners used their cars less as a result of shopping with the Food Ferry e-grocery.

6 DISCUSSION

In this section the results of this dissertation are first briefly summarised and then evaluated covering the contribution, relevance, validity, reliability and limitations. Finally, guidelines for future research are given, based on the results and experiences presented.

6.1 Summary and managerial conclusions

In this chapter the research results of this dissertation are first summarised in the Table 5. Then the managerial conclusions and conclusions based on the research results are presented.

Table 5 Summary of results in the dissertation.

Hypothesis	*Result*
Hypothesis 1: ***Home delivery operations are significantly more cost-efficient based on unattended reception than based on attended reception.***	Confirmed; however, the investments in the reception facility for unattended reception is supposed to be the major obstacle in implementing the service concept.
Hypothesis 2: ***The most cost-efficient home delivery model offering unattended reception is based on shared reception boxes.***	Confirmed; however, the level of customer acceptance of this type of "home delivery" model is unknown at the moment.
Hypothesis 3: ***Home delivery services reduce traffic and GHG emissions compared to the situation, in which customers make shopping trips using their own cars.***	Confirmed; however, the actual reduction depends on both the home delivery model selected and especially the market share of home shopping in the future. Additionally, it is supposed that using e-grocery and home delivery services would not significantly increase the usage of cars in spare time activities.

For developing the e-grocery and associated home delivery service offerings, some managerial conclusions and guidelines can be drawn based on this research work. According to the results presented in this dissertation, the most operationally cost-efficient e-grocery home delivery service is based on unattended reception. Unattended reception, which enables optimal vehicle routing and scheduling, would also be the best solution when considering the potential traffic reduction and environmental aspects.

Because of the somewhat high investment level required in customer-specific unattended reception facilities, it is estimated that these models will remain as niche services, at least in the short term. The niche customer group may consist of well-off families with children, living in a suburban area in one-family houses or row houses. Additionally, catering kitchens, bars, and kiosks may be suitable customer groups as well. Similarly, office deliveries may represent a potential market segment where companies could be willing to invest in customer-specific unattended reception.

However, using shared reception boxes, home shopping and unattended delivery services can be offered to a significantly wider customer base. Shared reception boxes may be placed, for example, in central bus and underground stations, petrol stations, supermarket and office car parks, apartment house cellars, or wherever the retailer believes it to be convenient for consumers. Because of shared usage, the utilisation level of the facility is higher than in the case of customer-specific unattended reception. The shared reception box concept allows interested customers to experiment easily with the service, and makes it easier for customers to adopt home shopping generally. For delivery companies, it is also a potential solution since the shared reception box units may easily be connected to the Internet, and a full audit trail of the delivery event can be provided. Additionally, according to the results in this dissertation, investment in shared reception box facilities can be justified by the cost savings in home delivery operations, and the payback period for the investment is reasonably low. However, customers must be involved in investments in customer-specific unattended reception facilities, since the cost savings in home delivery transportation do not justify the investments within a reasonable timeframe. As a managerial summary based on the numerical results of this dissertation, a "pre-selection tool" is presented in Figure 20.

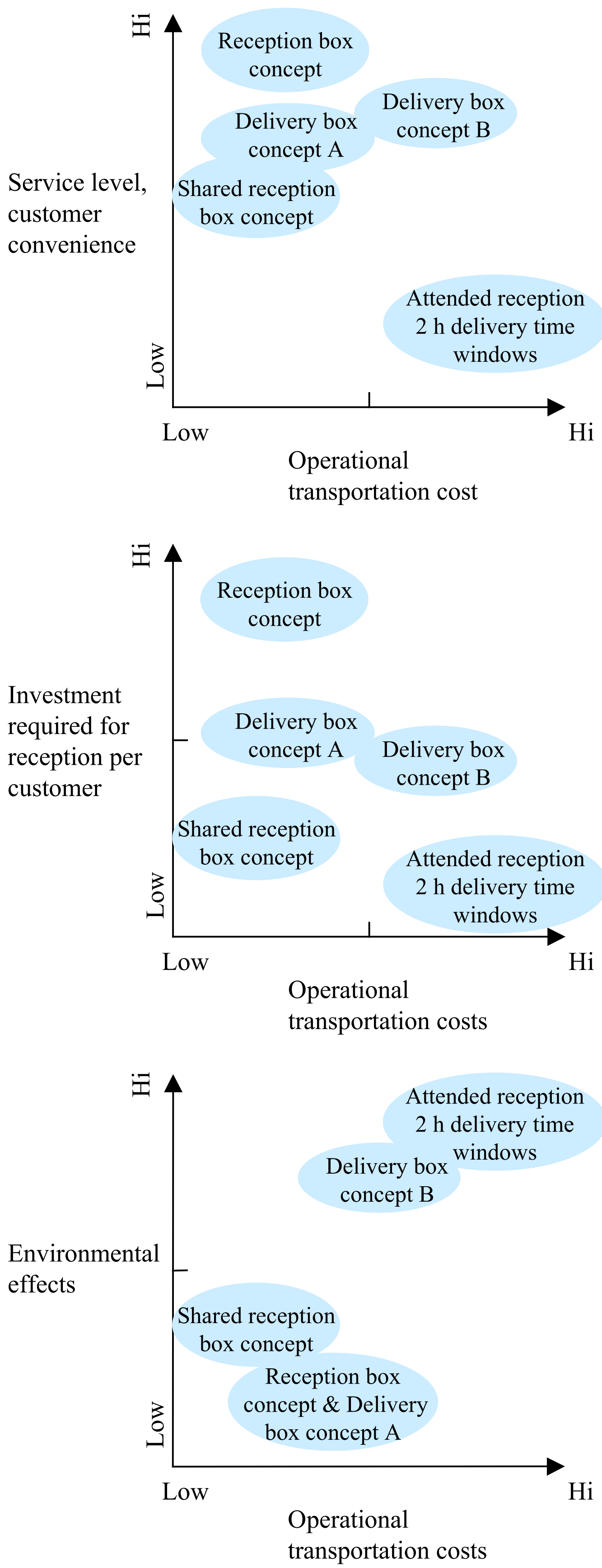

Figure 20 Pre-selection tool for selecting appropriate home delivery model.

This pre-selection tool can be used as a guideline for decision-makers responsible for developing or investing in the development of home delivery operations. In the pre-selection tool, customer service level, investments required, and environmental effects of the analysed home delivery models are presented regarding their operational cost levels. Presented in this way, the numerical results of this dissertation are in a more abstract form, which makes it possible for the reader quickly to identify the greatest differences among the home delivery models analysed.

However, it must be kept in mind that generalising the results in this simplistic way is extremely complicated since in reality the success in home delivery operations is highly dependent on the characteristics of the service area selected and resources available. For example, local road networks, rush hour characteristics, customer density, customer ordering frequency, number of depots, the number and type of vehicles used, and the cost of resources used are some of the key elements.

Because of the service area analysed in this dissertation, the pre-selection tool suggested is seen as the most suitable for developing home delivery services for suburban and urban areas. As in the urban and suburban areas, the shared reception boxes are also seen as a potential solution in city centres. This view is supported by the results of the pilot operations by Consignia, who tested five different versions of unattended reception facility (Rowlands, 2002). For the rural areas, either the already used shop-in-the-bus concept with a fixed timetable or shared reception boxes extending services in the village store, post office, or petrol station are seen as the solutions with the greatest potential in the future.

Moreover, it should be kept in mind that developing the operational capabilities and operations models is not enough. To grow, develop, and eventually become profitable, the e-grocery business needs higher customer demand. It seems that the best way to start developing the services and acquiring customers is to focus on selected consumer groups in densely populated areas. In addition, the management of Peapod currently supports this view. According to Marc Van Gelder, President and CEO of Peapod, "the whole business is about customer density" (Van Gelder, 2002b).

One way to achieve sufficient customer density level is through the co-operation of various online retailers, both e-grocers and other service providers. A potential solution would be to create shared home delivery services to be used by all the local retailers willing to offer home shopping services. Especially in the smaller markets, this would enable the critical customer mass to be reached more quickly. This would similarly ease the costs of providing various home delivery models based on both attended and unattended reception. Similarly, from the environmental point of view, shared home delivery services would be the best solution. Eventually, local customer requirements and the accepted price level would determine service development.

The pace of development will depend, however, on the general willingness to change current shopping habits. One of the central requirements for the success and growth of the e-grocery business, and home shopping generally, is that customers realise the costs associated with visiting supermarkets using their own car. These include petrol and maintenance costs and parking fees, as well as the financial value of their leisure time. Evaluating current costs helps the customer to accept the fee charged for order picking and home delivery services.

Additionally, the role of the government or communities in the development of home delivery services remains to be seen. By accelerating development of e-grocery and home delivery services, however, there is a possibility to offer better services to citizens, reduce car dependence in everyday life, reduce traffic congestion, and potentially reduce the environmental effects of traffic.

6.2 Contribution and relevance of the research

This dissertation presents a part of the pioneering work focused on developing e-grocery supply chain operations conducted in the Ecomlog research programme. The focus area selected in this dissertation was the development of home delivery operations in the e-grocery business. As the real-life examples presented in the introduction and literature review show, this topic is currently one of the two most important single problem areas in the e-grocery business. The other problem area, efficient order picking operations, is not covered in this dissertation but has been analysed by other researchers (Yrjölä, 2003; Kämäräinen, 2002; Yrjölä, 2001; Jaakola, 1999) in the Ecomlog research group.

The research work done during the Ecomlog programme has created new knowledge supporting the development of home delivery services. The results have been published in several academic journals. In this dissertation, the elements of this new knowledge are the cost differences between attended and unattended reception types of home delivery, the effects of tight delivery time windows in home delivery operations, analysing the home delivery models from the environmental point of view, comparisons with the situation in which customers do the shopping trip using cars, and payback periods for the investments required in facilities for unattended reception.

In this dissertation, the research results published in the five individual articles are combined and summarised using both detailed research questions and hypotheses. Additionally, in the dissertation the research work is more closely tied to the existing body of knowledge.

The research results showing that home delivery based on unattended goods reception is superior to a service with attended reception are in line with the basic body of knowledge covering the vehicle routing problem (Ballou, 1999; Solomon, 1987; Desrochers et al., 1992; Desrosiers et al., 1995; Fisher, 1995). These results are also in line with the research work by Laseter et al. (2000), who demonstrated that even in the larger US cities, the density of population will not allow for a low cost provision of home delivery services if the customer decides the timing (short delivery time window) of the service.

Furthermore, these results increase the current body of knowledge by presenting practically and comparably existing and emerging business solutions to the home delivery problem. In particular, the analysis comparing attended reception and various unattended reception models in home delivery has increased the body of knowledge. Additionally, this new knowledge is already being used by other researchers. For example, the thesis of Yrjölä (2003) builds partly on the research results published in some of the articles used as the basis for this dissertation.

Furthermore, Heiskanen et al. (2001), for example, have used some of these results in their report for the Ministry of the Environment.

Additionally, the results of this dissertation support the findings of Cairns (1997 and 1999), who reported positive environmental effects related to home delivery services. Compared to Cairns' work, this research analyses both mileage reduction potential and the effects on GHG emissions. This research also takes delivery time windows into account, and reveals this way the differences among various operations models, using real point-of-sales information in the modelling. In this focus area, the results increase the body of knowledge by presenting the environmental effects in the current situation and when using different home delivery models.

The relevance of this study is confirmed by the high priority given to the domain of business problems. The results are also seen to have potential value for practitioners (Eloranta, 2000). The relevance of this research work is in providing practical knowledge, for example, in the form of the cost levels associated with different operational home delivery models as well as in the form of new knowledge of the environmental effects associated with these service models. The payback period analysis based on the transportation cost savings and the investments required for unattended reception facilities is also considered relevant. This new knowledge has relevance for four different groups:

- Third party service providers (transportation & warehousing)
- Retailing companies (online grocers as well as traditional retailers)
- Manufacturers of reception facilities
- Governmental or communal decision-makers

Third party home delivery service providers can utilise these results in developing cost-efficient transportation service models, not only for e-grocery needs, but also in the home delivery business generally. It is assumed that these results also have relevance for those retailing companies willing to develop their currently available home delivery services, or who are simply planning their service strategy. S-Group and Wihuri, for example, in Finland have used this information in their e-grocery operations development. Currently, Ruokavarasto, a Wihuri grocery store chain that has taken over the S-Groups pilot operation based on unattended reception boxes continues developing e-grocery service models, offering both attended and unattended reception option (Peltonen, 2002).

In addition to the retailer's and home delivery service provider's points of view, there is a third commercial point of view from which these results are seen as relevant. Hollming Ltd in Finland has started the commercial development and manufacturing of unattended reception facilities partly based on the new knowledge created during this research work. Homeport, a UK based system provider for unattended home delivery services, has also used this information in their development work (Borsheim, 2000).

Furthermore, this research has shown that offering home delivery services includes the possibility of achieving positive environmental effects by potentially reducing traffic and traffic emissions. This type of knowledge has relevance for governments and communities who supposedly are involved in part of the investments to be made in developing home delivery infrastructure, serving for example elderly and disabled customers. In the UK, these results have already been taken into consideration by the Department for Transport, Local Government and the Regions (Davies, 2002), and in Finland by the Ministry of Transport and Communications (MINTC, 2002).

6.3 Validity and reliability of the research

According to Forrester (1961), the answers obtained from using any scientific methods are only as relevant as the questions asked, and the validity of the results is only as good as the assumptions on which the study is based. Validity, in this type of business-minded modelling with a constructive approach, requires that correct operational parameters be used.

In this dissertation, the original modelling results presented in Papers II and III were based on accurate information collection, real point-of-sale demand data, and modelling parameter selection based on several expert interviews (see chapter 4.2). Next, the original results were compared with relevant real-life information from the e-grocery pilot operation. The two-year e-grocery pilot operation set up in co-operation with the business partners and the Ecomlog research group was launched in June 2000. In the pilot operation, around 50 household customers used e-grocery and home delivery service based on the reception box concept. The piloting customers were located in the same test area that was used in the modelling in this dissertation. Based on the operational information collected, the model was revised slightly for Paper V.

The pilot operation was used to verify the validity and reliability of the research results achieved, as suggested by Mentzer & Kahn (1995) and Kasanen et al. (1993). The verification was conducted by measuring the efficiency of home delivery operations based on using customer specific reception boxes. Two home delivery rounds were measured with a stopwatch and afterwards, imitations of these two rounds were completed using the CAPS RoutePro vehicle routing tool.

Based on the comparison, in reality the vehicle completed a route consisting of the delivery of 24 customer orders to refrigerated reception boxes around 13 per cent faster than suggested by the routing tool. This test was carried out on October 5th, 2001 in good weather conditions, well before the rush hour. The second test was performed on November 23rd, 2001, shortly after the first snowfall and in poor weather conditions, but before the rush hour. In the second test, the vehicle completed a route consisting of the delivery of 22 customer orders to refrigerated reception boxes around 10 per cent more slowly than suggested by the routing tool.

The error margin found on the first round was probably due to the driver's good knowledge of the road network, the good timing of the delivery round, and the small number of customers served in the pilot operation, which provided a certain type of stability for the driver to improve the efficiency of the operation. In the second round, the error margin found was certainly due to the poor weather conditions. However, according to Ballou and Agarwahl (1988), this level of computational error may be acceptable where results must be obtained in short order and when good solutions, as opposed to optimal ones, are needed.

Based on the verification, the research results and the computer model were confirmed as being fairly reliable and valid for the analyses conducted. Additionally, accurate documenting and publishing of the settings, as well as the results, increase the reliability.

6.4 Limitations of the research

As the different home delivery models were analysed in a selected part of the Helsinki metropolitan area, the absolute numerical results of this dissertation can be generalised only in this geographical area. However, these results are not seen as the main contribution of this research.

More generally, the results of this dissertation indicate significant differences in operational efficiency and cost levels among different home delivery models, even if the same drop-off time assumption is used. This result is more broadly valid as a generalisation than the exact cost levels or absolute performance indicators.

However, the precise cost levels and deliveries-per-hour performance indicators shown as results in this dissertation can be taken as approximations and guidelines elsewhere. According to this research, the costs of vehicles and labour, vehicle capacity, location of the depot, customer density, driver experience, capacity of the local road network, rush hour characteristics, and typical weather conditions are some of the most important factors to be considered when developing home delivery operations.

Furthermore, in these analyses the drop-off time was the same (2 minutes) for all the home delivery models analysed. However, it is likely that in a real situation attended reception includes some customer service and takes more time than unattended reception. The time needed for customer service may also vary in different cultures. If the drop-off time would be higher in attended reception, the difference in cost levels between different home delivery models would be even greater than shown in these results. Additionally, the capacity of the local road network and rush hour characteristics are factors that affect not only the efficiency of each home delivery model, but also the differences between the models. Poor local road network and high congestion favour even more the usage of unattended reception facilities. More accurate analysing of these topics are left for further research and development topics.

Modelling

A limitation of the research is that the analyses of the home delivery models were conducted using only one vehicle routing tool, RoutePro (6.4.1). Additionally, following the advice of the CAPS representative (Lindholm, 2000) and the operating instructions (CAPS, 1998), only the Tree-algorithm was used. Parameter selection in the modelling work is seen as an additional limiting factor that was, however, taken into consideration in the verification phase. In brief, conducting the analysis with other similar tools would have increased the reliability and accuracy of the results. However, the relative differences between the operational home delivery models would presumably have been at the same level.

Several more general limitations may also be pointed out in the assumptions made in this type of modelling work. Browne (2001), for example, lists six parameters that are likely to affect trip generation in this type of modelling, and that should be taken into consideration when evaluating the results:

1) how customer behaviour will change as a result of home shopping,
2) whether companies use shared or dedicated home delivery systems,
3) what the customer order frequency is,
4) the quantity of returned goods,
5) delivery time constraints and the need for customer to be present, and
6) the location of the distribution depot.

Nevertheless, modelling such as that used in this dissertation provides a simplistic view of the issue. In the modelling, for example, the average consumer time used for shopping and travel costs are presented only to give implication of the consumer cost involved in traditional grocery shopping. However, these costs vary according to the consumer's valuation of his/her spare time, how often the store is visited, and whether a car or another means of transport is used.

Additionally, in this analysis it was assumed that in the current situation, all of the 1,450 ordering customers, that is, 1.6 per cent of the households in the test area, used their own cars to do the 1,639 shopping trips. In order to estimate better and analyse, for example, the overall traffic reduction potential in the future, several issues should be taken into account. These are, for example, the proportion of households having cars, using their cars for shopping trips, and using other means of transport when visiting the store. For future modelling work, it would also be important to include information on whether the customers come to the store from home or on their way home from work or hobbies. This would provide information based on which the location of shared reception boxes should be determined. A related open question is the shopping behaviour of non-car owners, which should also be examined closely in the future. If they are the most likely users of home delivery services, the result will be extra road traffic.

Data used in the modelling

The data used in the modelling was a sample of real point-of-sales data including detailed information about customers' traditional grocery shopping habits. The information was collected from five of the S-Group's supermarkets, and customers' street addresses were obtained from their loyalty cards. Only the orders exceeding 25 euro were taken into account. This limitation was to eliminate casual visits to the supermarket from the data. From the modelling point of view, the most important elements in this point-of-sales data were shopping time, customers' place of shopping, and customers' street addresses. Limitations to vehicle capacity utilisation were determined by the delivery time windows, shopping basket volume, and the number of orders.

However, using supermarket based shopping data for analysing the cost structure of the e-grocery home delivery operations restricts the validity of the results. The reason for using traditional grocery shopping data was simple. When the research work was started, no e-grocery shopping data was available, or the sample size was too small to be used in modelling work.

e-grocery pilot

In all, the tiny size of the e-grocery market currently is seen as a limitation in this research. Similarly, the tiny size of the e-grocery pilot operation is a limitation for further conclusions. For example, the e-grocery pilot operation used for verifying and improving the research results served only around 50 customers. Additionally, the two delivery rounds analysed contained only 22 and 24 orders. The scale of the pilot is therefore not sufficient to prove the constructive modelling results involving, for example, 720 deliveries a day (in Paper V) as absolutely correct. A larger scale of operations and greater number of different factors easily leads to unexpected problems. However, regardless of the small size of the e-grocery pilot operation, real-life information increases the practical utility and the reliability of the results, and helps in focusing on the critical issues in developing these operations.

6.5 Agenda for further research

Various operational home delivery models have been developed and are in current use. The search for viable, cost-efficient, and environment-friendly home delivery models is still in progress, and requires commitment to continuously refining the operational models and logistical networks. Further research and development work connected with e-grocery home delivery operations should be focused on analysing the market demand for various home delivery models in general. In particular, the knowledge of customer acceptance of home delivery services based on shared reception boxes would be essential. In addition, the needs of particular customer segments, as well as different residential areas should be analysed in the future.

Home delivery research should include, for example, evaluating the possible special needs of potential business customers such as bars or restaurants, cafeterias, catering kitchens, offices, and similarly the needs of families with children, single households, elderly people, disabled people, people in cities, and people in sparsely-populated areas. The research should also include analysis and evaluation of the requirements and potential benefits of combining the delivery material flows to and from B2C and B2B customers.

There is also a need to identify and develop appropriate revenue models for the services offered in different customer segments. This is especially so if the home delivery service is based on unattended reception, where the primary question is who makes the investment in the receiving facility (Kämäräinen & Punakivi, 2003).

Additionally, research should be supported by conducting pilot operations such as that of Consignia in the UK (Rowlands, 2001a), where alternative delivery models offering unattended reception are evaluated in different cities so that the best solutions can be pointed out and further developed. This type of large-scale experiment by a national postal service provider may also be seen as the first step towards developing shared home delivery systems for any company to use.

Shared home delivery systems would supposedly increase the cost efficiency of operations because of more extensive consolidation possibilities. Additionally, the general level of trust in home shopping as well as customer convenience could increase. Furthermore, shared home delivery systems would be the best solution from the environmental point of view. In developing shared home delivery systems, national postal organisations and dedicated service providers responsible for both information and material flows are seen as the most favourable partners for both e-grocers and online retailers of other physical products.

Additionally, the development of shared home delivery systems requires supporting research work that should be carried out in various geographical areas. These are, for example, big cities with high customer density and rural areas with low customer density. This would enable the building up of more reliable knowledge focused on the cost efficiency of different home delivery models. However, the availability of a suitable amount of real online shopping point-of-sales data or home delivery data is the key requirement for obtaining precise results. When concentrating on home delivery services, for example, according to Lee and Whang (2001), the cost of delivery is justified only if there is a high concentration of orders from customers located in close proximity, or if the value of the order is large enough. Similarly, according to Yrjölä (2003), sales per square kilometre is an important indicator affecting the cost structure of home delivery. Based on real point-of-sales data, it would be possible to analyse, evaluate, and develop more effectively the home delivery models and customer service level in practice. One simple tool for determining whether it is economical to deliver goods to a neighbourhood area in one trip has been presented by Lee and Whang (2001). *Delivery-value density* (DVD) can be computed by dividing the average total dollar volume of the shipment per trip by the average travel distance per trip. This would presumably be a useful measure in analysing, defining, pricing, and developing the home delivery models for different types of geographical areas. However, the critical requirement is the availability of real point-of-sales data.

Finally, changes in customers' shopping habits and the possible effects of home shopping on their leisure time activities should be examined and analysed in the future. In this way, new knowledge concerning the possible environmental effects of home shopping and home delivery services could be increased. This again might encourage governments or communities to invest in developing home delivery services.

References

ACNielsen (2002), "Grocery retailing in Finland in 2001 -Päivittäistavarakauppa 2001" (in Finnish), http://www.acnielsen.fi

Auramo, J., Aminoff, A., Punakivi, M. (2002), "Research agenda for e-business logistics -based on professional opinions", *International Journal of Physical Distribution and Logistics Management,* Vol.32, Iss.7, pp.513-531.

Aromaa, P. (1999), "Experiences and costs" (In Finnish), magazine article in *Tekniikan Maailma*, Vol. 47 No. 20/99, pp. 132-134

Aromaa, P. (2001), "TM Car Tests 1992-2001 -TM Käyttötestit 1992-2001" (in Finnish), magazine article in *Tekniikan Maailma*, Vol. 49 No. 20/01, pp. 144-146

Austria Farmer, M. (2000), "Webvan delivers charge for small orders", *CNET news.com*, Nov. 2000, http://news.cnet.com/news/0-1007-200-3579941.html

Austria Farmer, M. and Sandoval, G. (2001), "Webvan delivers its last word: Bankruptcy", *CNET news.com,* Jul. 2001, http://news.cnet.com/news/0-1007-200-6519317.html

@ Your Home (2001), "@ Your Home -New Markets for Customer Service and Delivery", Report to Retail Logistics Task Force of Foresight program, UK, p.46, http://www.foresight.gov.uk/servlet/DocViewer/doc=2857/

Ballou, R.H. and Agarwahl, Y. K. (1988), "A Performance comparison of Several Popular Algorithms for Vehicle Routing and Scheduling", *Journal of Business Logistics,* Vol. 9, No. 1, pp.51-65

Ballou, R. (1989), "Heuristics: Rules Of Thumb For Logistics Decision Making", *Journal of Business Logistics*, Vol. 10, No.1, pp. 122-132.

Ballou, R.H. (1999), *Business Logistics Management -Planning, Organizing and Controlling the Supply Chain*, Fourth Edition, Prentice-Hall Inc., New Jersey, p. 682.

Bartolotta, S. (1998), The consumer direct channel How the virtual retailer is winning new customers, *In Strategic Supply Chain Alignment Best Practice in supply chain management,* Ed. Gattorna J., Gower Publishing Limited, Brookfield.

Bentham, M. (2001), "Fridge door opens for home deliveries", *The Sunday Telegraph*, May 6, p.10, http://news.telegraph.co.uk/news/main.jhtml?xml=/news/2001/05/06/ncool06.xml

BearBox (2001), http://www.bearbox.com, November 2001

Bodin, L. (1990), "Twenty years of routing and scheduling", *Operations Research*, July-August 1990, Vol. 38, No. 4, pp.571-579.

Bonning, K., Rader, E. and Chavie, R. (1998), The global retail supply chain, *In Strategic Supply Chain Alignment Best Practice in supply chain management*, Ed. Gattorna J., Gower Publishing Limited, Brookfield.

Borgström, H. (1998), "Matomera först i Europa med enbart nätkunder" (in Swedish), *Dagens Industri,* 1998-11-02, (http://di.se/inetsspec98b/di0016.htm)

Borsheim, Turid (2000) personal communication with Ms. Turid Borsheim and Mr. Mark Lunn from Homeport Ltd., London, September 6, 2000

Bowersox, D.J. and Closs, D.J. (1989), "Simulation In Logistics: A Review Of Present Practice And A Look To The Future", *Journal of Business Logistics*, Vol.10, No. 1, pp.133-148.

Bowersox, D.J. and Closs, D.J. (1996), *Logistical Management the integrated supply chain process*, McGraw-Hill, New York, p.730.

Bowersox, D.J., Closs, D.J. and Stank, T.P (1999), *21st Century Logistics: Making Supply Chain Integration A Reality*, Council of Logistics Management, Oak Brook, p.264.

Boxcar (2002), http://www.boxcarsystems.com, Feb 2002

Brady, D. and Harrison, J. (1990), "Physical Diswtribution Management in Mail Order - The Grattan Case", In: *Retail Distribution Management*, pp. 223-239, Ed. Fernie, John, Kogan Page, London, p.244.

Bramel, J. and Simchi-Levi, D. (1996), "Probabilistic analyses and practical algorithms for the vehicle routing problem with time windows", *Operations Research*, May/Jun 1996, Vol. 44 No. 3, pp. 501-509.

Brooksher, K., (1999), "E-commerce and logistics", *Traffic World*, Vol. 260, Iss.7, Nov. 15, pp. 31-34.

Browne, M. (2001), "The impact of e-commerce on transport" paper presented in OECD/ECMT seminar, Paris, France.

Browne, M., Jackson, M., Allen, J. and Anderson, S. (2001), "Home delivery market size and operations in the UK", *Logistic Research Network 2001 conference proceedings,* Heriot Watt University, Edinburgh, UK.

Bräysy, O. (2001), "*Local Search and Variable Neighborhood Search Algorithms for the Vehicle Routing Problem with Time Windows*", Acta Wasaensia, No. 87, Mathematics 8. Operational Research, University of Vaasa, Vaasa, Finland

Cairns, S. (1996), "Delivering alternatives: Successes and Failures in Providing Home Delivery Services for Food Shopping", *Transport Policy,* Vol. 3, Iss.4, pp. 157-176.

Cairns, S. (1997), "Potential traffic reductions from home delivery services: Some initial calculation", *ESRC Transportation Studies Unit, University College London*, Ref.97/45, p.39

Cairns, S. (1998) "Promises and problems: using GIS to analyse shopping travel", *Journal of Transport Geography*, Vol. 6, No. 4, pp. 273-284.

Cairns, S. (1999), "Home Delivery: environmental solution or disaster?", http://www.ucl.ac.uk/transport-studies/tsuhome.htm
http://www.asgab.com/index.asp?mainframe=miljo/index.asp&meny=miljo

CAPS (1998), Operating manual CAPS101D, RoutePro Dispatcher, Operational Vehicle Routing, pp. 198-200.

CAPS (2002), http://www.caps.com/products/rprodisp/rpromain.asp

Carneal, T. (2001), "Online Grocers Eyes Wide Shut?", *Food Logistics*, Iss. 44, Sept. 15, pp. 23-26.

Christopher, M. (1998), *Logistics and Supply Chain Management-Strategies for Reducing Cost and Improving Service,* Pearson Education Limited, Great Britain, p.294.

Clark, G. and Wright, J. (1964), "Scheduling of vehicles from a central depot to a number of delivery points", *Operations Research*, Vol. 12, No.4, pp. 568-581.

CPFR.org (2002), http://www.cpfr.org

Cuglielmo, C. (2000), "Can Webvan deliver the goods?", *Inter@ctive Week*, February 7, 2000, http://www.zdnet.com

Croft, J. (2000), "Dynamid boxes clever", *Financial Times, Companies & Finance*, July 8., 2000.

Dagher, N., Soumitra, D. and De Meyer, A. (1998), "*Online Grocery Shopping*", 1998 INSEAD, Fontainebleau, France.

Danska, Kimi (2001), personal communications with Mr. Danska, sales representative for Helsingin KTK Oy, November 22nd, 2001

Danzig, G.B. and Ramser, J.H. (1959), "The truck dispatching problem", *Management Science*, Vol.6, pp.80-91

Davies, Lowri (2002), personal communications with Mrs. Davies, Research coordinator in DTLR (Department for Transport, Local Government and the Regions) UK, Helsinki 19th August , 2002.

Demkes, R. & Tavasszy L. (2000), "Benchmarking Infrastructure and Logistic Services Across Europe, Asia-Pacific and North America", IMRL 2000 Third International Meeting for Research in Logistics, Trois-Rivie'res, France

Department of Environment, Transport & the Regions (1998), " A new deal for transport: better for everyone", The Government's White Paper on the future of transport, London, http://www.detr.gov.uk/itwp/index.htm

Desrochers, M., Lenstra, J.K., Savelsberg, M.W.P. and Soumis, F. (1988), "Vehicle routing with time windows: optimization and approximation", In: *Vehicle Routing: Methods and Studies*, pp.65-84, Ed. Golden, B.L. & Assad, A.A., Elsevier Science Publishers, Amsterdam.

Desrochers, M., Desrosiers, J. and Solomon, M. (1992), "A New Optimization Algorithm for the Vehicle Routing Problem with Time Windows", *Operations Research*, March-April 1992, Vol. 40, No. 2, pp. 342-3534.

Desrosiers, J., Soumis, F. and Sauve, M. (1988), "Lagrangian Relaxation Methods for Solving the Minimum Fleet Size Multiple Traveling Salesman Problem With Time Windows", *Management Science*, Vol. 34, 1005-1022.

Desrosiers, J., Dumas, Y., Solomon, M. and Soumis, F. (1995),"Time constrained routing and scheduling", In: *Handbooks in Operations Research and Management Science , Vol. 8, Network Routing*, pp. 35-139, Ed. Ball M., Magnanti T., Monma C. and Nemhauser, G, Elsevier Science Publishers, Amsterdam.

DTLR (2002), A general letter sent on 16.1.2002 for feedback on DTLR formulated research priorities and individual projects based on the Foresight "@ Your Home" document, Department for Transport, Local Government and the Regions, UK.

Eisenhardt, K. (1989), "Building Theories from Case Study Research", Academy of Management Review, vol.14, No.4, pp.532-550

Eloranta E. (2000), "Characteristics of a Post Graduate Thesis- Research Methods in Industrial Engineering and Management", lecture to doctoral students, Helsinki University of Technology, 5.12.2000

EU (2002), The EU's Fifth Framework Programme (FP5), The Growth Programme, Research theme Sustainable mobility and intermodality http://europa.eu.int/comm/research/growth/gcc/guidedtour.html#top , http://europa.eu.int/comm/research/growth/gcc/ka02.html#top

Feare, T. (1999), "Building a new kind of on-line business" *Modern Materials Handling* Iss. 9, August 1/1999, http://www.manufacturing.net/mmh/index.asp?layout=articleWebzine&articleid=CA125164

Fernie, J., Pfab, F. and Marchant, C. (2000), "Retail Grocery Logistics in the UK", *The international Journal of Logistics Management*, Vol. 11, No. 2, pp.83-90

Finch, J. (2001), "E-grocery sales soar in Britain", *Guardian*, Feb. 23, 2001, http://www.guardian.co.uk/Archive/Article/0,4273,4140780,00.html

FINRA (2002), "Road traffic forecast for 1997-2030" (in Finnish), http://www.tieh.fi/tn/enn/enn9730.htm

Fisher, M. L. (1995), "Vehicle routing", In: *Handbooks in Operations Research and Management Science , Vol. 8, Network Routing*, pp. 1-33, Ed. Ball M., Magnanti T., Monma C. and Nemhauser, G, Elsevier Science Publishers, Amsterdam.

Forrester, J. W. (1961), *Industrial Dynamics*, MIT Press and John Wiley & Sons Inc., Cambridge, MA., New York

Gallup Web (2001), "Online Shopping -September 2001" (in Finnish), a quarterly published market research report by Suomen Gallup Web Oy, p.70.

GER (2001), "Global eCommerce Report 2001", Taylor Nelson Sofres -Interactive

GIB (2001), "GIB announces the discontinuation of Ready.be", GIB press release on 27.11.2000, http://www.gib.be/fs_06-01_en.html

Golden, B.L. and Assad A. A. (1986), "Pespectives on vehicle routing: exiting new developments", *Operations Research*, Vol.34, No.5, pp. 803-810.

Granfelt, J., Lehtinen, U. and, Hynynen, A. (1995), "The shopping habits of consumers 1994 and problems associated to shopping" (in Finnish), Liiketaloustieteellisen tutkimuslaitoksen julkaisuja Sarja B 119, The Helsinki Research Institute For Business Administration, Helsinki.

Harju, Sauli (1999) Personal interview at Inex Partners Oy, Finland, August 31, 1999

Heikkilä, J., Kallio, J., Laine, J., Saarinen, L., Tinnilä, M., Tuunainen, V. and Vepsäläinen A. (1998a), "First steps in electronic business- Ensiaskeleet elektronisessa kaupassa", Tekes digitaalisen median raportti 3/98, Helsinki.

Heikkilä, J., Kallio, J., Saarinen, T. and Tuunainen, V.K. (1998b), "Analysis of Expectations of Electronic Grocery Shopping for Potential Customer Segments", *Australian Journal of Information Systems*, Special Issue 1998, pp. 56-69.

Heikkilä, J., Kallio, J., Saarinen, T. and Tuunainen, V.K. (1999), "EC of groceries for elderly and disabled - Comparison of alternative service models", *Information Technology and People*, Vol.12, No. 4

Heiskanen, E., Halme, M., Jalas, M., Kärnä A. and Lovio, J. (2001), "Dematerialization: the potential of ICT and services", Finnish Environment 533, the Ministry of the Environment, Helsinki

Heiskanen, M. (2000). "There is not enough faith -Usko ei riitä" (in Finnish), magazine article in *Talouselämä* 7/2000, pp. 48-50

Henriksson, Pekka (2000), personal communications with Mr. Henriksson, transportation service provider for Helsingin KTK Oy, January 3rd, 2000

Hertta (2003), http://nettikauppa.k-supermarket.fi/hertta/ , (in Finnish) accessed on 13th january 2003

Hilden, Kalevi (1999), Personal interview at Valio Oy, Finland, November 1st,1999

Himelstein, L. (1999), "Can you sell Groceries like Books?", *Business Week,* July , 1999, pp. 26-29.

Holmström, J., Tanskanen, K. and Kämäräinen, V. (1999), "Redesigning the Supply Chain for Internet Shopping - Bringing ECR to the households", *Logistics Research Network conference proceedings*, Newcastle, UK.

Hollming (2001), http://www.hollming.fi/ , http://www.shop2box.fi , additionally personal communication with e-business manager Mr. Reino Aarinen in October 2001.

Holtari, Jyrki (2000), Personal interview at UPS (Finland) Oy, November 1st, 2000

Homeport (2002), http://www.homeporthome.com, November 2001

Hoover, W. E., Eloranta, E., Holmström, J. and Huttunen, K. (2001), *Managing the Demand-Supply Chain -Value Innovations for Customer Satisfaction*, John Wiley & Sons, Inc., New York, p.257.

Hoyt, D. (2001), "Tesco Delivers", Graduate school of business Stanford University, Case number EC-32, September 2001, p.11

Huhtakangas, P. (2000)."S-kanava is piloting the reception boxes- S-kanava kokeilee ruokapostilaatikkoja" (in Finnish), magazine article in *Kehittyvä Elintarvike* 4/2000, pp.14-15

IDC (2000), "Online grocery Sales will Skyrocket", June 13., 2000, http://www.businessweek.com/ebiz/0006/dm0613.htm

IGD (1999), "Retail Logistics 1999, IGD Annual Survey", http://www.som.hw.ac.uk/logistics/download.html

IGD (2001), "Retail Logistics 2001 -Benchmarking Supply Chains ", IGD Business Publication, UK, p. 318.

Ingram, B. (1999), "Boston bears watching", *Supermarket Business*, March, pp.41-45

Inkiläinen, A. (1998), "Managerial views on distribution systems", Doctoral Thesis, Helsinki School of Economics and Business Administration, HSE, A-140, Helsinki, p. 222.

Jaakola, T. (1999), "Local Distribution Center for E-Grocery -Verkkokaupan paikallinen jakelukeskus" (in Finnish), Masters Thesis in Tampere University of Technology, p. 92+17.

Johnsson, J. (1999), personal interview at Matomera in Malmö, Sweden, October 19, 1999

Jones, D. (2001), "Tesco.com: Delivering home shopping", *ECR Journal,* Vol. 1, No. 1, Summer 2001, pp. 37-43.

Junnakar, S. (2000), "Net grocer Streamline calling its quits", *cnet news.com*, Nov. 2000, http://news.cnet.com/news/0-1007-200-3658635.html

Jupiter (2001), "Consumer Packaged Goods Companies Could Be Lifeline To Online Grocers", Jupiter Media Matrix press release on 21.5.2001, http//:www.jmm.com/xp/jmm/press/2001/pr_052101.xml

Kallio, J., Kemppainen, K., Tarkkala, M., Tinnilä, M. (2000), "New distribution models for electronic grocery strores", LTT -Research Oy Publications, Helsinki, p. 33.

Kanerva, K. and Purola, J. (2001), "Logistiikka selvitys 2001", Liikenne- ja viestintäministeriön julkaisuja 52/2001, Liikenne- ja viestintäministeriö, p. 190.

Kasanen, E., Lukka, K. and Siitonen A. (1993), "The Constructive Approach in Managements Accounting Research", *Journal of Management Accounting Research*, Vol. 5, Fall 1993, pp. 243-264.

Knichel, B. (2001), "The Intelligent Supply Chain - Tesco Home Shopping", *CIES Conference Handout*, October 2001, Amsterdam, The Netherlands.

Knight, K. and Hofer, J. (1968), "Vehicle scheduling with timed and connected calls: a case study", *Operational Research Quarterly*, Vol. 19, No. 3, pp. 299-310.

KTM (2001), "Kasvihuonekaasujen vähentämistarpeet ja –mahdollisuudet Suomessa, National Climate Strategy, Government Report to Parliament", (in Finnish) The Ministry of Trade and Industry, www.vn.fi/ktm/3/ilmasto/index.htm, accessed April 2001

Kyyrö, H. (2000), "For Ykköshalli, e-grocery is also goodwill" (in Finnish), newspaper article in *Kauppalehti*, 21.3.2000, pp. 20

Kämäräinen, V., Saranen, J. and Holmström, J. (2001a), "The reception box impact on home delivery efficiency in the e-grocery business", *International Journal of Physical Distribution and Logistics Management*, Vol. 31, No. 6, pp. 414-426.

Kämäräinen, V., Småros, J., Holmström, J. and Jaakola, T. (2001b), "Cost effectiveness in the e-grocery business", *International Journal of Retail and Distribution Management*, Vol. 29, No. 1.

Kämäräinen, V. and Punakivi, M. (2001), "Development of cost-effective supply chain in the e-grocery business", *Supply Chain Management and Information Systems in Internet Age Conference proceedings*, December 2001, Hong Kong, China.

Kämäräinen, V. and Punakivi M. (2002), "Developing Cost-effective Operations for the e-Grocery Supply Chain", *International Journal of Logistics Research and Applications*, Vol.5, No.3, pp.285-298

Kämäräinen, V. (2002), "The development of cost-effective operations for the e-grocery supply chain", a Licentiate thesis in Helsinki University of Technology, Department of Industrial Engineering and Management, Helsinki.

Kämäräinen, V., Yrjölä, H. and van Abeelen, L. (2002), "A New Approach to Retailing in the Digital Economy", Helsinki University of Technology, Working paper. (www.tuta.hut.fi/ecomlog)

Kämäräinen, V. and Punakivi, M. (2003), "Unattended reception -A business opportunity?", *forthcoming in the International Journal of Services Technology and Management.*

Kämäräinen, V. (2003), "The impact of investments in operations efficiency on the e-grocery business system", Doctoral dissertation, Helsinki University of Technology, Helsinki.

Lambert, D. M. and Stock, J. R. (1993), *Strategic Logistics Management*, Richard D. Irwin, Inc., Homewood, p. 862

Lambert, D.M, Stock, J.R. and Ellram, L.M. (1998), *Fundamentals of Logistics Management*, Irwin/McGraw-Hill, Boston, p.611

Lardner, J. (1998), "Please don't squeeze the tomatoes online -Supermarkets of the future have no aisles", *U.S. News & World Report*, November 9, pp. 51-52.

Laseter, T., Houston, P., Chung, A., Byrne, S., Turner, M., Devendran, A. (2000), "The Last Mile to Nowhere", *Strategy + Business*, September 2000, Issue 20.

Lassila, A. (2000), "Package deliveries in huge growth - Paketti kuljetukset hurjassa kasvussa" (in Finnish), newspaper article in *Helsingin Sanomat*, 26.2.2000

Law, A. and Kelton, W. (2000), *Simulation Modeling and Analysis*, McGraw-Hill Companies Inc., Singapore.

Lawler, E.L., Lenstra, J.K., Rinnooy Kan, A.H.G. and Shmoys, D.B. (1985), *The Travelling Salesman Problem: A Guided Tour of Combinatorial Optimization*, John Wiley & Sons Ltd., New York.

Lawrence, J. and Pasternack, B. (2002), *Applied Management Science -Modeling, Spreadsheet Analysis, and Communication for Decision Making*, John Wiley & Sons Inc., New York

Lee, Hau L. and Whang S. (2001), "Winning the Last Mile of E-commerce", *MIT Sloan Management Review*, Vol. 42, Iss. 4, pp. 54-62.

Lehtonen, Joni. (1999), personal communications with Mr. Lehtonen, development manager of Schenker Kiitolinja Oy, December 12th, 1999

Lehtonen, J-M. (1999), "Supply Chain Development in Process Industry", Acta Polytechnica Scandinavica, IM 4, Industrial Management and Business Administration Series, Helsinki University of Technology, Finland

Lewis, H.T., Culliton, J.W. and Steele, J.D. (1956), "The Role of Air Freight in Physical Distribution", Harvard Business School, Boston Ma.

Lewis, A. (2000), "@ Your Service Future Models of Retail Logistics", Report to Retail Logistics Task Force of Foresight program, UK, p.36.

Lewis, C. (2001), "Leap of faith", *Logistics Europe*, April 2001, pp. 40-46.

Lindholm, M. (2000), personal interview of Mr. Lindholm a representative of CAPS logistics at Helsinki University of Technology, Finland, April 4th, 2000.

Magee, J.F., Copacino, W.C. and Rosenfield, D.B. (1985), *Modern Logistics Management -Integrating Marketing, Manufacturing, and Physical Distribution*, John Wiley & Sons, New York, p. 430.

Matikainen, Harri (1999) personal interviews of Mr. Matikainen, Logistics director of Hasrtwall at Hartwall Oy, Finland, September 1st, 1999 and October 15th, 1999

Matomera (2001), Press announcement 2001/03/26:"Matomeras verksamhet upphör- Matomera closing the operations" (Swedish), http://www.bergendahls.se/matomera/index.html

McKinnon, A. (1990), "The Advantages and Disadvantages of Centralised Distribution", In: *Retail Distribution Management*, pp. 75-89, Ed. Fernie, John, Kogan Page, London, p. 244.

McKinnon, A. (1996), "The Development of Retail Logistics in the UK" Report to UK Technology Foresight Programme Retail and Distribution Panel, School of Management Heriot-Watt University, November 1996, p.47.

Mendelson, H. (2001), "Webvan: The new and Improved Milkman", Graduate School of Business Stanford University, Case number EC-31, March 2001, p.15

Mentzer, J.T. (1989), "Symposium Feature: Approaches to Logistics Modeling", *Journal of Business Logistics*, Vol.10, No.1, pp. 104-105.

Mentzer, J.T. and Kahn, K.B. (1995), "A Framework Of Logistics Research", *Journal of Business Logistics*, Vol.16, No.1, pp. 231-249.

MINTC (2002), Ministry of Transport and Communications Finland, http://www.mintc.fi/www/sivut/suomi/ymparisto/ , and http://www.mintc.fi/www/sivut/suomi/ymparisto/sivut/dokumentit/tutkimus/ilmasto/ilmastofin.htm

Morganosky, M. and Cude B. (2000), "Consumer response to online grocery shopping", *International Journal of Retail & Distribution Management*, Vol. 28, No. 1, pp. 17-26.

Mäkelä, Kari, Kanner, Heikki, Laurikko, Juhani, (1996), "The road traffic emissions in Finland -Liisa 95 - emission model" (in Finnish), VTT Research notes 1772, VTT, Espoo.

Mäkelä, Kari, (1999), personal interview, VTT Yhdyskuntatekniikka, Finland October 21st, 1999.

Nasdaq (2000), "Streamline.com to be Delisted From Nasdaq National Market"- Press release on November 28, 2000.

Nettimarket (2002) http://www.nettimarket.com, (in Finnish) accessed on 13th January 2003

Niiniluoto, I. (1993), "The Aim and Structure of Applied Research", *Erkentniss* 38, pp.1-21

Nummenpää, J. and Ollikainen, T. (1999), "The Goods traffic in densely populated areas in Finland" (in Finnish), Publications of the Ministry of Transport and Communications 5/99, Ministry of Transport and Communications, Helsinki.

Nuutinen, P. (2002), "Tolerable traffic as the goal -Tavoitteena siedetävä liikenne" (in Finnish), newspaper article in *Helsingin Sanomat*, 2.2.2002, p. E2.

Näsi, J. (1980), "Liiketaloustiede soveltavana tieteenä: perusongelmien hahmotus ja analyysi" (In Finnish), University of Tampere, Series A2, Research report 8, p.44.

Ojala, Kimmo (1999) personal interview at Inex Partners Oy, Finland, August 31, 1999

Onal, H., Jaramillo, B.M. and Mazzocco, M.A. (1996), "Two formulations of the vehicle routing problem: An empirical application and computational experience", *Logistics and Transportation Review*, Vol. 32, Iss. 2, pp. 177-186.

O'Neill, B. (2001), " Grocery eTailing-Eating Their Words Industry analysts remain bullish on eGroceries but where's the beef? " http://www.accenture.com/xd/xd.asp?it=enWeb&xd=industries/products/cgs/egrocery.xml

Panimoliitto (2002), The association of Finnish Breweries online-address: http://www.panimoliitto.fi/ymparisto/kiertavatpakkaukset.htm accessed 19.12.2002

Pastinen, V. (1999), "Passenger Transport Survey 1998-1999 - Henkilöliikennetutkimus 1998-1999" (in Finnish), Publications of the Ministry of Transport and Communications 43/99, Ministry of Transport and Communications, Helsinki.

Peapod (2000), "Peapod Acquires Streamline.com, Inc.'s Operations in Two Key Markets; Exits Texas and Ohio; Announces Plans to Enter Baltimore-Washington" -Press release on September 7, 2000.

Peapod (2001), http://www.peapod.com, July 2001

Peltonen, K. (2002), "Wihuri and Hollming developing the e-grocery operations together - Wihuri ja Hollming panostavat yhdessä ruokaverkkokauppaan", (in Finnish) newspaper article in *Tekniikka& Talous*, 22.8.2002, pp. 5

Perman, S. (2000), "The eScout pledge: I, George Shaheen Promise to Do My Best, to Do My Duty to God and My Country, to Help Other People and to Beat the Living Crap out of the Competition", *eCompany Now,* September 2000, pp.147-154.

Perttunen, J. (1995), "Computational experiments on edge exchange heuristics for the euclidean travelling salesman problem", Acta Wasaensia, No. 33, Mathematics 5. Operational Research, University of Vaasa, Vaasa, Finland

Peters, E. (2000), "Meeting the e-Fulfillment Challenge", *Supply Chain Management Review*, November/December 2000, pp. 64-70

Posti (2001), Finland Post Corporation Annual Report 2001, http://www.posti.fi/finlandpost/annualreports/

Powell, M. (2000), "A perspective on the key issues in the development of food home shopping in the UK", *CIES -Supply Chain for e-Commerce and Home Delivery in the Food Industry Conference Handout*, May 2000, Berlin, Germany.

Powers, R. (1989), "Optimization Models For Logistics Decisions", *Journal of Business Logistics*, Vol. 10, No.1, pp.106-121.

Pullen, H. and Webb, M. (1967), "A computer application to a transport scheduling problem", Computer Journal, Vol.10, No. 1, pp.10-13.

Punakivi, M. and Saranen, J. (2001). " Identifying the success factors in e-grocery home delivery", *International Journal of Retail and Distribution Management*, Vol. 29, No. 4, pp. 156-163.

Punakivi, M., Yrjölä, H. and Holmström, J. (2001) "Solving the Last Mile Issue: Reception box or Delivery box?", *International Journal of Physical Distribution and Logistics Management*, Vol. 31, No. 6, pp.427-439.

Punakivi, M. and Holmström, J. (2001), "Environmental performance improvement potentials by food home delivery", *NOFOMA 2001 Conference Proceedings*, Reykjavik, Iceland.

Punakivi, M. and Tanskanen, K. (2002), "Increasing the cost efficiency in e-fulfilment by using shared reception boxes", *International Journal of Retail and Distribution Management,* Vol.30, No. 10, pp.498-507.

Priluck, R. (2001), "The impact of priceline.com on the grocery industry", *International Journal of Retail & Distribution Management*, Vol. 29, No. 3, pp. 127-134.

Pylvänäinen, E. (1996), "Shopping for groceries in localities of different sizes - Päivittäistavarakaupassa asiointi erikokoisilla paikkakunnilla" (in Finnish), Working papers 27/1996, National Consumer Research Centre, p.34.

Päivittäistavarakauppa (2001), "A brochure of Finnish grocery markets and annual grocery sales -Päivittäistavarakauppa 2001 esite" (in Finish), http://www.pty.fi/esite2001.html

Raijas, A. (1994), "The costs of customers in grocery shopping -Asioinnin kustannukset päivittäistavarakaupassa" (in Finnish), Publications 15/1994, National Consumer Research Centre, Helsinki, p.79.

Raijas, A. (2000a), "The consumer benefits and problems in electronic grocery store", Working paper, Helsinki School of Economics, Electronic Commerce Institute

Raijas, A. (2000b), "Electronic and traditional grocery shopping -Päivittäistavaroiden ostaminen elektronisessa ja perinteisessä kaupassa" (in Finnish), LTT-Tutkimus Oy Elektronisen Kaupan Instituutti, p.33.

Reda, S. (1998), "Internet Food Retailers Face Tough Picking, Delivery Issues", *Stores*, March 1998, pp. 50-51.

Reinhardt, A. (2001), "Tesco Bets Small - and Wins Big", *Businessweek Online,* October 1, http://www.businessweek.com/magazine/content/01_40/b3751622.htm

Reynolds, J. (2000), "eCommerce: acritical review", *International Journal of Retail & Distribution Management,* Vol.28, No.10, pp. 417-444.

Reynolds, J. (2002), "Charting the multi-channel future: retail choises and constraints", International Journal of Retail and Distribution Management, Vol.30, No.11, pp.530-535

Ring, L. and Tigert, D. (2001), "Viewpoint: the decline and fall of Internet grocery retailers", *International Journal of Retail & Distribution Management*, Vol. 29, No. 6, 2001, pp. 264-271.

Rowlands, P. (2001a), "Consignia's home delivery drive", *e.logistics MAGAZINE*, Issue 13, Sept. 2001, pp. 22-25.

Rowlands, P. (2001b), "Home delivery -the story so far", *e.logistics MAGAZINE*, Issue 14, Oct. 2001, pp.12-13.

Rowlands, P. (2002), "Why Consignia keeps coming up with more options", *e.logistics MAGAZINE*, Issue 22, Sept. 2002, pp. 16-18.

Ruokanet (2003), http://www.ruoka.net/ , (in Finnish) accessed 13th January 2003

Ruokarasti (2003), http://www.ruokarasti.net ,(in Finnish) accessed 13th January 2003

Ruokavarasto (2003), http://www.ruokavarasto.fi ,(in Finnish) accessed 13th January 2003

Sandoval, G. (2000), "Webvan defends business model despite woes", *CNET news.com*, November 13, 2000, http://news.cnet.com/news/0-1007-202-3662541.html

Sandoval, G. (2001a), "Webvan hikes delivery fees", *CNET news.com*, May 1, 2001, http://news.cnet.com/news/0-1007-200-5786526.html

Sandoval, G. (2001b), "Webvan files for backruptcy protection", *CNET news.com*, July 13, 2001, http://news.cnet.com/news/0-1007-200-6563050.html

Seppälä, U. (1996), "Developing logistics in the outer circle of the European Union", Licentiate's thesis, Helsinki University of Technology, p. 85.

Seppälä, U. (1997), "An Evolutionary Approach for Locating Economic Facilities", Acta Polytechnica Scandinavica, Ma 83, Mathematics, Computing and Management in Engineering Series, Helsinki University of Technology, Finland

Siemens (2002), "Siemens HomeDeliveryBox" (in Dutch) http://www.siemens.nl/hdb/default.asp, Jan 2002

Siikavirta, H., Punakivi, M., Kärkkäinen, M. and Linnainen, L. (2003), "Effects of e-commerce on greenhouse gas emissions case: home delivery service", *Journal of Industrial Ecology, Vol.6, No. 2, pp.83-97*

Småros, J., Holmström,J. (2000), "Reaching the consumer through e-grocery VMI", *International Journal of Retail & Distribution Management*, Vol. 28, No 2

Småros, J., Holmström, J. and Kämäräinen, V. (2000) "New service opportunities in the e-grocery business", *International Journal of Logistics Management,* Vol. 11, No. 1

SOK (2001), http://www.s-kanava.fi/s-box, July 2001

Solomon, M. (1987), "Algorithms for the Vehicle Routing and Scheduling Problems with Time Window Constraints", *Operations Research*, March-April 1987, Vol. 35 No. 2, pp. 254-262.

Solomon, M. and Desrosiers, J. (1988), "Time window constrained Routing and scheduling problems", *Transportation Science*, Vol. 22, pp.1-13.

Solomon, M. M., Baker, E.K. and Schaffer, J.R. (1988), "Vehicle routing and scheduling problems with time window constraints: efficient implementations of solution improvement procedures", In: *Vehicle Routing: Methods and Studies*, 85-106, Ed. Golden, B.L. & Assad, A.A., Elsevier Science Publishers, Amsterdam.

Spåre, H. and Pulkkinen, M. (1997), "Perceived access to grocery stores - Päivittäistavaroiden kauppapalvelujen koettu saavutettavuus" (in Finnish), Liiketaloustieteellinen tutkimuslaitos LTT, Series B 139, Helsinki, p.92

Statistics Finland (1996), "Finland in statistics on CD -1996" (in Finnish), http://tilastokeskus.fi/index_en.html, Statistics Finland, Helsinki.

Statistics Finland (2001), Finland in statistics: population projection, 21.2.2001, http://www.tilastokeskus.fi/tk/tp/tasku/taskus_vaesto.html#väestöennuste

Tacken, M. (1990), "Effects of teleshopping on the use of time and space", Transport Research Record 1285, pp. 89-91.

Taniguchi, E. and Van Der Heijden, R. (2000), "An evaluation methodology for city logistics*", Transport Reviews*, Vol. 20 No. 1, pp.65-90.

Tanskanen, K., Yrjölä, H., and Holmström, J. (2002), " The way to profitable internet grocery retailing - 6 lessons learned ", *International Journal of Retail & Distribution Management,* Vol. 30, No.4 , pp. 169-178.

Tesco (2001), http://www.tesco.com, July 2001

The Times (2000), "The e-milkman cometh", *THE TIMES Weekend Shopping*, September 2, 2000

Tuunainen, V.K. (1999), "Different models of Electronic Commerce -Integration of value chains and business processes", Doctoral Thesis, Helsinki School of Economics and Business Administration, HSE, A-153, Helsinki, p. 205.

Van der Laan, J.W. (2000), "The future of online food retailing", *Retail Economics,* March 2000, http://www.retaileconomics.com/aboutpub1.htm

Van Gelder, Marc (2002a), "Winning with "clicks and bricks", presentation at the annual conference of Council of Logistics Management (CLM), Oct. 1, 2002

Van Gelder, Marc (2002b), personal communication with Mr. Van Gelder, President and CEO of Peapod, October 1, 2002

VTT (2002), http://www.vtt.fi/rte/projects/yki6/liisae/miledate.htm (6.2.2002)

Webvan (2001), "Webvan to implement a 60-minute Delivery Window in all 10 markets", Webvan Press release on 4th of December 2000, http://www000208.webvan.com

Ykköshalli (2003), http://www.yhalli.fi (in Finnish) accessed 13th January 2003

Yli-Kovero, K. (2002), "When store changed to hypermarket- Kun kauppa vaihtui jättihalliksi" (in Finnish) newspaper article in *Helsingin Sanomat*, 13.10.2002, p. E3

Yrjölä, H. and Tanskanen, K. (1999), "An evolutionary approach for developing physical distribution in Electronic Grocery Shopping Logistics", *Logistics Research Network Conference Proceedings*, UK.

Yrjölä, H., Lehtonen, J-M. and Kämäräinen, V. (2000), "An Agenda for Electronic Grocery Shopping Supply Chain Research", *IGLS 2000 Conference Proceedings*, Austria.

Yrjölä, H. (2001), "Physical distribution considerations for Electronic Grocery Shopping", *International Journal of Physical Distribution and Logistics Management,* Vol. 31, No. 10, pp. 746-761.

Yrjölä, H. (2003), "Supply Chain Considerations for Electronic Grocery Shopping", Dissertation series No.3, Helsinki University of Technology, Industrial Management and Work and Organisational Psychology, Helsinki. (http://lib.hut.fi/Diss/2003/isbn9512263238/isbn9512263238.pdf)

YTV (2001), http://www.ytv.fi/liikenne/julk/tsli.html

Appendix I

During 1999-2002 the following 10 company partners have been involved in the ECOMLOG research programme:

- DNA Finland, the third biggest mobile operator in Finland,
- Fazer Confectionery, the biggest chocolate and sugar confectionery producer in Finland,
- Nokia, the world's leading mobile phone and network manufacturer,
- Norpe Ltd, a manufacturer of refrigerating equipment (a subsidiary of Hollming Ltd),
- Panimoliito, the Finnish brewery union,
- S-Group, the second biggest grocery retailer in Finland,
- Sonera, the biggest mobile operator in Finland,
- Trading House Hansel, an operator for public sector procurement and materials management in Finland,
- Unilever, an international grocery supplier, and
- Valio, the biggest dairy products manufacturer in Finland.

Appendix II

I Current state analysis (Yrjölä assisted by Kämäräinen)

The goal of the first phase is the identification of the essential supply chain issues involved in the emerging e-grocery business.

0. What are the essential issues in supply chain operations for the e-grocery business?

0.1 What are the market prospects and trends in grocery retailing?
0.1.1 What are the market prospects for grocery retailing and electronic grocery shopping internationally?
0.1.2 What are the market prospects for grocery retailing and electronic grocery shopping in Finland?
0.1.2.1 What consumer groups have the biggest needs for home delivery service?
0.1.2.2 How does the current laws regulating retailing affect electronic grocery shopping in Finland?

0.2 What is the different supply chain structures and transport volumes for major product groups in Finnish grocery retailing? (Breweries, Dairies, Meat industry)

0.3 What different solutions exist in early EGS operations?
0.3.1 Solutions for goods reception for the customer?
0.3.2 Solutions for order assembly?
0.3.3 What are the different combinations of solutions?

0.4 What is the cost structure of early EGS operators?
0.4.1 What is the cost structure for order assembly in a supermarket?
0.4.2 What is the cost structure for order assembly in a local distribution centre?
0.4.3 What is the cost structure for home delivery?

II Constructive phase

The results from phase I indicated that to gain insight into the operation and potential effectiveness of EGS detailed constructive research on the following issues was necessary:

1. What is the effective supply chain for electronic grocery shopping?
1.1 What is the impact of alternative goods reception modes (attended, reception box, delivery box, shared reception box) on home delivery effectiveness?
1.1.1 What is the impact of alternative goods reception modes on home delivery cost-effectiveness?
1.1.1.1 What is the impact of attended goods reception vs. reception box on home delivery cost? (Punakivi and Yrjölä)
1.1.1.2 What is the impact of other unattended goods reception modes on operational costs of home delivery? (Punakivi)
1.1.1.3 What is the impact of the alternative unattended goods reception modes on required investments? (Punakivi)

1.1.1.4 Can the operational savings in home delivery transportation justify the investments for unattended reception? (Punakivi and Yrjölä)
1.1.2 What is the impact of alternative goods reception modes on customer service? (Kämäräinen and Punakivi)?
1.1.2.1 In which situations is each alternative goods reception mode feasible?
1.2 What is the impact of alternative order assembly systems on the effectiveness of the e-grocery supply chain?
1.2.1 What is the effectiveness of order assembly in local distribution centre (LDC) compared to order assembly in the store?
1.2.1.1 What is the supermarket cost-structure? (Kämäräinen)
1.2.1.2 What are the cost differences between supermarket and LDC? (Kämäräinen)
1.2.1.3 How should order assembly in LDC be organised? (Kämäräinen and Yrjölä)
1.2.1.4 How should automation be used in LDC? (Kämäräinen)

1.3 What are the implications of changing from conventional shopping to EGS on the grocers' first tier suppliers? (Yrjölä)
1.3.1 What are the implications of changing from conventional shopping to EGS on breweries?
1.3.2 What are the implications of changing from conventional shopping to EGS on dairies?
1.3.3 What are the implications of changing from conventional shopping to EGS on meat industry?

III Focused research and strategic implications

2. What is the cost structure of EGS? (Yrjölä)
2.1 What is the cost structure for order assembly for EGS?
2.1.1 What is the cost structure for order assembly in a supermarket?
2.1.2 What is the cost structure for order assembly in a local distribution centre?
2.1.3 What is the feasibility of the hybrid model that combines LDC and supermarket?
2.2 What is the cost structure for home delivery?
2.2.1 What is the impact of customer density?
2.2.2 What is the impact of attended vs. unattended?
2.3 What is the cost impact of EGS on first tier suppliers?
2.4. Can e-grocery supply chain with home delivery be more efficient than conventional grocery supply chain?
2.5 What are the key performance indicators for EGS?

3. What is the required growth and customer acquisition strategy for EGS from operational efficiency viewpoint? (Yrjölä)

4. What are the wider implications in society of large scale EGS?
4.1 What are the potential implications on the environment
4.1.1 What are the environmental effects of alternative goods reception modes? (Punakivi)
4.1.1.1 What is the impact of alternative goods reception modes on mileage driven in urban traffic?
4.1.1.2 What is the impact of alternative goods reception modes on greenhouse gas emissions?

4.1.2 What is the impact on packaging and recycling? (Yrjölä)
4.2 What are the potential implications on employment? (Yrjölä)
4.3.What are the potential implications on legislation? (Yrjölä)

5. What is the market potential for supplying unattended reception solutions? (Kämäräinen and Punakivi)
5.1 What are possible revenue models for unattended reception? (Kämäräinen)
5.2 What are the most potential revenue models for a box supplier? (Kämäräinen)
5.3 How do consumers experience unattended reception? (Kämäräinen)
5.4 How do potential B2B customers experience unattended reception? (Kämäräinen and Punakivi)

6. How best implement EGS using reception boxes (Kämäräinen)
6.1 What kinds of service models are needed?
6.2 What are customer experiences and needs for the ordering interface?
6.3 What are customer experiences of using the reception boxes?
6.4 How reception box service should be priced? (Kämäräinen and Punakivi)

7. What is the basic requirements for the reception box? (Kämäräinen, Punakivi and Yrjölä)
7.1 Temperature requirements and size requirement based on shopping basket analysis? (Punakivi)
7.2 What are the possible other requirements?

8. How can grocery manufacturer's role be changed due to the EGS? (Kämäräinen)
8.1 What are alternatives for the grocery manufacturer?
8.1 What kind of marketing solutions can be adapted?
8.3 How grocery manufacturer can take a more active role in the grocery business?

Appendix III

In the modelling work reported in **Papers II, III, and IV** the limiting values of the vehicle fleet are the following:

- Max 60 orders
- Max 3000 litres per van
- Working time max 11 hours per van
- Working time max 5 hours per route
- Costs of van and driver: 22.5 euros per hour
- Loading time per route: 20 minutes
- Drop-off time per customer: 2 minutes

In **Paper III**, for delivery box solution 4a, the drop-off and pick-up of the delivery boxes is modelled with a 2-minute drop-off parameter. However, for solution 4b, where the delivery boxes are picked up during the next day without a new order being delivered, an additional 2 minutes were allowed for picking up the returned delivery box.

In the analysis reported in **Papers II and IV** the shopping baskets were home delivered on the same day as the actual shopping had been done. The daily amount of deliveries varied between 160 and 462 orders delivered. In **Paper III**, additional research was conducted, including modelling of 47 and 1639 deliveries per day, using the original point-of-sales data.

For **Paper V** the limiting values for the vehicle fleet were updated. The limiting values were verified within an e-grocery pilot. In this pilot operation, around 50 household customers located in the test area selected in this dissertation were provided with customer-specific refrigerated reception boxes (Huhtakangas, 2000; SOK, 2001). The average order size in this concept was only about 50 euros, due to the frequent (twice a week) home delivery service. The average physical size of the orders in the pilot operation is two 50-litre totes. For the additional modelling in Paper V, limiting values were as follows:

- **Max 40 orders per van (two totes per order)**
- Working time max 11 hours per van
- Working time max 5 hours per route
- **Costs of van and driver: 26 euros per hour**
- Loading time per route: 20 minutes
- Drop-off time per customer: 2 minutes
- Pick-up time per customer: 2 minutes (in concept 3B)

In **Paper V** concept 3B describes the same delivery box operating model as concept 4b in **Paper III**. In **Paper V** the cost efficiency of three home delivery models offering unattended reception and the standard home delivery model offering attended reception with two-hour delivery time windows was analysed. Using the original point-of-sales data as a pool of orders, various amounts of daily orders were selected for analysis. The number of daily orders in the analysis ranged from 20 to 720.

The geographical test area (135 km^2) selected for the home delivery modelling is here presented both as a list of the postal codes and in Figure 21 as a map. The map is a screen shot picture from the CAPS RoutePro vehicle routing tool.

ESPOO		
02110	02730	02230
02120	02100	02270
02160	02130	02600
02180	02140	02620
02240	02150	02630
02610	02170	02660
02680	02200	02710
02720	02210	02940
KAUNIAINEN		
02700	02750	
VANTAA		
01630	01600	01650
01640	01610	01710
01660	01620	
HELSINKI		
00390	00410	00420

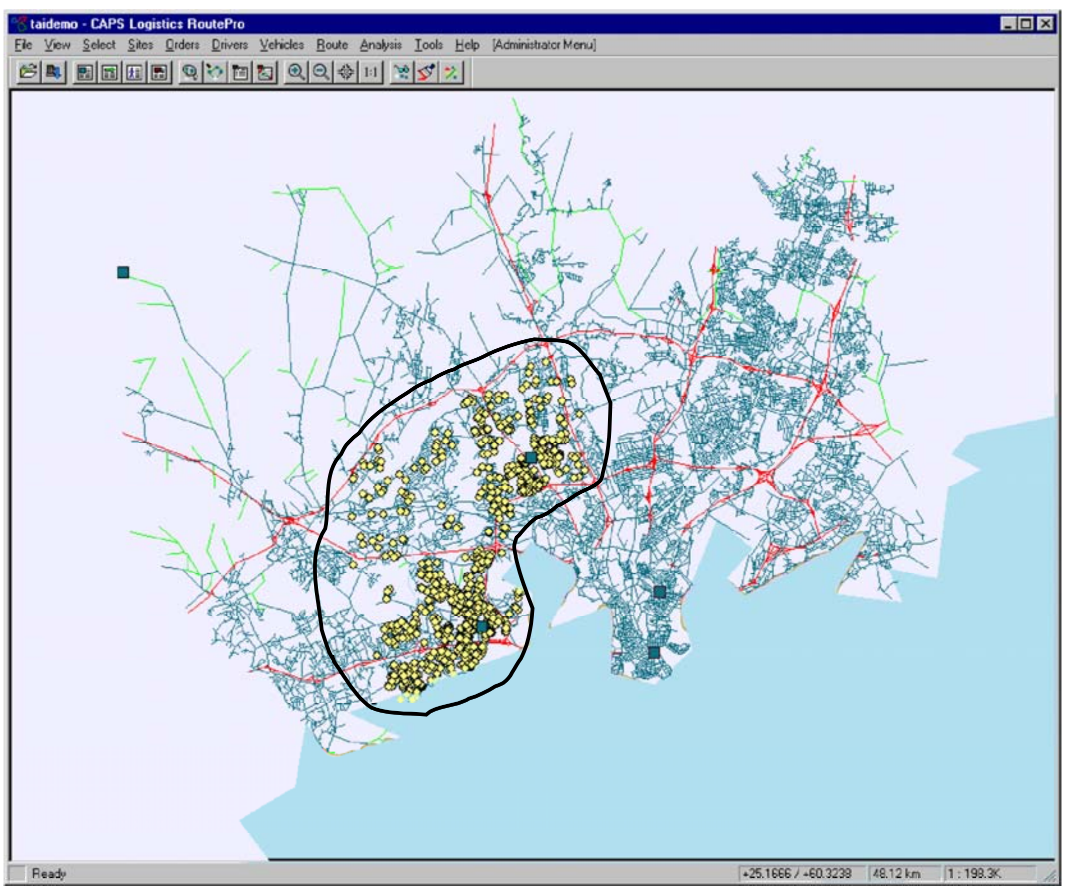

Figure 21 Map of the selected test area.

The general default speed for the distribution vans in the test area was set to 35 km/h. Additionally, in the model the following specific road type-based default speeds were used:

Highways: 45 km/h
State roads: 35 km/h
Arterial roads: 27 km/h
Collectors: 22 km/h
Residential roads: 15 km/h

Appendix IV

For the analysis in Paper II, four existing home delivery models (Cases 1-4) were identified. In the analysis the different home delivery models are also compared to the present situation, in which the customer's own car is used (Case 5). Moreover, the differences between attended and unattended reception are studied in the analysis (Case 6). The cases used in the analysis are described below, in Table 6.

Table 6 Description of the cases in the analysis (Punakivi & Saranen, 2001).

CASE	ORDER	DELIVERY	RECEPTION	DELIVERY TIME WINDOW	EXAMPLE
1	by 10:00	same day	manned	3 delivery time windows: 17-19, 18-20, 19-21	Matomera, Sweden Ruok@net, Finland
2	by 24:00	next day	manned	1 hour delivery time windows between 12 and 21	Ykköshalli, Finland Eurospar, Finland WebVan (½h), USA Tesco (2h), UK
3	by 24:00	next day	unmanned (reception box)	delivery between 8 and 18	Streamline, USA S-kanava, Finland
4 *)	by 24:00	next day (fixed day)	unmanned (reception box)	delivery between 8 and 18, once a week on a fixed customer chosen day	Optimal case in box concept
5 **)				all orders delivered with own car, simulating the situation where households are doing the shopping themselves	Traditional grocery shopping
6	by 24:00	next day	manned / unmanned (reception box)	unmanned: delivery between 8:00 and 18:00, manned: 1 hour customer chosen delivery time window between 8:00 and 18:00. The amount of manned receptions:0-100%	

*) Case 4 simulates the best possible case from the e-grocer's point of view, meaning that orders are sorted by postal code and devided evenly on all delivery days. This kind of situation can be reached by for example pricing.

**) Case 5 enables the comparison of the different e-grocery cases to the current situation where customers visit supermarkets.

Appendix V

In Paper V five home delivery models were modelled (Table 7). The first of the models describes the "standard" in home delivery, attended reception with 2-hour time windows. The following cases, 2, 3A, and 3B, describe models offering customer-specific unattended reception. Case 4 is the shared reception box concept. In the shared reception box concept various (5, 10, 20, and 30) unit locations were selected, whereas in the other cases the deliveries were made to customers' street addresses. The shared reception boxes were placed in central locations in the test area, such as busy bus or underground stations, petrol stations, or near current shopping centres. In the analysis the distribution centre was located in a suburban area, next to an existing shop.

Table 7 Description of the home delivery models (Punakivi & Tanskanen, 2002).

CASE	HOME DELIVERY CONCEPT & DESCRIPTION	EXAMPLE
1	**Attended reception with 2-hour delivery time windows**	**Peapod.com, USA Tesco.com, UK**
	Delivery hours 8:00-22:00 Customer locations based on POS data Number of orders per day varies from 20-720	
2	**Reception box concept**	**SOK, Finland Streamline, USA**
	Delivery time window 8:00-16:00 Customer locations based on POS data Number of orders per day varies from 20-720	
3A	**Delivery box concept, with pick-up of the box on next delivery**	**Homeport, UK**
	Delivery time window 8:00-16:00, pick-up on next delivery Customer locations based on POS data Number of orders per day varies from 20-720	
3B	**Delivery box concept, with pick-up of the box on next day**	**Homeport, UK Sainsbury, UK Food Ferry, UK**
	Delivery time window 8:00-16:00, pick-up on next day Customer locations based on POS data Number of orders per day varies from 20-720	
4	**Shared reception box concept**	**Hollming, Finland Boxcar Systems, USA ByBox Holdings, UK**
	Time window 8:00-16:00, "by the end of working hours" 5, 10, 20, 30 selected central locations of the shared reception box units Capacity of the shared reception box units varies: 8, 16, 24 and 32 customer-specific lockers per unit Utilisation rate of a shared reception box units in the analysis: 50% & 75% Number of orders (20-720) per day varies according to the combination of above elements	

Appendix VI

For the analysis in Paper III the following four home delivery solutions, 1 to 4, were identified. The home delivery solutions in the simulations are described in Table 8. Solutions 1 to 3 are presented and analysed earlier in Paper II (Punakivi & Saranen, 2001), focusing on the cost difference between unattended and attended reception. In Paper III, investigating a new alternative solution for unattended reception, the delivery box concept (4a and 4b), extends the analysis. Furthermore, in Paper III the payback periods for investments in the alternative solutions enabling unattended reception are analysed based on the differences in operating efficiency between attended and unattended reception.

Table 8 Description of the modelled solutions (Punakivi et al., 2001).

SOLUTION	ORDER	DELIVERY	RECEPTION	DELIVERY TIME WINDOW	EXAMPLE
1	by 10:00	same day	attended	3 delivery time windows: 17-19, 18-20, 19-21	Matomera, Sweden Ruok@net, Finland
2	by 24:00	next day	attended	1 hour delivery time windows between 12 and 21	WebVan, USA Tesco (2h), UK Ykköshalli, Finland Eurospar, Finland
3	by 24:00	next day	unattended reception box	delivery between 8 and 18	Streamline, USA S-kanava, Finland
4a	by 24:00	next day	unattended delivery box	Delivery time window 8-18, pick up of delivery box on next delivery	Food Ferry, UK
4b	by 24:00	next day	unattended delivery box	Delivery time window 8-18, pick up of boxes on next day 8-18 (14h-34h from delivery)	Food Ferry, UK

Conceptually, delivery box solution 4a is equivalent to the reception box solution. In delivery box solution 4a the pick-up of the delivery box is at the time of the next delivery. This requires investments in delivery boxes stored with each customer. Delivery box solution 4b makes possible better utilisation rates of a single delivery box but requires a separate drop-off and pick-up trip for each order. In the simulations the daily drop-offs and pick-ups can be scheduled on the same route, according to vehicle capacity.