An Assessment of the Sustainability of E-fulfilment Models for the Delivery of Fast Moving Consumer Goods to the Home

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ABSTRACT

Online retail sales are growing rapidly and have captured a significant proportion of the retail market in many countries. Although companies are under mounting pressure to reduce their environmental impact, the environmental effect of the different online distribution strategies remains unclear. Most previous studies of this subject have only included partial effects and consequences. To enable a more holistic understanding, this study proposes a more inclusive framework of environmental assessment based on life cycle analysis. This was applied to fast moving consumer goods (FMCG).

Previous studies have shown that the last mile delivery contributes significantly to the environmental impact of online retailing, mainly because of the nature of the home delivery operations, including narrow time windows and short order lead times. If consumers were to buy products online on a subscription basis and give the supplier more control over the replenishment process there might be less need for fast deliveries, creating opportunities to improve the efficiency of home deliveries and reduce their environmental impact. The study classified different forms of subscription arrangement, assessed their relative attractiveness to consumers and examined their likely impact on the supply chain. Consumer views on subscriptions were surveyed by means of focus group discussions and interviews. To assess the likely supply chain impacts of subscriptions, the literature on vendor-managed inventory was consulted.

A Life-Cycle Assessment (LCA) model was built to quantify and compare the environmental impact of various e-fulfilment models for FMCG products in the United Kingdom. This study reveals that the method of execution have a large influence on the environmental impact. In store-based retailing, the energy consumption within the supermarket is a significant contributor to the total greenhouse gas emissions. On the other hand, some forms of home delivery, involving for example the use of parcel networks with no pre-agreed time-slots and relatively high rates of delivery failure and customer collection, are also carbon-intensive. This contribution of consumer trips to the total footprint is much smaller in case of van-based deliveries where pre-agreed time-windows are used. Regardless of the business model, the total carbon footprint per item depends heavily on the number of items per delivery. Consequently, companies or consumers looking to decrease the environmental impact of online shopping should maximise the number of items per delivery. The study concludes with an assessment of the strengths, weaknesses and possible environmental improvements of each of the e-fulfilment methods, taking account of the possible role of subscriptions.

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CHAPTER 1: INTRODUCTION

Online retailing of fast moving consumer goods is rapidly growing and in 2012 was worth € 300 billion in Europe (IMRG, 2012). In the United Kingdom the share of online groceries is much higher than in other European countries. 19% of the UK population bought groceries online in 2011 (Eurostat, 2012a). This is expected to rise further to 40% by 2016 (van Essen, 2012). While the market is growing, the effects on the environment remain unclear. Several studies have been conducted on the environmental impact of online retailing, but only a limited number of these perform an environmental analysis of the fulfilment of fast moving consumer goods (FMCG) that are ordered online. Those that do however do not consider the full impact of online retailing on the environment. This study addresses this gap by developing a model to quantify and compare the full environmental impact of different retail models for FMCG and it is used to calculate the environmental impact of e-retail models in the United Kingdom.

This chapter first introduces online retailing and explains the motivation for the research topic chosen. A possible alternative to the current existing online retail models, in the form of a subscription service, is proposed. The objectives and research questions of the thesis are then outlined in the second section. In the third section the thesis structure is explained including an overview of the content of the remaining eight chapters.

1.1 Background and motivation

Online shopping, as we know it today, has been in existence for only 15 years. However, home deliveries are not new. TV and radio commercials, catalogues, and other advertisements have been persuading people to shop from home for many decades. Retailers have offered home deliveries for purchases made in store, mainly for large products like furniture, for much longer and the milkman had a delivery round long before the internet existed. While home delivery is not a new concept, more and more retailers are adding internet shopping to the services they offer to the consumer. Today many retailers offer home delivery combined with online sales for a diverse range of products. Supermarkets fulfil online orders from their shops, emerging new companies (pure-players) focus on the delivery of small non-food items and much furniture is now bought online.

Although it was expected, in the early days of online retailing, that manufacturers would bypass the retailer and sell directly to consumers, very few have so far set up online shops for the end consumer, particularly in the fast moving consumer goods (FMCG) sector. Only 6% of the purchases made in the Netherlands are served directly by the manufacturer of the product (Multichannel Monitor, 2010) and only 25% of the food and grocery manufacturers in the UK have considered creating their own online shop (IGD 2011, cited by anon, 2011b).

There are several reasons why manufacturers do not provide an online service. First bypassing the retailer, or disintermediation, might result in a channel conflict with their retailers. Second the sales volume might not justify the costs associated with selling products online and shipping to the consumer's home. Manufacturers have a smaller assortment of products than many retailers which might lead to smaller shopping baskets and therefore relatively high distribution costs. However, disintermediation can also result in lower (total) distribution costs as less handling is required (no shipment via the retailer). The retailer's profit margin can be eliminated or internalised in the manufacturer's profit. Besides that, the direct link with consumers leads to more demand and market insight, which could lead to a further increase in supply chain efficiency, not only economic efficiency, but also environmental improvement.

This research aims to quantify and compare the sustainability of different retail models, including the 'direct-to-consumer' retail model, for the supply of FMCG products from the manufacturer to the consumer. Existing retail models are included in the analysis. However, from discussions with several supply chain experts in one FMCG manufacturer, it became clear that current retail models may not be the most environmentally sustainable. Currently fast home delivery seems to be preferred. Faster deliveries generally have a larger impact on the environment due to inefficiency in the home delivery round (Siikavirta et al., 2003). There might be an underlying need for fast delivery by consumers; not running out of a product, especially for FMCG or groceries, might be more important to consumers than the speed of delivery. If retailers or manufacturers can offer a service which ensures high product availability at the consumer homes, like a subscription service, a new online business model might be generated. The discounts offered in existing subscription services suggests that additional savings can be made by the subscription provider leading to a economically-sustainable online business model.

A subscription is defined in the dictionary *"as an amount of money that you pay regularly to receive a product or service or to be a member of an organization"* (Cambridge Dictionary). Various dictionaries mention concert tickets, magazines, newspapers and books as things bought on subscription (Collins English Dictionary and Random house Dictionary). In this thesis only subscriptions for physical goods where the retailer performs the home delivery, either by itself or outsourced to a third-party provider, are considered. Cook and Garver (2002, p 39) define this type of subscription as *"a formal agreement to receive and pay for a specified product or service for a specified period of time"*. A subscription is therefore an agreement where consumers buy certain items, within a range of specified quantities over a given time period, in exchange for a price discount and consumer demand information (Cook and Garver, 2002).

Subscriptions can meet the need for product availability at the consumer home while the subscription provider might have more influence over the delivery date. Several companies offer the consumer a subscription service that guarantees product availability at home, for example the 'never run out' claim of both Amazon Subscribe and Save (2013) and the Small Batch Coffee Club (2011) among others. However, these companies deliver product at fixed time intervals, without knowing the actual consumption pattern of the household. Consumers can therefore still run out of stock, reducing the consumer experience. More sophisticated services might be needed to provide the consumer with products when needed and thereby providing a sustainable retail model that fulfils the consumer requirements and wishes in the long term. The consumer requirements of such service must therefore be identified before an attractive retail service can be designed.

1.2 Research objective and research questions

This research examines the sustainability of different online business models for FMCG manufacturers in terms of environmental impact and consumer service. Existing and new subscription models are taken into account to find a sustainable design for the online retailing of FMCG goods. The overall aim of the research is to determine:

A sustainable design for the e-fulfilment of FMCG products to the home,

To meet this aim it will be necessary to achieve two objectives:

To explore the supply chain options for manufacturers to sell their products online, either directly or indirectly (e.g. via retailers), to consumers.

To analyse and compare the environmental impact of each option, including traditional offline retailing.

From these objectives flow several research questions:

RQ1: What are the supply chain options for FMCG manufacturers to sell their products online?

This includes the following sub-research questions:

SQ1: What are the main logistics models likely to be applicable to FMCG online retailing?

SQ2: How should the new subscription model be designed from a consumer perspective? E.g. what are the consumer needs and preferences for home delivery?

SQ3: What are the factors influencing the environmental impact of the various e-fulfilment models?

RQ2: What is the relative environmental performance of online and traditional retail models?

Which includes the following sub-questions:

SQ4: How should the e-fulfilment model be designed to minimise the impact on the environment?

SQ5: What is the most sustainable design to market FMCG products in environmental terms?

1.3 Thesis structure

Figure 1.1 shows the content of the nine chapters in this thesis. Chapter 2 and 3 examine the current online retail models. The possibility of subscriptions being used for the e-fulfilment of FMCG products is explored in Chapter 5, 6 and 7. Chapter 8 combines the findings and investigates the environmental performance for each (online) retail model for FMCG. In Chapter 9 the findings are summarised and the practical and theoretical contributions of the thesis are explained.

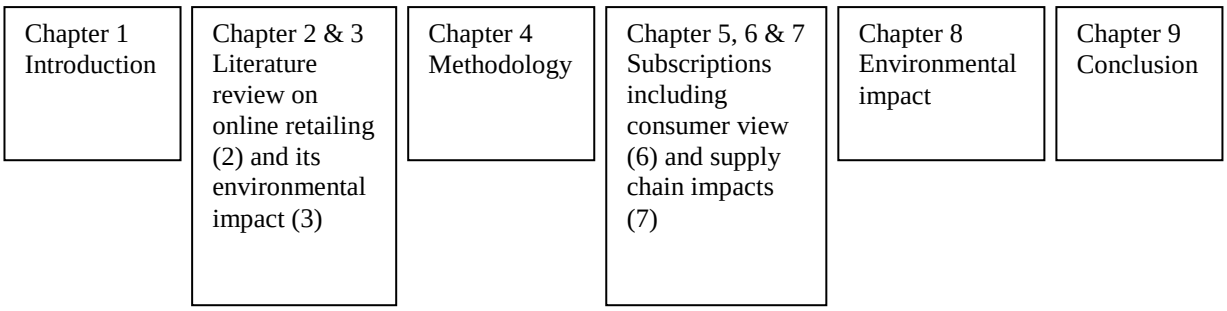


Figure 1.1: Outline of thesis structure

Chapter 2 summarises the literature of online retailing focusing on e-fulfilment operations. After defining the general concepts of e-commerce, the different fulfilment models and logistics processes behind online shopping are discussed.

Chapter 3 discusses the environmental impact of online retailing. All the processes behind online retailing are analysed and the environmental impact of product types examined. The aspects that need to be included when running an environmental assessment of online retail operations are identified.

Chapter 4 discusses the methodology applied in this thesis. It reviews the various research approaches and data collection methods available and justifies the choices made in this study. The various stages in the research, which include the use of a systematic literature review technique, interviews, focus groups, and a Life-Cycle Assessment, are outlined.

Chapter 5 discusses the potential benefits of subscriptions. Based on a literature review and industry examples of subscription services, a classification is developed which distinguishes 3 types of subscriptions. The potential impacts of each of the three subscription types are discussed.

Chapter 6 analyses the consumer opinion with respect to subscription services. The results of focus groups and one-on-one interviews with 112 consumers are analysed to determine the characteristics of potential customers and to gain insight into the requirements of a subscription service from a consumer point of view.

Chapter 7 looks into the supply chain impacts of subscriptions. Due to the analogy of automatic home replenishment programmes with Vendor Managed Inventory (VMI), the VMI literature was reviewed to identify potential benefits and disadvantages of subscriptions. The differences between subscriptions and VMI are further analysed to assess the potential influence of subscriptions on the environmental impact of home delivery services.

Chapter 8 describes the Life-Cycle Assessment (LCA) model used in this project to analyse the environmental impact of all relevant retail models for FMCG in the United Kingdom. Factors influencing the environmental outcome are identified, and the requirements for a sustainable retail model are discussed.

Chapter 9 concludes the thesis by summarising the main findings and assessing its overall contribution to knowledge. Limitations of the research and future research directions are also discussed.

CHAPTER 2: THE LOGISTICS OF ONLINE RETAILING

This is the first of two chapters reviewing literature relevant to the study. The purpose of this chapter is to give an overview of the process of online retailing for fast moving consumer goods (FMCG), focusing on the logistics behind the online orders. To do this, first the general concepts and definitions of e-commerce are defined that underpins this research. Thereafter the online customer and his or her expectations in online retailing is explained. In the second part of this chapter, the online fulfilment process for FMCG is outlined, explaining different fulfilment models and the logistic processes behind the online order. The environmental impact of online retailing is discussed in Chapter 3.

2.1 Introduction and definition

Online retailing is growing rapidly. In 2012 online turnover increased by 20% compared to 2011 reaching € 300 billion in Europe (IMRG, 2012). The majority of this turnover (60%) is generated in the United Kingdom, Germany and France (IMRG, 2012). 71% of shoppers in the United Kingdom buy online items at least once a year (Eurostat, 2012a). Also the number of people who buy groceries online is sharply increasing in the United Kingdom, reaching 19% in 2011, much higher than other countries. As shown in figure 2.1, this is expected to rise further to 40% by 2016.

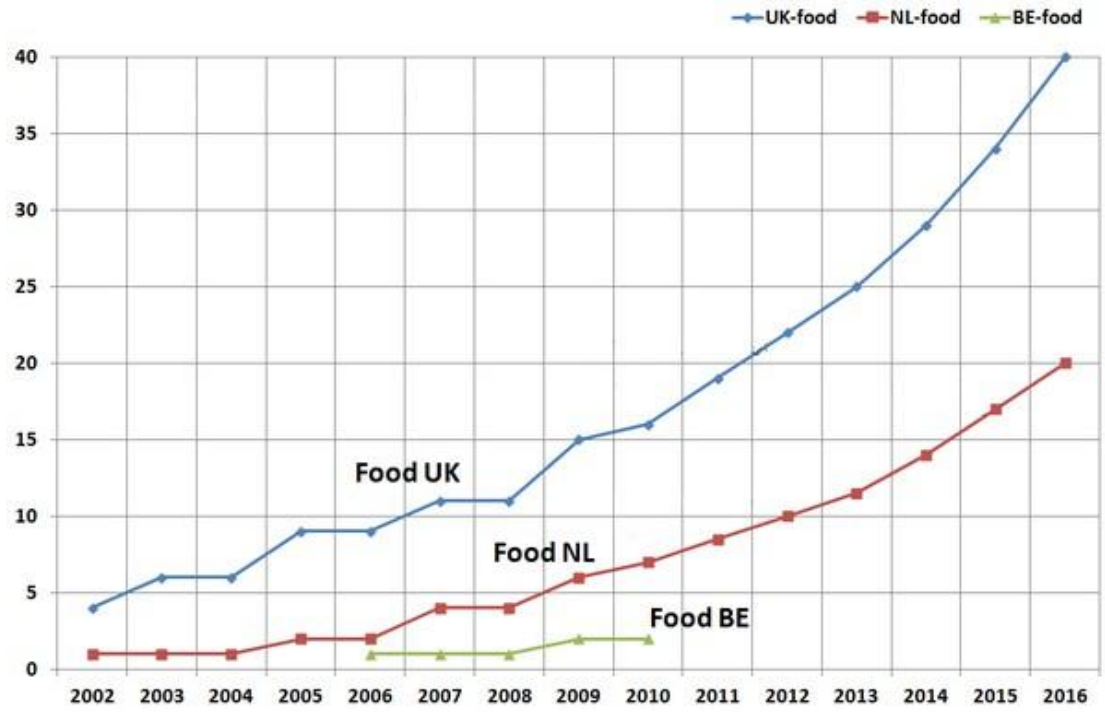


Figure 2.1: Percentage of consumers buying food online (Source: van Essen, 2012)

Groceries are more frequently and repetitively bought online than any other product category; 23% of the people who buy groceries online are ordering groceries on a weekly basis (Verdict, 2004). While this is growing, the effect of online ordering of goods and the associated fulfilment processes on the environment has still not been researched in detail. To assess the current state of knowledge on the subject a systematic literature review has been performed on the logistics of online retailing, and more specifically on its environmental effects.

Various definitions have been developed to cover different forms of electronic commerce. It is widely agreed that e-commerce transactions are performed by digital rather than physical means (Abukhader and Jönson, 2003) and is conducted over computer-mediated networks or over the Internet (Fichter, 2003). OECD (2003) refers to electronic commerce as commercial transactions that occur over open networks, such as the Internet and includes both business-to-business (B2B) and business-to-consumer (B2C) transactions. However, ECR Europe (2002) argues that e-commerce is more than the commercial transaction and includes the information flow, the physical fulfilment flow, the reverse flow, as well as the payment flow. One key aspect of online retailing is the fulfilment of the products purchased online, a subject investigated by, among others, Duffy and Dale (2002), Nicholls and Watson (2005) and George (2008). E-fulfilment includes all the processes, activities and functions arising between order capture and final delivery to the customer, including the physical process of delivery and providing and controlling the IT infrastructure. It includes the processes order capture, order processing, pick and pack, ship and after sales service, and returns handling (Pyke et al., 2001). E-fulfilment is therefore defined as *"performing or managing key functions in the physical process of delivering products in single units to individual end-users, whether business or consumer, where the Internet play a significant role in the ordering or execution; and providing or controlling the IT infrastructure to do this"* (Rowlands, 2003, p.23). It includes parameters like stock availability, delivery lead time and delivery scheduling (Duffy and Dale, 2002).

E-fulfilment is mentioned as a critical operation which can be the most expensive activity of e-retailers (de Koster, 2002a; Lummus and Vokurka, 2002). Besides that, the e-fulfilment process has also a crucial impact on service quality and customer satisfaction (Xing and Grant, 2006; Xing et al., 2010). In particular when customers order regularly, the fulfilment quality has a direct impact on the level of customer loyalty and overall success of the B2C e-commerce business (Paché, 2008). Not only

the delivery itself is important, also the real-time visibility of the inventory influences the service experience of customers (Jelassi and Leenen, 2003). The fulfilment process can be a barrier for consumers to shop online (Chen and Leteney, 2000). Four of the top five barriers to shopping online are related to the delivery (DfT, 2004). The service quality required by the online customer is discussed below. The e-fulfilment process and its influence on the costs is discussed thereafter.

2.2 The expectations of the online customer

Online customers are different from traditional shopping customers; online customers expect more competitive prices, fast delivery, and can switch easily to another website with similar products and services. The location of the shop is not relevant in e-commerce, giving the consumer access to many different retailers in a virtual market place (Tarn et al., 2003).

The most common reason to shop online is lack of time (Verdict, 2004). Other reasons are lack of transport, difficult to carry heavy or bulky items, and a dislike of physical shopping (Browne et al., 2001; Verdict, 2004). It is widely argued that the 'time-poor cash-rich' consumer is a potential online customer (ECR Europe, 2002). A classification of the different groups of online shoppers made by Allred et al. (2006) is shown in table 2.1.

Online shopper segment	**Explanation**
e-shopping lovers	This group spend the most money online (up to 25% of their expenditure) and represents a significant share of the online shoppers. They like the convenience of online shopping, not having to leave the house. However, this group does not convince other people to shop online.
e-value leaders	This is the largest online shoppers group. They are the most convinced group that online shopping is cheaper, has a better selection, and a better quality. Convenience is a less important reason to shop online. An important characteristic of this group is that they tend to lead the opinions regarding the online shop among their friends.
Socialisers	Although this group spend more money at local retail stores, they also actively spend in online shops. Socialisers, like e-value leaders, are likely to influence their friends to shop online. The difference is that they deeply dislike the hassles of online shopping and prefer to see the products before buying. They belief that local *Brick & Mortars* have lower prices than online shops. However, they like the convenience of occasional online shopping.

Table 2.1: Online shoppers segments (Adapted from Allred et al., 2006)

A considerable body of literature explores the service quality criteria of online retailing, including website design, information availability, security issues, ease of ordering and order delivery (Xing and Grant, 2006). For conventional retailing, the SERVQUAL instrument (Parasuraman et al., 1988) has been widely used to test the customer perception of service quality (Chiu et al., 2009). However, this instrument is not suitable for online retailing as it does not include the unique propositions of e-commerce such as interaction via websites (Jun et al., 2004). Different studies have developed dimensions to measure the e-service quality (Chiu et al., 2009). An overview of the e-service quality research is given by Sahadev and Purani (2008) and is shown in table 2.2.

Study	**Dimensions of e-service quality**	**Dependent variables considered**
Yoo and Donthu (2001)	Ease of use, aesthetic design, processing speed, security	Attitudes towards website, site equity, purchase intention, site revisit intention
Janda et al. (2002)	Performance, access, security, sensation, information	Satisfaction, positive word of mouth, future likelihood of returning, likelihood of complaining
Wolfinberger and Gilly (2003)	Fulfilment / reliability, web site design, privacy / security, customer service	Global quality, satisfaction, loyalty intentions, attitude towards website
Parasuraman et al. (2005)	Efficiency, system availability, fulfilment, privacy	Perceived value, loyalty intentions
Bauer et al. (2006)	Responsiveness, reliability, process, functionality, enjoyment	Perceived value, satisfaction, overall service quality
Colier and Bienstock (2006)	Ease of use, privacy, design, information, accuracy, functionality, order condition, timeliness, order accuracy, interactive fairness, outcome fairness, procedural fairness	Satisfaction, behavioural intention
Loiacono et al. (2007)	Ease of understanding, intuitive operations, information quality, functional fit to task, tailored communication, trust, response time, visual appeal, innovativeness, emotional appeal, online completeness, consistent image, relative advantage	Intention to buy and overall quality

Table 2.2: Studies on e-service quality (Adapted from Sahadev and Purani, 2008)

Of these dimensions, fulfilment is a crucial factor influencing the service quality perceived by consumers (ECR Europe, 2002; Huang et al., 2009; Lin et al., 2011; Semeijn et al., 2005; Sheng and Liu, 2010; Wolfinbarger and Gilly, 2003). Fulfilment quality influences significantly the trust in the online retailer (Chiu et al., 2009; Roman, 2007), and consequently influences the repurchase intentions of the consumer at that particular retailer (Chiu et al., 2009). A large amount of literature studies the service quality in general, but relatively little research focuses specifically on the fulfilment quality (Xing and Grant, 2006).

Customer service in the online market includes up-to-date stock-availability, convenient delivery times, and high product quality. Half of the consumers surveyed by Xu et al. (2008) were willing to pay more for convenience and faster delivery, but the other half prefer no or low delivery charges. Rabinovich et al (2008) found that customers do appear willing to pay higher delivery charges for the promise of a shorter fulfilment delay, which can lead to higher margins for the retailer. Offering competitive product prices is therefore not the only way to create customer value. However, it is unlikely that customers value the shipping and handling fee separately from the product price and therefore lower product prices are needed to avoid eroding customer demand when offering fast delivery against higher shipping and handling fees (Rabinovich et al., 2008).

Next to the delivery performance, the guarantee of the firm to solve any problems that might occur is an important aspect of online purchase satisfaction (Alzola and Robaina, 2010). This includes the return policy and access to a representative of the company. Both the delivery performance and the guarantee have a positive effect on the intention to place subsequent orders and the willingness of customers to recommend the company. However, the customer's perception of post-sale factors (delivery and guarantee) is influenced by the pre-sale experience of delivery information, order confirmation, and information on the delivery method (Alzola and Robaina, 2010).

Stock-outs, even a single stock-out experience, in online shopping can have a significant impact on customer satisfaction and lead to a lower repurchase intentions (Dadzie and Winston, 2007). Even though stock availability is often not checked when taking online orders (Duffy and Dale, 2002), product availability is considered as one of the most important parameters for customer satisfaction (Browne, 2009 cited by Lang, 2010). However, Jing and Lewis (2011) assessed the impact of stock-outs at a grocery retailer

in America and found that stock-outs can have both negative and positive effects on customer retention. In the short term, a stock-out could lead to a tendency of increased future buying (e.g. the customer reordering the item that he or she is missing from the previous order due to a stock-out). This is especially the case for those who shop online more often. In the long run cumulative stock-outs will reduce customer retention. The magnitude of this effect depends on the product type. In certain customer segments, for example the market for baby product, stock availability should be prioritised when it comes to the fulfilment of orders (Jing and Lewis, 2011).

According to the research of Dadzie and Winston (2007) the customer is more willing to look for substitutions when the customer expectations about website content, availability of product information and order placement service time are met or exceeded. Consumers are less likely to abandon an online retail website due to a stock-out situation if good product information is available and the website service speed meets or exceeds their expectations. Further, the product type and the amount spent on the product have an influence on the likelihood of substitution. Low priced books or CDs are more likely to be substituted then high priced clothes or personal entertainment products

Next to superior customer service, Anckar et al. (2002) identified another three ways to create customer value in the online grocery market: pricing, a broad and / or specialised assortment, and superior shopping convenience.

1. Pricing

Although competitive pricing is mentioned as a reason to shop online, several studies indicate that online prices are not significantly lower than those in the stores. A literature review by Jeffers and Nault (2011) shows no clear distinction between online and offline prices of consumer products, sometimes the studies report higher e-retail prices than in the physical shops and in other studies the online prices are significantly lower than the offline prices found. Also in the grocery sector there is no evidence found of lower prices online. Several grocery retailers claim on their webpage that the prices online and in-store are equal (Albert Heijn, Asda, Tesco). However, the price sensitivity in the grocery sector is found to be lower online than in supermarkets. Pozzi (2009) studied the groceries purchases of 11,640 USA consumers who bought items online and in the supermarket and found that the online consumers regularly used their past shopping list which reduces the chances of them switching brands online. A similar

study of Chu et al. (2010) in Spain concluded also that the price sensitivity is lower online than in-store and consequently the brand and size loyalty is higher online. They found that this effect is particular the case for food and sensory items and for light online shoppers, i.e. those shoppers that supplement their regular physical shopping trips with an occasional online shop.

2. A broad and / or specialised assortment

Online stores can offer a much larger assortment than any physical retail outlet, especially in peripheral regions where a large assortment is not available in conventional shops. Anckar et al. (2002) argue that a limited assortment is not considered as a competitive offering in the grocery business and that a one-stop-shop is needed to offer the convenience and time savings that is required by many consumers. However, Tanskanen et al. (2002) argue that 90% of the consumer shopping baskets consist out of 200 items that are regularly bought. Online orders include typically those regular bought products, while special items are continued to be bought in-store and therefore a limited assortment (which includes all these regular bought items) will be sufficient.

3. Superior shopping convenience

This includes the convenience of a one-stop-shop (e.g. broad assortment), the possibility to shop anywhere anytime (e.g. time saving), and an easy-to-use website. It is widely argued that online shopping will save time. Boyer and Hult (2006) show that the customer perception of time savings will increase as he / she gains experience in the online grocery shop. Scott and Scott (2008) argue that the time needed to place a typical online grocery order reduces by 40 minutes when consumers order more frequently and can reuse their shopping list.

E-fulfilment is a crucial aspect for online retailers. The quality of this process determines the purchase and repurchase decision of the consumer. For grocery retailing e-fulfilment quality includes a substantial assortment, a webpage and home delivery that is fast and convenient and a good product availability such that online shopping saves time compared to traditional shopping. Below the choices that a retailer has when setting up an online shop are discussed.

2.3 E-commerce business models

There are many different forms of online retailing. The main difference between these models occur in the area of fulfilment (Kämäräinen and Punakivi, 2002). Some companies, who traditionally sold their products in shops before starting to offer an online shop next to the existing physical shops, make use of multi-channel retailing (so-called *Bricks & Clicks* retailers). Other companies may distribute their products through the online channel only (so-called 'pure players'). Both situations are discussed below followed by an overview of the current business models.

2.3.1 Single channel

Pure players are companies that do not have an up-front store presence and sell products only via the internet (Xing and Grant, 2006, p.279). Pure-players have less cost in warehousing, retail property, in-store labour, rent and other operating expenses, but spend more on advertising, branding and customer acquisition, customer service contact, website development and maintenance, order fulfilment, and credit card processing (Min et al., 2008). These costs were higher than estimated by many entrants into the online retail market, leading to the failure of many pure players (Min et al., 2008). Several reasons have been mentioned for the collapse of grocery pure players. Laseter et al. (2000, cited by Fernie and McKinnon, 2003) argued that the main reasons were the limited potential for online sales in the early days of B2C e-commerce in combination with the high costs of delivery, selection-variety trade-offs, and the existing and well-established competition from conventional shops. The same reasons were mentioned by Anckar et al. (2002); overestimation of the size of market, failing in developing profitable business models and failing to achieve a competitive advantage over the existing supermarkets. The costs of picking and delivery of groceries were often too high for pure players to achieve profitability (Ring and Tigert, 2001).

The lack of face-to-face contact can result in difficulties in establishing trust. Also not having local stores makes it more difficult to handle returns. Existing *Brick & Mortar* retailers already have a physical infrastructure, an established brand name and a large customer base, resulting in lower costs to acquire online customers. A McKinsey study shows that traditional store-based retailers spend about $5 a person to bring their existing customers online, whereas pure players spend on average $45 per person to attract customers (Calkins et al., 2000). Min et al (2008) argue that it takes time to

accumulate an established brand name and loyal customers, which was another factor in the failure of many start-up pure players.

However, some pure players have evolved into extremely successful businesses. Amazon is profitable due to the expansion into niche markets, a guaranteed service, the elimination of split shipments (e.g. separate packages for each ordered item, which influences the packaging, shipping and order processing costs), inventory positioning closer to concentrated regional markets and a vast logistics infrastructure which makes its e-fulfilment more efficient than that of others (Min et al., 2008).

The fulfilment process of pure-players is often centralised. A pure-player can build a dedicated warehouse, which will be later explained in section 2.4.1. However, due to the high investment costs; more often they outsource their fulfilment operations. Outsourcing to a third-party logistics provider (3PL) can increase the speed to market and gives the possibility to expand quickly (Bayles, 2001). Due to unpredictable and volatile demand, especially in the start-up phase, outsourcing the picking and packing operations can be beneficial. Outsourcing offers the flexibility to accommodate the different demand levels (Lewis, 2001; Ricker and Kalakota, 1999). Besides that, outsourcing the fulfilment also gives the possibility to the online retailer to focus on the core competence and to increase the customer service quality (Bayles, 2001; Cho et al., 2008). However, also third party providers are not always performing well in e-commerce fulfilment (Bayles, 2001), which can lead to a negative impact on customer satisfaction (Cho et al., 2008).

Drop-shipping

Outsourcing to the wholesaler or manufacturer is called ‘drop-shipping’ (Netessine and Rudi, 2000). In a pure drop-shipping operation, the retailer carries no inventory (Ayanso et al., 2006) but customer orders are directly delivered from the suppliers’ inventory (Agatz et al., 2008b). The retailer takes orders for items that the supplier has in his inventory (Bailey and Rabinovich, 2006). Drop-shipping is more advantageous for the retailer than for the supplier, because the risks of shortage and over-stocking are incurred solely by the supplier (Hovelaque et al., 2007). However, it reduces the total supply chain inventory risks by combining the inventory of several retailers at one central stock point (Agatz, 2009). For that reason Bailey and Rabinovich (2006) found in a study about book sales that drop shipping is particularly used for less popular books or books in the decline stage of their life cycle, to reduce the risks of holding stock.

Generally, drop-shipping is used for non-perishable make-to-stock products (like books and CDs, household goods and gardening equipment) with a relative high wholesale price to make it beneficial for both the retailer and the supplier (Agatz et al., 2008b).

Drop-shipping reduces the retailer's costs of inventory carrying and warehousing (Ayanso et al., 2006; Rabinovich, 2005). However, both the ownership of the inventory and its management can be outsourced. Decisions regarding inventory locations, which influence the delivery distance, transit times and transport costs, are likely to be made by the supplier in the drop-shipping model (Rabinovich et al., 2008). Also the fulfilment task is outsourced, which can lead to a negative customer experience towards the retailer when the wholesaler or manufacturer is not able to deliver the product on time (Rabinovich, 2005). Yao et al. (2008) suggest sharing some portion of the revenue with the supplier as an incentive to improve the delivery reliability. The benefit of drop-shipping is that the e-retailer can focus on the marketing, customer acquisition, and order processing tasks (Rabinovich, 2005), while the supplier benefits from the extra sales generated through the e-retailers' website which give it access to a wider customer base (Del Franco, 2002, cited in Rabinovich, 2005).

2.3.2 Multi-channel

Brick & Click retailers supplement conventional stores with online shops (Burt and Sparks, 2003; Warkentin, 2001). The existing channel can be duplicated online which can lead to increased sales and exploiting economies of scale in the current operations (Lee and Shu, 2005). In the UK grocery sector some retailers, such as Tesco, ASDA and Sainsbury, have duplicated the existing offer in the online channel, offering the same products with the same prices and promotions. However, with this approach there is a chance that no extra sales is created, and that the online channel diverts demand from the existing offline channel to the online channel. Further, the online channel might have other (online) competitors and different customer needs which may require a different logistic set-up from the conventional channel (Lee and Shu, 2005).

The last mile delivery is often performed from local stores. However, when the volume is large enough, dedicated fulfilment centres can cost-effectively support home deliveries and reduce the pressure on local shops. After a successful period of fulfilling solely from local stores, Tesco is now opening highly automated distribution facilities for their home deliveries in London (Anon, 2011a).

2.3.3 E-fulfilment models

Based on the literature, typical business models for online retailing can be identified. The business models with a physical home delivery[1] are summarised in table 2.3.

Model	Explanation	Literature
Brick & Click – fulfilment from stores	Picking in local stores in high density areas	Distributed delivery centres (Ricker and Kalakota, 1999). Local Hero (ECR Europe, 2002). *Brick & Click* supermarkets (Scott and Scott 2006; 2008). Distribution from existing stores (de Koster, 2003).
Brick & Click – fulfilment from distribution centre	Distribution centres supply online orders and conventional stores	Distribution from existing distribution centres (de Koster, 2003).
Pure players – with own warehouse	Used mainly for low-margin products as books and computer industry, e.g. dry goods. Fulfilment is performed by parcel delivery.	Dedicated fulfilment centres (Ricker and Kalakota, 1999). Distance seller (ECR Europe, 2002). Distribution centres (Scott and Scott 2006; 2008).
Pure players – with third party fulfilment centre	Used when they struggle to manage unpredictable demand.	Third-party fulfilment centres or virtual warehousing (Ricker and Kalakota, 1999).
Hybrid strategies	Both fulfilment from local stores and from warehouses, either dedicated to online sales or also fulfilling the stores	Hybrid strategies (Scott and Scott, 2006; 2008). Hybrid structure (de Koster, 2003).
Partner fulfilment operations	No inventory, shops or product brands. Fulfilment is performed by partners	Partner fulfilment operations (Ricker and Kalakota, 1999).

Table 2.3: Business models of e-fulfilment identified in the literature

In line with the findings of de Koster (2003) the main characteristics of the different business models are (i) the location of order picking and packing (e.g. local store, warehouse), (ii) whether they outsource or not, and (iii) the home delivery process. The suitability of the business model depends on factors such as the required delivery time, product characteristics and the expected number of orders (de Koster, 2003). Since the beginning of online retailing business models have evolved. The initial strategy of several grocers to fulfil online orders via a purpose built e-fulfilment centre proved to be expensive, with as consequence that today most online grocers deliver from their local

[1] Excluded are physical home delivery of impulse buys as pizzas and physical home delivery of large items as refrigerators.

stores. For example, the e-fulfilment depots of Webvan in the USA and Sainsbury and Somerfield in the UK are closed down (Fernie and McKinnon, 2009). However, in the last couple of years, retailers start to open e-fulfilment centres again. The latest trends are summarised in table 2.4.

Country	Grocer	Recent change in the service offered
Belgium	Colruyt	Focus on Collect & Go. Start-up of pick-up points separately from Colruyt-shop.
Netherlands	Albert Heijn	Albert.nl delivers from 2 'fulfilment-factories'. In 2012 focus towards pick-up points instead of home deliveries.
France	Cdiscount of Casino, Auchan and Leclerc	Started with Drive-through (comparable with McDonalds drive-through).
UK	Tesco	Offers pick up at special section in the shop, or click & collect at drive-through in parking lot of supermarkets, next to home deliveries. Opening of 4 'Dotcom / dark stores'

Table 2.4: Trends in online grocery retailing (Source: van Essen, 2012)

Home delivery of grocery products is shifting towards one-hour time-slots, short order lead times (for example urbanfetch.com who deliver groceries in New York within one hour of ordering), delivery loyalty schemes where you pay a certain amount for free home deliveries over a certain period, and in-store or drive-through collection for online orders (Rimini, 2010). For other product types, unattended delivery options and parcel shops (next to post offices) are becoming more common (Law, 2010). These alternatives to attended home delivery will be discussed in section 2.4.2.

2.4 The logistics of e-commerce

Although the logistics activities behind e-commerce include the whole process of managing the procurement, movement and storage of materials, parts and finished products, the upstream supply chain is not likely to change due to grocery home shopping as both the e-fulfilment centres and shops are serviced from the same regional distribution centre (Cairns, 2005). Therefore only the e-fulfilment process of order picking, home delivery and returns are discussed in more detail below.

2.4.1 Order picking

Three types of e-fulfilment are possible (Agatz et al., 2008b; de Koster 2003; Scott and Scott 2006):

1. In-store fulfilment: online orders are picked from the regular retail shelves. Many supermarkets make use of this method, for example Tesco and Sainsbury. Examples in the United States are Albertsons.com and Safeway.com (Agatz, 2009).
2. Dedicated fulfilment or e-fulfilment depot: a purpose built facility to fulfil online orders. Examples include Ocado, Webvan[2] (Delaney-Klinger et al., 2003) and Freshdirect (Scott and Scott, 2008).
3. Integrated fulfilment: the online orders are fulfilled from existing distribution centres that also delivered to conventional stores. For example Wal-Mart (Coyle et al., 2009).

<u>In-store fulfilment</u>

Traditional grocery retailers have tended to use their existing physical infrastructure for online food shopping (de Koster, 2002a). Although the majority of grocery home deliveries have been picked in stores, Nicholls and Watson (2005) found in a survey under UK top 500 retailers that only 11.4% of the respondents made use of in-store picking in 2002.

The benefits of picking in store are low investments (Fernie and McKinnon, 2003; IGD, 2012; Ricker and Kalakota, 1999), fast response times (de Koster and Neuteboom, 2001 cited by de Koster, 2002a), increased utilisation of retail assets, pooling inventory of online and offline sales (improving ratio of inventory to sales), and the possibility of a fast roll out (Fernie and McKinnon, 2003; IGD, 2012). Disadvantages of in-store fulfilment are that the supermarket is not designed for efficient picking and the online order pickers impair the shopping experience for existing customers, especially at busy times (de Koster and Neuteboom, 2001 in de Koster, 2002a; Murphy, 2003). The low order picking efficiency in supermarkets leads to high labour costs per order (de Koster, 2002a) and availability is difficult to guarantee (Fernie and McKinnon, 2003).

Fernie and McKinnon (2003) argue, based on industry examples, that in-store picking may be more cost-effective and competitive than from a dedicated e-fulfilment centre.

[2] Webvan went bankrupt in 2001 (Fernie and McKinnon, 2003).

However, several researchers calculated the profitability of an e-fulfilment centre in the early 2000s and found a cross-over point from which the e-fulfilment centre becomes more cost-effective than fulfilling from existing stores (shown in figure 2.2). Kauhanen (2000, cited in Browne et al., 2001) estimated the required sales volume on £450K a week for a dedicated grocery warehouse to become profitable. A similar figure is calculated by Tesco, which estimated the required sales on a minimum of 5000 orders of £100 per week for the e-fulfilment centre to be profitable (Retail Logistics Task Force, 2001). However, Yrjölä (2003) calculated the required sales volume in Finland and determined that in-store picking of online orders is only beneficial in terms of cost below 1 to 3 million Euros of yearly sales depending on the cost structure of the retailer, while other grocers calculated a much higher sales volume for the e-fulfilment centre to become beneficial: Home Runs in the USA calculated a minimum of 8000 orders and Telemarket in France on 10 000 orders a week (Kämäräinen, 2003). Hafsa et al. (2002 cited by Durand and Pache, 2005) estimated that a dedicated warehouse becomes more profitable than fulfilment from the local supermarkets when 20% of the market share is online.

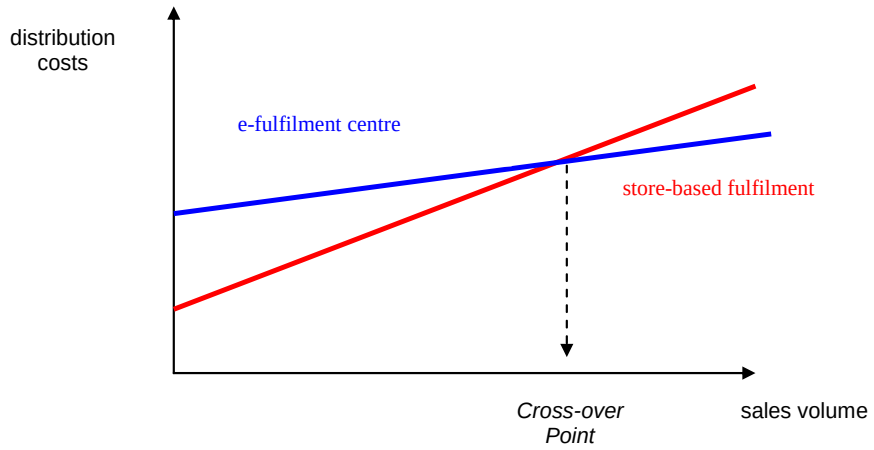


Figure 2.2: Break-even analysis of switch from store-based to e-fulfilment centre (adapted from Fernie and McKinnon, 2003).

The exact location of the cross-over point depends on the fixed costs of both the e-fulfilment depot and the stores and the variable costs like the handling and transportation costs and the extent to which pooling benefits occur between online inventory and inventory for in-store sales (e.g. safety stock requirements can be reduced) (Bendoly et al., 2007). The size and layout of shops, the nature of the upstream distribution system, product range, customer base and geographical location influence the cost functions and therefore the cross-over point (Fernie and McKinnon, 2003). The

above calculations are based on low automated e-fulfilment centres and much higher sales volumes (around US$ 300 million a year or 8000 orders a day) are needed when the fulfilment centre is highly automated (Kämäräinen and Punakivi, 2002) In addition to these economic factors McKinnon et al. (2003) suggested that in practice a maximum of around 600 to 700 orders a week could be handled by a local store.

Dedicated warehouse

Dedicated fulfilment centres tend to be used when the number of online orders increases beyond a certain scale or when a wider assortment is offered online than in stores (de Koster, 2002a). A purpose-built warehouse can lead to economies of scale (de Koster, 2002b). An average warehouse can store more products per square metre and uses 16 times less energy than a shop, depending on the degree of automation (Lovins, 2001). The space can be more efficiently utilised and orders can be picked at high speed (Browne et al., 2001). Automation such as conveyor belts and pick-by-light can be used to make the picking and packing process more efficient and reduces the number of mistakes (Scott and Scott, 2008). Also carousels and case-flow racks can be used to make small order picking more efficient (de Koster, 2002b). The picking speed for groceries in a dedicated fulfilment centre has been estimated between 300 and 450 items per hour, which is approximately 3 to 4 times faster than in-store picking (Delaney-Klinger, et al., 2003, Kämäräinen et al., 2001b). As argued earlier, a high throughput rate or high sales volume is needed to justify the investment and to avoid high inventory holding costs (Ricker and Kalakota, 1999; Browne et al., 2001; Fernie and McKinnon, 2003). This will be further discussed at the end of this section, under the automation heading.

Whether the orders are picked in an e-fulfilment centre or in a local supermarket has an influence on the perceived product quality (Boyer and Hult, 2006). New customers rate the product quality higher when picked from a supermarket, but repetitive buyers are more positive about the product quality when picked at a dedicated fulfilment centre. This may suggest that it takes a while to realise the advantage because of the initial concern about dealing with a fulfilment centre far away that they cannot physically see (Boyer and Hult, 2006).

Interestingly, the study by Boyer and Hult (2006) did not find a significant difference in the perceived product freshness between items store-picked and picked from a dedicated fulfilment centre, although the supply chain should be shorter when goods were picked

in a fulfilment centre. According to Tanskanen et al. (2002) each tomato in the supermarket is touched on average 11 times before it is bought, while it is only touched 3 times when delivered from an e-fulfilment centre. Fresh products can be delivered quicker to the consumer when using an e-fulfilment centre as it eliminates the movement to the local store (IGD, 2012). However, the last mile delivery is likely to take longer due to longer transport distances from the centralised e-fulfilment centre (de Koster, 2002b; Hovelaque et al., 2007). Another disadvantage with the dedicated fulfilment centre is that it is more difficult to dispose of products at or near the end of their shelf-lives than in a shop, where in-store promotions can be used to off-load this stock.

An overview of the advantages and disadvantages of e-fulfilment centres versus in-store picking is given by de Koster (2002b; 2003) and can be found in table 2.5.

	Advantages	**Disadvantages**
Order picking and delivery from local stores	Low investments, easy to set-up for companies with stores Fast response times Knowledge of customers and market	Stores not designed for efficient order picking Additional processes necessary (order packaging) Interference with existing customers Small service area High operational costs
Order picking from e-fulfilment centre	Layout, design fit for small-orders picking Economies of scale obtainable No interference with other processes Larger area can be served than from stores	High investments (depending on degree of mechanisation) Volume is needed Long transport distances; time needed

Table 2.5: Advantages and disadvantages of different fulfilment strategies (Source: de Koster, 2002b; 2003 with little modifications)

Integrated warehouse

It is very unusual for an existing central warehouse (for the traditional supply to shops) to be used for fulfilling online orders as these facilities are not designed for individual item picking and the packing of small orders for customers. They are designed primarily for storage, picking and handling of goods in cases (Bendoly et al., 2007). De Koster (2002b) argues that picking from a distribution centre designed for fulfilling supermarkets is also inappropriate due to differences in information systems, inventory

management procedures and the nature of the outbound transport operation. However, technical improvements may make it possible to have an automated handling system for a wide variety of product sizes and weights which can deliver highly efficient, multi-channel order-picking solutions (Rutter, 2009).

Automation

The fulfilment process in online retailing is challenging due to the small orders to the large number of different customers and the unpredictability in demand, i.e. huge potential customer base and high probability of demand fluctuations (Bayles, 2001; Du et al., 2005). These customers have also been conditioned to expect a very large product range in conventional supermarkets and the complexity of the picking increases with the product diversity. To respond to customers in the B2C environment, Tarn et al. (2003) argue that a flexible and automatic efficient fulfilment system is needed combined with a punctual and cost effective delivery system. Although many online retailers are currently using manual picking systems, automated handling systems can be more appropriate and cost-efficient solutions for the growing volumes of online orders and their high service level requirements (Rutter, 2009). Manual picking requires a large labour force while variability in the volume and pattern of online orders makes it harder to utilise the labour resources cost-effectively day by day. Automated handling systems result in higher pick rates at a feasible cost, reduced error rates, enhanced load security, ability to pick individual orders, and offer total traceability (Rutter, 2009). Automated systems also reduce the space needed, as they allow access to tightly packed shelves (Arminas, 2005). High investments in material handling hardware and information systems may be needed in order to achieve the high levels of accuracy and efficiency that is required in online retailing (Tarn et al., 2003).

Automation has to be able to offer high utilisation of warehousing and materials handling capacity to achieve cost savings (Kämäräinen, 2003). However, the capacity of the automated system must grow with demand to make sure that customer orders can also be fulfilled in peak periods (Arminas, 2005). This can mean that the average capacity utilisation is poor (Kämäräinen and Punakivi, 2002). Although the automated warehouse of Webvan was approximately 10 times more productive than traditional shopping by the consumer themselves (Lunce et al., 2006), the over-investment in automation was one of the main factors leading to the company's collapse (Kämäräinen and Punakivi, 2002). An automatic distribution centre is only beneficial when the

demand is stable and high (Kämäräinen and Punakivi, 2002). Therefore Kämäräinen (2003) argues that it is better to have the flexibility of using a more manual picking when demand fluctuates widely.

2.4.2 Home delivery

Home delivery, on the so-called 'last mile', encompasses the activities that physically move the product to the consumer (Agatz et al., 2008b). It is argued that grocery home delivery services can be cheaper than conventional shopping where consumers go to the supermarket (Punakivi and Saranen, 2001). This calculation is based on an assumed economic value of €3.36 per hour that consumers put on their free time (Punakivi, 2003). By internalising the order picking function that consumers have been performing themselves, retailers are incurring additional costs which must be passed on the customer (Delaney-Klinger et al., 2003). In the case of Webvan, the US grocer with 30 minute time windows and a centralised automated warehouse, the cost of home delivery was estimated at $10 to $20 per order (Delaney-Klinger et al., 2003). In the UK the cost of order processing, picking and delivery was estimated between £8 and £20 per order depending on the picking location and the utilisation of the van (Retail Logistics Task Force, 2001). These costs are determined in the early 2000s and are most likely even higher today. In most cases today the delivery costs paid by the consumer are not more than £5 per delivery, meaning that most online retailers do not charge their customers the full costs of home delivery (Nicholls and Watson, 2005; Retail Logistics Task Force, 2001) and must subsidise the operation out of the profit on the product sales.

One way to improve the profitability of home delivery is to incorporate incentive schemes (Campbell and Savelsbergh, 2006). These can be quite sophisticated incentive schemes, for example, providing time slots with incentives depending on whether the delivery van is in the neighbourhood, or by developing an easier scheme which encourages customers to accept wider delivery windows. In that way the demand can be spread more evenly over the different time slots (Campbell and Savelsbergh, 2006). Agatz (2009) showed that up to 10% can be saved if only certain time windows are offered in a particular neighbourhood. Deliveries in the same neighbourhood can then be combined in one (or just a few) delivery rounds instead of driving back and forth between different neighbourhoods.

Furthermore, short lead times between order and delivery increases the home delivery cost (Grando and Gosso, 2005). Same day deliveries are based on a dedicated courier

trip which often returns empty to be able to meet the deadline, increasing the last mile costs substantially. The consolidation possibilities that arise in next-day delivery can reduce the costs significantly. For example a parcel delivery from London to Birmingham can cost £19.90 for next-day delivery versus £272 for same day delivery. The same day delivery price is based on a dedicated vehicle and the distance, and a same-day delivery within the city might be as little as £10 (MacLeod, 2009). The situation is different for grocery products. These are often picked and delivered locally with means that the lead time between picking and delivery is much shorter. Tesco, for example, offers the possibility to deliver in the evening if the order is placed early in the morning and a grocery retailer in France gives the possibility to pick up the order 2 hours after placing it online (Croccel, 2011). This service is offered at the same delivery fee than placing the order earlier in the week.

Although the customer order value does not have a particular influence on the total delivery costs (Grando and Gosso, 2005), a higher customer order value reduces dramatically the relative costs of the delivery charge (Laseter et al., 2000). Grando and Gosso (2005) argue that time is the scarce resource in the delivery process and not the capacity. Therefore the cost to deliver a package will be the same regardless of size or value.

The cost efficiency of home delivery depends on a low average distance per order and the simultaneously high number of stops per hour (Punakivi and Saranen, 2001). There is a negative correlation between the customer density or drop density and the transit time of the truck and consequently with the cost of a single delivery (Grando and Gosso, 2005). Based on cost calculations for the Finish grocery market, Yrjölä (2003) found that a critical threshold exists at an average distance of 500 metres between drops. After this threshold a decrease in distance between drops (or an increase in sales) has no substantial effect on delivery efficiency (Yrjölä, 2003). However, this economy of scale in home delivery can only be reached in the unattended delivery situation (e.g. to a reception box) where packages can be delivered based on location on not on consumer availability (Yrjölä, 2003).

Small delivery windows lead to higher home delivery costs (Grando and Gosso, 2005). Agatz (2009) calculated that replacing half day time windows with 2-hour time slots increases the costs by up to 25%. Also Nockold (2001) argues that removing short time windows can improve the transport costs by 27-36%, depending on drop density and the

number of drops per vehicle. Saranen and Smaros (2001 cited by Campbell and Savelsbergh, 2005) found that a half-hour delivery window as offered by Webvan was 5 times more expensive than the unattended deliveries offered by Streamline.

Unattended delivery provides the lowest cost of home delivery (Grando and Gosso, 2005; Punakivi and Saranen, 2001). Unattended deliveries lead to lower delivery times and better planning of the delivery round (Grando and Gosso, 2005). The delivery time per drop can be reduced from 10 minutes to 4 minutes, because there is no customer present to check off all the items in the order (Rowlands, 2001b). According to research in Finland, the costs of home deliveries with a reception or delivery box is 44-53% lower than the standard of attended delivery within two-hour delivery time windows (Punakivi and Tanskanen, 2002). In the attended delivery situation, the delivery van has to drive back and forth, increasing the costs to about 2.7 times the cost of once-a-week unattended delivery (see figure 2.3) (Yrjölä, 2003). This is because the number of deliveries per hour will be 1.9 times higher (Punakivi and Tanskanen, 2002). Unattended deliveries also level the demand during the day and can permit night-time delivery, improving the utilisation rate (Kämäräinen et al., 2001b).

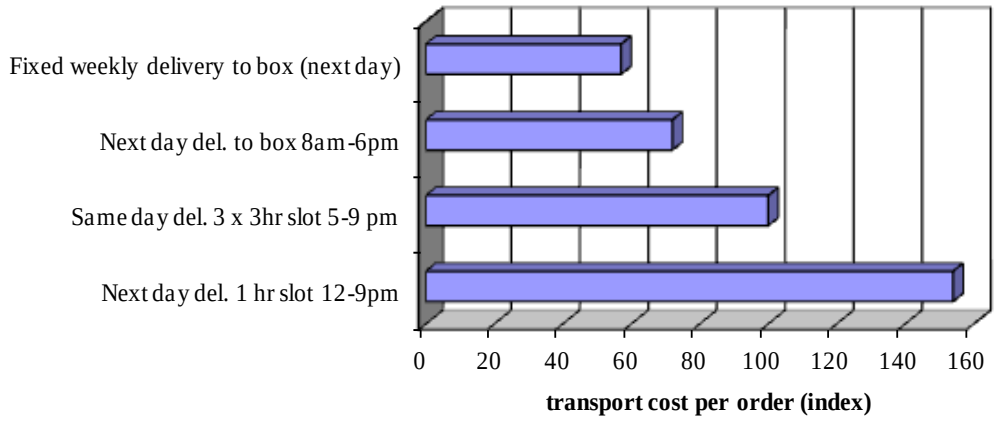


Figure 2.3: Relative cost of home delivery options (Source: Yrjölä, 2003)

However, attended delivery might be needed in some situations, for example for security reasons, perishable goods, or large goods (Agatz et al., 2008a). To benefit from the cost savings of unattended delivery and still provide a secure delivery, several alternatives to unattended delivery are developed. The main alternatives, including access to home or outbuilding, reception box, collection and delivery point (CDP), or delivery to a local agency (McKinnon and Tallam, 2003) are discussed below.

Access to home or outbuilding

One example of remote access control systems is Ahome4IT. Consumers can leave the key of their house or shed in a key box fixed to the outer wall of their house. Couriers, who want to deliver a package, can contact the company to gather the digital code of the key box, giving them access to the house or shed (Ahome4it, 2012).

Reception box

A reception box or drop box could be either a fixed internal box, a fixed external box, a mobile reception box, or a communal reception box (McKinnon and Tallam, 2003). Secure boxes for on the doorstep were offered by BearBox, Homeport, and Dynamid (Anon, 2001; Rowlands, 2001a). However, these companies moved their service to the business-to-business market or were withdrawn (Rowlands, 2006). Another box, which was built into the wall, was offered by Giraffe marketing (Rowlands, 2004). The price of these build-in reception system, including the refrigerated section, cost around £ 7K in the UK and was considered too high for mainstream adoption (Rowlands, 2004). Besides that, Xu et al. (2008) found in a survey of 125 online shoppers in the United Kingdom that consumers have concerns regarding the safety, space and planning permission regarding installing a secure box at the consumer's home and favour deliveries to neighbours over using a reception box. Kämäräinen and Punakivi (2004), however, found other consumer perceptions. They asked consumers in Finland, who used the reception boxes for 2 months, about their experiences. Consumers reported that the reception box saves time, gives flexibility, gives independence from supplier timetables, reduces the need for carrying groceries, decreases the amount of impulse buying, and increases systematic purchasing. Also e-tailers appear to be in favour of reception boxes as it is an effective and efficient way of minimising delivery costs (Xu et al., 2008).

In the communal reception box situation, for example offered by ByBox (Rowlands, 2008), the box is shared with other consumers and is available to the user for one-off deliveries. After paying an additional delivery fee to Bybox, the delivery is made directly to the locker box where consumers can pick it up at a convenient time (Bybox, 2012). Amazon started to offer a similar service with locker boxes in London in 2011 (Henderson and Lamkin, 2011). The development of this solution is slow in the United Kingdom due to missing investments from carriers or retailers (Anon, 2005). However, the take-up of communal reception boxes is higher on the continent, as illustrated by

Deutsche Post's Pack Station network and La Poste (Miller, 2008). In economic terms, the communal reception box is more attractive than a reception box. The payback period is calculated to be two or three years with an utilisation level of 75%, and three to five years with an utilisation level of 50% (Punakivi and Tanskanen, 2002). By comparison, an individual reception box will have a payback period between 6 and 13 years depending on the number of deliveries per day[3]. Further, the communal reception box provides low operational costs with a fairly small number (40-60) of deliveries per day (Punakivi and Tanskanen, 2002).

Collection and Delivery Point (CDP)

A CDP can be a local post office, workplace, existing retail outlets, or a purpose built collection centre. It offers the possibility to carriers to have a secured delivery without the need for re-scheduling deliveries to the consumers' homes or making more than one trip (Cherrett and McLeod, 2005). After early examples as Dropzone1, m-box, Urbandrop and Collectpoint (Anon, 2000), delivery to local CDPs declined and was rarely used within the United Kingdom despite the fact that most consumers are willing to collect purchased items from local CDPs (Xu et al., 2008). Although this option can save delivery costs and time, the study shows that e-tailers were not very keen to offer a collection hub option to consumers (Xu et al., 2008). In the recent years the CDP market is growing. Kiala, started in 2001, has grown to over 7000 CDPs in Belgium, France, Luxembourg, Spain, the Netherlands and in the last year also in the UK (Kiala, 2013a). And Collect+ has grown to over 5000 CDPs in the UK in the past 3 years (Collectplus, 2013). These CDPs are mainly small retailers who benefit of additional consumers visiting their store (Kiala, 2013b).

Purpose built collection centres are used in the grocery market. These pick-up points or drive-throughs are widely tested in France since 2004 (Cavill, 2009). In 2012 Albert Heijn opened its first pick-up point for groceries products in the Netherlands (see figure 2.4).

[3] The payback period is calculated by dividing the investment in the reception boxes by the reduced home delivery costs due to the reception boxes compared to a 2-hour delivery window.

Figure 2.4: Pick-up point of Albert Heijn in Tilburg, the Netherlands

Especially for groceries, where the product margins are already small, CDPs may be viable in the long term. It provides a convenient and cost-effective alternative to home deliveries (Chappell, 2000). These pick-up points are built in easy accessible areas, for example next to the motorway, making it easier to reach than the local supermarket (Albert Heijn, 2012).

Local agency

This option is an extension of the CDP concept where the operator provides a delivery service to the online customer's home at a convenient time (McKinnon and Tallam, 2003). One early example of this 'collection and delivery' service was Beck & Call[4] which operated in several London boroughs (Anon, 2000).

2.4.3 Returns

Returns are more likely to occur in the case of online sales due to the inability to see or feel a product before purchase (Tarn et al., 2003; Ofek et al., 2007). The average return rate for non-food items lies between 25 and 30% for online retailing while only 6 to 10% is returned in the conventional retail model (Edwards et al., 2010a). The majority of these returns are not caused by product faults or damages. Dissanayke and Singh (2006) found in a survey of 310 Australian e-business companies that almost 26% of returns were caused by the consumer changing his or her mind. In almost 18% of cases the product was returned because the consumer had clicked on the wrong item when ordering.

[4] Beck & Call was forced to close down due to a lack of customers (Ely, 2005)

While returns can have many causes and occur to some extent in all product groups, returns due to product inadequacies in matching product characteristics with customer expectations and errors in retailers' transactions, occurs for a relatively narrow group of products (Rabinovich et al., 2011). The return percentage of several product categories is given in table 2.6.

	Belgium (VIL, 2011)	**UK (Edwards et al., 2010a)**
Clothing and Shoes	25.6%	35-40%
Books, DVDs and CDs	6.7%	3-20%
Multimedia	3.8%	4-20%
Grocery	1.3%	-

Table 2.6: Return percentage of different product types in Belgium and the UK

Other factors that determine the return rate are speed and reliability of delivery. ECR Europe (2002) found that the later the order reaches the consumer, the higher the probability is that it will be returned.

A high return rate can lead to retailers pushing the extra costs of handling returns onto the consumer (Ofek et al., 2007). In a market where customers are less sensitive to price but regard the return policy as important, companies can ask for higher prices in return for a generous return policy (i.e. the whole or almost whole price paid would be returned). The high costs managing this returns policy can then be covered by the higher prices (Mukhopadhyay and Setopurtro, 2004). However, in more price sensitive online market operating on slimmer margins, a less generous returns policy may have to be offered.

Returns are handled differently for pure-players and *Brick & Click* companies. Multi-channel retailers offer, in most cases, the possibility to return the product to one of their stores (Agatz et al., 2008b). Several returning methods exist (Edwards et al., 2010a):

- Carrier collection: carriers take back the items while driving their delivery round.
- Postal service: the consumer brings the package to the local post office.
- Collection / delivery points: after notifying the retailer or parcel carrier, the consumer can bring the package to an agreed CDP.
- Multi-channel retailers can offer the possibility of returning the unwanted item to one of their physical stores.

In many cases, the returned low-value items will be scrapped. The costs of checking and repacking the products may exceed the product value (Rowlands, 2002). More saleable items will be repacked and resold as new (Morrell, 2001; Rowlands, 2002).

Returns are less an issue in the FMCG sector. However, home delivery is. The current delivery fee does not represent the full picking and delivery costs. In countries where the grocery retailers have generally a low profit margin, the picking and delivery costs cannot be funded out of the product sales profit. Unattended delivery and click and collect options can reduce the delivery costs and perhaps lead to further expansion of online grocery shopping in these countries. Another option is to bypass the retailer and sale directly to the consumer. Manufacturers can then subsidise the picking and delivery costs out of the retailers' margin. This is further assessed below.

2.5 Channel conflict

A manufacturer who establishes a direct channel and thereby bypasses the retailer becomes a direct competitor of the retailer. The potential tension that arises is called channel conflict (Tsay and Agrawal, 2004; Yue and Liu, 2006). Channel conflict is *"the situation in which one channel member perceives another channel member to be engaged in behaviour that prevents or impedes it from achieving its goals"* (Stern and El-Ansary, 1992, p.289). Channel conflict is an urgent concern for manufacturers adding a direct online channel (Jelassi and Leenen, 2003; Lee et al., 2003; Webb, 2002). Another type of channel conflict can occur within a company. This happens when the internet channel competes with its own traditional *Brick & Mortar* channel (Lee et al., 2003). This will be further discussed in the next section.

In both types of channel conflict cannibalisation of sales can arise. At this moment it is unclear if the extra online channel will generate extra demand, or that customers of the current physical channel will shift to the online channel (Agatz et al., 2008b; Rosenbloom, 2007). Pozzi (2009) analysed the grocery shopping history of 11,640 households and found that 30% of online sales shifted from offline supermarket sales and 70% represents new sales for the particular retailer. However, in this study only a single retailer was analysed and Pozzi did not investigate where the additional shop-based sales were lost by other retailers.

2.5.1 Within a Brick & Click company

Brick & Click companies with two channels must decide if they integrate or separate the online and traditional channel. Integration can offer benefits for cross-promotions, shared information, purchasing leverage and distribution efficiency (Gulati and Garino, 2000). However, it might also lead to internal customer conflicts in, for example, product pricing, advertisement, budget allocations and revenue goals (Webb, 2002). A separate online channel can focus on a different consumer segment (Gulati and Garino, 2000; Nicholls and Watson, 2005). However, in that case the company needs to divide their internal resources such as capital, personnel, products and technology between their online and offline channel (Webb, 2002).

2.5.2 Between manufacturer and retailer

Disintermediation or the elimination of intermediaries (which can be distributors, resellers, dealers or retailers) can improve supply chain efficiency and avoid distributor fees (Lee and Shu, 2005). Typical benefits of the direct online channel are better visibility of the demand pattern (Lee et al., 1997b), reduction in inventory as none will be needed by intermediaries (Laseter et al., 2003; Tsay and Agrawal, 2004), more control of distribution and pricing than when the products are sold via retailers (Hua et al., 2010; Lee et al., 2003; Tsay and Agrawal, 2004), and more valuable consumer information can be gathered (Lee et al., 2003). Some manufacturers have established direct channels in the past to be better able to utilise their production capacity (Webb, 2002) or to increase their profitability (Chiang et al., 2003; Hua et al., 2010; Yue and Liu, 2006). Another reason to bypass the retailer is to be able to offer the whole assortment online, especially when retailers offer only a small part of the manufacturer's total assortment and it creates more flexibility in experimenting with new products (Tsay and Agrawal, 2004). Furthermore, it creates the possibility to attract new customer segments (Hua et al., 2010; Yue and Liu, 2006) or targeting more precise markets (Webb, 2002). Besides that, disintermediation makes the supply chain more efficient and reduces order lead times, which can be extremely beneficial for perishable items. For example, FreshDirect managed to reduce the inventory between the supplier and the consumer from around 7 to 9 days to 1 day (Laseter et al., 2003).

Disintermediation also has disadvantages. Intermediaries often have long term relationships with the end-consumer. They have an established brand and product awareness through advertising and customer education. They can provide wide market

coverage, a broader assortment, offer customer support and can most likely fulfil demand efficiently and satisfactorily (Tsay and Agrawal, 2004). They may also be able to generate more sales of the manufacturer's products than the manufacturer itself. This is partly because the manufacturer will be unfamiliar with direct selling to consumers. Dealing directly with consumers can greatly increase their transaction costs (King et al., 2004). Generating enough sales to become profitable may also be difficult, especially in markets where the consumer demands variety (Lee and Shu, 2005). Besides that, the risk of being delisted from the retailer's shelves might be an important reason not to bypass the retailer (de Koster, 2002b). Several manufacturers have tried to bypass the retailer, but have given up quickly for one of the reasons.

2.6 Conclusion

Since the opening of the first online Pizza Hut almost 20 years ago, online retailing is greatly developed. The fast growth of dot-coms in the beginning was of short life with the bubble bursting in 2000. But also after the collapse of the many dot-com companies, the online retail market has been greatly evolved. This chapter reviewed therefore the literature on online retailing since 1995, taking into account that the landscape is changed and that the findings of the early studies might not be applicable today. Also, most research on e-fulfilment is done in Finland (as part of the ECOMLOG project[5]) and in the United Kingdom. The nature and rate of the online retail growth between these countries, and other countries, has varied a lot. Also the home delivery services vary significantly between the countries. This make is even more difficult to generalise and extrapolate the results of previous research. Even so, this chapter provides an overview of the concepts of online retailing and discusses the logistics aspects behind an online order.

E-fulfilment differs from traditional fulfilment to stores in a number of ways. It is more difficult to manage due to the large number of small orders to be picked and delivered to the homes of numerous consumers in markets in which demand is relatively volatile (Bayles 2001; Du et al., 2005). At the same time there is less room for mistakes; the consumer expects an even higher service quality than in conventional shopping (Dadzie and Winston, 2007). This is especially important as the nature of the fulfilment process influences the repurchase intention of the consumer and therefore future sales (Chiu et al., 2009). Providing an efficient fulfilment process is therefore crucial.

[5] ECOMLOG project, running from 1999 to 2002 at the Helsinki University of Technology, studied cost-efficient distribution models for e-grocery shopping in Finland.

The organisation of the fulfilment process depends on the presence and nature of a physical channel. *Brick & Click* retailers, and especially grocery retailers, often make use of their local stores for the picking of online orders. Due to low investment costs, in-store picking is cost-effective with low online sales and is therefore suitable for a fast roll out of the online business (Fernie and McKinnon, 2003). When sales increase above a critical threshold, a dedicated e-fulfilment centre becomes economically beneficial. Where exactly the cross-over point is located depends on the handling and transportation costs, inventory pooling opportunities, and the fixed costs of the stores and e-fulfilment centre (Bendoly et al., 2007; Bretthauer et al., 2010). Pure players either make use of purpose-built e-fulfilment centres from the start, or (more often) they outsource the fulfilment allowing them to focus on the core competence of marketing and customer acquisition while benefiting from lower distribution costs (Bayles, 2001).

The home delivery service is influenced by the customer density, the time-windows offered, and the lead time between order and delivery. Lengthening delivery times, load consolidation and unattended delivery can substantially reduce transport costs per order. However, in some sectors of the online market home deliveries are shifting towards the more expensive solutions such as same day delivery (even within 90 minute after ordering) and one-hour time slots, offering greater convenience at the expense of much reduced transport efficiency. Also solutions where the consumer can decide when to pick up a package, like click & collect, CDPs and secure locker boxes, are emerging more frequently and can reduce the home delivery costs while improving the customer service.

Some of the early research on online retailing suggested that it would create an opportunity for manufacturers to sell direct to consumer and bypass retailers. However, until today little evidence exists of this, particularly in the FMCG sector. Even though there are threats in bypassing the retailer, like delisting, manufacturers can work together to offer the products directly to the consumer. One of such partnership example is alice.com, an online marketplace in the United States that sells product directly from the manufacturer to the consumer (Alice, 2013). With one in four FMCG manufacturers in the United Kingdom looking to open an online shop in the future, disintermediation might perhaps be still in its infancy.

Despite increase in amount of research there as still major gaps in our knowledge. For example the relative environmental impact of different e-fulfilment systems is still

unknown. It is sometimes argued that online retailing has a lower impact on the environment than traditional retailing. Also in the grocery sector several claims are made (for example by Ocado). However, as shown in this chapter, many factors influence the performance of the e-fulfilment. For example, time windows and the use of unattended delivery systems can greatly influence the kilometres driven and therefore the transport emissions. The overall outcome will not only depend on the distance driven, but also on the energy use in the picking location and on the consequences of online retailing like returns. Therefore the environmental outcome will depend on the design of the e-fulfilment model. The next chapter will therefore review the literature and studies available on the environmental effect of online retailing.

CHAPTER 3: ENVIRONMENTAL IMPACT OF ONLINE RETAILING

In this chapter the environmental impact of e-commerce is assessed. For this purpose, the literature search on online retailing is extended with a search for papers that conduct an environmental analysis of online retailing, including both carbon footprint studies and full Life Cycle Assessments (LCAs) of online retailing. Those studies measure and quantify the environmental impacts of online retailing. Carbon footprint studies measure the environmental impact in carbon dioxide (CO_2) emissions, while LCA studies can measure several environmental impacts of a certain product of service (Finkbeiner, 2009).

In the first part of this chapter, the environmental impact of the different processes behind online retailing are examined, including ICT operations, supply chain impacts and consumer behavioural changes. The second part of the chapter focuses on different product types and their impact on the environmental footprint of online retailing relative to conventional retailing. The concluding section discusses the aspects that must be considered when conducting an LCA for an online retailing operation.

3.1 Introduction

Several studies have been conducted on the environmental impact of online retailing. For example, Weber et al. (2009) conducted a LCA study on the online purchase of a flash drive and Edwards and McKinnon (2009) performed an environmental analysis of the online purchase of books. Due to differences in scope, system boundaries and assumptions in these studies, it is still not possible to give an definitive answer to the question whether online retailing is generally better for the environment or not. Decisions about system boundaries, assumptions and approximations make a LCA of online retailing extremely difficult (Abukhader, 2008; Matthews et al., 2001b; Rizet et al., 2010b; Yi and Thomas, 2007). Rizet et al. (2010b) compared several carbon footprint studies of the ‘so-called’ last mile for consumer goods and found that the results may vary from 21 to 650 gram CO_2-eq per kg mainly reflecting differences in assumptions. Assumptions about the number of products purchased and delivered at one time, distance, trip chaining, and the geographical boundary drawn around the supply chain are critical (Rizet et al., 2010a;b). The impact of failed deliveries, product returns, trip chaining and browsing trips can have an important impact on the environmental outcome (Edwards and McKinnon, 2009), though these effects are often not included in

the LCA studies (see for example Weber et al., 2008 or Liyi and Chun, 2011). Potential changes in transport systems and consumer travel behaviour are also often excluded, despite the fact that they can significantly influence the environmental impact of e-commerce (Abukhader, 2008; Abukhader and Jönson, 2003).

To assess the environmental impacts and consequences of online retailing it is useful to categorise the effects of e-commerce into first, second and third order effects (Fichter, 2003). The first-order effects include the production and use of ICT infrastructure. The second-order effects arise from supply chain processes, while the third-order effects result from changes in consumption patterns or habits. These effects and some examples are listed in table 3.1.

Effect	**Caused by**	**Examples**
First-order	Infrastructure	Terminal equipment such as the PC, mobile phones Network infrastructure servers, routers, etc.
Second-order	Application	Supply chain Change in warehousing, transportation, packaging etc. Consumer travel due to failed deliveries and returns
Third-order	Changes in consumption patterns, new habits, and rebound effects	Increase in consumption Changes in consumer travel behaviour

Table 3.1: Categorisation of environmental effects of online retailing (adapted from Abukhader and Jönson 2003; Türk, 2001)

3.2 First-order effects

These effects arise from the production, use, repair and disposal of ICT equipment used for e-commerce transactions, the associated use of hazardous substances, the related energy consumption and the generation of electronic waste (Abukhader, 2008; Fichter, 2003). Although they are not often considered in environmental assessments of e-commerce, many of the externalities of e-commerce are associated with the first-order effects (Yi and Thomas, 2007). It is not known how much of the energy consumption in the production and use of the ICT infrastructure is attributable to e-commerce as opposed to other ICT activities, and the extent to which e-commerce is creating additional waste of electrical and electronic equipment (WEEE) (Fichter, 2003).

In the LCA study of Sivaraman et al. (2007) a part of the energy used in the manufacture and disposal of a computer is allocated to the online ordering process by using a burden factor: i.e. a ratio of the number of hours of computer use for the

ordering to the total number of hours the computer is used in its entire lifetime. In this study the assumption is made that it will take 7 minutes to order one DVD and 5 minutes for each subsequent DVD. Other research (Weber et al., 2009) uses an upper bound estimate of 11 to 20 minutes of shopping online for a CD. This time is assumed to be fully allocated to the purpose of buying the CD, although often computer users perform multiple computing tasks at the same time (Weber et al., 2009). In a LCA study of Marks and Spencer (Collins and Aumônier, 2002) it was estimated that a customer spends 10 minutes on a PC per product ordered. Scott and Scott (2008) argue that grocery shopping takes about 20 minutes when reusing a past shopping list, while consumers who place an online grocery order for the first time spend approximately an hour. With a mobile app this can be even further reduced (Drell, 2012). HomePlus in South Korea is one of the first examples of a service offering customers the possibility to do grocery shopping while waiting for the train, using a Smartphone app (Tesco, 2011). The use of Smartphone apps is increasing. An online grocer in the UK reports that the percentage of consumers using the app increased from 12% to 18% between 2010 and 2011 (Ocado, 2012), reducing the environmental impact of placing an online order.

Besides the energy used by the computer, Sivaraman et al. (2007) also included the direct energy use of lighting and air conditioning / space heating in the customer's room while the DVD is being ordered. Williams (2002) also distinguishes between the total life cycle energy for the computer and direct energy use in lighting and heating appliances. He argues that relatively little energy is used in the production phase of lighting and heating appliances, compared to the usage phase, and therefore the production impacts can be ignored. On the other hand, the production of computers contribute significantly to the total life cycle energy of computers and omitting that would affect the environmental results. However, it is not clear if any energy related to lighting and heating will be saved if the consumer would not shop online. Attributing this impact to the online order is therefore questionable.

Next to the ICT operations at the consumer's house, the construction, use and ultimate disposal of computer servers for data warehousing, hosting, back-up, and system management functions will also have a negative impact on the environment, both in terms of energy consumption and in landfill, and hence need to be incorporated into the environmental assessments (Matthews et al., 2001b). The search engines, which consumers typically use before buying online, run on servers which have a further

negative environmental impact. For example, it was estimated that the average Google search (including both the Google servers and the consumer PC) emit 7g of CO_2 (BBC, 2009). Google, on the other hand, argues that they are directly responsible for only 0.2g of CO_2 per search (Clark, 2011). This illustrates the difficulty of establishing an accurate and agreed set of emission factors for some of the first-order effects of online shopping.

3.3 Second-order effects[6]

The second-order effects can yield environmental benefits as a result of increased resource productivity in the retail supply chain due to online retailing (Fichter, 2003; Yi and Thomas, 2007). The result depends, however, on several key parameters, including additional packaging, shipping distances, choice of transport modes, population density, order return rates, and trip chaining (Fichter, 2003; Matthews and Hendrickson, 2001; Williams, 2002). These parameters significantly change the outcome of the environmental analysis of e-commerce versus traditional retailing. The second-order effects of B2C e-commerce will be discussed in greater detail below for particular stages in the supply chain.

3.3.1 Production, Inventory, and Order Picking

According to Kämäräinen et al. (2001a) warehouse picking and packing can be more efficient than in-store picking, especially when the warehouse is designed for home deliveries. Warehouses generally use less energy per square metre than retail stores, up to 16 times less for manual warehouses (Lovins, 2001; Romm et al., 1999). Routing products through warehouses and bypassing conventional shops therefore reduces the space-related energy use per product. Automated sortation in the parcel hubs, through which most non-food online orders are channelled, is however relatively energy-intensive. This is also the case for the mechanised picking of orders in some of the distribution centres of online retailers. Specific warehouse energy consumption per item depends on a range of factors, including the nature of the product, the types of handling equipment used, the nature of the racking, the space utilisation and degree of mechanisation (Marchant, 2010). To calculate the energy per product channelled through a warehouse or shop, Edwards et al. (2011) suggest dividing the building's

[6] Rebound effects are often called second-order effects. In this review, however, rebound effects are categorized as third-order effects.

average energy consumption by the average number of items handled and the average length of time they spend there.

Besides the electricity used per square metre, centralised picking and packing of customers´ orders reduces the number of inventory locations and therefore the inventory in the supply chain and the warehouse space needed (Matthews and Hendrickson, 2001). However, the centralisation of warehousing will increase the outbound delivery distances (Siikavirta et al., 2003). A decentralised system on the other hand, where picking and packing are performed in stores, keeps the products consolidated for longer which increases the delivery efficiency (Cairns, 2005). It also shares building space, heating and lighting with conventional retailing, reducing the incremental energy and other resources required per order picked. The net environmental effect of these options is not clear and therefore both situations need to be examined when assessing the environmental impact of online retailing. Further, decisions have to be made about whether to include only the incremental energy or to average the energy over the items equally. Choosing the method of allocating the energy used for heating and lighting in conventional retailing to specific online orders is also subjective matter.

E-commerce might allow producers to more closely match supply to demand fluctuations, which can result in lower levels of inventory and production waste (Caudill et al., 2000; Siikavirta et al., 2003). Online retailing might lead to just-in-time replenishment, reducing waste or overproduction, but might also reduce the transport efficiency (Caudill et al., 2000; James and Hopkinson, 2001). However, these effects of e-commerce on production (and the consequential effects on transportation) are difficult to quantify because of the variability of production operations (Caudill et al., 2000).

3.3.2 Packaging

Within the online retail channel some forms of packaging can be reduced. For example, secondary packaging (i.e. cases or ‘outers’), typically involving the use of cardboard cases, can be reduced when electronic products are directly shipped to the end-consumer (Caudill et al., 2000). On the other hand, direct delivery to the home often requires additional primary packaging to prevent product damage during transit (Williams, 2002). This means that individual items, which are normally supplied in bulk within secondary packaging to shop shelves, need now to be individually wrapped for home delivery, increasing the total packaging needed. However, within the e-commerce market there is less need for the on-shelf merchandising function of primary packaging,

making it possible to clad products in more basic, less colourful materials (Sarkis et al., 2004). Amazon, for example, offers the option of 'frustration free packaging', reducing the packaging material and number of colours (Rice, 2009). Others argue that attractive packaging is needed even in online retailing; it enhances the perception of value, increasing the customer experience and increases the degree of product retention (MacLeod, 2011).

3.3.3 Transport to the home

Research shows that significant savings can be made by replacing the personal shopping trips in cars or buses with home delivery by van. Edwards et al. (2009a) calculated that the collection of one book or another small non-food item from a shop by car in the United Kingdom can generate, on average, 24 times more CO_2 than a van delivery to the home. Also shopping by bus can be 7 times more CO_2-intensive versus home delivery with a van. However, this conclusion is based on the following assumptions:

- The car or bus trip is made for the sole purpose of shopping
- First delivery to the home is successful
- Purchased items are not returned
- Home deliveries and shopping trips are made over an average distance
- Only one item is purchased / delivered at a time
- There are no differences in road network or traffic conditions

The impact of home deliveries is particularly sensitive to drop density (i.e. the number of drops per delivery round). An average rural delivery round results in five times higher emissions than in a normal city centre (Edwards et al., 2009a). Increasing the drop density, will increase vehicle fill and reduce CO_2 emissions per order (Edwards and McKinnon, 2009). Consumer preferences on order lead time, frequency of delivery, return policy, time windows etc. will also have an important effect on the efficiency of home delivery. For example, there will be very little net increase in energy use and emissions when parcel carriers collect items as part of their usual delivery round or when couriers take items back when their representatives are delivering in the area (Edwards et al., 2009a). Furthermore, as outlined in Chapter 2, wide delivery windows significantly reduce the kilometres driven (up to 93% of total km driven by consumer and retailer compared to traditional retailing) and therefore improves the delivery efficiency (Siikavirta et al., 2003). The proportion of failed deliveries is another important performance metric in online retailing. Failed delivery rates are reported to be

between 12% and 60% in the UK (Song et al. 2009). Three options are possible: the delivery company makes a redelivery, the consumer picks up the item at a collection and delivery point (CDP), or the consumer picks up the item at the carrier's depot. Which solution is the most favourable in environmental terms depends on the delivery failure rate, the redelivery failure rates, the distance between the customer's home and the carrier depot and CDP, the modes of transport used by the consumers, and the level of trip chaining (McLeod et al., 2006). A survey in the United Kingdom suggests that 87% of the people use their car to pick up a missed delivery at the carrier's depot, 6% walk, 2% cycle and 5% take the bus, but when the package can be picked up at a local CDP; 48% would walk, 43% take the car, 5% cycle, and 4% take the bus (Cherrett and McLeod, 2005). It found a significant relationship between the distance the consumer has to travel and the likelihood that they will take the car. Therefore, it is important to offer CDPs close to the consumer. Edwards et al. (2009b) argue that as there is a dense distribution of post offices in the UK people can walk or cycle to a post office resulting in the greatest environmental saving. Song et al. (2009) found in a survey of residents in West Sussex (UK) that walking to a near post office would be an option for 40% of the 379 respondents. However, for CDPs to become a more efficient option for the handling of failed deliveries than a redelivery attempt followed (if necessary) by the consumer picking up the products at a carrier depot, a substantial number of personal trips to the carrier depot must be eliminated (representing around 6% of the total orders) (Song et al., 2009). A CDP might also have limited capacity for the storage and handling of packages held there (Edwards et al., 2009b).

A CDP can also be used for the direct delivery of consumers' orders. As argued in Chapter 2, the use of unattended delivery would improve delivery efficiency on the 'last mile' and therefore the impact favourably on the environment. A study by the Flanders Institute for Logistics in 2009 (cited by Kiala, 2010) showed that replacing home deliveries by deliveries to a CDP can reduce the CO_2 emissions with 60%. The distance driven by the delivery van is greatly reduced (by more than 5 times) while consumers can often (in 51% of the cases) pick up the package on the way to another location without having to travel any additional mileage.

Most studies include only the distance driven and the related energy use and externalities. In practice, however, the home delivery of online orders also depends on many other factors, including the type of vehicle used, its fuel consumption, load capacity, methods of loading and unloading etc. (Gevaers et al., 2009). Also factors

such as distance between the picking location and the market area, the density of the customers, and the routing of the delivery vehicles influence the distribution performance (Hesse, 2002). All these factors should be considered when analysing the environmental performance of the home delivery.

3.4 Third-order effects

The third-order effects include wider changes in the economy, lifestyles and consumption patterns (Fichter, 2003). These are essentially rebound effects[7] which offset some of the other efficiency and environmental benefits that accrue from B2C e-commerce. For example, online retailing may lead to greater consumption of goods due to price reductions (James and Hopkinson, 2001). Another possibility is that online consumers will substitute other forms of personal travel for the trips that they would have made to the shops (Abukhader, 2008; Edwards and McKinnon, 2009). The customer response to e-commerce will, therefore, have a significant impact on the net environmental effects.

One important requirement to make e-commerce beneficial for the environmental is the reduction in consumer travel by car (Hesse, 2002; Matthews et al., 2002; Rizet et al., 2010a). Previous studies show that personal trips are crucial in the environmental outcome (Edwards et al., 2009a; Weber et al., 2009). Depending on the mode of transport, the distance, and the number of items in the shopping basket, the consumer trip can account for more energy use per product than the total energy used in transporting it from the factory to the shop (Browne et al., 2005). Several studies focus on the distance driven in the home delivery of groceries compared to physical shopping (Punakivi and Saranen, 2001; Siikavirta et al., 2003). In the case of 'pure substitution', the vehicle km can be reduced by 70% by a switch to home deliveries (car based shopping trips replaced by van home deliveries) (Cairns, 2005). However, others argue that online shopping has almost no influence on the distance travelled by consumers (Cullinane et al., 2008; Weltevreden and Rotem-Mindali, 2009). Also Mokhtarian (2004) argues that online shopping saves almost no consumer travel, because shopping trips are often combined with trips to other locations or some items are still purchased in stores on top of shopping online and getting the items home delivered. Complete substitution of the traditional shopping trip by a home delivery of consumable products is unlikely (Erber et al., 2001; Hesse, 2002; Mokhtarian, 2004). In the case of consumer

[7] As mentioned earlier, rebound effects are in this review categorized as third-order effects.

goods, and especially groceries, products are often bought as part of a larger shopping basket. It is likely that a part of the shopping trips will remain despite the online ordering and home delivery of certain products. Online shopping of groceries is often complementary to buying in store, rather than substituting shopping trips (Hand et al., 2009). Rotem-Mindali (2010) even argues that access to online shops may stimulate or generate physical shopping. To calculate the real environmental impact of e-commerce, the influence of online shopping on the consumer trip must be taken into account completely. Four ways are identified of how online shopping can have an influence on consumer travel (Mokhtarian, 1990; Salomon, 1985):

1. Substitution; the physical trip to the shop is eliminated by the online purchase
2. Complementary; consumers go to the shop, despite the online purchase, to inspect the products, collect the item (click and collect concept), buy accessories for the products, or to buy the product after finding it online.
3. Modification; the amount of travel stays the same but the characteristics of the trips are changed, like the transport mode or trip chaining.
4. Neutrality; there is no effect on travel behaviour because the online purchase would not have taken place if the product was not available online.

Browsing trips, to inspect the products in the shops before buying it online, are common and are estimated to apply between 17% (DfT, 2009) and 78% (RAC, 2006) of the online purchases in the UK. Other impacts of e-commerce on travel can be changes in shopping frequency and the distance between the shop and the consumer (Mokhtarian, 2004). Online shops might be further away than shops were the consumer would have bought the product if an online service were not possible. Further, it is important to note that eliminating shopping trips made by the most sustainable transport, walking or cycling, and replacing them with a home delivery by van will not result in an environmental benefit (Keskinen et al., 2001 cited by Mokhtarian, 2004).

Because consumer travel has a significant impact on the environmental outcome of the online channel, it is important that the calculations are accurate and realistic (Edwards et al., 2011). Several researchers have studied the effect of online shopping on physical shopping trips. An overview of these studies can be found in appendix B. These studies show different results. The effect of e-commerce on travel behaviour can differ from case to case which makes it difficult to model the full energy and environmental impact of online retailing (Edwards et al., 2011; Hesse, 2002; Rizet et al., 2010b).

To summarise, the following impacts (shown in table 3.2) need to be considered when analysing the environmental impact of online retailing.

First order effects • Impacts related to the use of computer, tablet or Smartphone and part of the manufacturing, maintenance and disposal impacts of the device. • Impacts of use and manufacturing, maintenance and disposal of computer server of retailer and search engine.
Second order effects • Impacts related to the inventory and picking and packing operations at the relevant locations. • Additional packaging used for the home delivery and saved secondary packaging used for bulk shipment. • Transport modes and distances of home delivery, including drop density and vehicle fill, time windows, lead time, etc. • Returns and failed deliveries, including the destination and their consequences on home delivery performance and consumer transport.
Third order effects • Changes in consumer transport including mode of transport, distance and trip chaining, basket size, and trip frequency. • Changes in consumption

Table 3.2: Aspects of online retailing influencing the environmental outcome

3.5 Relevance of product type

The freight transport implications, and hence the environmental consequences of e-commerce, depend to a large extent on the characteristics of the products sold (Hesse, 2002). The type of product has an influence on several parts of the supply chain, including the point of divergence, the location of the order-picking operation and the different energy requirements of the shops, warehouses and vehicles (Edwards et al., 2011). Customer buying behaviour also varies by commodity type. Several researchers have suggested a distinction between search products, experience products and credence products[8] to help understand the consumer shopping behaviour (Girard et al., 2002; Hsieh et al., 2005; Korgaonkar et al., 2006). Mokhtarian (2004) advocates the classification of consumer goods by purchase frequency / price of the item, which is usually also related to the size of the area over which the search for the product is performed. When analysing the environmental impact of online retailing, the last mile

[8] The quality of search products can be assessed before purchase, the quality of experience good is difficult to determine before purchase but can be assessed when using the product, and the quality of credence products is at any stage difficult to assess by the consumer, for example vitamins (Girard et al., 2002).

delivery process plays an important role. The last mile delivery is usually the most emission-intensive link in the supply chain (Edwards and McKinnon, 2009; Edwards et al., 2009a; Gevaers et al., 2009; Weber et al., 2008). The environmental impact is therefore significantly influenced by the design of the e-fulfilment process (Matthews et al., 2002; Sivaraman et al., 2007). To analyse the efficiency of the last mile, Gevaers et al. (2009) differentiate three groups of product:

- High value goods: laptops and other electronics
- Low to medium value goods: DVDs and books etc.
- Very low to low value goods: food and other fast moving consumer goods.

Rotem-Mindali (2010) argues also that product value is likely to affect the way in which consumers find product information, make the purchase and receive the delivery. He contends that the richness and quality of information and other basic product attributes such as consignment weight and size are likely to have an impact. Browne et al. (2001) focused on three product categories: groceries, small packages and large items. They argue that large items often have to be inspected before purchase and require a more professional delivery. Given the importance of product type to the last mile and therefore to the environmental impact of e-commerce, it is helpful to categorise products for this purpose. Table 3.3 summarises the main attempts to classify them in terms of their online retail requirements.

	Groceries / FMCG	Medium value / small package	High value / large items
Service level			
Lead time	Rapid delivery required (Cairns, 2005; Gevaers et al., 2009; Madlberger and Sester, 2005)		
Time window	Tight time windows required (Cairns, 2005) which makes pooling of goods difficult (Gevaers et al., 2009)	Extremely few parcel deliveries offer timed delivery (Browne et al., 2001)	
Frequency	Several times per week (Gevaers et al., 2009)		
Type of Delivery			
Delivery requirements	Frozen / chilled (Cairns, 2005). Home delivery is preferred in most cases (Madlberger and Sester, 2005).	Home delivery preferred, but CDPs / deposit boxes also accepted (Madlberger and Sester, 2005).	Professional delivery (Rotem-Mindali, 2010)
Unattended delivery	Reception boxes (Cairns, 2005; Gevaers et al., 2009).	In most cases not unattended, but CDPs are used (Gevaers et al., 2009)	In most cases not unattended, but CDPs are used (Gevaers et al., 2009)
Costs	Expensive delivery (as proportion to total product value) due to vehicle requirements, time needed at each stop, and need for picking locally due to short lead time (Browne et al., 2001)	High percentage of failed deliveries due to nobody home and not making use of unattended delivery (Gevaers et al., 2009)	High percentage of failed deliveries due to nobody home and not making use of unattended delivery (Gevaers et al., 2009)
Consumer behaviour			
Demand	Predictably stable (Cairns, 2005)		
Returns	Low return rate (Cairns, 2005)	High return rate (Browne et al., 2001)	Medium return rate (Browne et al., 2001)
Browsing trips			Customers want to see the products before buying (Browne et al., 2001)

Table 3.3: Assigning characteristics to product types (adapted from Gevaers et al., 2009)

There is close alignment between the Gevaers et al (2009) and Browne et al (2001) product classifications making it possible to combine them into three categories of purchase. The remainder of this section will examine the LCA issues associated with each of these product categories.

3.5.1 High value / large items

LCA studies in this category can be found for personal computers. Gay et al. (2005) modelled the life cycle energy and emissions (of carbon monoxide, nitrogen dioxide, hydrocarbons and carbon dioxide) for personal computers distributed in the USA through two channels: via traditional shops and distributed directly to the consumer making use of a third party provider. It was assumed that the online retail model made use of air transport, while the traditional retail model included only truck transport. They found that online retailing of personal computers can save 40 to 50% of life cycle energy compared to traditional retailing when air transport is assumed to be used for 10% of the orders. When air transport increases to 75%, the amount of nitrogen dioxide and carbon dioxide becomes greater than in traditional retailing channel. Caudill et al. (2000) performed a similar LCA study on the direct online sales of computers in the USA. They found that the use of air transport in e-commerce results in substantially more energy use (increase by 9%) and CO_2-emissions than in conventional retailing by truck. When no air transport is used, the energy savings generated by e-commerce are very moderate; energy is only reduced by 1%. They argue that larger savings (up to 11%) are only possible if e-commerce is utilised to reduce inventory and waste. Reijnders and Hoogeveen (2001) calculated the impact of the online retailing of personal computers assuming that retail stores are bypassed. Their study, conducted in the Netherlands, suggests that online retailing leads to lower energy use per item. No air transport was assumed and therefore this result was broadly in line with the findings of Caudill et al. (2000) and Gay et al. (2005). However, Reijnders and Hoogeveen also argue that lower prices online will result in increased consumption, and therefore e-commerce may result overall in a larger amount of energy use and emissions than conventional retailing.

Even though the largest energy savings can generally be achieved in the upstream processes like reduction in production waste and inventory, last mile transportation is still important. Eliminating private transport, particularly by car, leads to significant savings. Caudill et al. (2000) calculated that between 8.8% and 33.4% of the energy

savings come from eliminating consumer transport, depending on the amount of air transport. Gay et al. (2005) found that in terms of CO_2 the relative importance of consumer transport is even higher. Consequently, the third-order effects, often associated with personal travel, play an important role in the case of high value goods. As argued earlier, e-commerce does not necessarily eliminate consumer transport. People are more willing to travel to inspect and compare expensive goods prior to an online purchase (Edwards et al., 2009a). Besides that, internet searches can also lead to information on high value goods that result in people making longer shopping trips than they would have done if they had no access to the internet (Rotem-Mindali, 2010).

3.5.2 Medium value / small packages

More studies can be found for medium value goods. Fichter (2003) compared several studies of online book retailing and found that "*neither traditional nor e-commerce retailing per se show better environmental performance*" (p.30). Weber et al. (2008), on the other hand, conclude from their LCA study that the online purchase of a flash drive from buy.com results in lower CO_2 emissions and energy use than in the traditional retail channel. Eliminating consumer transport, which is responsible for 65% (1820 g) of the CO_2 emissions in traditional retailing, does outweigh the increased emissions from packaging, last mile delivery, and ICT impacts. They found that there is only a 20% likelihood that retail systems would have lower emissions than the e-commerce system. This assumed the use of truck transport in the e-commerce parcel delivery. When air transport is used the probability that traditional retail has a lower footprint is raised to 50%. This contrasts with the finding of Matthews and Hendrickson (2001) that online book retailing was environmentally superior in terms of energy, greenhouse gas emissions, conventional air pollution, and the amount of hazardous waste generated to traditional book retailing, even when the book delivery included an air freight service. However, they assume a 35% return rate in traditional retailing while 0% returns are included in the e-commerce model. Furthermore, they do not include first or third-order effects in their calculations. Edwards and McKinnon (2009) do include third-order effects such as trip chaining, browsing trips, returns and failed deliveries. They found that the last mile transport CO_2 emissions are heavily dominated by consumer travel, either to shops to buy products, to return products or to collect an order after a failed delivery. On balance, online shopping appeared to have a smaller carbon footprint than traditional shopping in the case of small non-food items.

The above studies assume a dedicated car trip for the purchase of the product in the traditional scenario, whereas in practice consumers often make multiple purchases on the same shopping trip, spreading the environmental impact per product. Matthews et al. (2001b) argue that the marginal effect of buying a book at the mall is small when this purchase is not the sole purpose of the trip and energy / emissions can be spread across a broader range of purchases and activities. Another distinguishing feature of the online purchases of products in this category, particularly clothing, is a high return rate. This is estimated to be 20-40% for online sales of fashion clothing, while it is only 2-4% for high street purchases of these products (Edwards et al., 2011). However, two environmental studies relating to the distribution of garments, Collins and Aumônier (2002) and Liyi and Chun (2011), do not take returns into account.

In a comparison of LCA studies in the US and Japan, Matthews et al. (2002) concluded that the relative environmental impact of online and store-based retailing depends on their implementation. In the US the higher use of air freight and packaging in the online supply chain outweighs much of the benefit from reduced passenger trips, leaving the final balance very sensitive to the return rate, order size and population density. The LCA study in Japan, on the other hand, showed that the relative environmental benefit of internet shopping depends on the population density and shoppers' preferred transport mode. In urban areas where walking and cycling is preferred, the additional packaging and fuel use by couriers tends to give online retailing a greater environmental impact, whereas in rural areas heavy reliance on personal shopping trips by car favours e-commerce (Matthews et al., 2002). Also Williams and Tagami (2003) found in their LCA study that the more frequent use of public transport in dense urban areas, makes conventional retailing of book relatively more energy efficient in Japan. In contrast to Matthews et al. (2002), Williams and Tagami (2003) found that e-commerce led to higher energy per book than traditional retailing in both urban and in rural areas. The discrepancy is caused mainly by the adoption of different assumptions, for example in number of items bought and the distance to the store.

In their comparison of the environmental impact of online and conventional retailing, Weber et al. (2008) found that freight transport, customers' computers and network use and data centre electricity consumption had a minor impact on the comparison (less than 15% of the CO_2 emissions altogether), while consumer transport (65% of retail scenario), wholesale warehousing (26% of retail and 31% of e-commerce scenario), secondary packaging and last mile delivery (respectively 22% and 32% of e-commerce)

were the major contributors. Collins and Aumônier (2002) found that in traditional retailing the consumer transport (43%) and retail shop (48%) are the major contributors (in terms of energy), while in e-commerce the last mile delivery (87%) followed by packaging (11%) are the biggest contributors. They assumed that the energy in the distribution centre was equal for both the e-commerce and traditional retail channel and therefore excluded it from the study.

3.5.3 Groceries / FMCG

Several studies show that grocery online shopping can have a less damaging effect on the environment than conventional grocery retailing (Rizet et al., 2010a; Siikavirta et al., 2003). The Swedish Environmental Protection Agency (quoted by Persson and Bratt, 2001) estimates that if 10% of all grocery purchases were to take place via the internet, transport energy and CO_2 emissions would be reduced by 7% and NO_x emissions by 10%. Siikavirta et al. (2003) simulated transport delivery rounds based on data from a Finnish grocery retailer and found that home delivery reduces vehicle-kms by between 46% and 93% depending on the time windows.

Again, as with other product groups, the results depend on the context and assumptions (Fichter, 2003). The type of vehicle, its fuel efficiency and the type of fuel used have a strong impact on greenhouse gas emissions, as well as the nature of local road networks and the timing of deliveries (Siikavirta et al., 2003). In the case of this product group, the third-order effects exert a significant influence on the environmental impact (Fichter, 2003). It is likely that many people do grocery shopping by car because of the quantity and bulkiness of the products purchased in the typical weekly grocery trip. Reliance on online shopping for grocery products may reduce the probability of certain categories of consumers acquiring a car. It has been found that rural dwellers not owning a car tend to make greater use of online shopping, while 30% of the students in a university survey stated that online shopping reduced their need for a car (Cullinane et al., 2008).

Overall, the online sale of low to very low value goods has the potential to reduce environmental impact. The ‘weekly shop’ for groceries is typically made by car often with limited trip-chaining opportunities, and so replacing it with a home delivery can eliminate a significant amount of car travel. Online grocery retailing is also characterised by low return rates (Cairns, 2005). The tendency to increase the bulk buying of FMCG products favours e-commerce as the delivery charge becomes a

smaller proportion of the total bill and the relative convenience increases (Cairns, 1996). The degree to which grocery shopping trips are substituted by home deliveries can be limited, however, by the common practice of buying standard, branded, packaged and / or bulky items online, but continuing to shop for fresh, higher-value bakery, meat and delicatessen products by conventional means (Barrett 1995a in Cairns, 1996). Under these circumstances, home deliveries can supplement personal shopping trips generating additional vehicle movement and increasing the overall environmental impact of online retailing.

3.6 Conclusion

Most comparative analyses of the environmental impact of conventional and online retailing suggest that the latter has the potential to yield a net environmental benefit. These comparisons are, nevertheless, underpinned by numerous assumptions and specific to particular groups of products. No set of clear guideline or framework yet exists defining which parameters to include when running an environmental analysis of online retailing. The literature reviewed in this chapter reveals the difficulty of conducting an LCA of internet retailing. It shows that the life cycle energy use and other environmental impacts depend on a broad range of factors, many of which vary widely between product groups (Edwards et al., 2011; Gevaers et al., 2009; Hesse, 2002). These variations in the energy and other emissions mainly reflect differences in the nature of the supply chain, the amounts of packaging used and the shopping / travel behaviour of the online consumer (Matthews et al., 2002; Weber et al., 2008). The use of LCA is further complicated by the inclusion of third-order effects, relating to wider rebound effects on the economy, patterns of consumption and consumer lifestyles (Mokhtarian, 2004). These also depend on the nature of the product being purchased online (Gevaers et al., 2009; Madlberger and Sester, 2005; Weltevreden, 2007).

The nature of the order fulfilment operation is an important determinant of the environmental impact of online retailing (Matthews et al., 2002; Sivaraman et al., 2007). More research is needed to determine which configurations of the e-fulfilment system minimise life cycle energy use and other environmental effects. This system includes warehousing activities, order-processing, packaging, and distribution to the home (Abukhader and Jönson, 2003; Türk, 2001). Studies which compare different fulfilment strategies with the same set of assumptions are therefore needed.

The impression is sometimes given that, at the 'last mile', there is perfect substitution of a home delivery for a personal trip to the shop ('pure' form of online retailing). Where this occurs, personal travel is eliminated and only freight movements are included in the calculation. It is common, however, for the online purchase to continue to involve some personal movement (Erber et al., 2001; Hesse, 2002; Mokhtarian, 2004). For example, consumers may make browsing trips to inspect the items prior to purchase. They may opt for a 'click and collect' option, collecting the goods from, for example, a shop, depot or locker-bank, or they may have to collect them if attempts to deliver to the home have failed. They may also have to make personal trips to return unwanted or defective products. Besides that, online shopping is often complementary rather than substituting for shopping trips, especially in the case of consumer goods, meaning that the frequency of physical shopping trips is not necessarily reduced by online shopping (Hand et al., 2009; Hartman group, 2013). Mokhtarian (2004) suggests therefore to see shopping as a process rather than a single activity. The inclusion of personal travel in online purchasing should not be overlooked (Edwards and McKinnon, 2009). It can have a dramatic effect on environmental and energy impacts, particularly where the trip is made by car, when it is dedicated to the online order only, and related to the acquisition of a single item. Where the energy consumption and emissions can be spread across the purchase of numerous items or a range of trip purposes, the personal travel element in the calculation sharply declines (Edwards et al., 2010b; Rizet et al., 2010b).

Despite the complexity of running an LCA study on online retailing, it is expected that the development of LCA studies in this field will help to distinguish the environmental impacts of different e-fulfilment systems and to identify possible improvements in the environmental performance of particular fulfilment strategies. In Chapter 8 a LCA model is developed that analyses the environmental impact of different fulfilment strategies for FMCG. Besides the existing fulfilment options, new options will be explored that can improve the environmental footprint of online retailing even further.

CHAPTER 4: RESEARCH METHODOLOGY

This chapter describes the research methodology applied in this thesis. It starts by outlining different philosophical perspectives on the choice for the research methods. Later sections discuss and justify the choice of methodology used. The concluding section outlines the specific application of the methods in this project.

4.1 Research philosophy

A researcher adopts either explicitly or implicitly a particular paradigm. Kuhn described a paradigm as "*the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community*" (Kuhn, 1996, p.175). The paradigm shapes the research approach adopted for a particular project. Creswell (2003) argues that the approach chosen varies from time to time and depends on the research problem, the personal experience of the researcher and the audience for which the research will be carried out. Other authors argue that the nature of the paradigm adopted depends on the ontological, epistemological and methodological viewpoint of the researcher (Arlbjørn and Halldorsson, 2002; Guba, 1990). Bryman and Bell (2011) combine both viewpoints and argues that the ontological and epistemological questions together with personal values, the politics of business research and practical considerations influence the nature of the research undertaken. To understand the significance of this claim it is necessary to explore the concepts of ontology and epistemology. This is done in the next two sections.

4.1.1 Ontology

Ontology is defined as *"a theory of the nature of social entities"* (Bryman and Bell, 2007, p.730).

Ontological considerations are about the nature of reality and questions about what can be known (Guba and Lincoln, 1994). It describes the way in which we think about reality, what the world is and contains, and its fundamental features and principles (Solem, 2003). The two extreme ontological viewpoints one can take are objectivism and constructionism (Bryman and Bell, 2011). Researchers taking the objectivist view argue that a reality exists. Social entities exist and should be considered as external or independent to social actors. Because the social entities cannot be influenced by the social actors, these entities can be considered as objective. On the other side, researchers taking the constructionist or subjectivist view argue that social entities are built from

perceptions and actions of social actors. Social entities are not pre-given but produced by and revised through social interaction (Bryman and Bell, 2011). In this case reality is *"a projection of individual consciousness"* (p.494), and entities or phenomenon are judged and interpreted before they can be understood (Morgan and Smircich, 1980).

Guba and Lincoln (1994) developed a similar division between the standpoints of researchers, calling them respectively realism and relativism. They argue that the realist standpoint can be further divided in three positions. Naive realism refers to reality that can be discovered by examining "*immutable natural laws and mechanisms*" (p.109). Critical realism assumes that reality exists, but cannot be perceived by humans due to their "*imperfect sensory and intellective mechanism*" (Cook and Campbell, 1979, p.29 cited by Guba, 1990). The third position, historical realism, claims that a virtual reality exists that is shaped by humans and constructed into a structure which is taken as real (e.g. natural and immutable).

The ontological thoughts described above are just examples, the different assumptions about human nature form a continuum of theories that intervene (Morgan and Smircich, 1980; Solem, 2003).

4.1.2 Epistemology

Epistemology is defined as "*a theory of knowledge*" (Bryman and Bell, 2007, p.727).

Epistemology describes what should be considered as acceptable knowledge. It discusses how the world can be understood and how this knowledge is communicated to others (Bryman and Bell, 2007). Epistemology consists of *"reasoning processes, guarantees of truth, proofs, axioms of validity, or any other logic underlying a methodology"* (Solem, 2003, p.440). Epistemology is broadly discussed, especially in the social science where it is often asked whether the same approach as in natural science can be used in studying social phenomena (Bryman and Bell, 2011). The answers to the epistemological questions are constrained by the answer given to the ontological question, i.e. can reality be examined with objective detachment (Guba and Lincoln, 1994).

Guba and Lincoln (1994) identify two main epistemological positions: objectivist and transactional / subjectivist. In the objectivist epistemology the researcher and the object to be researched are assumed to be independent. The influence of the researcher on the objects reduces the validity of the outcome and needs to be minimised and, if possible,

eliminated. A rigorous method will protect the outcome from biases and assure the truth of the findings. Accurate observations and measurements and empirical analysis of the relationships are encouraged (Morgan and Smircich, 1980). Some researchers may argue that an absolute objectivity cannot be reached but still strive to come as close as possible to objectivity (Guba and Lincoln, 1994). The transactional / subjectivist position has a different starting point arguing that the researcher is not independent from the object, but is interactively linked. The outcome of the research is created in the process of interaction between the researcher and the object or at least related to the values of the researcher (Guba and Lincoln, 1994). The emphasis is on the understanding of the processes, framed by the researcher as a human being (Morgan and Smircich, 1980). Between those two extreme viewpoints is a continuum of other beliefs (Morgan and Smircich, 1980; Solem, 2003). One example is 'modified objectivism' (Guba, 1990). It suggests that complete independence between the object and researcher is not possible and that the researcher should therefore strive for objectivity by explaining the predisposition of the researcher such that other researchers can interpret the results with that in mind.

4.2 Research paradigms

The epistemological and ontological foundations of research can be further explained with respect to paradigms (Bryman and Bell, 2011). A paradigm includes *"claims about the world, methods for gathering and analysing data, and habits of scientific thought and action"* (Godfrey-Smith, 2003 p.77). Kuhn (1996) argued that within normal science, one paradigm is guiding the research. There are no debates about the fundamentals as a consensus about fundamentals is reached. Consensus is needed in order for scientists to make progress, both theoretically and experimentally. Constant debate about the fundaments would be time-consuming and distract the scientist from doing detailed work and revealing discoveries (Godfrey-Smith, 2003). A single paradigm will therefore tend to dominate a research field.

Abrahamson (1996 p.257) argues that management researchers follow management fashions: "*a relatively transitory collective belief, disseminated by management fashion setters, that a management technique leads rational management progress*". A 'management fashion' is a form of paradigm. When successful, many researchers will adopt it. However, when the outcome is less successful, other management fashions will be used at the same time.

Näslund (2002) argues that in complex and applied research areas such as logistics, there should be no predominant paradigm. Not all research questions can be solved with the same approach and therefore more paradigms are needed. Many different paradigms are developed, possibly leading to confusion and inconsistency (Hassard, 1991). The different paradigms form a continuum ranging from qualitative to quantitative methods (Ticehurst and Veal, 2000) as depicted in figure 4.1.

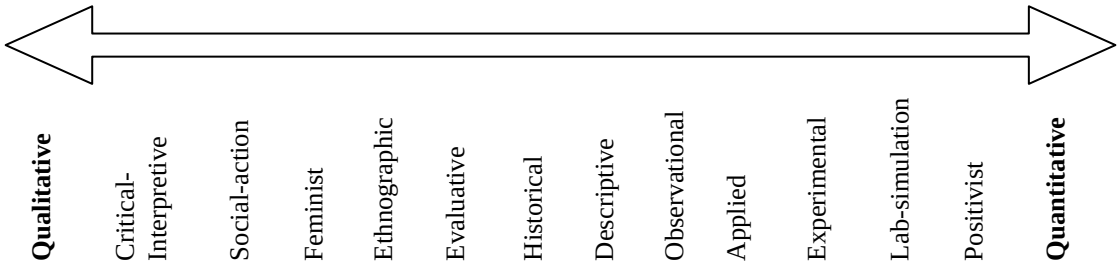


Figure 4.1: Continuum of paradigms (Ticehurst and Veal, 2000)

The quantitative end of the continuum is associated with positivism while the qualitative end is represented by interpretivism[9]. They are discussed in the next two sections.

4.2.1 Positivism

Positivism was for the first time described by Comte in 1830 and is further developed by Durkheim in 1895 (Crotty, 1998). Both argue that social science must proceed in the same way as natural science (Katzav, 2009). According to positivists reality exists and is independent from the social actors, i.e. in line with the ontological position of objectivism. Reality is considered to be objective, tangible and can be decomposed to allow it to be explained and predicted (Mentzer and Kahn, 1995). Ideas must be reduced to a smaller set of ideas which can be tested (Creswell, 2003). The researcher is assumed to be detached or independent of what is studied (Smith and Dainty, 1991; Ticehurst and Veal, 2000). This objectivity is shown in the research approach; the choice of what to study should be determined by objective criteria and quantitative measures should be used to enable the growth of knowledge (Easterby-Smith et al., 2008). Quantitative research is then required to establish validity and reliability (Creswell, 2003). Generalisability is another important aspect of positivism and should be tested with statistical probability. Therefore the samples used in the research need to

[9]Social constructionism or constructivism are one of the group of approaches called interpretivism (Easterbry-Smith et al., 2008).

be of sufficient size to so that the findings can be generalised to a wider population (Easterby-Smith et al., 2008).

Hypotheses need to be generated which can be tested (Bryman and Bell, 2011; Easterby-Smith et al., 2008). A researcher develops a theory, hypothesis or claims about the world, collects data or evidence that can support or reject the hypotheses and makes rational considerations to understand the world (Creswell, 2003). He / she aims to establish causal relationships and measure their significance (Creswell, 2003; Lin, 1998; Näslund, 2002). The objective of positivistic research is to explain consistently why one action leads to a certain outcome rather than another outcome (Lin, 1998). Positivists argue that knowledge is a cumulative process, new knowledge is added to the existing knowledge and false hypotheses are rejected (Näslund, 2002). Because pre-knowledge is needed to generate hypotheses, positivism is more suitable for better known phenomenon (Denzin and Lincoln, 2000).

The positivist paradigm is widely used in logistics research (Mentzer and Kahn, 1995; Näslund, 2002). Logistics research has grown due to applying the positivist paradigm to areas such as physical distribution, transportation and inventory management (Aastrup and Halldórsson, 2008). For example, highly abstract and mathematic modelling is successfully used to optimise inventory and supply chain processes (Bertrand and Fransoo, 2002). However, mathematical models cannot describe or explain organisational aspects of logistics, as they ignore the perspective of the institutions and people being studied (Daft and Lewin, 1990; Humphreys, 2003; Mangan et al., 2004).

Applying positivism to social science in general has attracted much criticism regarding the absolute truth of knowledge (Ticehurst and Veal, 2000). Positivism needs to adapt and recognise that it is impossible to make claims with certainty about the behaviour and actions of humans, sometimes called post-positivism (Creswell, 2003). Post-positivism recognises that absolute truth can never be found. Popper (2002) calls this falsification: hypotheses cannot be proven, but only rejected.

4.2.2 Interpretivism

In the early 20th century thinkers like Wilhelm Dilthey, Edmund Husserl, and Max Weber started to reject positivism and the idea that social science should be researched in the same way as the natural sciences (Katzav, 2009). Interpretivism, contrary to positivism, does not predict and explain reality, but tries to understand phenomena (Easterby-Smith et al., 2008; Mentzer and Kuhn, 1995). Interpretivism argues that

people or other social entities are different from natural objects and advocates research that is more subjective (Bryman and Bell, 2011). Reality is not objective or external to the social actors, but is constructed by social actors (Easterby-Smith et al., 2008). The process of creating social phenomena through action is called enactment (Weick, 1988). One example of enactment is the Hawthorne effect: where workers' behaviour is changed merely because they know they are being observed (Katzav, 2009).

Interpretivists argue that there is no reality outside the perception of people (Ticehurst and Veal, 2000). Based on the background of the individual and cultural and historical settings, the social actors understand and develop subjective meanings of the world (Creswell, 2003). This is sometimes called 'priming' (Katzav, 2009). Not only participants are influenced by their background, but also the researcher. The researcher's interpretation of the findings is shaped by his or her experience and background (Creswell, 2003).

Interpretivists explain how certain variables interact or are related. Different objectives of interpretivist research can be "*to understand what general concepts ... mean in their specific operation, to uncover the conscious and unconscious explanation people have for what they do or believe, or to capture and reproduce a particular time, culture, or place so that actions people take become intelligible*" (Lin, 1998, p.162). The understanding is generated during the interaction with people (Creswell, 2003). An important concept within interpretivism is sense-making. People make *"structures to help make sense of what is going on around them"* (Easterby-Smith et al., 2008, p.26). Theories and meanings are generated inductively in the course of qualitative research (Creswell, 2003). Research involving the collection and analysis of qualitative data is sensitive to ideas and the meanings of the individuals studied. It permits broad and rich descriptions and can therefore be used in interpretivist studies (Alvesson, 1996 cited by Näslund, 2002).

4.2.3 Critical Realism

Positivism and interpretivism are two extreme positions. Critical realism represents a compromise between these two extreme viewpoints. It starts in the realist ontological position; that reality (both natural and social entities) exists and has an influence whether or not it is observed (Easterby-Smith et al., 2008). The events that occur and that can be observed are generated by objects, entities and structures which might be unobservable (Archer et al., 1998). Critical realists also recognise that *"concepts are*

human constructions" (Easterby-Smith et al., 2008, p.62). Although natural laws exist there are also social structures which are created by the social activities (Mingers, 2004). These social systems and entities interact in the physical world. The world and our interpretation of it are not constant, but are changing over time (Archer et al., 1998). Therefore, critical realism argues that science has not only the purpose of verification, but also one of discovery (Guba, 1990). Exploration is therefore an important part of science in the critical realism perspective.

The interactions of different objects, which can be conceptual, social, psychological, or material, require a variety of research methods (Mingers, 2004). The human and social elements in management research demand a holistic approach and a range of methodologies (New and Payne, 1995). Adopting multiple perspectives is also useful for overcoming the difficulty of gaining direct access to reality. Applying the critical realist approach often, therefore, involves using different research techniques, a practice now widely known as 'triangulation' (Easterby-Smith et al., 2008).

The ontological, epistemological and methodological position of the three paradigms described above are summarised in table 4.1 below.

Paradigm	Positivism	Interpretivism	Critical Realism
Ontology	Objectivism / Realism Reality exists out there and is driven by immutable natural laws and context-free generalisations. Some of these generalisations take the form of cause-effect laws	Constructionism / Subjectivist / Relativist Realities exist in the form of multiple mental constructions, socially and experientially based, local and specific, dependent for their form and content on the persons who hold them.	Critical realism Reality exists but can never be fully apprehended. It is driven by natural laws that can be only incompletely understood.
Epistemology	Objectivist It is both possible and essential for the inquirer to adopt a distant, non-interactive posture. Values and other biasing and confounding factors are thereby automatically excluding from influencing the outcomes.	Transactional / Subjectivist Inquirer and inquired into are fused into a single entity. Findings are literally the creation of the process of interaction between the two.	Modified objectivist Objectivity remains a regulatory ideal, but it can only be approximated, with special emphasis placed on external guardians such as the critical tradition and the critical community.
Methodology	Experimental / manipulative Questions and hypotheses are stated in advance in propositional form and subjected to empirical tests under carefully controlled conditions.	Hermeneutic / dialectic Individual constructions are elicited and refined hermeneutically, and compared and contrasted dialectically, with the aim of generating one (or a few) constructions on which there is substantial consensus.	Modified experimental / manipulative Emphasise critical multiplism. Redress imbalances by doing inquiry in more natural settings, using more qualitative methods, depending more on grounded theory, and reintroducing discovery into the inquiry process.

Table 4.1: Three paradigms and their ontology, epistemology and methodological standpoint (adapted from Guba, 1990)

4.2.4 Critical realism in the background of this thesis

Within logistics, positivism has been the main standpoint for many years (Aastrup and Halldórsson, 2008; Daft and Lewin, 1990; Mangan et al., 2004; Mentzer and Kahn, 1995; Näslund, 2002). However, it has also been argued that multiple paradigms are needed to solve the wide ranging nature of problems within logistics (Daft and Lewin, 1990; Näslund, 2002; Solem, 2003). Critical realism, in representing a compromise between positivism and interpretivism, is therefore well suited to logistics research. It is considered to be well suited to the present research project

This research assesses the environmental impact of both existing retail fulfilment models and new subscription-based models. Because very few studies exist that study the supply chain impact of subscriptions, an exploratory study is needed. Exploratory studies are conducted when no or very limited knowledge is available on a problem or issue (Collis and Hussey, 2009). As argued in Chapter 1, the new subscription model will be evaluated on the environmental performance and on the acceptance of the model by the consumers. Both quantitative environmental analysis and qualitative consumer research are therefore applied in this research. As argued by the critical realist (see for example Mingers, 2004) this combination of qualitative and quantitative research methods is often needed to assess a new phenomenon.

4.3 Methodology

A methodology describes how the researcher is going to find the knowledge (Guba, 1990). It is the *"strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcome"* (Crotty, 1998, p.3). The choice of methodology is constrained by the ontological and epistemological choices already made by the researcher (Guba and Lincoln, 1994).

The methodological approaches within certain paradigms are shown in table 4.1 above. When the researcher adopts a positivist paradigm, an empirical test is needed to verify the hypotheses. The interpretative paradigm is based on the interaction between the researchers and the objects to be studied. The critical realist adopts two methodological approaches (Guba, 1990). The first one is triangulation, e.g. the use of multiple sources for data, investigators, theories and methods. Relying on different sources decreases the distortion of interpretations and makes sure that the researcher comes as close as

possible to objectivity. The second is an approach which attempts to redress four key imbalances that one encounters in trying to do objective research.

1. Rigour and relevance
2. Precision and richness
3. Elegance and applicability
4. Discovery and verification

Of these the rigour-relevance gap is widely discussed (Daft and Lewin, 1990; Shrivastava, 1987; Starkey and Madan, 2001). Management research must be both rigorous and closely related to a real practical problem (New and Payne, 1995). *"Logistics is a practice-oriented and solution-based discipline"* (Aastrup and Halldórson, 2008, p.748). It therefore requires research in more natural settings, the use of qualitative methods, the use of grounded theory[10], and reintroducing discoveries (by which research questions and hypotheses emerge) into the research (Guba, 1990). The 'design science' methodology tries to overcome this imbalance. It aims at reconciling the rigour-relevance problem in management science (van Aken, 2005).

Design science or Design-based research

Even though the idea to reduce the gap between academic research and practice is not new and has its roots in the beginning of the 20th century (Daft and Lewin, 1990), design science is a fairly young methodology, developed by Simon (1984) and further developed by van Aken (2004). The goal of design science is to develop scientific knowledge, to solve managerial problems using both quantitative as qualitative methods and combining descriptive research with prescriptive research (van Aken, 2004).

Several researchers have argued that design science is similar to action research (Cole et al., 2005; Järvinen, 2007). Action research generates knowledge by changing the social system (Susman and Evered, 1978). Action research and design science both try to reduce the gap between rigour and relevance and both give the researcher the opportunity to work with the decision-makers while a project is underway (Cole et al., 2005). However, design science, in contrast to action research, requires the explicit development of a solution[11] to a relevant problem, while action research can also focus on behavioural changes (Holmström et al., 2009). Grounded theory produces theory

[10] Grounded theory is the process of *"discovery of theory from data systematically obtained from social research"* (p. 2 Glaser and Strauss, 1967).
[11] A solution can be a concept, model, method or an implemented prototype or system (Hevner et al., 2004).

based on data (Glaser and Strauss, 1967). However, it does not focus on solving relevant problems (Gregory, 2011). So although grounded theory can be used in design science to generate knowledge and solve problems, it does not include the identification of a relevant problem (Holmström et al., 2009).

The general approach of design science is outlined below. This is followed, in section 4.4, by a discussion on how design science is implemented in this thesis.

Publication / discipline	**Phase 1**		**Phase 2**	**Phase 3**	**Phase 4**
March and Smith (1995) IT	**Build** Construct an artefact for a specific purpose		**Evaluate** Compare / determine the performance of the artefact.	**Theorise** Construction of theory explaining the performance. Both internal working as interaction with environment.	**Justify** Testing theories on validity. Empirical and / or theoretical research.
Holmstrom et al (2009) Operation management	**Solution incubation** Framing the problem and initial design of the requirements for the solution.		**Solution refinement** Empirical testing of the solution design.	**Explanation I** Analysis and interpretation of results from theoretical point of view. Generalise findings.	**(Explanation II)** Further generalisation. Applicability not limited to context under study.
Van Aken (2004, 2005, 2007) Management	**Problem Definition and Defining Specifications** Understanding the problem and desired performance		**First and second redesign** Synthesis of a design for a solution and evaluation of design against specifications.	**Technical rule justification** Systematically test effectiveness within context of intended use.	**Grounding** Test technical rules in multiple contexts.
Reeves (2000, 2006) Education	Analysis of Practical Problems by researchers and Practitioners in Collaboration	Development of Solutions Informed by Existing Design Principles and Technological Innovations	Iterative Cycles of Testing and Refinement of Solutions in Practice	Reflection to Produce 'Design Principles' and Enhance Solution Implementation	

Table 4.2: Design Science methodology

Phase 1

Understanding the problem is the first step in design science (Holmström et al., 2009; van Aken, 2004) and should be done collaboratively with practitioners to identify real problems (Reeves, 2006). The research objective is defined in this stage, as well as the desired performance against which the solutions will be assessed (Holmström et al., 2009; van Aken, 2007). It is important that the problem is framed by the researcher's and / or practitioner's points of view and background knowledge. Therefore this phase in the design science is subjective and inductive. Design science can also be used to match existing solutions to new problems (Offermann et al., 2011).

The first solution, which can be a concept, model, method or prototype is also designed in the first phase. The specifications of the solution should give enough detail to be able to implement it in a test environment, but may still be incomplete. March and Smith (1995) argue that the utility and feasibility of the solution must also be demonstrated at this phase.

Phase 2

In the second phase the solution is tested empirically. With an iterative process, the solution is developed or improved towards a design that fulfils the requirements and has no negative side-effects (Holmström et al., 2009; Reeves, 2006). Van Aken (2007) proposes that one makes an outline design for the solution, followed by a detailed redesign. The first redesign is made by the researcher who makes use of the available knowledge to design a solution for the specific problem.

The evaluation can be performed by calculations, simulations or simply verbal arguments (van Aken, 2007). Which evaluation method is preferred depends on the nature of the solution and the performance criteria (Hevner et al., 2004). In some cases it will involve mathematical modelling, often based on theoretical data, while, in others, more empirical data are used, much of it qualitative. Holmström et al (2009) argue that there is only one way to evaluate the design: by implementation of the solution in an empirical context. They argue that implementation is needed to be able to refine the solution based on the unintended consequences in the original design. Once a suitable outcome is found, the solution must be discussed with the direct stakeholders and modified in the light of their feedback (van Aken, 2007).

Phase 3

In the third phase the findings which satisfy the requirements of phase 2 can be generalised. Further research can try to explain why and how the solution worked or not (March and Smith, 1995). The characteristics of the solution and the interactions with the environment need to be explained. Van Aken (2004) called this a technical rule: "*a chunk of general knowledge, linking an intervention or artefact with a desired outcome or performance in a certain field of application*" (p.228). The theory in this phase may still be context dependent, although the same solution might be systematically introduced in several contexts (Holmström et al., 2009). However, the prescription must not hold only for a specific situation but for a class of problems or a certain field of application (van Aken, 2004).

The generalisability of the findings does not have to be statistically proven, but can be based on theoretical reasoning. It has to explain to which research program the results relate, the novel insights or contributions to theory (Holmström et al., 2009).

Phase 4

In the ideal situation the solution is not only applicable in the limited empirical context of the study. Broader generalisations are preferred (Winter, 2008). March and Smith (1995) call the fourth phase justification. The scientific claims made in phase three need be tested for validity, with empirical and / or theoretical research. The scientific evidence might support or refute the theory, which gives future direction to the development of additional or better solutions. The validation needs to be linked to assumptions in the underlying paradigm and methodology (Shrivastava, 1987). For design science this means that the utility of the solution needs to be demonstrated (Offermann et al., 2011).

The starting and ending phase for the research depends on the novelty of the research. Exploring a problem and inventing a design for a new problem is one of the strategies of design science that is regularly used (Offermann et al., 2011).

The remainder of this chapter explains the different stages of design science as applied in this thesis, followed by a discussion on each of the research methods applied.

4.4 Research Design

The objective of this research is to find a sustainable design for the e-fulfilment of FMCG products to the home. Following the design science approach, the research was divided into four phases:

Phase 1: Review of literature and business examples

Discussions with supply chain experts were held to identify the problem and the desired outcome. The discussion showed that there is a feeling that the current home delivery of FMCG products could be executed more efficiently to reduce the costs and environmental impact of deliveries. The current speed and flexibility of these deliveries is partly in response to customer needs and expectations. If these needs could be addressed in another way, last mile distribution might be executed in a more efficient way.

To understand the problem in detail and assess the current state of knowledge, a systematic literature review of online retailing was conducted. This review showed that the overall environmental impact of the online FMCG retailing is unknown, and due to the different assumptions and system boundaries in the different studies, it is difficult to compare the performance of the existing retail models.

Existing models of e-fulfilment in the FMCG sector were then examined using an internet search and analysis of available industry data. Examination of business examples is another way to derive design propositions (Plsek et al., 2007). This identified subscriptions as a possible means of supplying FMCG products directly to the home in an economically and environmentally sustainable way. Based on the literature review and business examples, 3 possible types of subscriptions service were differentiated.

Phase 2: Evaluation of e-fulfilment models

The second phase of the research is related to the evaluation of the e-fulfilment models against the specifications identified in Chapter 1. As explained earlier, the new subscription-based e-fulfilment model must be feasible from a consumer perspective and must outperform the main existing retail models from an environmental point of view.

To assess the opinion of consumers regarding a new subscription service for FMCG, focus groups and interviews are held with potential subscribers. Focus groups are a useful tool for gathering feedback on new concepts which can then be used for further refinement of the concepts (Greenbaum, 1998; Rodrigues et al, 2010). Because the focus groups showed that subscriptions are only appealing for a subset of the population, interviews are held to find the characteristics of these consumers. One-on-one interviews can be used to gather more in-depth insight into variations in individual purchasing behaviour (Crabtree et al., 1993). Focus groups are then held with this subset to discuss the concepts of subscriptions, examine its strengths and weaknesses and consider how it can be refined.

The literature review showed that knowledge of the environmental impact of online retail models is very limited, and a comparison between them is difficult to make. A holistic method is therefore needed which can compare the different models based on the same assumptions and system boundaries. Life-Cycle Assessment (LCA) can compare different models against a range of environmental criteria (Guinée et al., 2002). However, the parameters and their relationships still need to be identified and modelled. This is based on the literature review and discussions with supply chain and LCA experts.

Because the use of subscriptions is a new concept in the FMCG market, its supply chain effects are unknown. These effects need to be assessed in order to calculate the environmental impact of subscriptions. Due to the similarities between automatic replenishment of consumer goods within the household and Vendor-Managed Inventory (VMI) further back along the supply chain, VMI literature is used to extrapolate findings from Business-to-Business (B2B) to Business-to-Consumer (B2C) markets. Using findings from other areas and exploring commonalities are important steps within design science (Holmström et al., 2009).

Phase 3: Sensitivity Analysis

A sensitivity analysis is performed to examine the relationships between different operational parameters and environmental impacts. For example, the influence of shopping basket size on environmental impact of the different retail models is examined in detail. The sensitivity analysis helps to understand the robustness of the results (Guinée et al., 2002) and shows under which conditions the solutions, or in this case the

the e-fulfilment models, might work. Based on this, conclusions are drawn about the sustainability of the fulfilment models and areas of improvement are identified.

Phase 4: Justification of the research

In the fourth phase the research is justified. Due to the novelty of this research, actual performance evaluation is not necessary (March and Smith, 1995; Offermann et al., 2011). However, the quality and utility of the research should be demonstrated. The contributions of this thesis, both theoretical and practical, are discussed in Chapter 9. The validity and reliability of the research is discussed in section 4.6.

The steps discussed above are summarised and shown in table 4.3.

Design science phase	**Place in thesis**	**Purpose**	**Research method**
Phase 1	Chapter 1	Problem definition and desired outcome	Discussions with supply chain experts
	Chapter 2 & 3	Understanding the problem	Literature review
	Chapter 5	Development of initial solution	Literature and business examples, followed by classification of 3 types of subscription services
Phase 2	Chapter 6	Consumer opinion regarding subscriptions	Focus groups and interviews
	Chapter 7	Supply chain impacts of subscriptions	Analogy with VMI literature Supply chain calculations
	Chapter 8	Environmental impact of online retail models for FMCG	LCA model
Phase 3	Chapter 8	Evaluation of environmental results	LCA model including sensitivity analysis
Phase 4	Chapter 4 & 9	Justification of results; validation and utility	Experiment of subscriptions in real world

Table 4.3: Overview on research goals and steps for each design science phase

4.5 Methods of Data Collection

Each of the methods mentioned above is explained in the remaining sections of this chapter.

4.5.1 Secondary Data: Literature review

Research on e-commerce is not limited to one discipline, but can be found in logistics, finance, marketing, information systems, etc. (Wareham et al., 2005). Although the focus in this literature search is on the logistics aspects, relevant studies are published in other areas. Research in this area requires therefore a cross-disciplinary or holistic focus necessitating a systematic literature review to combine the knowledge available in different disciplines in one thorough examination of the existing literature. Systematic reviews help with searching for knowledge in a fragmented and contested area (van Aken et al., 2006). A systematic review increases the rigour and decreases researcher bias (Tranfield et al., 2003). Through the synthesis of the literature, the systematic review builds reliable knowledge (Denyer and Neely, 2004).

Tranfield et al. (2003) provide clear guidelines for conducting the systematic literature review and recommend the following steps:

Stage I – Planning the review
Phase 0 – identification for the need for a review
Phase 1 – Preparation of a proposal for a review
Phase 2 – Development of a review protocol
Stage II – Conducting a review
Phase 3 – Identification of research
Phase 4 – Selection of studies
Phase 5 – Study quality assessment
Phase 6 – Data extraction and monitoring progress
Phase 7 – Data synthesis
Stage III – Reporting and dissemination
Phase 8 – The report and recommendations
Phase 9 – Getting evidence into practice

Table 4.4: Stages of systematic review (Source: Tranfield et al., 2003)

In the first stage, the review protocol is developed. The goal and specific areas of interest are determined and discussed both within the university and with any sponsors. A scoping study is performed to determine the size and relevance of the literature. The search strategy is outlined in the research protocol and the criteria for the inclusion and

exclusion of the studies are determined. The review protocol developed before conducting the literature search can be found in appendix C.

In the second stage the literature is searched in the predefined places with predefined search strings. The articles are reviewed against the inclusion, exclusion and quality criteria as proposed in the review protocol. Of the 27 296 journal papers, books and articles which were identified for the present study, 536 are selected for further reading. Due to resource limitations, the literature is not reviewed by several reviewers. However, the literature list and literature synthesis was read by the supervisors and sponsors.

The goal of the synthesis is to map what is already reported in the literature, indicate to what extent consensus is reached and to identify key emerging topics and research questions (Tranfield et al., 2003). The result of the thematic analysis of the selected literature is reported in Chapters 2 and 3.

4.5.2 Focus groups

Focus groups can be used for different types of studies; explanatory, exploratory or descriptive. Explanatory focus groups can give more in-depth insights than a questionnaire, survey or interview (Rodrigues et al., 2010). The focus groups purpose is then to verify the findings of earlier research via triangulation (Frey and Fontana, 1993; Morgan, 1988). In exploratory studies, focus groups can be used to seek pre-knowledge and identify constructs for a survey or other quantitative research (Calder, 1977; Kreuger, 1994). It can help to define the research problem or topic (Rodrigues et al., 2010), to develop hypotheses (Calder, 1977), or to understand the social context and nuances in a later research setting (Frey and Fontana, 1993). Especially when the research topic has not yet been extensively studied, focus groups can shed light on the relationships between variables (Rodrigues et al., 2010). New concepts or prototypes can be tested in a focus group setting. The strengths and weaknesses of the concepts can be discussed to allow further refinement of the concept (Greenbaum, 1998). Exploratory focus groups can discuss differences in motivation and behaviour between different categories of people, needed before designing a large-scale study (Kreuger, 1994). Descriptive focus groups, on the other hand, can be used to explore new research areas (Morgan, 1988) or to examine the current state of research (Rodrigues et al., 2010). Findings from descriptive focus group research can stand on their own with no further data collection necessary, although the research is usually part of a larger project

(Morgan, 1988). In all other cases, focus groups do not replace extensive research methods but tend to supplement them (Greenbaum, 1998).

The advantage of focus group discussions is the rich data that can be collected. The interaction amongst the participants generates new ideas and insights (Ghauri and Grønhaug, 2002; Greenbaum, 1998; Morgan, 1988; Patton, 2002). This interaction is a key part of the data collection process (Rodrigues et al., 2010). However, it also results in the researcher having less control than in semi-structured interviews (Bryman and Bell, 2007). Also, dominant views of some members can inhibit opinions of the other participants (Patton, 2002). Further, when participants are in a competitive situation or when confidential information needs to be discussed, focus groups are not suitable (Greenbaum, 1998).

Before conducting a focus group, a discussion guide needs to be prepared which the moderator / facilitator can use to lead the group discussion (Greenbaum, 1998). When conducting exploratory research, a low level of moderator involvement is preferred (Morgan, 1988). In that case, the moderator lets the participants talk by asking probing questions (Greenbaum, 1998). Typically a focus group consists of 6 to 10 participants. This ensures data richness while it is still possible to control the group (Krueger, 1994; Morgan, 1988). Others argue that more than 8 participants would be too difficult to moderate and present analytical problems (Barbour, 2007). In some cases fewer participants can be beneficial. When the participants are experts and can give more input due to their knowledge, a minimum of 4 participants per session is acceptable (Krueger, 1994). Smaller groups can give more depth to the discussion because there is more time per person (Greenbaum, 1998).

Focus groups need to be conducted in series until theory saturation is reached (Rodrigues et al., 2010). Theory saturation is reached when no new or relevant data emerges from the focus groups and the moderator can predict what the next group is going to say (Bryman and Bell, 2007). When the various groups are relatively homogeneous, fewer groups are needed to reach theory saturation (Morgan, 1988). Generally after the third or fourth group of a particular kind, theory saturation is reached (Calder, 1977; Krueger, 1994). Theory saturation is needed to reduce the occurrence of bias and ensure the credibility of the findings (Rodrigues et al., 2010). However, when focus groups are conducted together with other research methods (e.g. methodological triangulation) the risk of bias is reduced and theory saturation is less important

(Rodrigues et al., 2010). Because focus groups are conducted in series, results from the first focus group session can be used to select a different group of participants for the subsequent sessions to gain a broader perspective on the issues (Barbour, 2007).

When theory saturation is reached, the results of the focus group discussions can be analysed. This analysis must be based on the overall opinion of the group and not on the views of the dominant participants (Greenbaum, 1998). Therefore focus group comments need to be analysed for frequency, extensiveness, and intensity. Comments that are made more often, elaborated more extensively or that are communicated with a different speaking pattern (faster, louder etc.) can be more important for the participants (Krueger 1994). A frequently used method for summarising the focus groups results is content analysis (Morgan, 1988; Stewart et al., 2007). In content analysis different categories are defined and the focus group transcripts are coded according to these categories. Some researchers argue that the content must be quantified by the number of times mentioned or percentage of discussion devoted to a certain category (Morgan, 1998). This would make the results more objective, eliminating researcher bias (Brymann and Bell, 2007). However, focus groups are subjective and generally produce qualitative data (Greenbaum, 1998). Although content analysis may lead to numerical results, focus group results are qualitative and it is therefore not possible to draw statistical conclusions (Morgan and Krueger, 1993). It is usually not possible to generalise the findings of the focus groups due to the small sample size (Greenbaum, 1998; Krueger, 1994).

Justification for using focus group discussions in this study

It is argued that focus groups are especially useful for unexplored and new topics (Threlfall, 1999) and for exploratory market research (Easterby-Smith et al., 2008). The objective of the exploratory focus group research in this thesis is to gain insights into consumer preferences regarding subscriptions for FMCG products. Because the participants are asked to give their reaction and opinion on systems that currently do not exist, concept descriptions are used as external stimuli. Concept descriptions can be used to communicate new concepts to participants in a clear way (Greenbaum, 1998). Concepts of different types of subscriptions are tested to understand the viability of the different options from a consumer point of view.

As suggested Rodrigues et al. (2010) focus groups are conducted in series until theory saturation is reached. Generally after the third or fourth focus group theory saturation

should be reached (Calder, 1977; Krueger, 1994). In this research a sequence of four focus groups has been used. The first four focus groups showed that the participants had very limited experience with online shopping, which influenced their opinion on subscriptions. Participants with online shopping experience were therefore selected for the second and third focus group session, each including another 4 focus groups, after which theory saturation was reached. A total of 12 focus groups are therefore held.

Small focus groups of four participants were used. All the participants are responsible for grocery shopping and are therefore well-experienced in FMCG shopping and are potential users of subscriptions. It is therefore expected that each participant can give a large amount of information about their current shopping behaviour and their opinion on the new systems proposed. The research setting and results of the focus groups are presented in Chapter 6.

4.5.3 Interview methodology

Interviews can be used to seek knowledge about what people know, do, think and feel, and improve understanding of facts, behaviour, beliefs and attitudes (Robson, 2011). Interviews, like focus groups, capture the perspectives of the participants on a topic of interest (Crabtree et al., 1993; Patton, 2002). Three types of interviews are distinguished in the literature:

1. Structured interviews have a regular format and generate a standard set of responses to facilitate statistical analysis (Ghauri and Grønhaug, 2002). The interviewer reads a list of predetermined questions in the interview (Robson, 2011; Saunders et al., 2003). In that way, quantitative analysis can be performed on the data collected for either descriptive research or for statistical analysis in explanatory research (Saunders et al., 2003).
2. In semi-structured interviews the interviewer has more freedom and can decide to add or omit certain questions, depending on how the interview goes (Robson, 2011; Saunders et al., 2003). The interviewer is guided by an ‘interview guide’ which contains a list of themes and questions he can discuss with the respondent (Bryman and Bell, 2007). This list is carefully designed; the sequence of the questions is predetermined to minimise the bias in the interviews (Ghauri and Grønhaug, 2002). Semi-structured interviews tend to ask what, how and why questions, mainly in exploratory studies (Saunders et al., 2003). Besides that,

semi-structured interviews shed light on the relationship between variables in an explanatory study (Saunders et al., 2003).

3. Unstructured interviews are an informal discussion exploring certain aspects in depth (Robson, 2011; Saunders et al., 2003). The interviewee can talk freely about events, behaviour and beliefs that are related to the topic. The interviewer requires greater skill to be able to ask subsequent questions that enrich the data collected (Ghauri and Grønhaug, 2002). A topic guide is therefore needed to advise the interviewer on which topics to further explore and which to discard (Easterby-Smith et al., 2008). Unstructured interviews are mainly used in exploratory studies (Saunders et al. 2003), or in ethnographic studies (Easterby-Smith et al., 2008; Robson, 2011).

Which type of interview to use depends on nature and objective of the research. Also a combination of interview types is possible within one research project (Saunders et al., 2003).

Interview participants are in a unique position to tell the interviewer what they do and why. Underlying motives can be investigated in the dialogue with the participants (Robson, 2011). Interviews, compared to surveys, have therefore the possibility to gather rich data. However, a disadvantage of interviews is that they are time-consuming (Easterby-Smith et al., 2008; Robson, 2011). When relatively simple questions are asked, a questionnaire survey might therefore be a more efficient method of data collection. Besides that, interviews, and especially unstructured ones, can introduce bias because of a lack of standardisation (Robson, 2011).

Before conducting the interviews, an interview or topic guide needs to be prepared. The interview guide describes the questions that the interviewer is going to ask. The questions must be carefully selected based on the objectives and research questions of the study (Ghauri and Grønhaug, 2002). The questions and comments of the interviewer should not influence or lead the interviewee's responses (Bryman and Bell, 2007; Saunders et al., 2003). Interviewer bias can also result from other non-verbal behaviour of the interviewer which influences the responses.

Besides interviewer bias, interviewee bias can also reduce the quality of the interview. This happens, for example, when the interviewee is withholding some information or does not want to tell everything. Especially when discussing confidential or sensitive

information (Saunders et al., 2003). However, this problem is even more likely to appear in focus groups (Crabtree et al, 1993).

Justification for using interviews in this study

There is very little literature available comparing one-on-one interviews with focus groups. Crabtree et al. (1993) argue that focus groups are less suitable for gaining a detailed understanding of individual behaviour. Subtle variations in the perceptions of the individuals can only be found with one-on-one interviews.

Given the limitations of focus groups, one-on-one interviews were also conducted as part of this research. In the first session, 20 participants are asked about their perception of grocery shopping, online shopping and the possibility of automatic subscriptions. From these interviews, several characteristics of the individuals are identified which influence their attitudes to automatic subscriptions. This was further tested with two sessions of one-on-one interviews with two categories of consumers, one of time-stressed individuals and the other with non-time-stressed participants. The approach and findings can be found in the second part of Chapter 6.

4.5.4 Life Cycle Assessment (LCA)

LCA is a *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle"* (ISO 14040, 2006, p.2). This means that the environmental impact of a product or service is assessed from the extraction of resources through to disposal of the product and includes production, distribution and use of the product or service (Guinée et al., 2002). Besides calculating the environmental impact, LCA can be used to compare the environmental impact of different products or services to make a choice of which product or service to use (Guinée and Heijungs, 2005).

The LCA approach consists of four phases, illustrated in figure 4.2. Each of the phases is discussed from a theoretical point in more detail below. The detailed LCA model which is built and used in this thesis is outlined in Chapter 8.

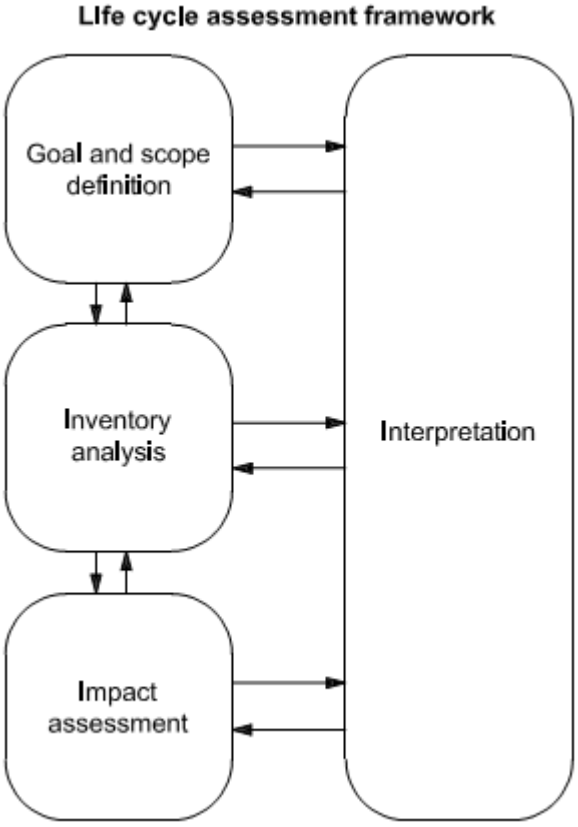


Figure 4.2: Stages of an LCA (Adapted from ISO 14040, 2006)

Phase 1: Goal and Scope definition

The reason for carrying out an LCA study, taking account of the intended audience and use, should be discussed before conducting the LCA (Guinée et al., 2002; ISO 14040, 2006). The study objective and research questions determine if LCA is the most appropriate tool and the value of LCA must therefore be explained in relation to the specific topic (Guinée et al., 2002). One of the key decisions is the choice of functional unit to be subjected to the LCA.

The environmental outcome of the product or service depends not only on the materials used but also on the environmental, technological and economic consequences of the new product or service (Finnveden et al. 2009). Therefore it is important to include the performance of the product or service in the functional unit. The functional unit should give *"an unambiguous definition of the service or function that the compared products* [or services] *must provide"* (ILCD, 2010, p.336). It describes the main functions fulfilled by the product or service and indicates the range of functions included in the analysis (Guinée et al., 2002). The functional unit must be carefully chosen so that valid comparisons can be made.

Phase 2: Inventory analysis

In the second phase of the LCA approach, the inventory analysis, the system boundaries are delimited and the model is built. For each process or module identified, relevant material, energy and environmental data has to be collected. All choices made in the development of the model, including choice of data and calculation method, must be clearly indicated as these choices will influence the results (Guinée et al., 2002). For example, the data quality will influence the quality of the results and depends on factors like the technological, geographical, and time-related representativeness, its completeness, uncertainties in the data and methodological appropriateness and consistency (ILCD, 2010). Therefore both the reliability and the validity of the data need to be assessed (Guinée et al., 2002). This will be further discussed in phase 4 below.

When data cannot be collected, it can be necessary to ignore or 'cut-off' the process. However, instead of excluding processes for which no data are available it is recommended that unknown data inputs are estimated (Guinée et al., 2002). ILCD (2010) suggest using estimation for the less relevant processes and only to exclude irrelevant flows. When cut-offs are used, the overall completeness or cut-off percentage on the environmental impact needs to be stated. Unfortunately, determining which processes are important for the environmental outcome is difficult without having the data (Finnveden et al., 2009). Iterative loops between the inventory analysis and impact assessment might be needed.

When processes are used for more than one product, their environmental impact should be divided among the different products, normally based on relative mass, energy content, or economic value of the products (Guinée and Heijungs, 2005). The international standard (ISO 14044, 2006) proposes a hierarchy of solutions for allocating the environmental impact to certain items. The preferred solution is to divide the process into sub-processes which should avoid the need to allocate. When this approach is not possible, the system boundaries should be expanded, including the co-products of the products, so that allocation is again avoided. When neither option is possible, the 'principle of physical causality' can be applied. This means that the allocation is based on quantitative changes in the input and output flows in response to changes in number of the products delivered by the system. The last solution is to apply

other principles of causality like economic values (Finnveden et al., 2009; Guinée and Heijungs, 2005; ISO 14044, 2006).

Phase 3: Impact assessment

The inventory analysis ends with a list of resource extractions and emissions. To understand the results and compare alternatives more easily, further aggregation of the list is preferred. The impact assessment phase aggregates all emissions and other resource flows that contribute to a particular type of environmental impact (Guinée and Heijungs, 2005; Guinée et al., 2002).

The ISO 14040 (2006, p.2) defines the impact assessment as a *"phase of LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of the product system"*. The first step in the impact assessment is characterisation. A characterisation model must be chosen which translates the emissions from the inventory assessment into contributions to the impact category (Guinée and Heijungs, 2005). The mathematical model quantifies the resource extractions and emissions into a single unit. Examples of impact categories are climate change, stratospheric ozone depletion, human toxicity, and acidification (Guinée et al., 2002). The next step, normalisation, is an optional step and is not required by the ISO 14040 (2006). However, it is strongly recommended for any LCA (Guinée et al., 2002). Normalisation rates the characterised indicator results in terms of their relative importance (Guinée and Heijungs, 2005).

Two types of impact category indicators exist: midpoint and endpoint. The midpoint indicators show the relative outcome of the system under study at a reference flow level (ILCD, 2010). It divides the emissions calculated for the functional unit by, for example, the total annual global emissions emitted. Other examples of reference values are total annual environmental impacts in a country or region, or the average annual elementary flows per citizen (ILCD, 2010). It shows therefore the contribution of the functional unit to the total emissions like CO_2, without making any claims about the relevance or extent of the damage this causes. The endpoint indicators relate to a specific damage, for example, number of species. It describes therefore the environmental relevance of the impact category for the functional unit (Guinée et al., 2002). This is visually explained figure 4.3. Normalisation and weighting, which are both not shown in figure 4.3, can start from midpoints or endpoints.

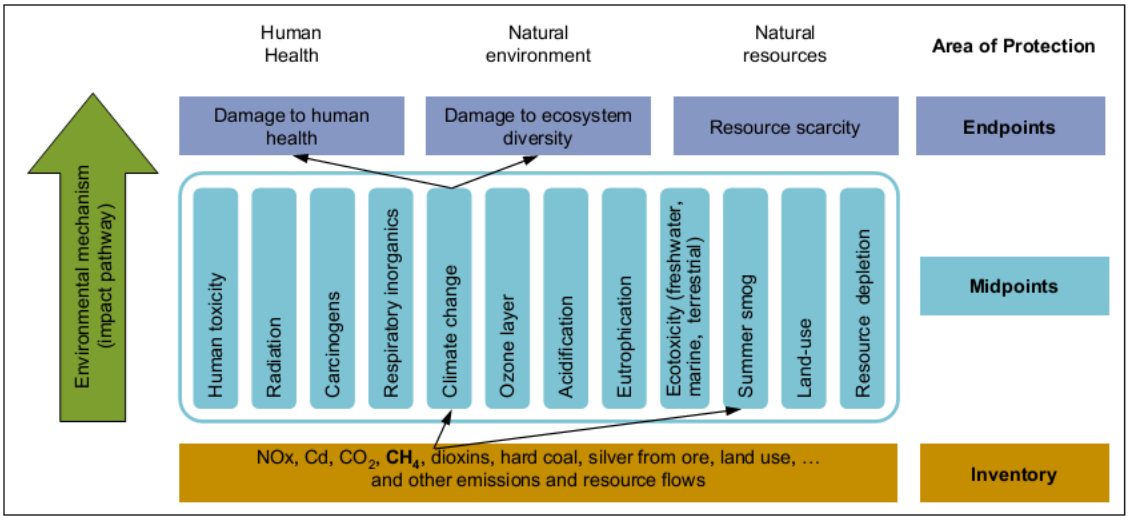


Figure 4.3: Life cycle impact assessment (Source: ILCD, 2010)

Several researchers argue that endpoints include a higher degree of uncertainty than midpoints. The process of weighting the different impact categories into a certain damage or area of protection is often based on social science and external costing methods (Finnveden et al., 2009; McKone cited by Bare et al., 2000). The reliability of the endpoint approach depends on the impact category. For example, the endpoint calculations for climate change is *"encumbered with large uncertainties due to the many unknowns of the global climate system and the long time-horizon of some of the involved balances"* (Finnveden et al., 2009, p.10). On the other hand, midpoint indicators only indicate the relative importance of the product or system against the reference and do not show the absolute severity of the problem. Therefore, depending on the impact category, the uncertainty increase between the midpoint and endpoint can be justified by the improved insight into the damages the product or system causes (Finnveden et al., 2009; UNEP 2003). This is the case, for example, for acidification and photochemical ozone formation while an endpoint analysis for climate change includes too much uncertainty to be justifiable at this point in time (Finnveden et al., 2009). Besides that, midpoint indicators also include uncertainties, particularly for certain types of externality. For example, data and methods on calculating greenhouse gases or ozone depletion are well reported (for example by the International Panel of Climate Change), but other environmental indicators like toxicity and land use may be incomplete and inaccurate (van Hoof et al., 2013). An incomplete reference scenario leads to overestimation of the relative impacts of the product or system on the total emissions reported in the world. A justification of the choice of impact category used must therefore be given.

Other possibilities in the impact assessment phase are grouping and weighting. Grouping combines category indicators into sets which are defined in the goal and scope definition, for example impact categories related to a certain input, and are based on subjective choices (ISO 14044, 2006). Weighting is the process by which the impact categories are multiplied by a weighting factor. One example is the monetary approach, where the impact categories are translated into monetary values (Guinée and Heijungs, 2005). Weighting is useful for tradeoffs where improvements at one impact category are achieved at the expense of another impact category (Finnveden et al., 2009). The weighting factors are generally normative / subjective and are based on value assumptions (ILCD, 2010). The ISO standard does therefore not recommend weighting (ISO 14044, 2006).

Phase 4: Interpretation

The life cycle interpretation phase evaluates the findings and discusses the conclusions and recommendations in relation to the defined goal and scope of the LCA (ISO 14040, 2006). It analyses the robustness and reliability of the results and gives an overall conclusion (Guinée et al., 2002; Skone, 2000). As discussed above, the reliability of the results are influenced by the data quality. A proper evaluation of the data quality is necessary, but a *"generally agreed standardized method for overall assessment of data quality is lacking as yet"* (Guinée and Heijungs, 2005, p.6). To assess the data and to evaluate and analyse the LCA results, the following approaches are recommended by the LCA handbooks (Guinée et al., 2002; ILCD, 2010; ISO 14044, 2006):

Consistency check: the assumptions, methods, models and data need to be consistent with the goal and scope of the research. It is advised to check for unexpected outcomes on the basis of expert knowledge and a comparison with previous studies (Guinée et al., 2002).

Completeness check: ensures that all data is available and complete and checks the model on assumptions and errors. Skone (2000) advices to use a checklist to assess all scenarios on whether the data is complete and in line with the goal and scope definition (e.g. for example with the system boundaries).

Contribution analysis: analyses the contribution of the various processes or life cycle stages to the overall output (Heijungs and Kleijn, 2000). As argued earlier, an iterative loop between inventory analysis, impact assessment and interpretation might be needed (Guinée et al., 2002).

Sensitivity and uncertainty analysis: the robustness of the results when parameters change can be tested with a sensitivity analysis (Guinée et al., 2002). This analysis determines how the uncertainty in the outcome of the model can be attributed to changes in the input parameters (EPA, 1995; Saltelli et al., 2008). Uncertainty analysis calculates the total error ranges or uncertainty of the results (EPA, 1995; Guinée et al., 2002; Saltelli et al., 2008). It calculates how uncertainties and assumptions affect the reliability of the results (ISO 14044, 2006). Three types of uncertainty in a LCA models are identified (Huijbregts et al., 2003):

- Parameter uncertainty is the uncertainty in the input data regarding process inputs, environmental discharges and technology characteristics (Lloyd and Ries, 2007). It includes data inaccuracy, data gaps, unrepresentative data for example other region or unrepresentative age (Björklund, 2002).
- Model uncertainty is defined as the uncertainty in models used to derive emissions and characterisation factors (Lloyd and Ries, 2007).
- Scenario uncertainty includes variability in the normative choices made when constructing scenarios and includes, for example, choices regarding time horizons and geographical scales (Huijbregts et al., 2003; Lloyd and Ries, 2007).

No guidance regarding the uncertainty analysis is provided by the ISO standard (ISO 14040/44, 2006). However, when decisions are made with the LCA model (and disclosed to the public), a sensitivity analysis is needed to assess their robustness (Guinée et al., 2002; ILCD, 2010). Despite this recommendation in the LCA handbooks, in most LCA studies a sensitivity analysis and/or an uncertainty analysis are not carried out due to the complexity and the resources and time needed for this kind of analysis (de Koning and Guinée, 2008; Guo and Murphy, 2012; Huijbregts, 1998; Lloyd and Ries, 2007; Maurice et al., 2000).

The studies that do consider uncertainty are mostly limited to parameter uncertainty and exclude model and scenario uncertainty (Bare et al., 2000; de Koning and Guinée, 2008; Finnveden et al., 2009). Lloyd and Ries (2007) found only 24 LCA studies that included some form of sensitivity and uncertainty analysis, and of these only 9 included scenario uncertainty and 8 model uncertainty. Standard data, methods and procedures for analysing the uncertainty in LCA are lacking (de Koning and Guinée, 2008). Due to the complexity of conducting a full sensitivity and uncertainty analysis, it is considered as good practice to implement a partial sensitivity analysis (Guinée et al., 2002). This

means that for those issues that are identified in the impact assessment (mainly in the contribution analysis) a sensitivity analysis must be performed (ILCD, 2010).

Justification for the use of LCA in this study

In the United Kingdom, 'carbon footprinting' has become popular, promoted by non-governmental organisations, companies and private institutions rather than by academic research (Weidema et al., 2008; Piecyk, 2012). Carbon footprint is defined as *"a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product"* (Wiedmann and Minx, 2008, p.5). Carbon footprinting is easier to calculate. However, carbon footprint relies on one indicator, CO_2 emissions, which can vary inversely with other environmental indicators (Weidema et al., 2008). For example, catalytic converters and diesel particulate filters increase the carbon footprint of car travel (Finkbeiner, 2009). LCA can however provide a holistic approach, bringing the different environmental impacts across different life cycle stages into one consistent framework, thereby increasing the rigor (Guinée et al., 2002).

In this thesis an LCA model is built to quantify the environmental impact of several e-fulfilment models. Primary and secondary data is used as much as possible for the input of each specified parameter. As suggested by Guinée et al. (2002) in the case of a lack of data, estimated data was used. Further, allocation was used to divide the impacts of the consumer trip over the different destinations and purposes of the trip. Because the purpose of this research is to quantify the environmental impacts of online and traditional retailing, it would not be fair to include the emissions of trips to locations which are irrelevant to online / traditional shopping. Trip-chaining has normally a positive effect on the environment and would reduce the emissions to a specific location. Therefore emissions of the consumer trip are allocated to the online / physical shopping based on the dedicated distance driven for that purpose.

The next step was to aggregate the results into an impact category. With the normalisation approach within the LCA software, the relevance of the different impact categories are assessed. As a result of such an assessment, it was decided that the present study should focus on climate change potential, as expressed in CO_2-equivalents. The LCA approach, followed by the environmental results of the online retail models, is further outlined in Chapter 8.

4.6 Research quality

Validity and reliability are widely applied criteria for quantitative research. However, these criteria might not be suitable for qualitative research. A consensus seems to be achieved that the concept of validity and reliability, as developed for quantitative research, are not applicable to qualitative research (Bryman and Bell, 2007). Varieties to these terms were developed, ranging from a slight modification of the concepts to the development of alternative criteria (Bryman, 2012; Seale, 1999). The evaluation standards depends on the methodology and methods used in the research (Creswell, 2012). Within the critical realist paradigm, the concepts of validity and reliability are, although slightly adapted to qualitative research, applied to evaluate the quality of the research (Chioncel et al., 2003). Maxwell (1992) outlined three criteria to assess the quality of qualitative research within a critical realist perspective, which are also applied in this research, called descriptive validity, interpretative validity and theoretical validity.

Descriptive validity refers the accuracy of the findings, it explains if the researchers have described what actually happen and have included all important findings. Johnson (1997) argues therefore to involve multiple researchers in recording and describing the research when doing qualitative research.

Interpretive validity discusses if the findings describe what the participants meant. An essential part of qualitative research is understanding the 'participants perspective' which is grounded in the language of the participants, in the words and concepts he or she uses (Chioncel et al., 2003).

Theoretical validity refers to the validity of the theory abstracted from the participants views. It both includes the validity of the concepts constructed and their relationships between these concepts. Theoretical validity describes therefore a type of validity that comes close to both construct validity (e.g. if the research measures the constructs that is being built in theory) and internal validity (e.g. if the changes are caused by the independent variable) (Maxwell, 1992).

To ensure descriptive and interpretative validity of the qualitative research, all focus groups and interviews held in this research are recorded. In that way, direct connotations and language of the participants can be used when writing the report. During the interviews and focus groups minutes were taken from the viewing room which is helpful for first analysis of the results. Concepts and relationships discussed

with the participants could be identified, which is the first step for theoretical validation (Chioncel et al., 2003). Between the interviews, the findings are directly discussed between the two researchers involved. Focus groups are conducted until theory saturation is reached, and individual differences are further tested with interviews. A decision tree is constructed which is validated with two groups of consumers, those who fit the profile for possible automatic subscriptions subscribers and those who do not. The report is read by the other researcher for cross-checking the results which ensures descriptive and theoretical validity (Johnson, 1997).

Validation procedures for the complete LCA model and its results, are lacking (Guinée et al., 2002; Ciroth and Becker, 2006). To assess the quality of the results, the LCA handbooks recommend therefore to evaluate the validity and reliability of the input data (Guinée et al., 2002; ILCD, 2010). For that purpose, all input values and their sources were collected in an excel file such that the representativeness, completeness and consistency of the data over the different e-fulfilment models could be assessed. This file was evaluated by an supply chain expert and an LCA expert. Thereafter, a contribution analysis was performed and the results were compared with earlier studies. A similar pattern was found; the last mile contributes significantly while ICT impacts and utility consumptions in DCs, CDPs and cross-docks were relatively small. The key parameters were further assessed with a sensitivity analysis. The sensitivity analysis confirmed the importance of these key parameters on the overall greenhouse gas emissions of the e-fulfilment models and identified under which circumstances the e-fulfilment models provide a sustainable home delivery.

4.7 Conclusion

This chapter has outlined the research methods used in this study. Several paradigms are explained, of which critical realism is chosen as the most appropriate for this research. Several researchers have criticised the dominant positivist approach in logistics and argue that the human aspects in logistics require different approaches. These human behavioural aspects are better accommodated with a critical realist framework. Research, according to the critical realist, must focus on solutions for relevant problems. These solutions can exist or can be developed in the process of research. A ‘design science’ methodology has been applied in this research to combine existing knowledge with the process of creating new solutions to find sustainable e-fulfilment models for FMCG products.

Each of the steps in the design science approach is explained and justified in this chapter. A combination of one-on-one interviews and focus groups are used to investigate the consumer opinion of new e-fulfilment models. The environmental performance is analysed using the widely applied Life-Cycle Assessment (LCA) approach. Even though widely applied, no standard LCA model for online retailing exists. The studies that conducted an environmental analysis of online retailing have different system boundaries and made different assumptions. Based on earlier work, a LCA model is built in this thesis which incorporates all important factors and consequences of online retailing and is used to calculated the environmental impact of the different e-fulfilment models for FMCG in the United Kingdom with the same set of assumptions.

CHAPTER 5: SUBSCRIPTIONS

E-commerce and online shopping are growing substantially each year, offering consumers much greater convenience in the way they shop. This convenience is achieved in two ways; by retailer assuming responsibility for the order picking and home delivery activities. The consumers still have to think and decide about what and when to order, remember to place the order, and actually place the order (Småros and Holmström, 2000).

With the current IT systems available, retailers can do much more to be 'connected' to the consumers, thereby providing an even more convenient service. In the B2B environment, information exchange and practices such as vendor-managed inventory (VMI) between supply chain partners has resulted in increased service quality and reduced supply chain costs. Something similar can also be applied to B2C e-commerce. Retailers and manufacturers can make agreements with the end-consumer about the products they buy and when they will be delivered. These companies can participate in the consumers' inventory management and planning activities and offer the them a service which guarantees product availability without them having to place a separate order each time (Småros and Holmström, 2000). A service like this can possibly fulfil consumer demand while at the same time reducing costs and emissions across the supply chain. It would, however, require a commitment from the consumer in the form of a subscription.

This chapter examines the possible use of subscriptions within the online retail market. It presents the results from a literature review and search for examples of subscription operating in practice (section 5.2). Based on the information collected, a classification of subscription types is made (section 5.3). The potential impacts of the various types of subscription are assessed. In section 5.4 the collaboration aspects of subscription services and the implications for the supply chain if subscription services were introduced are explored. Section 5.5 considers the consumer viewpoint on subscriptions, based mainly on findings in the literature. In section 5.6 an overview is given of the product types likely to be most appropriate for the different subscription models.

5.1 Introduction

Back in 1999, technologies to reorder groceries automatically were being explored (Neff, 1999). Electrolux and Frigidaire designed a refrigerator with a bar-code scanner that placed orders automatically (Småros and Holmström, 2000). Streamline, an early entrant into the US online grocery market, offered a 'don't run out' service that replenished certain products at an agreed time (Nasdaq, 1999). These initiatives failed or were never implemented in practice. However, subscription relationships with end-consumers can increase consumer satisfaction and reduce costs: *"developing subscription relationships with end-consumers will lead to increased planning time which will results in dramatic cost reductions and superior consumer value and satisfaction through lower costs, increased convenience, and improved availability of supply"* (Cook and Garver, 2002, p.37).

Despite the claim that supply chain benefits will accrue from subscription services for physical products, there has been little subsequent literature on the replenishment of products in the consumer's home. A literature search on subscriptions showed that the majority of the papers on the subject related to products like newspapers, magazines, music, broadband, telephony, and digital documents (for example, Lewis, 1995; Madden et al., 2004; Round and Bentick, 1997). Some papers discussed the success and challenges of the vegetable box schemes (for example, Chiffoleau, 2009; Geen et al., 2006; Haldy, 2004). Only two papers considered the influence of subscriptions on the supply chain (Cook and Garver, 2002; Småros and Holmström, 2000). Although not mentioning subscriptions, the ECOMLOG project at the University of Helsinki explored the opportunities of including the consumer in the supply chain collaboration to achieve better planning and control. This project focused on the development of a new tool to supplement existing replenishment models (Holmström et al., 1999; Småros and Holmström, 2000). On a similar theme was the MyGrocer project, which aimed to provide automatic replenishment of home supplies through monitoring of radio frequency identifiable consumer goods (Roussos et al., 2001). Although this project concluded that information sharing and collaboration with the consumer creates the opportunity to monitor product purchasing and usage habits (Kourouthanassis et al., 2002), data protection and privacy concerns were preventing further implementation (Roussos and Moussouri, 2004).

Due to the limited reference to working examples of subscription services in the literature, a separate search for commercial subscription services was conducted on the Internet (see table 5.1). For certain products, the services found showed similar characteristics. For example, the purchase of socks by subscription tends to have a minimum length of one year which needs to be paid upfront and renews automatically after the first year. Of these companies offering a similar service, a few representative examples are chosen subjectively to illustrate the service offered. This resulted in 31 companies. The information available on each of these companies websites was analysed to determine the type of products, prices and discounts, delivery times and the level of communication between the company and the consumer.

5.2 Characteristics of subscriptions services based on industry examples

In this thesis only subscriptions for physical goods are examined, where the retailer performs the home delivery, either itself or through an outsourcing arrangement with a third-party logistics provider. A subscription is defined here as "*an agreement to receive and pay for a specified product or service for a specified period of time"* (Cook and Garver, 2002 p 39) A full list of industry examples can be found in table 5.1. Unfortunately, like many early entrants in the online retailing business, subscription services were not always successful.

Industry example sorted on product type	Subscription description	Costs / Discounts	Products
Groceries Ocado 'Delivery Pass' (www.ocado.com)	Consumers subscribe to free grocery home deliveries, as often as they want, without any further delivery charge.	Monthly subscription fee. A minimum order value, like they have with one-off orders, still remains and no price discount on the products is given[12].	The products in the basket and delivery time can be freely chosen each time the consumer places an order.
Groceries Ocado 'Reserved' (www.ocado.com)	Consumers sign up for a regular delivery day and time on a weekly or fortnightly basis.	The service is free, however the delivery charge has to be paid and the minimum order value is still applicable. Again no discount on product prices is given.	A suggested order (based on previous orders and consumer requirements) is created automatically by Ocado one week before the actual delivery and can be changed by the consumer prior to the delivery.
Groceries Streamline[13] 'Personal Shopping List'	Automatic replenishment of groceries specified by the consumers in their 'Personal Shopping List'.	Monthly subscription fee.	Consumers can choose the products from their frequently purchased list. A typical weekly order was included. Consumers could add or delete items from the weekly order at any time (Nasdaq, 1999). The weekly delivery of groceries was combined with dry cleaning services, fresh flowers, rental videos, et. (Bovet and Martha, 2000).

[12] The Ocado 'Delivery Pass' is replaced by the Ocado 'Smart Pass' in 2013 which offers the additional benefit of lower prices (Ocado, 2013).
[13] Streamline, an early USA online grocer, is closed down in 2000.

Groceries Streamline 'Don't run out'	The 'don't run out' service of Streamline automatically reordered products at a specified time interval, without consumer interface (Nasdaq, 1999). This advanced subscription scheme automatically replenished the consumer's inventory of continuously needed items (Tanskanen, et al., 2002).	No information	The 'don't run out' list of products could be manually complemented with other items, which the consumer did not order regularly (Bovet and Martha, 2000)
Groceries Ikan (www.ikan.net)	Consumers scan the barcode of items they have consumed. Ikan sends the information to an online shopping list, that the consumer can then either print before their next shopping trip or send it to an online retailer.	No discounts. Full product price and delivery charges (if any) should be paid. Besides that consumers have to pay for the device.	Although developed for groceries, all products with a barcode can be scanned. Products without a barcode can be added with the voice control.
Vegetable box schemes Abel & Cole (www.abelandcole.co.uk), Damhead (www.damhead.co.uk)	Vegetable box schemes are quite common and provide an additional selling channel for the farmers to supplement the traditional channel (Haldy, 2004). Normally, the consumer cannot choose an appropriate time slot for the weekly delivery, unlike from an online grocery retailer, and deliveries are made per area.	Low delivery fee; the wide delivery time windows allows the delivery van to serve more households, up to 75 per day per van (Tinham, 2011).	The local farmer offers different sizes of vegetable and fruit boxes, sometimes complemented with other supermarket products that can be freely chosen by the consumer. The content of the vegetable and fruit box is chosen by the farmer and varies seasonally.

Wine M&S wine club (www.marksandspencer.com/Wine-Club-Wine-Food-Wine/b/163787031), essentially wine (www.essentiallywine.com), Waitrose wine direct (www.waitrosewine.com), wine club (www.wine.com)	Home delivery of a box of wine at regular time intervals until the customer ends the contract. Attended delivery is normally required, but time slots cannot be chosen by the customer.	Automatic payment (direct debit or credit card). Discount on wine varies between 3 and 30%	Consumer can choose the type / price of the wine box. The supplier selects the wine for each delivery. In some cases the customer gets a notice of the wine choice and can modify or cancel his order.
Coffee The Golden Coffee Box (www.goldencoffeebox.com), Coffee Real (www.coffeereal.co.uk), Has Bean Coffee (www.hasbean.co.uk), Urban Coffee (www.urbancoffee.co.uk)	Regular delivery of coffee with a minimum contract length between 5 weeks to 1 year.	Whole amount needs to be paid up front. In some cases credit card details are used to offer a rolling subscription after the minimum contract. Product discount up to 50%	Consumer can choose between different coffee boxes (variations in quantity and type / region of coffee). The supplier can select the coffee which fulfils the requirements.
Water Water for work and home (www.waterforwork.co.uk), Poland spring direct (www.polandspring.com)	Annual subscription on regular delivery of water directly to the consumer's door. The consumer cannot choose a time slot for the delivery.	Year contract. Poland spring direct uses the credit card details to offer a rolling subscription after the year contract.	Fixed product.
Groceries and household products Amazon 'Subscribe and Save' (www.amazon.com; www.amazon.co.uk)	Consumers can subscribe for a product or several with one, two, three or six months delivery frequency.	15% product discount and free shipping on routine items.	For each delivery the consumer gets an email to remind him and to give him a chance to make updates. Products included in this service are coffee and tea, baby and child care, personal care, household supplies, etc..

Socks monthly socks (www.monthlysocks.com), sokabonnement (www.sokabonnement.nl), blacksocks (www.blacksocks.com)	The subscription has a minimum contract length of 1 year and renews automatically either with a full year or from delivery to delivery until cancelled.	Total payment up front. No delivery charges.	Fixed product, e.g. same size and colour at each delivery.
Boxers Manpacks (www.manpacks.com), monthly boxers (www.monthlyboxers.com), boxer direct (www.boxerdirect.nl)	Regular delivery of one or two boxers. Delivery can through letterbox.	Monthly boxers and boxer direct have a minimum contract of one year, thereafter the possibility to cancel at any time. Manpacks send an invoice with each delivery.	Fixed product, e.g. same size and colour at each delivery.
Razor blades Razwar (www.razwar.com), Blademail (www.blademail.co.uk)	Razwar delivers blades for a specified period and number of times, while Blademail sends blades each time a payment is made.	Both companies require complete payment upfront.	Fixed product.
DVD / Book Club Columbia house (www.columbiahouse.com), Friends and Heroes DVD club (www.friendsandheroes.com/dvds), Disney movie club (www.disneymovieclub.go.com)	Agreement to buy a certain amount of products in a year. Consumers get several DVDs or books at a large discount by signing the contract that they will buy a certain number of DVDs or books in the next year at the normal price.	First order with large product discount and free delivery, remaining orders against normal product price and shipping and processing costs.	Free choice of DVDs / CDs or books out of large assortment.

Newspapers in Belgium and the Netherlands[14] Telegraaf (www.telegraaf.nl), Volkskrant (www.volkskrant.nl), NrcNext (www.nrcnext.nl), de Standaard (www.standaard.be)	Agreement between the publisher and the consumer where the consumer pays a subscription fee and the publisher delivers the newspaper five or six days a week to the consumer's home.	Fixed subscription fee, no further (delivery) costs. Significantly lower product price, up to 45% per newspaper	Daily newspaper
Heating oil CPL petroleum home heating oil (www.cplpetroleum.co.uk)	The product inventory level is monitored and shared at pre-set time intervals with the local depot. When necessary a delivery will be arranged.	No information.	Fixed product.

Table 5.1: Industry examples of subscription services

[14] In the United Kingdom newspaper delivery is usually via a local newsagent, where the consumer pays the newsagent for the delivery service.

From these examples, it can be concluded that the design of the subscription services vary. In some subscription services the consumer agrees to take several deliveries, whereas the products, amounts, time of delivery and delivery frequency are flexible or open. In these cases, the total number of deliveries to be made is often not fixed in advance and so there is no contract length as such. When the frequency of deliveries is specified in the 'contract' the consumer can, in some cases, still choose which products will be included in the next scheduled delivery. In other cases the consumer cannot choose the products for each delivery, and either the products are exactly the same in every delivery or the retailer chooses the products within agreed constraints. Although the promise is made to the consumer that they will never be out of stock in this constrained type of subscription, excesses or shortages are possible if the customer's consumption pattern does not fit the agreed replenishment scheme. For example, giving a party might temporarily increase the consumer's demand whereas a holiday would have the opposite effect. This would suggest that more sophisticated systems are needed to monitor the true consumption pattern and thereby reduce the need for consumer interaction.

The subscription services offered to the consumer described above are based on profiling. This means that the orders are created on the basis of the consumer's buying habits. This data does not reflect the day-to-day changes in a customer's demand, only historical information about their past behaviour (Småros and Holmström, 2000).

In the B2B area, several automatic replenishment programs exist (Buzzell and Ortmeyer, 1995). Suppliers can recommend a replenishment order which the buyer reviews and approves, possibly with some modification (similar to Ocado 'Reserved'). The second option is that the retailer gives the supplier a 'blanket authorisation' to pick, pack and transport orders, following an agreed contract (similar to Streamline 'don't run out'). A third possibility is that the retailer prepares the orders using automatic replenishment systems. Based on actual product usage and the continuing monitoring of stock level information, sellers replenish or restock the inventory (Myers et al., 2000). Normally the retailer sends information to a manufacturer who uses the data to construct a 'computer-generated replenishment forecast'. The forecast is then shared with the retailer before being executed (Levy and Grewal, 2000). The inventory information sent can be either flow control based (i.e. capturing consumption with a barcode scanner) or inventory count based (i.e. at regular intervals

the inventory status of certain products is collected) (see figure 5.1) (Småros and Holmström, 2000).

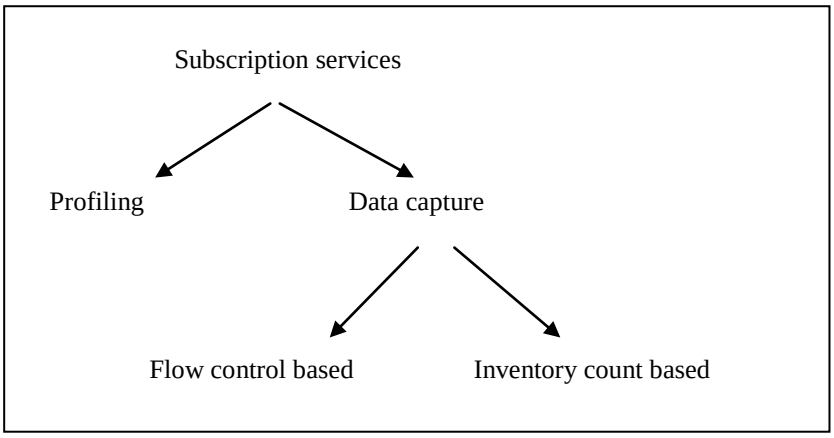


Figure 5.1: Alternatives for data capture (Source: Småros and Holmström, 2000)

In the B2C market, a few sophisticated examples exist of automatic replenish. One example is the Ikan; a barcode scanner which consumers can use to scan grocery products which are then collected in an online shopping cart. When the 'shopping' is completed, the consumer can either send the online list to an e-retailer or the consumer can print the list to do the shopping themselves in store (Ikan, 2011[15]). The Ikan, and the early attempt of Electrolux to provide a similar service, are based on flow control.

Another method to capture consumption data is by an inventory count. At pre-set times the inventory is counted and the information is sent to the retailer. Such a system is currently operated by CPL petroleum (see table 5.1) and can also be applied in kitchen cupboards. Inventory count based data capture utilises automatic scanning techniques, such as Radio Frequency Identification technology (RFID), and sends the information directly over the Internet to the retailer. No consumer interaction is required, making the system convenient for the consumer. Items can be tagged with a low frequency tag, which can store product information but also a record of when the product was bought. Unfortunately, these two-way tags, capable of reading information, are relatively expensive (compared with barcodes) making the system relatively expensive to implement, though the steadily decline in the unit cost of RFID is making them more affordable. Besides that, RFID tags on consumer level leads to concern about consumer privacy (McGinity, 2004).

[15] The webpage of Ikan is since mid 2012 not active.

Automatic replenishment gives the consumer the convenience of not having to think about re-ordering the products. The e-retailer then takes over the task of inventory management, and provides this service, in addition to home delivery (see figure 5.2).

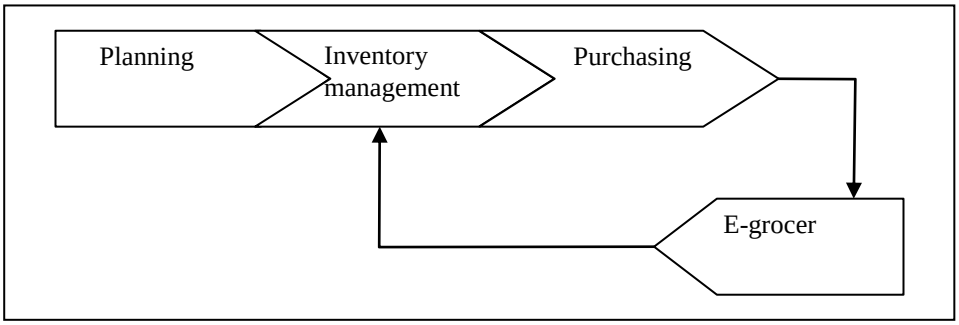


Figure 5.2: E-retailers can manage the purchase and inventory management process of households (Source: Småros et al., 2000)

Analysis of the data available on the websites of the 31 companies identified, reveals four key differentiators:

1. The way in which the delivery or replenishment of products is planned,
2. The degree of freedom the consumer has to alter the product mix
3. The required interaction level between the subscriber and the subscription provider
4. The length of time between order receiving and delivering

The options that companies have for these characteristics are grouped and discussed below.

5.2.1 Delivery / replenishment options for subscription services

This characteristic specifies when the deliveries will be triggered or scheduled. The possibilities[16] are summarised in table 5.2:

[16] Another possibility will be no requirement for further orders. A single delivery will then be accepted, for example Amazon 'Subscribe & Save' where consumers can cancel the subscription after the first delivery. However, the idea behind Amazon 'Subscribe & Save' is to ship the same products after a fixed time interval and is therefore included in the option 'regular deliveries'.

Options	Examples
1. Delivery planned by consumer a. Number of deliveries specified in contract, timing can be chosen by consumer b. Incentive in subscription to order several times within time period	1a. DVD / Book Club 1b. Ocado 'Delivery Pass'
2. Regular deliveries a. On a specified day b. After fixed time interval	2a. Ocado 'Reserved' Streamline 'Personal Shopping List' Vegetables box scheme Streamline 'Don't run out' Newspaper delivery 2b Poland Spring direct
3. Consumer VMI a. Flow control b. Inventory count control	3a. Ikan 3b. CPL petroleum home heating oil

Table 5.2: Possibilities for the planning of deliveries in the subscription service

The first possibility (1 in table 5.2) is an agreement situation where the shopper can decide when the next delivery will be. No time interval or days for the future deliveries are specified. It is possible that the agreement specifies the number of deliveries to be made in the future or the subscription provides an incentive to the consumer to order several times within a period. For example, when the consumer pays a fixed amount per month to earn free deliveries, the consumer will probably order several times a month to benefit from the subscription service.

In the second option, 'regular deliveries', products are shipped on a specified day or after a fixed time interval. In some cases no consumer interaction is needed after subscribing to the service and products will be automatically delivered. In other cases an order is needed for each delivery offered in this regular delivery service. In this case, the customer buys the right to a delivery on a specific day, but is not required to use the scheduled delivery. In practice, companies in this kind of scheme will deliver a suggested order when no customer order is received.

Although observed in only two of the 31 companies included in the study, a third possibility exists; the timing of the deliveries is based on the inventory held by the consumer. When the household inventory is running low, a new delivery is scheduled. This will be referred to as 'consumer VMI'. The inventory information can be based on flow control, inventory count control, extrapolation of past demand or an estimation of consumption. In the last case the inventory (or the amount of product

supplied to fill up the inventory to a certain level) is counted by the driver as part of the home delivery service. The inventory data is then used (possibly with other information, like weather conditions in the home heating oil case) to determine when the next delivery will be required to guarantee the customer not running out of stock. Other possibilities for 'consumer VMI' are a barcode scanner or RFID tags on the product packaging. A situation where the shopper has to check the inventory and has to give this information manually (e.g. for example by creating an online shopping card) to the subscription provider, is not an example of consumer VMI, but belongs to the normal customer online retailing handling activity.

5.2.2 Product variability in the subscription service

This characteristic specifies the agreement made on the products to be supplied. It describes how the products in the deliveries will be determined. The possibilities are shown in table 5.3:

Options	**Examples**
1. Consumer free to choose a. Completely free b. Within specifications / requirements	1b. Ocado 'Delivery Pass' Ocado 'Reserved'
2. Variable products (chosen by the subscription provider)	2. Vegetable box scheme
3. Fixed products	3. Amazon 'Subscribe & Save' Streamline 'Don't run out' Poland spring direct CPL petroleum home heating oil

Table 5.3: Possibilities of the agreement on products variability

In the first option the consumer can choose products separately for each delivery and independently of the products in previous or future deliveries. The products delivered might be completely unspecified or minimum specifications must met, for example a minimum order value.

Other subscription services are more constrained. The second possibility describes the situation where the subscription provider can choose products within a range specified in the contract. It is possible that the shopper can influence the choice of the subscription provider to a certain extent (e.g. certain products he / she dislikes), but the subscription provider has always flexibility to choose the products in each delivery.

One example is the vegetable box which contains a variety of vegetables dependent on seasonal availability.

In the third possible case, the so-called 'fixed products' option, products are specified in the contract and cannot be changed in principal by either the consumer or the subscription provider. It is possible that the products might slightly change through time in response to the growth in the consumer needs or preferences that change over time, for example the nappy sizes that increase as the child grows.

5.2.3 Interaction level in the subscription service.

This characteristic relates to the amount of consumer interaction that is needed in the subscriptions service. The possibilities are:

Options	**Examples**
1. Initial order triggers regular flow of deliveries (e.g. no customer interaction needed / possible afterwards)	Vegetables box scheme Streamline 'Don't run out' Newspaper delivery Poland spring direct
2. Start-up order to start 'flow' of deliveries but with possibility to adjust (e.g. add / remove items, cancel) orders	Ocado 'Reserved'[17] Amazon 'Subscribe & Save'
3. Order to subscribe to service plus orders for each delivery a. Order specifies time and products b. Order specifies time c. Order specifies products	3a. Ocado 'Delivery Pass' DVD / Book Club[18]

Table 5.4: Type and amount of orders in the subscription service

The first option occurs in those situations where, once the subscription has started, little changes can be made. In some cases it may be possible to cancel the orders for a couple of weeks when going on holiday. However, essentially deliveries will continue without any further consumer interactions until one of the parties ends the agreement or the contract period has ended. It is regularly possible to supplement the deliveries with other products out of the assortment of the subscription provider. These products are then delivered one-off and are not part of the subscription service.

[17] Suggested order will be delivered when no adjustment is made, but idea is that products can be freely chosen by consumer at each delivery

[18] There are Book clubs that send the shopper the next delivery even without an order, but this happens only when the shopper does not fulfil his part of the agreement e.g. to order additional products.

The second option also normally functions without any consumer interaction. However, the shopper has here the possibility to change the products per delivery and can cancel the deliveries. In some cases, depending on the contract, the subscription service can also be cancelled at any time. This gives the consumer more flexibility than in option 1 where he / she is more 'locked' into the contract.

The third possibility describes the situation where an order is needed for each delivery. The order can specify when the next delivery will be, which products will be in the next delivery, or a combination of both. Normally, there will be no deliveries made without any order specific to the delivery.

5.2.4 Order lead times within subscription services

The order lead time specifies the time between the order (e.g. delivery time and products known to the subscription provider) and the actual delivery to the shopper's home. The possibilities are:

Options	**Examples**
1. Short (delivery within few days after placing order)	Ocado 'Delivery Pass' DVD / Book Club Ocado 'Reserved'
2. Long ('fixed' deliveries and 'fixed' or ' variable' products)	Vegetables box scheme Streamline 'Don't run out' Newspaper delivery Poland spring direct
3. Real time data	

Table 5.5: possible order lead times within subscriptions

The first option, 'short order lead time', describes the situation where the system is highly responsive and orders are delivered within a maximum of a few days.

In the second option, 'long order lead time', the order is placed well in advance. This means that both the delivery time and the products in the delivery are known more than a few days before the delivery. In this case it is not the order that triggers the pick, pack and ship process but the delivery is triggered by a time lapse. For example, in the coffee subscriptions a pack of coffee is send every week for the length of the contract.

The last option, ‘real time data’, means that the subscription provider can follow the real consumption data, either by flow control or by inventory count control. The delivery is then triggered by the inventory reaching the safety stock.

The four characteristics outlined above can differentiate subscription services. The numerous permutations of these characteristics suggests that subscription services can be very diverse. The first two characteristics, delivery and product flexibility, influence the required consumer interaction and order lead time of the subscription service. This will be further explained in the next section.

5.3 Classification of subscription types

All combinations of the four characteristics were assessed and grouped into subscription types which have a similar impact on the supply chain. This resulted in three different subscriptions types. Not all of the possible combinations are likely to occur in practice. For example when the consumer can choose when the next delivery will be, an order will be placed most likely just before he or she wants to receive it and consequently the order lead time will be short. Only the combinations that are likely to occur in practice will be discussed below.

5.3.1 Flexible subscriptions

The flexible subscription service describes the situation where the consumer can choose the products at each delivery and / or the delivery date. The different situations are visually represented in table 5.6, 5.7 and 5.8.

Characteristic	**Combination of characteristics shown in grey**		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.6: Combination 1 - Consumer choose products and delivery date separately for each delivery

When both the delivery date and the products can be freely chosen by the consumer for each delivery, an order will be necessary for each delivery and consequently the

order lead time will be short. Industry examples of this subscription type are Ocado 'Delivery Pass' and DVD / Book clubs.

Characteristic	**Combination of characteristics shown in grey**		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.7: Combination 2 – Consumers choose products separately for each scheduled and fixed delivery

In combination 2, the products can still be freely chosen by the consumer before each delivery, but the delivery date will be scheduled and cannot be changed by the consumer. An order before each delivery will be needed to specify the products that the consumer wishes to receive in the next delivery, and most likely the order lead time will be short. However, in practice a suggested order is created and shipped to the consumer when he or she did not place an order on time, reducing the need for an order before each delivery. The consumer has still the possibility to adjust the suggested order to his wishes before the shipment is made and therefore the order lead time will be short. Examples are Ocado 'Reserved' and Streamline 'Personal Shopping List'.

Characteristic	**Combination of characteristics shown in grey**		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.8: Combination 3 – Consumer cannot choose products separately for each delivery but can choose the delivery date of each delivery

Although no real world example has been found, in the third combination (shown in table 5.8), the consumer cannot choose the products once the subscriptions service is started. The products can still be chosen by the subscription provider (variable products) or both the consumer and the subscription provider are confined to the

products specified in the contract (fixed products). An order is still needed for each delivery in which the consumer specifies the time and day for the next delivery, and consequently the order lead time will be short. In the case of fixed products, where the consumer places the next order when he or she needs the specified product, the situation becomes close to what is called automatic subscriptions. The difference is, however, that consumer interaction is needed in this situation and that the subscription provider has no access to actual consumption data.

Regardless of the constraints on the mix of products in the order, a delivery might happen at regular times or at times chosen by the consumer. The flexible category of subscriptions requires an order before each delivery to specify the products and / or the delivery time for the next delivery. This requirement makes the order lead time an important service criterion. The main difference with regular online sales lies in this case on the nature of the relationship between the subscription provider and the consumer.

A flexible subscription is therefore defined as: *a subscription arrangement in which the consumer can freely choose the products within each delivery and / or the timing of each delivery within the subscription service.*

5.3.2 Fixed subscriptions

In fixed subscriptions the consumer cannot choose the products or the delivery time. Once the fixed subscription is started, products are delivered to the consumer's home without any consumer interaction. This will be shown in table 5.9 and 5.10.

Characteristic	**Combination of characteristics shown in grey**		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.9: Combination 1 – Variable products on predetermined delivery dates

When both the delivery time / date and the products cannot be chosen by the consumer, there is no need to place an order before each delivery. In most cases an order to start the flow of deliveries will be sufficient and the time between the order

and the subsequent deliveries will be relatively long. However, it is possible that companies still offer some flexibility to the consumer to make minor changes to the subsequent orders, for example to cancel the orders when going on holidays. An example of such services is the vegetable box scheme.

Characteristic	**Combination of characteristics shown in grey**		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.10: Combination 2 – Fixed products on predetermined delivery dates

The second situation (shown in table 5.10) is almost similar to combination 1 (shown in table 5.9), except that the products are fixed and cannot be chosen by the subscription provider. Also here it is possible that companies do allow the consumer to adjust subsequent orders. Examples of such service are Amazon 'Subscribe and Save' and newspapers, socks or coffee subscriptions.

The fixed subscription is defined as: *a subscription where the consumer cannot choose the products in each delivery and the deliveries are made at a fixed time interval*.

5.3.3 Automatic subscriptions

In automatic subscriptions, real consumption data or inventory data is captured from the point of consumption. Orders are created and shipped to the consumer when the inventory is running low. The delivery time and products within the delivery depends on when and which products need to be replenished, however, the products that are monitored are fixed and defined in the subscription contract. With inventory count or flow control based technology, the real consumption data is captured and sent to the subscription provider, without the need for consumer interaction. In some cases it may be possible to adjust the upcoming orders. One industry example is the CPL petroleum home heating oil. This combination is shown in table 5.11.

Characteristic	Combination of characteristics shown in grey		
Deliveries	Delivery planned by consumer	Regular deliveries	Consumer VMI
Products	Consumer free to choose	Variable products	Fixed products
Orders	Initial order	Start-up order with possibility to adjust	Orders for each delivery
Order lead time	Short	Long	Real time data

Table 5.11: Combination 1 – Automatic subscriptions

The automatic subscription is defined as: *a subscription service in which the products specified in the contract are monitored at the consumer's home and replenished by the subscription provider when the consumer's inventory is running low.*

5.3.4 Summary of subscriptions classification and typology

Based on the industry examples reviewed, three groups of subscription services are identified: 'flexible' subscription, 'fixed' subscription and 'automatic' subscription. The classification of these groups is illustrated in figure 5.3.

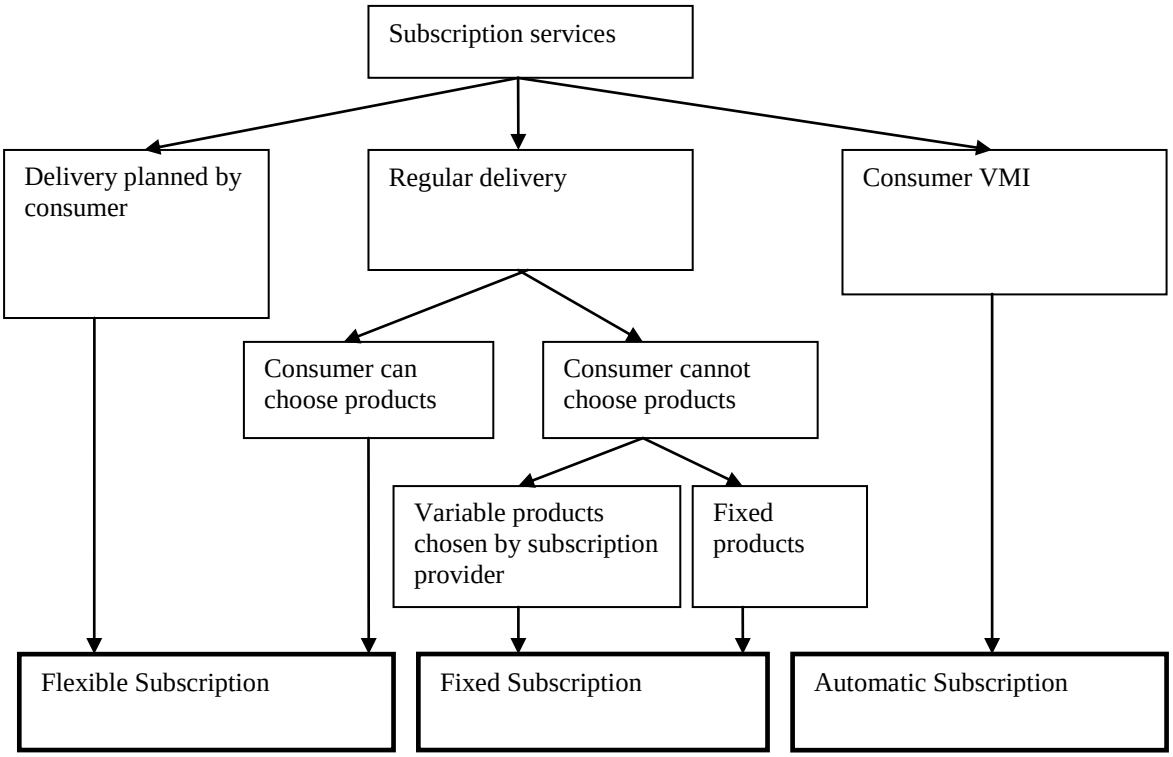


Figure 5.3: Classification of subscription services

Cook and Garver (2002) identify what they consider to be the main characteristics of subscription services. These are summarised in table 5.12.

Characteristic	Description
Consumer relationship	Long-term collaboration involving a series of long-term contracts that revolve around sharing information and demand planning.
Demand planning	Supply chain and end consumer collaboration to jointly determine demand assortment, quantities, timing and delivery location.
Critical information flow	Consumer demand and preferences
Manufacturing plan	'Make to plan' approach
Manufacturing operations	To minimise total supply chain costs, new subscribers are supplied with the first product after the subscription is included in the production. The order lead-time will be longer than the operation lead-time.
Inventory strategy	Use a strategy that enables the supply chain participants to manufacture and deliver the product by the due date at minimum total supply chain cost.

Table 5.12: Subscription supply chain characteristics (adapted from Cook and Garver, 2002)

According to Cook and Garver (2002) placing the final consumer at the core of the supply chain will achieve significant supply chain efficiencies. Collaboration with the end-consumer and the 'extra' information flow that appears due to this collaboration are discussed in the next section (section 5.4). This leads on to an exploration of the ways in which management of the supply chain can be modified to take advantage of this ´extra´ information. Cook and Garver (2002) argued also that subscriptions services are not relevant for all consumers and products. This applicability of subscriptions will be discussed in sections 5.5 and 5.6.

5.4 Collaboration between the retailer and the consumer in a subscription scheme

A subscription service is based on an agreement between a retailer and a consumer for the supply of certain products for a specified period of time. With this contract, retailers build a long term relationship with their consumers. Meyers et al. (2000) argued that within the B2B market, locking supply chain partners into long term agreements enhances the strategic positioning of the company. Automatic replenishment programmes create barriers to competitors and therefore make it more difficult for competitors to enhance their market share. Consumers are no longer exposed to all products available on the market when doing their shopping. The consumer's decision to do business is moved from purchasing (each time they are in the supermarket) to the moment when they subscribe to the service. The consumer becomes less sensitive to the price and place and does not choose the vendor that has

the lowest price on the day of purchase or is situated nearest the consumer's home (Småros and Holmström, 2000). For companies this may, eventually, lead to less need for marketing (Cook and Garver, 2002). Where consumers commit to a longer term subscription, large discounts (in some cases as high as 35% compared to normal online sales price) are given to the consumer (see for example the subscriptions Razwar.com and CoffeeReal.co.uk). When the subscription price is lowered over time, the barrier for consumer to ending the arrangement and switching to a competitor becomes bigger, strengthening the relationship even further (Cook and Garver, 2002).

Competitive advantage is also reinforced by the increased customer service. 'Automatic' subscription services provide consumers with an extra value added service (i.e. inventory management). At the same time, the retailer has the opportunity to more closely view and analyse the consumer end of the demand chain (Småros and Holmström, 2000).

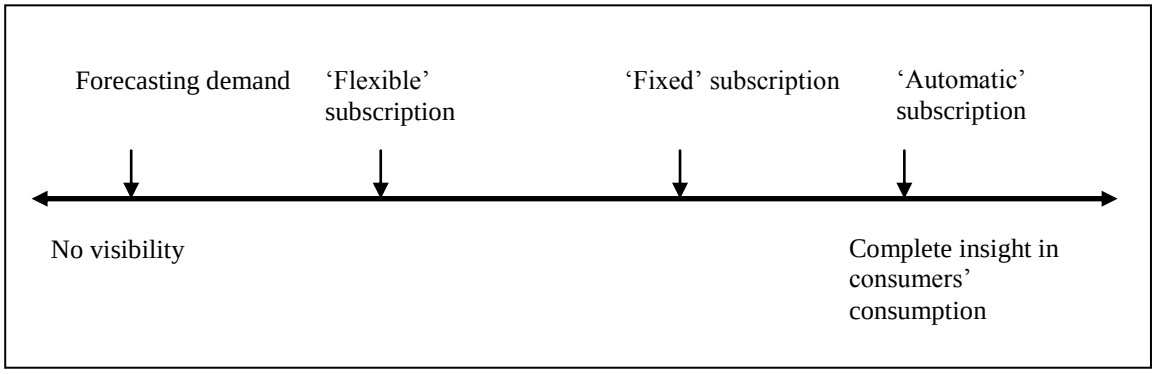


Figure 5.4: Variation in the visibility of consumers' consumption patterns for different types of subscription

Knowledge about the consumer can be used to introduce new products that better fit the consumer's needs or to more efficiently target the right consumer segments (Plummer, 1974). Consumer data also gives the supplier greater insight into pattern of demand at the micro-level. By gaining greater understanding of demand variability the supplier can reduce uncertainty in the processing of incoming orders (Holweg et al., 2005). Due to improved visibility of consumption patterns, the supplier can better manage his inventory. In an ideal subscription service, the supplier would know the exact demand in advance and consequently there would be no need for inventory from the demand side. However, in practice subscription services will only be a part of the total demand and therefore inventory will always be needed. When the supplier has more advanced information about the upcoming orders, either due to fixed orders in

the subscription service or evidence of demand stability[19], it can lead to inventory cost reduction.

A subscription service can also promote a more stable demand. Consumers are no longer influenced by promotions to buy larger quantities than normal. Promotions, price reductions and advertisements by the retailer, lead to increased demand volatility (Byrne and Heavey, 2006). However, it is likely that some consumers will be reluctant to enter subscription arrangements because then they will miss promotion and discount opportunities.

Very little research appears to have been done on the use of subscriptions to promote collaboration with the end-consumers. In contrast, several studies have shown that collaboration between supply chain partners in the B2B area can reduce supply chain costs and increase customer service (Cook and Garver, 2002). Forecasting demand or waiting until orders appear, leads to high inventory costs and / or lower customer service due to reduced product availability (Disney et al., 2003; Levy and Grewal, 2000). On the basis of this B2B experience one might extrapolate that similar collaboration on the last link in the supply chain might yield similar cost savings and service benefits (Cook and Garver, 2002).

Unpredictable demand and inaccurate information about demand patterns leads to high inventory, especially for upstream partners in the supply chain. This is widely known as the bullwhip effect. The bullwhip effect, also known as Whiplash effect, occurs when the demand order variance is larger than that of sales, and the distortion tends to increase as one moves upstream (Lee et al., 1997a). Sharing consumption data along the supply chain and having more accurate data helps to suppress the bull-whip effect (Buzzell and Ortmeyer, 1995; Myers et al., 2000). This effect can also have an adverse effect on customer service at the bottom end of the supply chain due to the inertia of the production / distribution system and miss-allocation of inventory (Holweg et al., 2005).

To take real advantage of the consumption information generated by subscription schemes, companies need to incorporate it into their production and inventory control processes to improve supply chain synchronisation. From a study of Holweg et al. (2005) it appears that if the vendor is not able to exploit the consumption information

[19] Seasonal and weather dependent products need forecasting and safety buffers, which generally mitigate the benefits of subscription services (Holweg et al., 2005).

at a tactical planning level, the bullwhip effect remains. Disney et al (2004) showed also that in theory the amplitude of the demand signal should decrease when the consumer sales-data is shared with all members of the supply chain. However, under some circumstances, sharing information can lead to high inventory costs, even when forecasts and replenishments are made together (e.g. CPFR[20]) or the upstream supplier is managing the retailer's stock (e.g. VMI). When supply chain partners do not fully understand and use the consumption information, the bullwhip effect remains (Disney et al., 2004).

Holweg et al. (2005) argue that this benefit only appears when the supplier is close and dedicated to the consumer. When a factory supplies to many customers, more effort is needed to reach critical mass which is needed to implement synchronized production planning. Hence the return on an individual customer subscription will be smaller, making it less economically viable. It can also be difficult for large suppliers to find a use for the extra demand data gained through the subscription. On the other hand, the coordination of inventory (for example VMI) can provide good results when implemented correctly (Disney et al., 2004; Lee et al., 1997b). In a true VMI setting, the vendor is able to optimize his production process and significant cost reductions can be achieved without any reduction in service level (Claassen et al., 2008).

If the vendor is able to use the consumption information, savings can be achieved. When the manufacturer is certain about the orders for the agreed period, the order lead-times can be extended so that they are longer than the actual operation lead time (see figure 5.5).

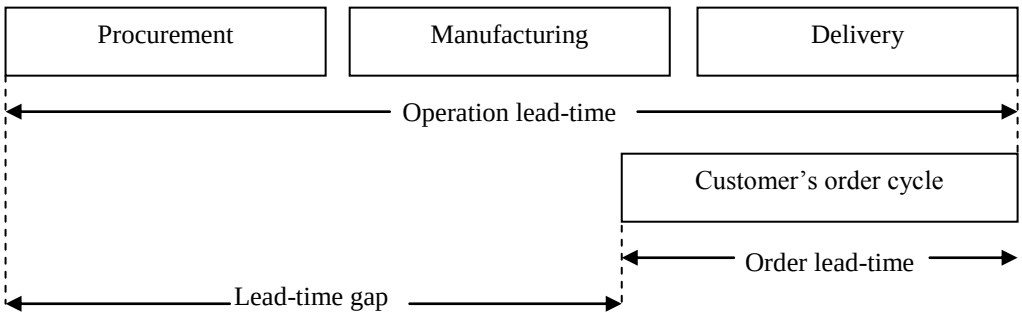


Figure 5.5: The lead-time gap (adapted from Christopher, 2011)

[20] Collaborative Planning, Forecasting and Replenishment (CPFR) tries to improve the accuracy of the forecast in demand through improved communications between the supply chain partners (Attaran and Attaran, 2007). The information is used to synchronise production plans and replenishments in the supply chain (Fliedner, 2003).

By eliminating the lead-time gap, the manufacturer can minimize the total supply costs (Christopher, 2011; Cook and Garver, 2002; Harrison and van Hoek, 2008). The product can be manufactured and shipped in large quantities well in advance to large population centres and then packed and shipped with other products to the consumers' home (Cook and Garver, 2002). Bovet and Sheffi (1998) argued that subscriptions would lead to the rise of 'the replenishment service specialist': i.e. third party service providers who combine consumer goods from different manufacturers at convenient locations and deliver a mix of products to individual households based on their consumption pattern. This illustrates how the development of subscriptions could create a new business opportunity for logistics service providers.

Subscription schemes could also help to improve transport efficiency, particularly at the local level. When, in a fixed subscription model, the need to deliver orders to particular customer locations is known well in advance, delivery rounds can be designed in a more efficient way (Bovet and Martha, 2000). Besides that, with the greater frequency of home delivery, the consumer has more incentive to invest in a reception box. Reception boxes can be installed at the consumers' homes, enabling unattended delivery.

Overall subscription services, especially involving long fixed contracts, reduce the supply chain risks and costs. This can lead to substantially lower subscription prices than offered in the shops (Cook and Garver, 2002). Besides that, the number of transactions is also reduced, reducing the costs and prices further (Buzzell and Ortmeyer, 1995; Cook and Garver, 2002).

5.5 Consumer perspective on subscriptions

The home delivery of the subscription products saves the consumer shopping time and is therefore a valuable benefit for 'time-poor' people. Some of the time saving due to home delivery is also achieved by the standard form or internet shopping (Haldy, 2004). Where internet shopping is combined with a subscription scheme, the potential time savings are greater. The inventory management service in the more fixed subscription services, where replenishment is routine and does not require customer interaction, requires even less time than internet shopping (see figure 5.6). This makes the advanced subscription services also more convenient for the consumer. Once the service is set-up the consumer does not have to do anything to have the products replenished.

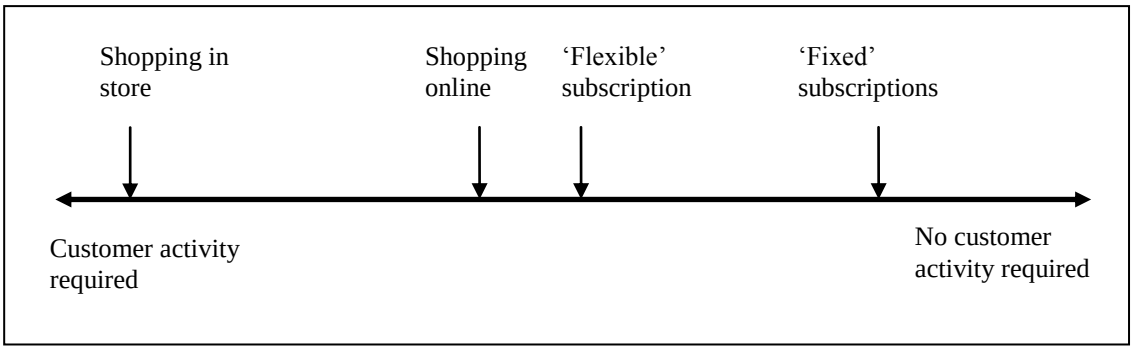


Figure 5.6: Time savings for customer for different shopping methods

Another benefit for the consumer is the assurance of the availability of the product (Cook and Garver, 2002). Due to the long order lead times (in the 'fixed' subscription services), the supplier can guarantee product availability on the scheduled delivery date. However, even when the consumer is supplied with the same products at a regular interval, the consumer can experience stock-outs or oversupply (Myers et al., 2000). Consumer demand fluctuations arise from time to time due to holidays and parties. The subscription service should be flexible enough to be able to handle these planned and unplanned changes in demand. Other planned changes in demand can be built in the subscription service to enhance customer service, for example in the case of dog food gradually increase the order size as the animal grows from puppy to adult dog (Cook and Garver, 2002). The subscription services, where the products are automatically shipped after a fixed time interval, are most suitable for repetitive continuous demand, e.g. product demand is stable and frequent (Småros et al., 2000). Brand loyal products are often bought on a regular basis and are therefore a suitable candidate (Cook and Garver, 2002).

Subscription services can also provide price discounts to consumers. Price sensitivity of home delivery is illustrated by the case of milk. A difference of 15 pence per pint between the home delivery price and the price of a pint in the shop resulted in a decline in milk home delivery (Hill and Lynchehaun, 2002). By offering a price discount, people are more willing to switch to a subscription service and more likely to resist the temptation to lured by the short-term promotional offers of competitors. One benefit of the subscription supply chain is the direct link to the supplier which can lead to increased trust and hence greater customer loyalty (Haldy, 2004; Gefen, 2002). Trust is also important when consumer data is gathered, processed, and stored for further use. A study by Kourouthanassis and Roussos (2003) shows that consumers are often reluctant to provide information to suppliers especially in case of inventory

count methods, for example when RFID tags are used and the supplier gains visibility of the consumer's inventory. Privacy and the use of personal data were the main concerns of participants. Where consumers gain confidence in a subscription service they are more likely to trust suppliers with consumption data.

People who dislike shopping are also more likely to subscribe to the service (Cook and Garver, 2002). The different shopping experience can attract new categories of customers (Haldy, 2004). Products that are boring to shop for or are difficult to handle (for example heavy and bulky items) are therefore candidates for subscription services.

5.6 Product types

Based on the limited literature on subscription services, the following table gives an overview of the benefits accruing from the different subscription options and indicate which product types are most appropriate for this type of distribution.

Benefit for	Benefit	Product type
Benefits for all types of subscription services		
Consumer	Price discounts	Expensive products
	Better shopping experience for those who dislike shopping	Bulky / heavy products
Supplier (e.g. e-retailer or manufacturer)	Competitive advantage	
Manufacturer	Higher margins	
	Better consumer understanding (due to direct link with consumer)	
Benefits for 'fixed' or 'automatic' subscription services:		
Consumer	Time savings (due to inventory management)	
	Convenient	
	Assurance of availability	Continuous demand products, like most FMCG products
Supplier (e.g. e-retailer or manufacturer)	Inventory savings (due to better planning)	Continuous demand products
	Inventory savings (less products in inventory)	Expensive, continuous demand products
Manufacturer (only small dedicated manufacturer)	Strategic planning, supply chain efficiency	Continuous demand products

Table 5.13: Overview benefits of subscription services

For most benefits in ‘fixed’ and ‘automatic’ subscriptions, continuous demand is needed. To be able to plan the production, inventory, and delivery very efficiently, the orders need be known well in advance which is only the case in the situation where the consumer has an agreement with the supplier for specific products delivered at specified times for a specified period of time, e.g. ‘fixed’ subscription. The other benefits, such as time savings and convenience for the consumer, can also be reached when the demand is less continuous. However, in that case the system must be flexible enough to handle irregular demand without direct interaction within the consumer, meaning that automatic reordering programmes (data capture programs such as barcode / voice scanning or RFID tags) are needed. When the demand is repetitive and stable (i.e. continuous), ‘fixed’ subscription is also suitable.

Which (continuous demand) products are the most suitable for subscription supply chains is difficult to predict. Consumers are all different. They buy different products at different frequency and vary in their sensitivity to promotions. A study of Småros et al. (2000) showed that the products that are bought on a continuous basis differ between the consumers. They argue that it is not possible to offer one subscription service that efficiently fulfils all the consumers’ need. Besides that, the consumer wants to vary certain products sometimes (Småros and Holmström, 2000), or consumption patterns change over time (Småros et al., 2000). This problem can be alleviated by combining the subscription service with customer profiling, where suppliers collect data on the consumers’ consumption habits and analyze the data to better follow the consumers’ preferences (Småros and Holmström, 2000). However, participants in the study of Kourouthanassis and Roussos (2003) rejected the claim that a software system could accurately predict consumer wishes just by collecting historical data and monitoring habitual purchases.

Information / communication technology (ICT) is emerging rapidly and becoming more accepted in the consumers lives. With the mobile phone the consumer has an additional means of contacting the e-retailer and therewith more control over their purchase. M-commerce makes automatic replenishments and subscription services more attractive (Peppers and Rogers Group, 2001). The smart phone can give the consumer more control over replenishment than their PC at home or at work.

5.7 Conclusion

While flexible subscriptions yield a competitive advantage for the subscription provider, either by increasing consumer loyalty or the consumer's agreement to order more products, fixed and automatic subscription offer greater supply chain benefits. The long order lead time for fixed subscriptions allows the company to plan its activities well in advance. The greater the certainty this brings, the easier it will be to optimize production planning and distribution. However, production planning can only be optimized if the order lead time is longer than the actual operation lead time. Automatic subscriptions also create the possibility to optimize the production planning. However, the optimization is then based on the increased insights gained from consumption data. Using this data can theoretically reduce the demand variability due to promotions, stock-outs at the consumer home and order batching by the consumer. Automatic subscription can also further enhance distribution efficiency by increasing the degree of delivery flexibility.

Due to a lack of real world examples, the opportunities for empirical research in the field of subscriptions is limited. However, lessons can be learned from the B2B sector where practices such as VMI have been in existence for many years and been the subject of several published studies. This allows some general conclusions to be drawn about the application of VMI principles to the replenishment of inventory at consumers' homes. The wider supply chain implications of introducing VMI in a B2C setting will be investigated in Chapter 7.

In the next chapter, the consumer perspective on subscription services will be further examined. More research is needed to assess consumer acceptance of subscription service. Does the consumer want to give up the freedom of choosing the products each time they shop in return for more convenience, time savings and possibly price discounts? And does the consumer want to be locked into such a subscription service? The consumer willingness to enter such an agreement will depend on the design of the subscription service. Numerous interviews have been held with consumers to provide answers to these questions. The results of this survey will be reported in Chapter 6.

CHAPTER 6: CONSUMER VIEWS OF SUBSCRIPTIONS

The viability of using subscriptions as a means of distributing FMCG products directly to the home depends the degree of acceptance by consumers. To gain an insight into consumer preferences for subscriptions in the FMCG sector, three series of 4 focus groups were conducted. This chapter starts with a discussion of the research setting for the focus group discussions. It then summarises the results of these discussions. The focus groups sessions were supplemented by 68 one-on-one interviews to identify the characteristics of potential customers of automatic subscriptions. A final round of 3 focus groups discussion were then held with those potential subscribers exhibiting these characteristics to discuss the concept of automatic subscriptions in greater detail with them. The sequence of focus groups and interviews is shown in table 6.1.

Consumer research phases	12 focus groups (3 sets of 4 focus groups)	68 one-on-one interviews divided over three days (20, 38 and 10 consumers)	Final set of 3 focus groups with most likely group of subscribers
Place in text	Section 6.1 and 6.2	Section 6.3	Section 6.4

Table 6.1: Summary of consumer research and outline of chapter

6.1 Focus group setting

The focus group research was carried out in three separate series of discussions in Belgium and the UK. The results of the first set of discussions influenced the selection of participants and questions for the second and third sets of focus group discussions. The number of participants in each focus group discussion is shown in table 6.2.

First focus group session: Belgium August 2012 (BE1)	BE1.1: 4 consumers
	BE1.2: 4 consumers
	BE1.3: 4 consumers
	BE1.4: 2 consumers
Second focus group session: Belgium December 2012 (BE2)	BE2.1: 4 consumers
	BE2.2: 4 consumers
	BE2.3: 4 consumers
	BE2.3: 3 consumers
Third focus group session: UK December 2012 (UK)	UK1.1: 4 consumers
	UK1.2: 4 consumers
	UK1.3: 4 consumers
	UK1.4: 3 consumers

Table 6.2: Number of focus groups participants

6.1.1 Participants

In the first set of focus group discussions, four were held with 'head of households'. A market research company selected the participants from their panel based on the requirement that the participants were responsible for the purchase of groceries. The focus groups were conducted in Brussels, Belgium. Consequently most participants had a Belgian nationality. The focus groups each consisted of 4 female participants with an average age of 45, except for the last focus group which had only 2 participants due to late cancellations.

The experience of these participants with online grocery shopping was very limited: only one person ordered regularly groceries online and another person had once made use of the click & collect option. The other participants never used click & collect or home deliveries for grocery products. After conducting the first focus group session, it appeared that the consumers were negative towards the concept of subscription. One possible explanation of the negative reaction was that consumers disliked the prospect. However, the reaction of the consumers might also be influenced by the fact that they had very limited experience with online grocery ordering. The general perception of the participants regarding online ordering, and mainly online ordering of fresh food, was not positive. The same reasons were mentioned for not liking the subscription concept and online grocery shopping. Therefore, consumers who already use online shops for groceries were selected for the second and third focus group sessions. The switch to a subscription service will be smaller for them than for consumers who have never used online shopping, which might lead to a different outcome.

Although the participants in the second focus group session were specifically selected because of their experience of shopping for groceries online, the experience of these Belgian participants with online shopping was still limited and in most cases not more than making one time use of the 'click & collect' service. Of the 15 Belgian participants, only 2 consumers said that they shop regularly online.

Online grocery shopping is much more established in the United Kingdom than in Belgium, with relatively 19% and 3% of the people buying groceries online (Eurostat, 2012a). The third focus group session was therefore conducted in the United Kingdom. A market research company selected 15 consumers who purchase groceries online. Most of the UK participants started with online shopping when they were pregnant, or just thereafter when shopping with their children resulted in a bad

experience, and never stopped using it because it appeared to be more convenient than physical shopping. Half of the consumers ordered their groceries every week online, and the other half shopped every other week online.

6.1.2 Research setting

The main purpose of the focus group discussions was to test the consumers' reaction towards two types of subscriptions: fixed subscription and automatic subscription. The consumers were first asked about their opinion of grocery shopping and online shopping. The reason for this is twofold. It gave them an introduction to the topic with something to talk about which is comparably easy which makes them feel comfortable. And secondly the discussion about general online shopping permitted an investigation of the relationship between views on online retailing and subscriptions. Due to the reaction of the first focus group participants, the questions and definition of the concept were slightly modified before conducting the second and third focus group sessions. The following changes are made:

- The possibility of providing an emergency shipment as part of a fixed subscription was eliminated.
- Different wording was used to describe the automatic subscriptions concept. Less focus was placed on the company controlling inventory at the consumer's home, and more on the convenience of automatically replenishing groceries.

The concept descriptions used in the focus groups can be found in appendix D.

All focus groups were held in a focus group viewing facility. The focus groups were videotaped and minutes were taken during the focus groups discussions in the viewing room by the author of this dissertation.

6.1.3 Background information

Online grocery shopping with home delivery in Belgium is currently available from Delhaize (Caddyhome.be) and Colruyt (Collivery.be). More grocery retailers are offering the online service without home delivery, where consumers pick up their groceries in a local store, i.e. the click & collect concept. This is offered by Carrefour (Carrefour.eu), Colruyt (Collectandgo.be) and Delhaize (Delhaizedirect.be).

The home delivery service of Delhaize is offered in most regions in timeslots between 9:00-12:00 and between 11:30-14:00 from Monday to Friday or only certain days of

the week, and on Saturday between 9:00-11:30 and 11:30-14:00. In Brussels more time-slots are offered in the late afternoon and early evening (until 8pm). An SMS is sent to the customer the day before or on the day which indicates the expected delivery time. Colruyt offers three time slots; morning, afternoon and between 9:00-16:00 from Monday to Friday. The delivery charge is depending on the basket value and is shown in table 6.3.

Caddyhome		**Collivery**	
Shopping basket value	**Delivery charge**	**Shopping basket value**	**Delivery charge**
€0-€100	€9	<€60	No delivery made
€100-€150	€7	€60-€125	€18
€150-€300	€5	€125-€250	€7
> €300	No delivery charge	> €250	No delivery charge

Table 6.3: Delivery charges at Caddyhome (caddyhome.be) and Collivery (collivery.be)

It is important to note that the Caddyhome and Collivery services do not offer the full assortment and that prices and promotions online are different from in-store (Caddyhome.be; Collivery.be). The service is mainly used by older people who may be less mobile (Schrameyer, 2011).

Click & Collect is available in certain supermarkets of Delhaize between 9:30-11:30, 11:30-14:30 and 14:30-19:30 from Monday to Friday (Delhaizedirect.be). Colruyt has a similar system with two time slots: between 11:00-13:00 and 15:00-19:45 (Collectandgo.be). Carrefour offers timeslots of one hour between 11:00 and 20:45 on Monday to Saturday (Carrefour.eu). If ordered before midnight, the products can be collected the next day. The flexibility of not having to wait at home and be able to pick up on the chosen time and day makes the service attractive for a wider market segment, resulting in thousands of orders a week at Delhaize Direct (Schrameyer, 2011).

All three retailers prepare the online orders in totes, for which the consumer pays a deposit which is paid back to the consumer when returning the tote to the supermarket. All three supermarkets offer (almost) the same assortment, product prices and promotions as in the supermarket. The deposit value and service fees of the click and collect services are shown in table 6.4.

Shopping basket value	Service fee Delhaizedirect	Service fee Collect and Go Colruyt	Service fee Carrefour
€0-€100	€4.50	€5.50	€4.50
€100-€150	€3.50	€5.50	€4.50
€150-€200	€3.50	€5.50	No service fee
> €200	No service fee	€5.50	No service fee
Deposit per tote	€4.75	€5.95	€4.75

Table 6.4: Charges and tote deposit for Delhaize, Colruyt and Carrefour

In the United Kingdom online shopping and home delivery is offered by Asda, Ocado, Sainsbury, Tesco, and Waitrose. Home deliveries are more common in the UK than in Belgium and all five retailers offer home deliveries. The click & collect services of these retailers are, however, more focused on non-food products and only Asda and Waitrose offer this service for grocery items.

Asda offers home deliveries throughout the week between 7 am and 10 pm. The delivery charge varies between £2.50 and £5.50 depending on the day, time and whether it is a 2-hour or an 8-hour time-slot. Sainsbury offers 1-hour time windows. Depending on the basket value and the day and time, the delivery charge is between £2.95 and £6.95. A minimum order value of £25 applies. Waitrose picks, packs and delivers the orders free of charge with a minimum shopping value of £50. Tesco and Ocado, offer next to one-off home delivery also a delivery subscription, called, respectively, Delivery Saver or Smart Pass. After paying a fee, both Ocado and Tesco offer free deliveries within specified hours, either only during the mid-week or unlimited, when the minimum order value of £40 is reached. The Smart Pass of Ocado also offers 10% discount on favourite brands as part of this service.

Asda offers a click & collect service with 2-hour time slots. At a specially designed click & collect collection point in the car park the staff puts the ordered groceries in the customer's car. The service cost £1.50. Sainsbury and Tesco offer a click & collect option to the consumers free of charge for their general merchandise items, but not for groceries. Waitrose offers the possibility to collect the items in store after online ordering, with 2-hour time windows between 9:00 and 20:00. Like their home deliveries, this service is free of charge. The delivery charges for home delivery and click & collect fees are shown in table 6.5.

	Asda	Sainsbury	Waitrose	Tesco	Ocado
Home delivery	£2.50 to £5.50	£2.95 to £6.95	free of charge	£3 to £6	£0 to £6.99
Click & Collect	£1.50	n/a not for groceries	free of charge	n/a not for groceries	n/a
Minimum order value	£25	£25	£50	£40 for delivery saver	£40

Table 6.5: Charges for home delivery and click and collect services in the UK

Generally the prices and promotions in store are exactly the same as online, although some vouchers can only be redeemed in the supermarkets.

6.2 Focus group results

This section discusses the results of the focus group discussions. First the opinion of the participants regarding conventional and online shopping is described, followed by the reaction of the participants to fixed and automatic subscriptions. In each section, views of the Belgian participants are first discussed, followed by those of the UK participants. Differences between the two groups are then reviewed.

6.2.1 Consumer attitudes towards conventional shopping

Generally speaking, grocery shopping is not seen as a hassle but nor is it often regarded as a fun activity. A divide appeared among the Belgian consumers between those who like shopping and those who do not feel they have the time for shopping. Those who do not like shopping argued that the following aspects reduce the quality of the shopping experience. The reasons are sorted on frequency with on top the most often mentioned reason.

- Having to wait at the cashier, for up to 30 minutes in some cases. The recently introduced self-scan[21] eliminates the waiting time at the cashier and is seen as an improvement. However, some participants argued that this does not make a difference due to the frequent checks requiring them to unload their bags. The self-scan gives a better overview of the spending in the supermarket which is seen as beneficial as this helps the participants with their money / budget management.

[21] Self-scan is a handheld barcode reader which consumers take with them while going through the aisles. Consumers scan the products before putting it in their bag. At the end the cashier/system decides if the products need to be checked before the payment can be made.

- Takes a lot of time, especially if the decision what to eat is made in the store or when they want to benefit of all the promotions.
- Having to search for products / not having a good overview. Shops that have a clear indication on where products can be found are preferred.
- More stores need to be visited to get all products that are consumed within the household, due to brand-specific preferences.
- The non-availability / out-of-stock of one of the items required or products at the end of their due date.
- Heavy and voluminous products. Heavy products are especially challenging for elderly people. Bulky products are more difficult when shopping with small children; limiting the space in the shopping trolley.
- Busy parking lot and therefore no suitable parking place.
- Unfriendly staff particularly when they have to deal with many mistakes in product prices and promotions at the checkout.
- Short openings times.

Those who do like grocery shopping argue that they like to explore new products and to see new product designs. The people who do like shopping generally have more time. Grocery shopping is often a social aspect of their life and a reason to get out of the house. They argue that they like to talk to other people in the supermarket, or that they like the interaction with their own children in the store.

6.2.2 Consumer attitudes towards online shopping

The participants from the United Kingdom were selected on their experience of online shopping and so online grocery shopping with home delivery was their main shopping method. They are very positive about online grocery shopping and mentioned the following benefits:

- Online shopping can make it easier to manage the shopping budget. Most participants are conscious of the prices and try to control the spending on groceries. Several participants argued that they try to minimize the number of physical shopping trips because they always spend more than they intended when they are in the supermarket. In the online shop this is not the case because they look for things specifically needed, resulting in less impulse buys. The number of impulse purchases tends to be higher when accompanied by children in the supermarket. They generally do not get involved in online

shopping process. They also argued that it was easier to see price changes, as they see the product price every week. And it is easy to delete items if the order becomes too expensive.

- It saves a lot of time. It is easier to find products online than in store. In the store you easily spend 1 or 2 hours doing groceries. Because they are able to reuse the list with favourite items for a large part, the online shop takes only 20 minutes to a half hour. Others are able to do it in 10 minutes. Although not everyone is convinced that it really saves time compared to physical shopping.
- It is less stressful. Online shopping saves the hassle of shopping with children.
- It is more convenient.
- Tend to forget fewer items; they can check their inventory at home while doing the online grocery shopping. It is also easier to check online if they got all the items needed.
- It removes the need to carry heavy / bulky products.

However, there are also disadvantage of shopping online:

- Sometimes they receive fresh products with a short sell-by date. They argue that, if picked themselves, they would buy products with longer due dates, e.g. the items at the back of the shelf. For a few participants the short due date is a reason to not buy fresh products as vegetables, meat and bread online. However, for the majority of the participants this was not an important issue and they would accept lower quality fruit to avoid going to the supermarket themselves.
- Some participants did not like the substitutes offered when products were not available. They went to the supermarket later that week to get the items that were not delivered. For most participants, however, the substitutions are appropriate and normally accepted.

As mentioned earlier, the experience with online grocery shopping of the Belgium participants, in contrast to the UK participants, was very limited. Only three persons, out of 29[22], did order groceries online from time to time in Belgium. The focus group participants showed a dislike for online grocery shopping. The reasons they mentioned why they are not shopping online are discussed below.

[22] This includes all participants from the first (BE1) and second (BE2) focus group session in Belgium.

- The most often mentioned reason was that they want to feel, touch and see the products before buying, especially fresh food. Typical responses were:
  "*I can't imagine buying fresh vegetables, meat, fruit, fish on the internet. Because I want to see them I want to smell them I want to feel them*".
  "Who buys apples from the internet… I have to see them, are they fresh?"
  They argue that they normally take the products at the back of the shelves that have the longest due date, while orders picked for an online orders are likely to have the shortest due date. However, the majority of the participants that argued that never actually shopped online for their groceries, and so this is merely a suspicion and suggests a lack of trust in grocery retailers to supply the freshest products.
- Online shopping is perceived as more expensive than going to the shop themselves due to the delivery charge. This is also the reason why one participant chooses to use click & collect, which is sometimes free of charge. For some participants the delivery charge is reasonable. Some participants also claimed that product prices are higher online than in the store on top of the delivery costs.
- The home delivery waiting time is longer than going to the shop yourself. The online purchasing process can also be time-consuming, particularly finding products in the right category, searching for promotions online and deleting items because the total shopping basket price is beyond budget takes time. They argued that it takes about an hour to make the online shopping list, or even 2.5 hours when you do it for the first time. However, they also recognised that once you get more practice, the time to order the items online is likely to be reduced. One person, who had ordered online for 3 years, argued that it only takes 15 minutes now she is used to it.
- Having to wait at home during the day to receive the order is inconvenient. Delivery has to be in the evening. One solution is that you have it delivered to a collection and delivery point, but then you still have to go out to pick up the package on the right times, within the opening times. This makes it difficult for those working fulltime.
- There is a wide variation in the purchasing behaviour for particular types of product. Some people make the choice what to eat in the shop, when seeing all the products and highly value freshness. For them visiting the shop is important. Others argue that certain branded products are suitable for buying

online such as shampoo and dishwashing liquid. Some people accepted that online retailing could cater adequately for some classes of product, while others argued that splitting grocery shopping between online and conventional channels makes no sense as they are already in the store to buy the other products.

- The risk of missing out on promotions was a disincentive to using online shopping.
- Consumer reluctant to spend more time behind computer. This was especially mentioned by those who use computers on their work.
- Some consumers go shopping for the social contact.
- The product substitutes in the online service are not appropriate. Someone else cannot choose what will be a reasonable substitute.
- The differences between the products are difficult to see online, which resulted in some cases in ordering the wrong product. And not all products are available online.

Members of the Belgium sample did, however, concede that for some people online shopping might improve their lives. Other reasons to shop online, especially for the heavy items, are not having of a car, or having back problems. They argued that home deliveries are more relevant for those buying really big quantities, people without a car and those that are less mobile.

In line with the UK participants, the Belgium participants argued also that one benefit of online grocery shopping is that you are able to see the total price before ordering. However, the self-scan in the supermarket has the same functionality, largely offsetting this potential benefit of online shopping.

6.2.3 Fixed subscriptions

Fixed subscriptions in the form of magazine subscriptions were used by several people in the focus groups in Belgium. The reasons offered for using this type subscription are that it is very easy, removes need to visit the shop and the magazines are offered at a lower price than in store. Having it home delivered and getting the discount makes a subscription attractive. The majority of the participants argued that a similar discount of 20 or 30% would convince them using the subscription service for grocery products, especially the larger families.

The fixed subscription concept is perceived by the Belgium participants as an attractive possibility for regular grocery purchases. However, others argued that it is only attractive as long as there is the flexibility to cancel orders when they have still stock or are going on holiday and / or to cancel the agreement when the personal situation changes. Also when new products are introduced, the subscription service should allow the possibility to change to the new product. The nature of the product as well as the quantity, must be flexible over time to meet the needs of the consumer. One of the main reasons for not using this service would be the lack of control. Some participants were afraid that there would be 'too much push', their cupboards would be constantly full and the service would not adjust to variations in consumption.

In the follow up focus groups in Belgium, the possibility to cancel and adjust orders in fixed subscription was included in the concept description. However, the participants still argued that fixed subscription was likely to push too much products onto the consumer. They argued that subscribers could have more product at home than they really needed because it is easy to forget to cancel or use less than normal, leading to an oversupply of products.

In both series of focus groups in Belgium, the participants argued that the time needed to find out which products are bought at which intervals is a disadvantage. If a subscriber wants a delivery earlier, he or she needs to change the order, resulting in a lot of work. The consumer has to be aware how much he or she uses on average, and keep track of what they need, to be able to use the service. That could take time and be complex. Another participant argued however that variations in consumption will not be a problem as excess products could be given away to family or friends.

Other possible reasons for not using this subscription service related to the burdens of online shopping outlined earlier: the requirement to be at home for receiving the package and the risk of missing out on promotions, even though it might be possible to cancel the deliveries at the times that there is a better promotion. These consumers want to take advantage of promotions and buy different quantities and variations of the product depending on the offers. However, a large discount could reduce this flexibility requirement. Also they argued that the rate of consumption is not perfectly stable. Even though they can cancel and adjust the orders, they still feel as if their freedom is reduced. They argued that they do not like having this kind of regularity imposed on their life.

As discussed earlier, many consumers in Belgium, suspected that perishable food would be of lower quality online (e.g. short due date) and so this type of product is not considered as suitable for fixed subscriptions. Some participants argued that fixed subscriptions could be used for regular products, in addition to shopping fresh food in store. In the opinion of focus group members, suitable products to have on a fixed subscription are cereals, milk, water, toilet paper, kitchen paper, tinned tomatoes, laundry and cleaning products, butter, lemonade, toothpaste, and potatoes. Branded products with long shelf life that are standardised would also be suitable.

In the UK fixed subscription is also perceived by some consumer as being 'forced'. They would lose the freedom of choosing when to order online even though they order now every week at the same time. The participants would not feel in control over the deliveries in fixed subscriptions. They would find it more stressful than normal online shopping, because they have to keep on top of it. They fear that they would forget to adjust the order and get products delivered that they do not want. Over time the household inventory would then accumulate.

Further, a subscription offered only for some types of products is not seen as beneficial, because it separates their shopping baskets in two different systems. This will result in two things to think about and in two different times that they have to be home to receive the products. In that case the products could probably be more easily added to the normal online shopping basket with a couple of clicks.

However, some argued that this subscription will work for the majority of items on their favourite list. The products on their favourite list are selected for home delivery every week. Others argued that milk and bread are not products for which their demand is perfectly stable, and are therefore not suitable for fixed subscriptions. Another participant argued that subscriptions would work for necessities that you need monthly, but not for food or groceries that you buy weekly and try to vary more. However, most participants did not agree and argued that those products with relatively stable demand, like cleaning products, are often bought on promotions. They do not want to miss out on these promotions.

Other disadvantages mentioned of fixed subscription are the need for additional home storage space and the risk that oversupply of products would reduce the likelihood that any money is saved.

Concerns about fixed subscriptions	BE1 (n=14)	BE2 (n=15)	UK (n=15)
Fears of having cupboards full, must be able to cancel deliveries	6	1	9
Must be able to change products to include new items or other flavours	5	8	3
It would be difficult to keep track of, a lot of work is required.	1	7	9
Fears of missing out on promotions	3	2	3
Delivery issues, must be at home for delivery	1	4	5
Fixed subscriptions products	**BE1**	**BE2**	**UK**
Only interested in service when full grocery basket is offered in service	0	2	0
Service suitable for regular / stable products	7	7	3
Service suitable for mainly heavy products	0	4	0

Table 6.6: Summary of focus group responses on fixed subscriptions

6.2.4 Fixed with emergency shipments

The second concept introduced to the participants was the concept of fixed subscription but with the possibility to request emergency shipments if the inventory at home is running low. The emergency shipments are designed to deal with the problems of variable consumption. However, not all participants were convinced of the benefits of emergency shipments. The majority of the participants argued that the lead time on emergency shipments are too long to fulfil immediate needs when running out of products. It would be faster to go to the shop. Other participants argued that this would only be the case when having an unexpected stock-out; more often they can see it coming. Then a lead time of one day will be sufficient. The majority however agreed that stock-outs do appear unexpectedly from time to time.

Moreover, emergency shipments only resolve stock-outs, but not the fear of having too much products supplied. Instead of emergency shipments, flexible content / quantities in the regular deliveries would also solve the problem of variable consumption and would be preferred. Another disadvantage is the costs of the emergency shipments. To be attractive, the emergency shipment must not come with an additional delivery costs.

Therefore the majority of the participants did not see the benefit of emergency shipments and preferred more flexibility in the deliveries of fixed subscriptions to emergency shipments. This concept was therefore not further considered and was not discussed with the participants of the second and third focus group sessions.

6.2.5 Automatic subscriptions

The third concept described the situation where products are automatically replenished before running out of stock at home. By scanning each item before throwing it away the company would be able to see an up-to-date inventory status of each customer. The focus groups showed a strong dislike for automatic subscriptions. They argued that automatic subscriptions would take over control of their lives. One participant described this situation as, "*Big brother is watching you*". Although some argued that the customer loyalty card gives more or less the same information to the supermarkets, the majority of the participants felt that automatic subscription would go well beyond store data collection. Supermarkets do not know what is bought in other stores. Automatic subscriptions assume that the products of a particular class are bought from one company, which is not always the case at present. Further, it was also doubted whether the subscription provider could satisfactorily forecast the consumer demand to be able to keep household inventories adequately replenished.

In the second focus group session, a slightly modified form of automatic subscription was presented which still described that replenishments are made after scanning products but did not discuss explicitly that the supplier knows or controls the households inventory (see appendix D for the concept descriptions). Even though these consumers understood that the company would be aware on the amount of inventory at their home, the consumer reaction towards automatic subscription was less fearful than in the first focus groups. The majority argued that the consumer was in control, and could simply scan those items that they wanted to have replenished. In this service they only get the items they ordered and not have them pushed into your home as with fixed subscription.

The scanning process was seen as digitising of the shopping list. After scanning there is no need to think about it until the order gets delivered. They argued that it is easier and takes less time than finding out the replenishment frequencies of each product as in fixed subscription.

Scanning, however, is more difficult for the consumer than visually checking their stock. The participants argued that it is too much work to scan everything, children could start to play with the scanner, and it is easy to forget to scan something before throwing it away, although some participants argued that you will get used to scanning after a while. Also the additional communication with the subscription provider, for

example to tell them when on holiday and are not able to receive deliveries makes it more complex than physical shopping. Several respondent were convinced that automatic subscription would not be easier than going to the store.

Other negative points mentioned about automatic subscriptions are:

- The costs of the subscription; have to buy a scanning device.
- The limited possibility to vary brands and risk of missing new products on the market
- The need for more than one scanner, when you have several online suppliers.
- Missing out on promotions
- Worry that you do not see the current price when scanning the items

However, it is also argued that it might be beneficial for large families. Others argued that it is only suitable for small households, otherwise the scanning process will be too chaotic.

The participants argued that not all products are suitable for automatic subscriptions. The concept is only suitable for certain products which are regularly used. For example beer, water, toilet paper, kitchen paper, etc, products that are not changed / varied very often, but are frequently consumed. As discussed earlier, this results in the consumer having to adopt two shopping methods, automatic subscription and normal shopping, which makes it more difficult. Combining everything in the normal shopping trip is easier. On the other hand, some focus group members argued that the shopping is already divided among several supermarkets or over online and offline orders and that therefore automatic subscriptions could be incorporated within this 'multi-channel' framework.

In both Belgium and the UK some consumers wanted to decouple the scanning process from the ordering, giving them the chance to approval the final order before the purchase was made. If it were possible to go with the scanner to the supermarket, that would add another benefit. This allow consumers, especially for those without a car, to scan new items in the store and get them home delivered in their next scheduled delivery.

In the UK, automatic subscription could supplement well-established systems of grocery home delivery. Regular online shoppers suggested that a scanner which put all the scanned items into their online favourite items list would be beneficial. However,

automatically reordering of the products that are scanned is not attractive to most participants. They prefer to confirm the order before sending it to the retailer.

According to the UK participants, the largest benefit of automatic subscription is that it reduces the chance of running out. Especially products which are not bought every week and are easy to forget, like toothpaste, would be suitable for automatic subscriptions. Others would use it for all grocery products. However there are also worries that they forget to scan the items before throwing the empty package away, mostly because they have bins on different places in their house, or that not everyone in their household will scan before throwing away. Also an oversupply of products is possible with the scanner. Kids can play with it and scanning items for fun or items are bought in the store forgetting that the item is scanned and on the way.

The UK focus group participants wanted a similar service level from automatic subscription as they do receive now from their online supermarket, including

- The possibility to amend orders until the night before the delivery
- Choosing between alternative delivery times

The findings are summarised in table 6.7.

Issues of automatic subscriptions	BE1 (n=14)	BE2 (n=15)	UK (n=15)
Subscriptions take over control, consumer does not feel in control.	6	2	0
Demand cannot be forecasted by the company, company don't know how many products will be needed.	2	0	0
Not possible to vary products	1	3	0
New products will be missed	0	3	0
Missing out on promotions	0	1	3
Must be possible to cancel deliveries	0	1	0
Must be possible to see what is scanned and will be ordered	0	5	1
Must be possible to amend order until night before delivery to include or delete some products	0	4	5
Only preferred when orders are not automatically processed, but approval needed.	0	1	1
Consumer must have the possibility to choose delivery date and time	0	1	2
Issues with scanning			
Scanning is difficult and is more complex than a visual check what is left	3	4	5
It is easy to make mistakes in scanning	1	1	1
Children play with the scanner	1	2	7
Easy to forget to scan and throw package away without scanning	3	3	2
Easy to scan and wait until it gets delivered, easy to use system	1	5	2
Consumer feels in control, just scan the items that are needed	0	6	1
Would like to have the possibility to use the scanner in the supermarket	0	1	3
Automatic subscriptions products	**BE1**	**BE2**	**UK**
Only interested in service when full grocery basket is offered in service	0	3	4
Service suitable for regular / stable products	1	4	1
Service suitable for mainly heavy products	0	3	2
Service reduces the change of running out of not frequently bought products	0	1	2
Would try the service when on the market	4	2	1

Table 6.7: Number of times aspects of automatic subscriptions were mentioned by participants in the focus group sessions

Even though focus group members identified many concerns about automatic subscriptions, several indicated that they would try this service if it were available on the market.

6.3 Characteristics of potential subscribers

From the focus group discussions it was established that automatic subscriptions would be acceptable to only a subset of the population. To gain more insight into the characteristics of this subset, twenty one-on-one interviews[23] were conducted. Participants were asked about their shopping behaviour and how they plan their grocery shopping before questions were posed about their views on automatic subscriptions. The complete interview guide can be found in appendix E. Several characteristics tend to influence the reaction towards automatic subscriptions:

- amount of time available
- interest in new products and product variation
- susceptibility to promotions.
- tendency to stockpile products at home
- effectiveness with which they organised their grocery shopping

Consumers with a similar combination of characteristics appeared to have a similar attitudes towards automatic subscription:

- Extremely time stressed consumers who want to do the shopping as fast as possible without paying attention to promotions or product variations appear to like automatic subscription for time saving. Those who are extremely time stressed would like to combine automatic subscription with click & collect and / or home deliveries.
- More organized consumers that hold inventory at home were generally positive towards automatic subscriptions.
- Disorganized persons who regularly run out of products were also likely to use automatic subscriptions to reduce the chance of forgetting items.
- Promotion-seekers disliked automatic subscription. However, some interviewees argued that they would go through the advertisements or look up promotions online and use that information to scan those items that are on promotion, effectively combining automatic subscription with access to promotions.

[23] Interviews were held with participants of a research day. In one hour time they participate in a couple of interviews and experiments by different researchers, of which this research took 10 minutes per participant. All participants are the head of household and are primarily responsible for grocery shopping.

- Consumers who enjoy the social experience of going to the supermarket disliked automatic subscriptions.

The consumer profiles identified based on the interviews can be found in table 6.8 below.

Consumer profile	Time-stressed	Inventory keepers	Promotion lovers	Organized	New items / variety seekers	Explanation	Preferences
A	Yes	Yes	Yes	Yes	Yes	Tries to minimise shopping due to lack of time. However, does like to shop, trying new products and switching brands when there is a good promotion.	Automatic subscription can be handy sometimes but still want to go to the supermarket from time to time. Scanning items instead of making list would save time.
B	Yes	Yes	No	Yes	No	Extremely time stressed, good job, does not look for promotions or new items and want to be as quick as possible out of the shop.	Would love automatic subscriptions.
C	Yes	No	No	No	No	Shops not very organised. Walks through the aisles and remembers out of the head what she needs. Sometimes there is stock at home but not very frequent.	Automatic subscription is liked as long as it is home delivered, else the scanning would take her even more time.
D	No	No	Yes	No	Yes	Chaotic person, keeps no inventory, runs out frequently.	Would like a system that makes it easier to remember products. Automatic subscription (including delivery) is less interesting because variation due to promotions and new items is preferred.
E	No	Yes	Yes	Yes	n/a	Organized stock keepers with enough time to go to the supermarket.	Not interested in this service.
F	No	Yes	Yes	Yes	n/a	Search for promotions at home, and plans shopping from there.	Would use automatic subscriptions, but scan only when they want to receive the products.

							They check promotions beforehand and then scan those items on offer.

Table 6.8: Consumer profiles of 20 interviewees.

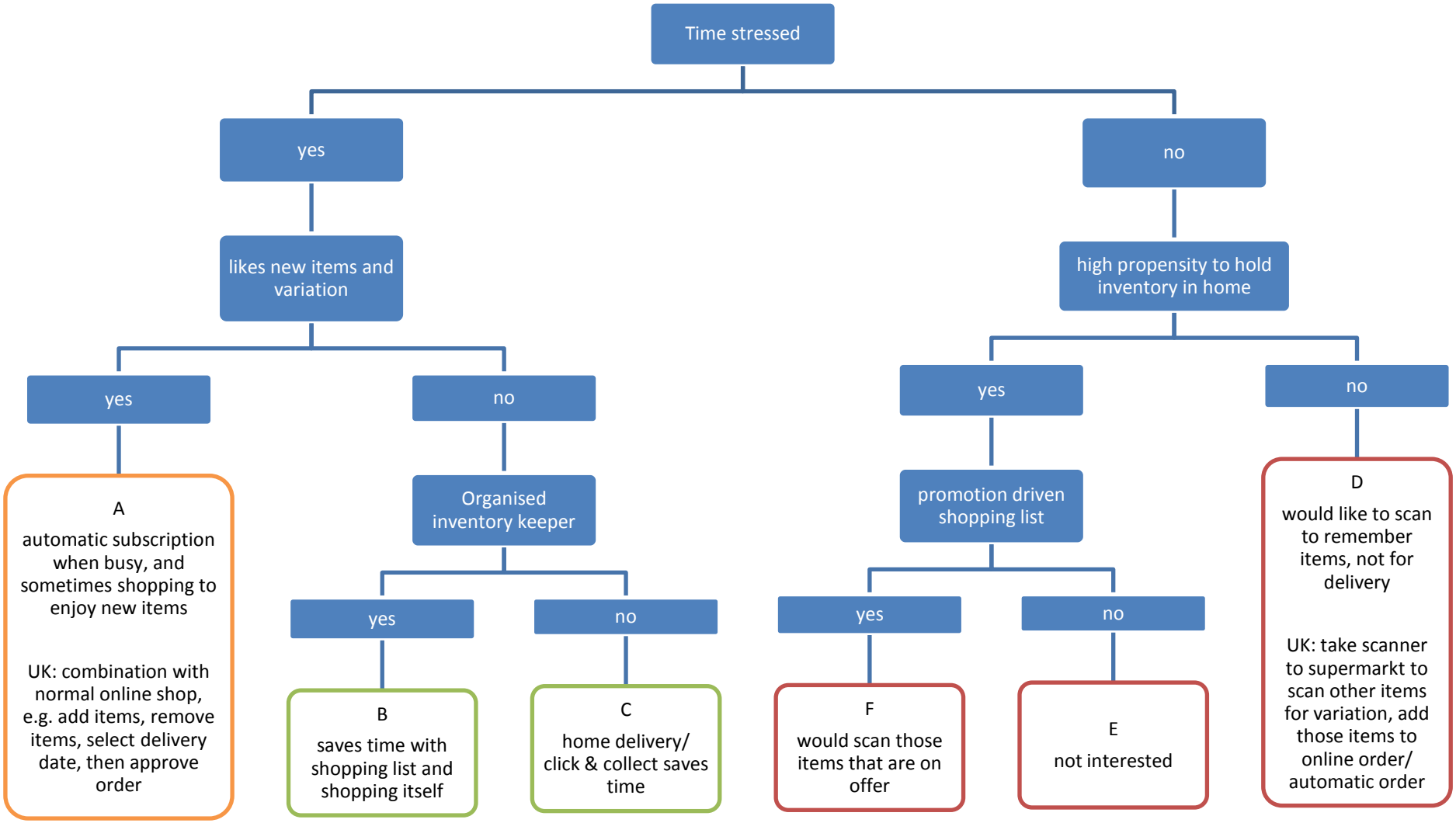


Figure 6.1: Decision tree based on Belgium participants in focus groups and interviews

To show the linkages between characteristics in the consumer profiles a decision tree was constructed (figure 6.1). To validate this decision tree, 38 consumers in the follow-up interviews[24] were first asked about these characteristics before their opinion on automatic subscriptions was determined. Of these consumers, only three argued that they had not enough time to do grocery shopping. This was expected because the interviews were held during the day. Time-poor consumers with a full-time job do normally not participate in surveys during the day. Ten time-poor consumers in full-time posts were invited to an evening session. A market research company selected those consumers based on the following criteria; 1) head of household primarily responsible for grocery shopping, 2) have a full-time job, 3) feels in a hurry due to lack of time during household shopping, 4) do not like household shopping, and 5) do not spend additional time in supermarket to search for promotions or new items.

Those interviews confirmed that time-poor consumers are more likely to use automatic subscriptions. Time-poor consumers who regularly forget items and are frequently out of stock would like a service to manage their inventory and reduce the number of trips to the store. Organised consumers would like to use the service to reduce the amount of time spent in searching for products in the online shop. The interviews confirmed that shoppers who enjoy the social aspect of shopping and those consumers who try to buy items in promotions were not interested in the service.

The interviews also revealed two other reasons why consumers might not want to use automatic subscriptions:

- It might be too technical or modern for some consumers, particularly in the older generation.
- Some consumers think they do not need automatic subscriptions. Planning product replenishments and going to the shop is easy and routine for them. Especially if they have to go to the shop already for fresh food[25] they believe that automatic subscriptions will not save any time.

[24] A similar setting was used for these interviews. 10-minutes interviews were held with participants of a research day, which were all head of household and are primarily responsible for grocery shopping.
[25] Almost all Belgian participants believed that the quality of fresh products picked for them would be of bad quality and therefore they prefer to buy those products in store themselves.

6.4 Specific requirements of target group

Directly after the one-on-one interviews with the time-poor consumers, focus group discussions were held with these consumers to determine the specific requirements of these consumers.

Fourth focus group session: Belgium May 2013 (BE3)	BE3.1: 3 consumers
	BE3.2: 4 consumers
	BE3.3: 3 consumers

Table 6.9: Number of focus groups with time-poor consumers

According to these time-poor consumers, automatic subscriptions saves time and the majority of the time-poor consumers would use the service. However, several issues need to be addressed to make the service convenient for them.

The first requirement is the improvement of convenience of the home delivery and click & collect options. Both must be in the evening. For home deliveries an one-hour time slot is required and click and collect points must be on the way to home. Further it must be possible to park the car close to the click and collect point. Two third of the participants preferred home deliveries above the click and collect option.

Secondly, it must be possible to vary certain products in flavour or brand. Some consumers would like to have a catalogue for ordering items that they do not currently stock while others like to have automatic subscriptions for those products that are every time the same, such that they can focus their physical shopping trips on choosing other brands and flavours for variation of more easy to carry items.

Suppliers would have to avoid making replenishments too early, e.g. more than a week before usage, especially of bulky items like detergent, would not be accepted. Consumers would like the opportunity to specify the maximum amount of items per product.

The requirements of the time-poor consumers on automatic subscriptions are summarised in table 6.10 below.

Requirements of automatic subscriptions	Time-poor consumers (n=10)
Only for bulky / heavy items, basic items	6
Must be available for full grocery basket	1
Evening delivery / click & collect	2
1-hour delivery	5
Option to specify maximum amount of inventory	3
Cancellation / confirmation option for each delivery	1
Would try service when on market	8

Table 6.10: Requirements of consumers likely to use automatic subscriptions

6.5 Conclusion

Even though fixed subscriptions are already used by many focus group participants in the form of magazines, few are likely to be interested in the regular delivery of groceries on a subscription basis. The participants, in both Belgium and in the UK, disliked the resulting loss in control and feared that suppliers would push inventory into their homes. On the other hand, not having the place the orders every time makes this concept more attractive (e.g. convenient) than normal online shopping to some categories of consumer. However, to make the service appealing some flexibility might be required allowing consumers to cancel and / or amend deliveries in the subscription service. Emergency shipments are not needed according to most participants. When consumers running out of stock, the items are needed immediately and are likely to be replenished much more quickly by a shopping trip than a home delivery.

Several participants argued that fixed subscriptions could be possible for regularly purchased and stable-demand products, particularly for those products with a long shelf life, uniform quality (e.g. no fresh products) and a heavy or bulky character. Monthly bought necessities are therefore more suitable than weekly bought food. This is reflected in the product groups currently sold on subscription by, for example Amazon Subscribe and Save products like nappies, coffee, tinned food, wines, beverage, cleaning products, etc.

Automatic subscription was perceived negatively by the first focus groups. The participants feared a lack of control over the automatic replenishments. They do not want to share information about the amount of inventory at home with the company. It was considered as a 'home intrusion'. In the second and third series of focus groups, where a modified subscription concept was presented, the focus groups participants showed a more positive reaction to automatic subscription.

The home scanning process for automatic subscription was seen as potentially more complex than going to the store, while fixed subscription was more accepted as shopping method in addition to normal shopping. In the UK both fixed and automatic subscription would add complexity to the already mature online grocery market. Online shopping, as used today, is very convenient and is used in a manner to control spending. The UK participants, however, were more positive about automatic subscriptions than the Belgian participants. Automatic subscriptions reduce the chance that you forget items. This can be especially beneficial for items that are bought on a monthly basis. The overall results of the surveys of consumer opinions are summarised in the table 6.11.

Subscription benefits / disadvantages	Belgium / non-online grocery shoppers	UK / frequent online grocery shoppers
Fixed subscriptions – Advantage	- Easy to use	- Positive as long as they have to agree to order, no automatic shipment
Fixed subscriptions - Disadvantage	- Oversupply of products - Adding work to cancel / adjust products / deliveries - Missing out on promotions, or a lot of work to cancel when there is a promotion - If not full grocery range, still have to go to the shop, adding more work - Takes time to find out frequency of different products	- Adds complexity next to online shopping list - Oversupply of products, consumption is not stable. - Takes control, even though consumers order already the same products very frequent - Long lead time between ordering and receiving products - Must be able to choose the delivery slot
Automatic subscription - Advantage	- Digital shopping list, must be able to agree before ordering - Follows consumption - Less work than fixed subscription, don't have to adjust orders	- Seen as attractive if used together with normal online shopping order (not separate) - Especially useful for those products consumers don't order every week and are mostly not on offer - Scanner can be used in supermarket, to order products for next home delivery - They are in control, scan only when you empty pack and want to reorder
Automatic subscriptions - Disadvantage	- Not for all products still have to go shopping, adds more work - Company knows how much inventory consumers have - Want to choose delivery slot themselves - Must be able to cancel products - Missing out on promotions, new products	- Separate list would add more complexity / work - Missing out on promotions, normal online order list is made after viewing promotions, less control of money

Table 6.11: Overview on benefits and disadvantages of fixed and automatic subscriptions

Automatic subscription was considered more beneficial for less mobile consumers. but unlikely to appeal to those who see shopping as a social aspect of their life. Participants who indicate that they would use automatic subscription when offered on the market are generally the time-stressed with less interest in promotions or product variation. Follow-up interviews with time-stressed consumers revealed that they would be interested in automatic subscriptions if they met a specific set of requirements.

CHAPTER 7: SUPPLY CHAIN IMPACTS OF AUTOMATIC SUBSCRIPTIONS

This chapter examines the possible impacts of automatic subscriptions on the supply chain. To explore the potential advantages and disadvantages of automatic subscriptions, the vendor managed inventory (VMI) literature is reviewed to see to what extent this essentially business-to-business practice might be applicable in a business-to-consumer setting. Opportunities for adopting VMI for B2C transactions are analysed in section 7.1. The potential effects of automatic subscriptions are discussed in section 7.2. The overall findings are summarised in section 7.3.

7.1 Analogy with Vendor-Managed Inventory

From the analysis in Chapter 5 it became clear that access to additional demand information does not always lead to better production and inventory planning. Subscription providers, dealing with many individual households, may find it difficult to put the extra consumption data to good use. The similarities and differences between automatic subscriptions and VMI were explored in the literature and discussed with supply chain experts to assess the possible supply chain implications.

7.1.1 VMI in the B2B environment

VMI is defined by Disney and Towill (2003, pp.201) as *"a supply chain strategy where the vendor or supplier is given responsibility of managing the customer's stock".* The replenishment decisions relating to the retailer's inventory are made by the supplier (Waller et al., 2001). To make this possible the retailer gives the supplier access to real time inventory information and point-of-sale (POS) data (Sari, 2008).

Inaccuracies in forecasting demand can lead to high inventory costs, poor customer service, due to lower product availability (Levy and Grewal, 2000), both symptoms of the bullwhip effect. VMI is considered to be an effective countermeasure for the bullwhip effect (Disney and Towill, 2003) which, if left unchecked, leads to "*increased demand uncertainty, reduced customer service due to the inertia of the production / distribution system, lost revenues due shortages, reduced productivity of capital investment, increased investment in capacity, inefficient use of transport capacity, and increased missed production schedules"* (Holweg et al., 2005, p.11). The practice of sharing data along the supply chain can improve inventory management (Buzzell and Ortmeyer, 1995; Holweg et al., 2005; Myers et al., 2000).

The key benefits of VMI identified in the literature are summarised as follows:

- Reduced stock-outs in the supply chain (e.g. improved on shelf availability) (del Cid et al., 2000; Kuk, 2004; Roussos and Moussouri, 2004; Sari, 2008; Waller et al., 2001).

- Typically a 50% reduction in inventory for both parties in a VMI partnership (Disney and Towill, 2003). This is due to reduced cycle stocks of both retailer and manufacturer due to increased replenishment frequency (Yao and Dresner, 2008) and reduced safety stock (Kuk, 2004; Roussos and Moussouri, 2004). With visibility of inventory and point-of-sale data (POS-data), VMI can lead to lower inventory levels due to improved production planning, reduced demand variability, and the pooling of orders (del Cid et al., 2000). These benefits are further explained below.

- Lower ordering costs (del Cid et al., 2000; Kauremaa et al., 2007; Sari, 2008). This can justify the more frequent replenishment and smaller cycle inventories. The regular updates on inventory and point-of-sales data give the manufacturer the opportunity to respond to changes in demand before large shortages or excesses occur (Vergin and Barr, 1999). This can result in shortening the order review period, eliminating large, infrequent orders from some customers resulting in an improvement for all customers (Waller et al., 2001).

- Orders batched with VMI will lead to fewer truckloads increasing vehicle utilization by an average of 13% (Disney et al., 2003). However, a case study in the UK grocery sector shows less optimistic results: commercial pressures and non-VMI customers that require dispatch of vehicles at certain points can reduce the vehicle fill rate (Potter et al., 2007).

- Better utilization of manufacturing capacity (Sari, 2008; Waller et al., 2001). VMI is associated with higher profit margins, likely due to higher production efficiencies (Kulp et al., 2004). Both production and transportation can be more efficiently scheduled[26] (del Cid et al., 2000).

- Increased sales due to improved availability (del Cid et al., 2000; Vergin and Barr, 1999)

[26] In their research, del Cid et al. concludes that production efficiency is a benefit of VMI for the manufacturers. However, in their discussion of benefits of VMI found at several companies, the only benefit for manufacturers discussed is the market position / increased sales.

The performance of VMI depends on the extent to which the manufacturer can use POS-data and / or inventory data in the planning of their activities (del Cid et al., 2000). Holweg et al. (2005) argue that the bullwhip effect remains if the manufacturer is not able to use the data at a tactical planning level. The data needs to be incorporated into the production and inventory control processes. Disney et al. (2004) show that in theory the bullwhip effect should weaken when POS-data is shared with all members of the supply chain, but when VMI is implemented without the understanding and use of the data, it can remain strong. Linking demand information to supply chain planning seems to be essential (Kuk, 2004). A critical mass seems necessary to exploit the additional demand visibility available from VMI partners, especially for production planning (Småros et al., 2003; Vergin and Barr, 1999). Although the majority of the academic articles highlight the advantages of VMI, it is recognised that VMI needs to account for 30-40% (Andel, 1996 cited by Vergin and Barr, 1999) or even 50% (KPMG, 1996) of total sales before many of the benefits summarised above can be realised. Increasing the VMI adoption rate (i.e. the percentage of sales managed with VMI) reduces overall demand variability, although the magnitude of this effect depends on the demand characteristics of the product (Småros et al., 2003). Furthermore, the inventory level at the retailer can only be reduced with VMI when the manufacturer is able to forecast the demand more accurately and therefore can manage the inventory better (del Cid et al., 2000).

Other disadvantages and limitations of VMI identified in the literature are summarised as follows:

- Demand forecasts are often not shared; when the demand uncertainty increases the performance of VMI substantially decreases (Sari, 2008). Also POS-data is not always shared (Claassen et al., 2008).

- High level of detail required for planning, high administration costs, ineffective ordering and fulfilment processing. Large companies in particular can have difficulty in handling the complexity and vast quantities of information (Kuk, 2004). Not having an appropriate system to integrate the information can lead to an increase in replenishment work for the supplier (Kauremaa et al., 2007) and no or limited benefit from the demand visibility (Kumar and Kumar, 2003).

- Difficulty of achieving critical mass. Some retailers believe they can manage their inventory better than manufacturers can with VMI, and so are reluctant to

enter a VMI arrangement (del Cid et al., 2000). This reduces the VMI adoption rate.

- More stock-outs may appear for non-VMI customers to guarantee product availability for VMI customers (Kumar and Kumar, 2003). There can therefore be negative impacts on non-VMI customers. However, Waller et al. (2001) argue that introducing VMI for some large customers can result in a decrease in backlogs for non-VMI customers.

- Not setting the right parameters. When VMI is performed under the conditions of minimum and maximum inventory levels, the flexibility given to the supplier can affect the performance of VMI. A low maximum stock quantity and inappropriate penalties result in higher costs under VMI (especially for the supplier) than under a traditional retailer-managed regime (Fry et al., 2001).

- VMI does not necessarily lead to higher order frequencies. Often, ordering and inventory-monitoring costs have already been reduced by electronic data interchange (EDI) and the internet. This has already reduced the constraining effect of ordering costs on replenishment frequency (Mishra and Raghunathan, 2004).

While research using simulation modelling suggests that VMI is likely to have a positive impact on supply chain efficiency, empirical analysis casts doubt on its practical, operational benefits (Kauremaa et al., 2007). For example, Yao and Dresner (2008) conclude from their analytical study that VMI leads to inventory reductions between 15 and 71% (both in cycle inventory and safety stock), while Vergin and Barr (1999) found that only one out of the 10 companies they interviewed claimed to have reduced their internal inventory as a result of the application of VMI.

7.1.2 A comparison between VMI and the use of subscriptions

In this section the B2B VMI process is compared with the process of automatic subscriptions to identify similarities and differences between the two. Based on the literature (Kumar and Kumar, 2003; Pohlen and Goldsby, 2003; Xie, 2004), it can be concluded that a typical B2B VMI arrangement takes the following form (shown in figure 7.1).

1. The consumer buys products at the shop. His or her choice is influenced by several factors including promotions, price, location, etc.

2. Point of sale data is collected when the consumer buys the products. This information (although it might be already aggregated to shop or distribution centre level) is shared with the vendor.

3. Data about inventory levels at the distribution centre (DC) is shared with the vendor.

4. Based on these two types of data exchange, the vendor creates a purchase order (invoices are matched and payments will be made).

5. The required replenishment order is transported to the retailer's DC.

6. The retailer distributes the products to the shop based on historical demand. In the case of promotions, additional products can be shipped to the shop.

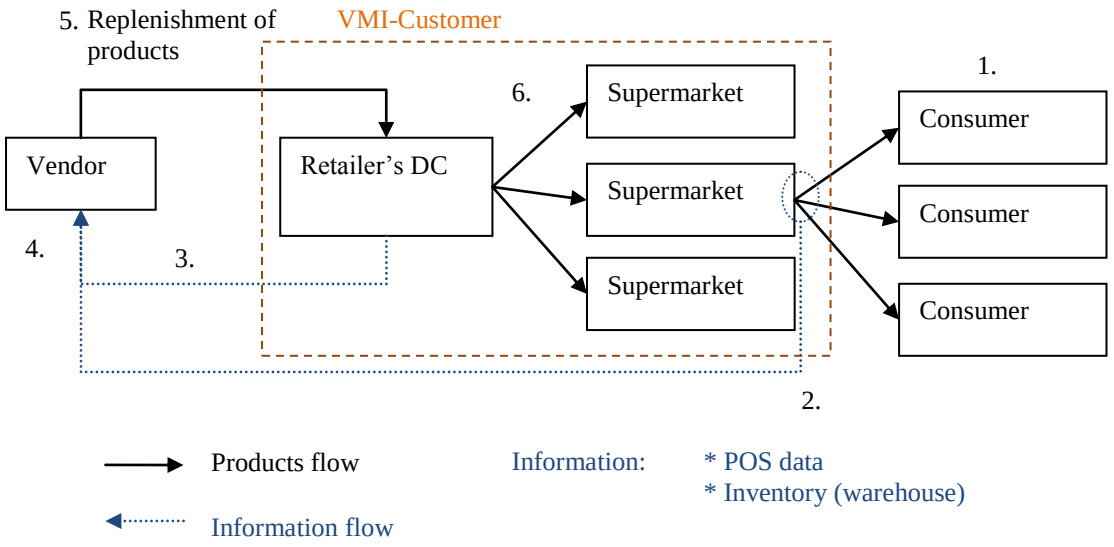


Figure 7.1: B2B VMI product and information flows in a retail setting

In a B2C subscription service supplies are replenished directly at the consumers' homes. The replenishments are made by the subscription provider, which can be a retailer, producer or other vendor. Based on the analysis in Chapter 5 and the VMI@home system of Xie (2004) it is expected that an automatic subscription service would include the following steps, shown in figure 7.2:

1. Consumer subscribes to automatic replenishment of certain products.

2. The retailer / vendor receives the order.

3. Set-up of the necessary hard / software and the retailer / vendor starts to monitor the inventory / consumption rate of the end-consumer.

4. Retailer/vendor creates a purchase order (invoice and payments are arranged).

5. The products are transported to the consumer's house.

6. The consumer receives the products and adds them to his / her inventory.

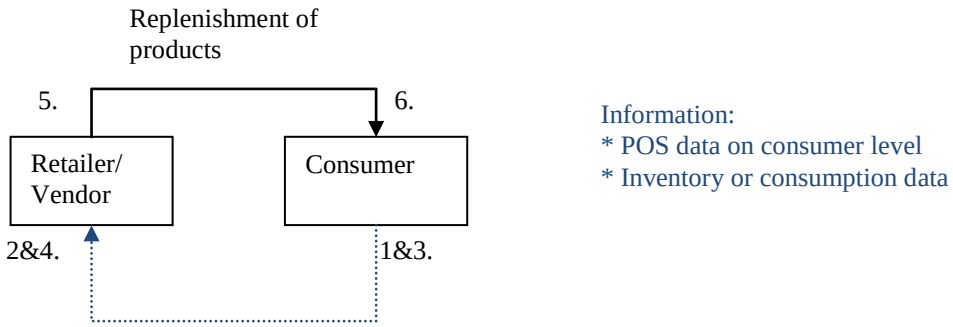


Figure 7.2: Automatic subscription process steps

A comparison of these process steps reveals several similarities between automatic subscriptions and VMI. In both situations it is the supplier who manages the inventory of the customer. Depending on the nature of the agreement, both the consumer in the subscription arrangement and the retailer in the VMI system can limit the maximum number of items in their inventory. In both cases, the supplier has some delivery flexibility as long as the customer does not run out of stock. This delivery flexibility within the VMI arrangement allows the supplier to consolidate customer orders thereby achieving higher load fill in the vehicles (Waller et al., 2001). Likewise, within a B2C subscriptions system, the delivery round can also be more efficient as the subscription provider has more freedom to select a delivery date and time. Earlier research has shown that wider home delivery time slots can reduce costs (Nockold, 2001; Yrjölä, 2001) as well as greenhouse gas emissions (Siikavirta et al., 2003). This is further discussed in section 7.2.

There are also fundamental differences between subscriptions and VMI. The first major difference is order size. Because VMI monitors the inventory of large customers, increasing the replenishment frequency of these customers leads to a significantly smoother demand signal (Waller et al., 2001). In the case of final consumers, on the

other hand, orders are of much smaller quantities. In addition, the demand variations in the households' inventory will generally be much smaller. Consequently, the upstream supply chain benefits of monitoring the inventory in consumers' homes are likely to be smaller, even at a collective level, than B2B VMI.

Promotions, price reductions and advertisements by the retailer tend to increase demand variability. Consumers stockpile significantly more during promotions (Ailawadi et al., 2007; Guo and Villas-Boas, 2007; Hendel and Nevo, 2002; 2006) reducing the tendency to buy in the short term, leading to a low replenishment frequency. With automatic subscriptions replenishments occur after consumption in accordance with agreed rules. Because consumers subscribing to the service are no longer able to participate in store promotions[27], the resulting demand variability induced by promotions will be reduced, or eliminated in the case of 100% subscriptions.

Another difference is the data type. While VMI gives the supplier access to inventory data and POS-data (del Cid et al., 2000), automatic subscription tends to monitor the actual consumption data by end users. Any demand distortion, due to 'order batching' by the consumer at the shop, can be reduced with automatic subscriptions.

Based on the review of literature on B2B VMI and the comparison with consumer VMI, the potential advantages and disadvantage of subscriptions are summarised in table 7.1 below.

[27] This depends on the agreement between the subscription provider and consumer. There exists a possibility that the consumer would buy the products in store when the promotion in store results in a lower product price than offered within the subscription service.

VMI – advantages	Automatic subscription / consumer VMI
Reduced inventory at both vendor and retailer	Inventory reduction for the consumer will be small (small order quantities). Inventory reduction for the subscription providers will depend on the usability of the extra insight into the pattern of demand and the effect of the long order lead time.
Increased customer service: Reduced stock-out throughout the supply chain. Less stock-outs at the vendor result in increased customer service towards the retailer, and increased on-shelf availability leads to improved customer service for the consumer.	Inventory and on-shelf availability at the consumer's home have another meaning. For example nearly 10% of products normally purchased are typically out-of-stock at home, resulting in lost sales[28] (McGoldrick and Barton, 2007). Subscribers will most likely not accept stock-outs which can result in the cancellation of the subscription, leading to lost sales for the subscription provider.
Increased replenishment frequency and smaller cycle inventories	A small increase in replenishment frequency might appear due to the elimination of stockpiling during promotions. However, this depends on the shipment frequency within subscriptions.
Better insight in demand: Demand insight from inventory and POS-data of VMI customers (large customers)	The insight comes from the consumption data of a single household.
Smoother production planning due to better demand insight. However, critical mass might be needed for the vendor to achieve any benefits.	The degree to which the subscription provider can improve the production planning depends on the usability of the extra demand insight (critical mass might be needed) and the effect of long order lead times (in an ideal situation complete make-to-order is possible).
Efficient transport planning due to flexible delivery date and ability to consolidate loads to a greater degree	**Efficient delivery round** due to flexible home delivery date. Long order lead time might lead to efficiencies in long distance transport
Increased sales due to lower stock-out level	Less stock-outs at consumers homes and increased sales due to offering subscriptions service (e.g. competitive advantage)
Lower ordering costs	**Ordering costs / effort:** Extra service provided to consumers (inventory management)

[28] Resulting in an estimated annual loss to FMCG manufacturers of £9bn in the UK. Highest stock-out rates are found in beer, carbonated drinks and snacks while only 2% of the consumers run out of basics such as milk and toothpaste (McGoldrick and Barton, 2007).

VMI Disadvantages	Automatic subscription / consumer VMI
Still demand variability e.g. promotional demand: Forecasts are not shared	**Promotions** have no / limited effect on subscriptions. Demand variability due to promotions will be eliminated for subscribers who are no longer able to participate in promotions.
Complex data (large IT system needed)	**Complex data** assimilating household inventory data from large numbers of homes
No / limited use of additional insight into demand pattern; critical mass needed to use data in production planning – difficult to achieve	Critical mass would be needed to realise the benefit of using consumption data in production planning.
Trust: Retailers might believe that they can manage their inventory better than the vendor and therefore not participating in VMI.	**Trust:** Consumer might not believe that the retailer is able to adequately manage their inventory. Privacy and data security worries might put consumers off subscription.
Limited flexibility in inventory amounts reduces the performance of VMI	Consumers might restrict the number of items in their inventory, especially for voluminous products. This will increase the number of replenishments made by the subscription provider to guarantee product availability at home reducing delivery flexibility.

Table 7.1: A comparison of the effects of B2B VMI and B2C automatic subscriptions

The potential advantages and disadvantages of subscriptions were discussed in a workshop with five supply chain and VMI experts of a large FMCG manufacturer. The meeting consisted of two parts. In the first half hour the literature findings of B2B VMI were presented and discussed with those experts to get a practice point of view on the benefits and disadvantage of VMI in a supplier-retailer setting. In the second part the potential effects of subscriptions on the supply chain were presented and the five experts gave their opinion on this, based on their experience with VMI in the B2B setting.

The experts argued that the upstream supply chain benefits of B2B VMI are small. The critical mass needed to exploit the insight from the POS-data into the production planning process to optimize production and inventory, is not generally reached. Besides that, the insight gained from VMI is limited because production planning horizons in the FMCG sector are relatively long. It is not possible to utilise the advanced information gained about demand patterns from VMI in the production planning process. Also the inventory is not reduced significantly by VMI because much

of the ordering is already done fairly frequently and automatically over the Internet. Vehicle fill constraints (the preference of full truckload) limit the possibility for more frequent shipments. Due to these limitations, the largest benefit of B2B VMI is increased customer service and improved partnership with the retailer, which leads to increased sales to some extent.

Based on the VMI experience, the opinion of the supply chain and VMI experts is that the most likely benefit of automatic subscription is an increase in sales and customer service. Even if the subscriptions are offered in all countries which a certain factory supplies, only a small percentage of the total sales will be ordered through a subscription service. It is therefore very unlikely that the subscriptions will reach the critical mass in the near future. The experts consulted indicated that more than 30% critical mass might be needed to be able to achieve production benefits, and so at the low level of subscription uptake expected no production benefits are likely. It is also likely that individual household consumption data will be even more difficult to handle and process than retail POS-data. Large sophisticated IT-systems would be needed requiring a substantial IT investment. The benefit of having the additional point of use data from a subscription service would therefore be minimal, according to the supply chain and VMI experts consulted.

However, not all findings of B2B VMI can be extrapolated to the B2C context of automatic subscriptions. Important differences exist between B2B VMI and B2C automatic subscriptions. The small orders of households require a different delivery than large orders from retailers. A combination of different customer orders in a delivery round is more likely with subscriptions. Also, the consumers buy and manage their goods in a different way from retailers and might make less than optimal choices due to promotions or stock-outs, which might increase the benefits of establishing a VMI relationship. These differences must be analysed in greater detail before conclusions about the supply chain effects of automatic subscriptions can be drawn. This is discussed in more detail in the next section.

7.2 Supply chain effects of automatic subscriptions

Large savings could be achieved in the last mile when delivery time windows are removed and more deliveries can be made in a round. Automatic subscriptions, where deliveries are planned by the subscription provider, can result in significant savings in the last mile delivery costs, especially when unattended delivery is used. According to a

Finnish case study on last mile delivery performance, weekly unattended delivery can reduce the kilometres driven by more than 5 times compared to online shopping with next day deliveries in one-hour time slots (Yrjölä, 2003). This calculation is based on the assumption that the consumer can choose the delivery date. With the delivery flexibility inherent in automatic subscriptions, deliveries to consumers in the same area can be combined to reduce the distance driven even further. In automatic subscriptions, deliveries are made when the inventory of the particular household is running low. Depending on how the subscription service is designed, the subscription provider can exercises a large degree of control over the delivery date and time windows. Deliveries can be made in off-peak hours, when traffic levels and delivery costs are lower. The trade-off between customer service and delivery efficiency must be carefully analysed by the subscription provider to maximise the benefit of this additional control.

Another possible benefit of automatic subscription is the improvement of inventory management at consumer level. Companies that can make replenishment decisions for the consumer based on his or her actual consumption data can try to stabilise household inventory levels. To analyse if companies can better manage the household inventory than consumers themselves, data on the consumption and purchase history of consumers would need to be obtained. The current situations can then be compared with the optimised inventory management under automatic subscriptions and the potential improvements assessed. A master thesis project (Valantasis-Kanellos, 2012) was set up to collect the necessary household inventory data. A diary study of one month in both the UK and Belgium for several FMCG products was carried out. Consumers were asked to report their inventory and purchases of certain products each week for one month. The consumption and inventory levels of 51 households were estimated. As an example, the inventory of shampoo of several households is shown in figure 7.3 below. This illustrates variations in household purchasing and inventory behaviour.

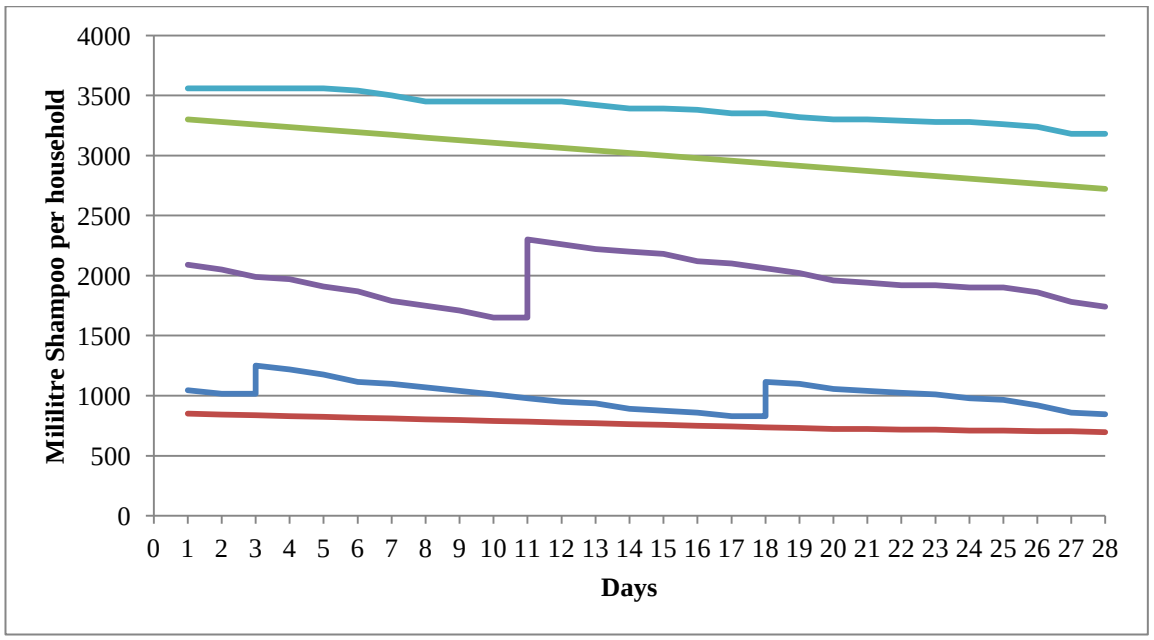


Figure 7.3: Inventory of shampoo at five households in Belgium (based on the weekly inventory status points and purchases) over a period 28 days

As can be seen in figure 7.3 not all households made replenishments during the monitored period of one month. Many of the products monitored have a replenishment cycle of once in two weeks to once in a couple of months. In most cases only one or zero replenishments were made in the period monitored. Consequently, the data gave only limited insight into the replenishment frequency and stock levels of consumers and it is therefore difficult to extract 'normal' shopping behaviour for these products from the data.

The data was collected at product level, for example shampoo, toothpaste, detergent, etc. and no distinction was made between the different use made of a particular class of products in a particular household. For example, one household can have a different shampoo for him and for her and each with a different demand pattern. Combining those two products in the inventory count can result therefore in an aggregation of two products with different usage rates.

The study did find that the majority of the people had run out of one of the nine products selected for this study in the last two years (Valantasis-Kanellos, 2012). However, in half of the cases the replenishment was made within 1 day. This implies that the effect of stock-outs on the consumption pattern was likely to be small, for the products included in this study. Many of the products in this study are considered as necessities and are therefore almost immediately replenished if they stock out; different findings are likely for products like snacks and carbonated drinks, where a stock-out (or

an almost stock-out) occur regularly, leading to lower consumption (McGoldrick and Barton, 2007). Further the study by Valantasis-Kanellos confirmed that promotions massively influence the quantities purchased.

To collect the purchase history for several products over a longer period of time, a database containing 6 months of historic orders placed by several thousands of consumers in an online shop were obtained. It was hoped that analysis of this large data base would reveal clear patterns in the pattern of demand for specific products, some of which might become candidates for a subscription service. Although this database shed light on the average basket size and frequency of ordering, several factors made it difficult to analyse the repetitive purchase behaviour of consumers:

- The online shop was only recently opened. The available data showed the purchases of consumers in the first 6 months of the shop and the majority of the orders were first-time orders. On average the consumers had placed only between 2 and 3 orders.
- In the orders of the 650 consumers that placed 6 orders or more, many products bought were on offer. Gift boxes and testers have been sold for only a limited period of time and many orders were triggered due to these promotions. Many of these products were discontinued after the promotions and sales probably moved to another product or to purchases in another shop.
- The product codes changed every couple of months. Because it is not known (from this database) which, if any, product code replaces which previous one, it was very difficult to analyse repetitive product orders.

The combination of these factors resulted in a substantial variation in the composition of the online shopping baskets in this sample, which made it difficult to analyse the purchase history of a product over a longer period of time. Moreover, no information was available on the purchases the consumer made at different locations. Nor were any separate data available on the amounts of inventory in the shoppers' homes. Therefore it was impossible to calculate or even estimate inventory levels at household level or stock-outs at the consumer house, and hence no conclusions could be made about the efficiency of their replenishments. Future research, possibly using a modified, future version of this database, will therefore be needed to analyse whether automatic subscriptions will be able to manage replenishments at the consumer level more efficiently than the consumers themselves.

7.3 Conclusion

Important differences between B2B VMI and automatic subscriptions exist. While the increased insight into demand patterns in VMI comes from the retailer inventory information and POS-data, automatic subscriptions gather information on consumer's household inventory and actual consumption data. Given the important differences in the way that individual consumers and business buy goods and manage inventory, it would be wrong simply to extrapolate from B2B VMI experience to the B2C subscription context. Subscriptions offer a means of suppressing the bullwhip effect at the bottom of the supply chain, often caused by promotions. The research discussed in Chapter 6 showed that consumers are more willing to subscribe to essential products with a replenishment frequency of monthly or less than for food items with a weekly replenishment frequency. Stock-outs in this 'essential' product category are however much smaller than for many grocery items (McGoldrick and Barton, 2007). The differences between consumer and retailer inventory management capability must be analysed more carefully before conclusions about the effects of automatic subscriptions on the supply chain can be drawn.

However, important lessons can be learned from B2B VMI. Critical mass is needed before the benefits in production planning can be realised. Consultations with supply chain experts suggested that subscriptions would have to represent around 30% of the total sales of a FMCG manufacturer to have much impact on the production planning process and the likely level of adoption would be much lower. Also the complexity in handling the individual households' consumption data might make it difficult to exploit the data to improve the inventory. The upstream supply chain benefits of automatic subscriptions are therefore likely to be small.

Efficiency improvements are, nevertheless, possible in the last mile delivery. Earlier research has shown that widening the delivery time windows can substantially increase the degree of load consolidation and reduce the kilometres driven per order. Automatic subscriptions can eliminate the need for immediate replenishment while meeting the promise of guaranteed delivery before running out. However, the delivery freedom of the company depends on the ability of the consumer to receive the package at a time set by the subscription provider. A reception box, or another form of unattended delivery, might be needed to maximise the delivery efficiency gains from automatic subscriptions.

CHAPTER 8: LCA MODEL FOR ONLINE SHOPPING FOR CONSUMER GOODS

In this chapter the LCA model is explained and the results of the environmental analysis of the different e-retail models are presented. Following the LCA handbooks (Guinée et al., 2002; ILCD, 2010), this chapter starts by defining the goal and scope of the LCA research in section 8.l, followed in section 8.2 by an explanation of the model used for the environmental assessment. The different retail models are discussed in section 8.3. The relevance of the different environmental indicators are assessed in section 8.4. The results of the various fulfilment options are presented for climate change potential (expressed in CO_2-equivalents) in section 8.5 and 8.6. The findings are summarised in section 8.7.

8.1 Goal and Scope definition

The goal of this study is to assess the environmental sustainability of the different forms of distribution to the consumers' home. An LCA model was developed to quantify the environmental impact of different fulfilment models for FMCG products. This includes the most widely utilised e-retail channels as well as the traditional brick & mortar model. The study aims to analyse which factors play an important role in the environmental performance of the different options.

8.1.1 Functional unit

For the purposes of this study the functional unit is described as: the acquisition and fulfilment of one consumer product.

With the functional unit, the study intends to capture the supply chain environmental impacts from the purchase of a single generic FMCG product purchased over the internet (e-fulfilment) or via traditional retailing (Brick & Mortar). Emissions associated with the product itself (its manufacture, use and end-of-life processes) are not included. For clarification, this does not mean that only purchases of one item are considered. When the model is used to quantify results for a product that is part of a larger shopping basket, the environmental impact for one item is calculated by dividing the environmental impacts of the shopping basket by the number of items in the basket. Dividing by the number of items and drops is considered as a good allocation method for assigning emissions to individual items in the last mile (Edwards et al., 2010b). Generally the delivery van utilisation is not limited by weight or volume but by the

number of orders in a delivery round due to the narrow delivery time windows (Siikavirta et al., 2003). And parcel companies, who deliver normally without pre-agreed time slots, are looking for high drop density rates per round to improve the delivery efficiency.

However, choosing one consumer item as the functional unit has also limitations. No distinction is made between the types of consumer item. For example, no allowance is made for differences in the weight and volume of the product. This conflicts with the observation that the consumers' choice to shop via a specific retail channel depends on the nature of the products he or she intends to purchase. For example, online grocery shops are mainly used for stock-up trips containing a larger share of heavy and bulky products than shopping trips to a supermarket (Chu et al., 2008; Pozzi, 2009). However, when appropriate caution is taken in interpreting the findings, choosing the item as the functional unit can be a suitable approach. The choice of 'item' enables allocation of the footprint at item level and reconstructing the footprint, on a bottom-up basis, for higher-level entities (basket, drop, order, parcel) as a summation of items.

8.1.2 System boundaries

The environmental impact of one consumer product following either the online or conventional retail channel is compared from the point of divergence between these channels and the point of consumption, as suggested by Edwards et al. (2011). In the case of FMCG products investigated in this study, this point of divergence is the point of production. Therefore all impacts from the movement and storage of products from the factory to the consumer (and back in case of returns) are included in the model. Impacts from the raw material sourcing, product manufacturing, product use and disposal are excluded.

The following elements are included in the analysis:

- Transportation of products from manufacturing to manufacturer or retail DCs, shops and e-fulfilment centres.
- Transportation of products to the homes, including home delivery, Collection and Delivery Point (CDP) and consumer travel. Besides the tailpipe emissions, the emissions from the production and distribution of the fuel and the full life-cycle (production, maintenance, operations and disposal) of the vehicles are included. Also included are the construction, renewal and disposal of roads.

- Production, distribution, and recycling of packaging used specifically for last mile delivery.
- Additional transportation due to failed deliveries and returns.
- Utility use during warehousing of products in DCs controlled by either retailer or manufacturer. This includes impacts from the production, distribution and use of electricity, fuel, natural gas and water.
- Utility use from shops (e.g. supermarket) and e-fulfilment centres.
- ICT operation from product ordering and tracking by the e-commerce business, search engines and consumer. A share of the production, distribution and disposal of the computers, infrastructure, routers etc. is also included.

The following elements are excluded for further analysis:

- The manufacturing and use of the product.
- The manufacturing and disposal of primary and secondary packaging. Primary packaging[29] is considered as an indistinguishable part of the consumer item and is therefore assumed to be equal in the different retail channels and therefore excluded from the environmental assessment. Also excluded is the possible reduction on shelf-ready packaging and other secondary packaging[30] due to online retailing.
- The buildings infrastructure used in the fulfilment, including the production, maintenance and disposal of the building. Only the utility consumption is included in the model.
- The impacts of reception boxes for unattended delivery.
- Utility use in the consumer's home during online product purchases (e.g. energy associated with the use of lighting and heating).
- Rebound effects of having more time free due to online shopping or potential effects of changed consumption due to online shopping.

[29] Primary packaging is defined here as all packaging directly used to pack products individually, excluding packaging added for transportation.
[30] Secondary packaging is defined here as packaging used to group items together for transportation.

The processes / activities included in the system boundaries are mapped into one single LCA model architecture, following the flow of goods through the supply chain. The model is shown in figure 8.1 and each module will be discussed in more detail in the sections below.

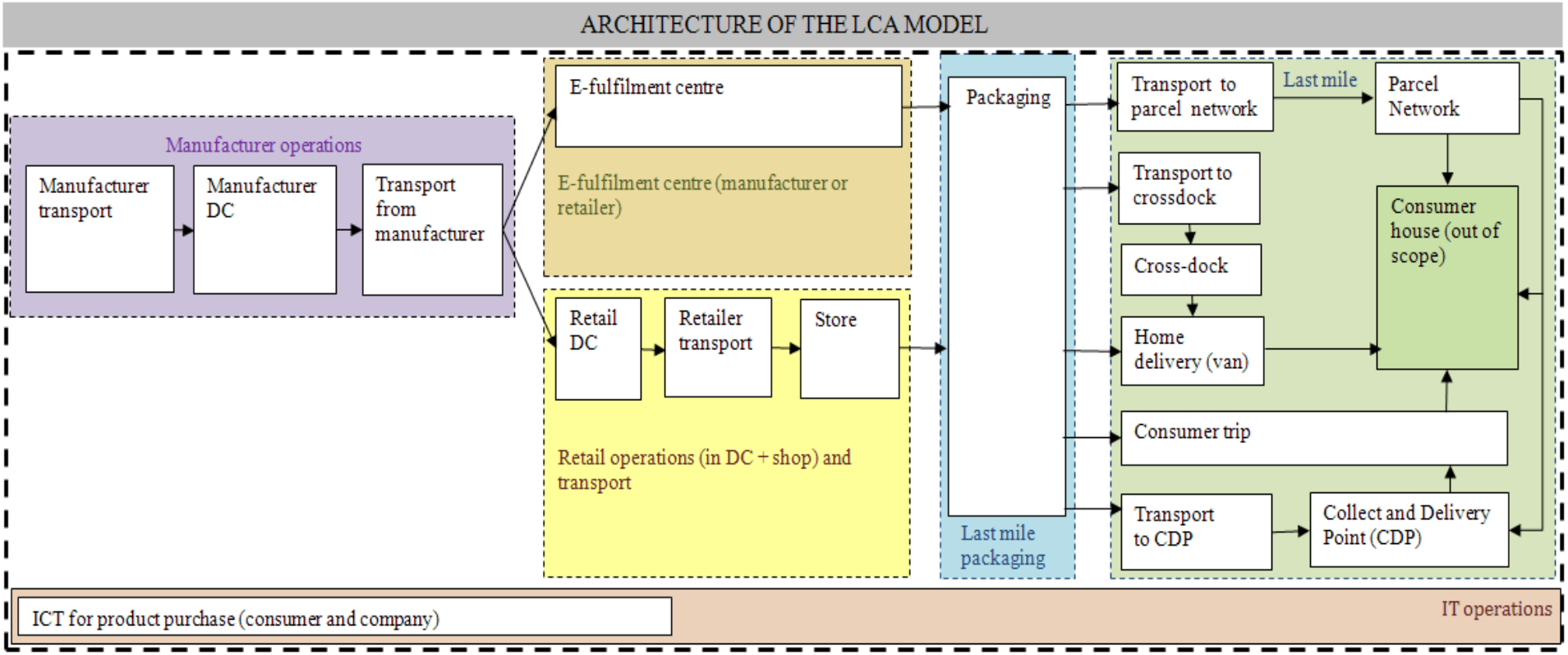


Figure 8.1: Model for the environmental analysis of online shopping of consumer goods

8.2 Inventory analysis

In this section each module in the environmental assessment framework of online retailing (figure 8.1) is discussed in more detail. Links with previous research is made and similarities and differences between the model outlined here and previous work is discussed. The relationship between the different parameters and calculations made in the LCA model can be found in appendix F. Primary and secondary data is used for the input of the values of the more than 400 parameters for each scenario. Even though the LCA model is developed to quantify the environmental impact of different retail models across different regions, the model is applied here for the United Kingdom. Consequently, average industry data of the UK is used. For all 'background processes', like the production of electricity and the life cycle impacts of vehicles, IT-equipment and packaging material, the EcoInvent Database (Frischknecht et al., 2007) is used as provided in SimaPro (PRé Consultants, 2011).

All the parameters and their corresponding values in the different models are listed in an excel file and then input into the LCA software tool SimaPro. The excel file makes it possible to easily compare the parameter values across the different retail models. For each deviation between the values, an explanation is provided. The full list was discussed with a supply chain and LCA expert to evaluate the completeness and consistency of the data.

8.2.1 Consumer trip

As argued in Chapter 3, previous research suggests that the reduction of consumer travel by car is essential for realising an environmental benefit from B2C e-commerce (Hesse, 2002; Matthews et al., 2002; Rizet et al., 2010). However, complete substitution of the traditional shopping trip by a home delivery of consumable products is unlikely (Erber et al., 2001; Hesse, 2002; Mokhtarian, 2004). In the case of consumer goods, and especially groceries, products are often bought as part of a larger shopping basket. It is likely that shopping trips will still be executed despite ordering certain products out of that basket online and getting these home-delivered. This suggests that analysing the purchase of a single item on one shopping trip would be unrealistic. More relevant is to look at the influence that online shopping can have on conventional shopping trips in terms of frequency of shopping, the location / distance to the shops and the transport mode chosen by the consumer (Mokhtarian, 2004).

Besides including the complementary trips to the supermarket, it is also important to include consumer trips that arise from failed deliveries and returns (see Chapter 3). An LCA model on online retailing should therefore include the consumer trips that are associated with failed deliveries, returns and complementary shopping as well as picking up products at a collection and delivery point (CDP). For each trip the transport mode, distance, and the number of items transported in the trip are determined in order to analyse the environmental impact of the personal shopping trips at an item level.

Transport mode

In many environmental assessments of online retailing the car is included as the only possible transport mode. Walking or cycling is regularly excluded from the analysis (see for example, Collins and Aumônier, 2002; Sivaraman et al., 2007; Weber et al., 2009). However, on average, the car is only used in 65% of the shopping trips in the UK (DfT, 2011). Excluding the more sustainable transport modes will lead to an overestimation of the environmental impact of personal shopping trips. Therefore a broad range of transport modes and fuel types (diesel, petrol, LPG, electric and hybrid) are included in the model and average values for transport modes used in the UK are taken from the National Travel Survey (DfT, 2011). EcoInvent data is used to define the environmental implications for the different transport modes, including production, maintenance and end-of-life impacts of the vehicle, as well as the road infrastructure and vehicle operations (production and combustion of fuel). For public transport this includes the average load factor (number of passengers).

Distance

The total mileage driven can be exactly the same with or without the purchase of the item. Where a trip is being made for other purposes, so called ‘trip chaining’, and the shop is on the route, there will be no net increase distance travelled. Therefore it is important to include only the miles which are actually reduced by shopping online. So only the proportion of the trip made specifically with the intention of buying the product, e.g. the dedicated distance. This includes the total length of the round trip to and from the store or CDP, adjusted for the distance to other locations on the same round trip.

Shopping basket

The consumer shopping trips, and especially grocery shopping trips, usually involve more than one item. As discussed earlier, the environmental impact of the shopping trip is divided by the number of items in the shopping basket.

Returns

Different returns options are possible. Carriers can collect the unwanted items at the consumer's home in the course of a delivery round, or the consumer can bring the items to a store or collection point (Edwards et al., 2010b). Another possibility will be to return the items directly to the carrier depot (McLeod et al., 2006). All these possibilities (shown in figure 8.2) are included in the LCA model.

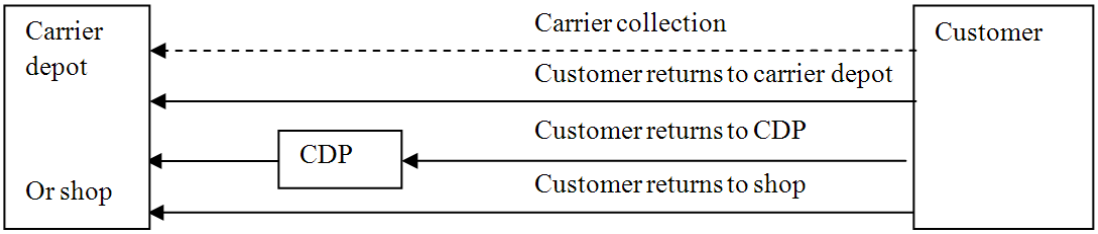


Figure 8.2: Return options (adapted from Edwards et al., 2010a)

Also here the modal split for each particular location is taken into account as it appears that people make different transport mode choices for different locations. For example, on average 87% of the people go by car to the carrier depot and 43% goes to a CDP by car (Cherrett and McLeod, 2005).

Failed deliveries

After a failed delivery, several options are possible (shown in figure 8.3); the item can be left with a neighbour, it can be left outside the premises, a subsequent delivery attempt can be made to the consumer house, the item can be returned to the carrier's depot for collection by the consumer, or it can be delivered to a collection and delivery point (CDPs) or shop (Edwards et al., 2009b).

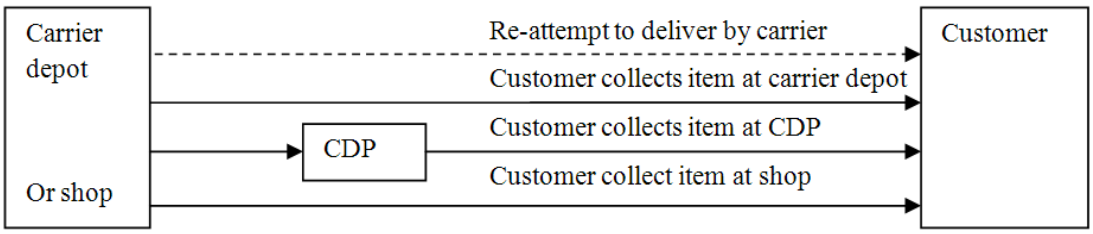


Figure 8.3: Failed deliveries methods

The number of items in the failed order is assumed to be equal to the original number of items in the order and consumer travel behaviour is assumed to be similar for all trips to the same locations for returning unwanted goods. It is likely that the same shops will be selected for picking up failed deliveries as returning unwanted items, therefore the level of trip chaining and the choice of transport modes are assumed to be equivalent to trips for returning items.

8.2.2 Nature of the home delivery performed by the retailer

Much research has been done on the van delivery part of the last mile. Several papers discuss the efficiency of the van delivery round. For example, the effect of time slots on the distance driven is discussed by Nockold (2001), Grando and Gosso (2005) and Punakivi and Saranen (2001). From these papers it can be concluded that the delivery round performance, e.g. the distance driven per order delivered, depends on the following factors:

- The shopper density, both geographically and temporal. The location of the drops in one particular delivery round, e.g. only the drops that can be or have to be delivered during that round, influence the delivery performance.
- Time windows: a short time window results in driving back and forth between the consumers, increasing the distance driven per order.
- Order lead time: limits the opportunity for load consolidation and has a similar effect to the duration of the time window.
- Operating hours or working hours of the driver can limit the maximum length of the delivery round. The maximum number of drops is then influenced by the time needed for each drop, the distance and road conditions.

<u>Distance and number of drops in the delivery round</u>

The relationship between the above factors and the distance driven per order is not straightforward. Due to the limitations of the software package Simapro, where only simple linear calculations can be made, the effect of the non-linear factors on the distance driven cannot be included in the model. The input parameters in the model are therefore the total round distance (including failed deliveries but excluding returns) and the number of orders delivered on the delivery round. In this model, the home delivery performance is calculated on the basis of attended delivery, 2-hour time-slots, which is

currently offered by most online grocery retailers in the United Kingdom. As argued earlier, widening this time window would lead to a reduction in distance driven and therefore improve the environmental footprint of the home deliveries while 1-hour delivery slots would have the opposite effect. The effect of widening the time-widows is further discussed in section 8.6.2.

Returns

Picking-up returns can be treated as part of the normal delivery round, or a van can be specifically dedicated to picking up returns in a separate delivery round. To have the flexibility to include both strategies, the values of the return round trip can be adjusted separately from the normal delivery round. A consequence of this is that the normal delivery round needs to be calculated without returns. The distances driven for returns are therefore calculated separately and added to the total van distance driven.

Failed deliveries:

Because the input data used for the delivery round distance and the number of drops already included failed deliveries, the home delivery impacts of failed deliveries are not calculated separately. However, depending on the failed delivery strategy, the failed deliveries can have an effect on consumer transport. This is, as discussed earlier, included in the consumer trip module.

Number of items in the order

As discussed above, the transport emissions of the last mile are allocated with respect to the number of drops in the delivery round and not by weight or volume. Consequently, there is no need to define the load factor of the van. The maximum load factor is implicitly included in the model, e.g. when the van cannot serve all its customers in one delivery round, the delivery round will be split in two or more delivery rounds to serve all customers, resulting in different values for the delivery round distance and the number of orders delivered.

Transport mode

Most home deliveries performed by the retailers themselves are with a van. Several types of fuel are taken into account (diesel, petrol, biofuel, electric and hybrid). Only a van smaller than 3.5t is included in the model due to data availability in Simapro. Also a car is included in the home delivery as couriers are delivering the products (mainly non-

food products) to the consumer's home with their own private car (Yodel, 2013). Further, a bike is included as there are examples of bikes being used for city deliveries (UPS, 2011). EcoInvent data is used for calculating the environmental impacts of the vehicles and fuel used in the home delivery.

8.2.3 Additional cross-dock options in the home delivery process

Additional cross-dock options are possible between the point at which the online order is picked and the home. For example Ocado (2010) makes use of local cross-docks (or 'spokes') to increase their distribution efficiency. Groups of customer orders are transported by truck to a cross-dock where they are separated into smaller batches for the last link to the consumer's house.

Cross-dock

A cross-dock station will often account for only a small percentage of the total environmental footprint. For example, in case of Ocado (2010), it represents only 3.2% of the company's total CO_2-eq emissions. As a consequence, the cross-dock will only be taken into account at an aggregate, top-down level, i.e. the total annual consumption of utilities (electricity, water, heating / cooling gas, and fuel) at the cross-dock is divided by its annual throughput (the number of items through the cross-dock annually). The construction, maintenance, land use and disposal of the cross-docks are not included.

Transport to cross-dock

The transport from the retailer to the cross-dock station is normally performed by a truck. A 28t gross-weight truck is included in the model (due to data availability). Several fuel types are taken into account (diesel, biofuel, hybrid, and natural gas). It is assumed that the truck makes a delivery round starting and ending at the retailer's premises or at the cross-dock station. During the delivery round, the truck can deliver to one or more cross-docks. The total delivery round distance and related externalities are divided by the number of items in the truck at the start of the delivery round.

8.2.4 Collection and delivery points (CDP)

Similar to the cross-docks, the CDPs are expected to account for only a small percentage of the total environmental footprint. The environmental impact of the CDPs is therefore calculated in a similar way to the cross-docks.

8.2.5 Home delivery via the Parcel network

A parcel network comprises a regional truck movement to the depot of a third party provider, depot handling, a long haul transport to another depot and again depot handling, and a local delivery round (NTM, 2010). The externalities associated with these nodes and links in the network (shown in figure 8.4) are weighted by the percentage of items they handle.

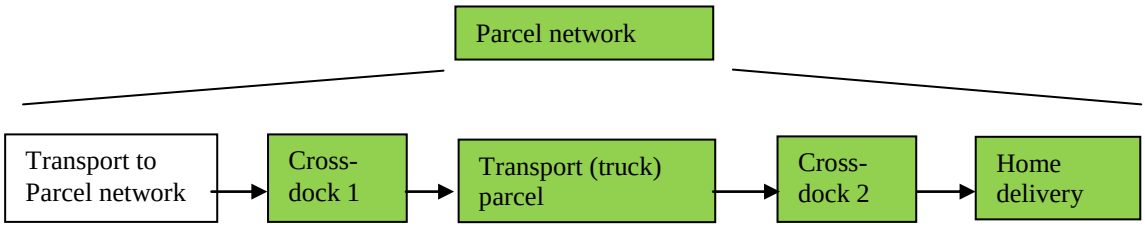


Figure 8.4: Overview of parcel network stages (based on the approach of NTM, 2010)

The environmental impact of all the line-haul transport links is calculated in a similar manner to the 'transport to cross-docks' described earlier. The impact of depot handling is calculated in the same way to the 'cross-dock' module. In the LCA analysis local collection and delivery rounds within the parcel network are treated similarly to home delivery operations. To offer a faster service parcel carriers often despatch orders in smaller numbers increasing the environmental impact per order. Therefore the number of items in a parcel delivery is a critical variable in the LCA. This is further explained in appendix F.5.

8.2.6 Shop

Energy use in buildings is often excluded from the environmental impact assessments of online retailing. However, online retailing can have an impact on the number of retail stores, warehouses and depots (James and Hopkinson, 2001; Reijnders and Hoogeveen, 2001; Siikavirta et al., 2003). The utility use (e.g. electricity, water, fuel, and gas) of the shop is divided by the total number of items sold, either online or by physical shopping. The utility use is taken from the Building Research Establishment (BRE) database (Pout et al., 2002) and the average throughput from IGD Retail Logistics report (Watkins, 2005). Similar to previous modules, the construction, maintenance, land use, and disposal of the premises are excluded. Impacts from refrigerants are also excluded. Although refrigerants are responsible for a significant part of the carbon emissions of

supermarkets (15.89% of the CO_2 emissions of Tesco in 2010-2011 were from the refrigerants, Tesco, 2012), these emissions can be fully allocated to fridge and freezer products, and are therefore outside the scope of this study.

8.2.7 Retailer transport and retail DC

Only one type of retail DC is included in the calculations, however, the utility use per square metre and the throughput can be adjusted to the different scenarios. The same calculation method is used as for 'cross-dock', 'CDP' and 'shop', described above. The environmental impact of the retailer transport is calculated in the same way as for the other forms of truck transports outlined earlier.

8.2.8 E-fulfilment centre

The utility use and throughput depends on the degree of automation and therefore several types of e-fulfilment centres are included in the model; manual warehouse, automatic warehouse and an unspecified warehouse. Depending on the retail model, one of these e-fulfilment centres is selected.

8.2.9 Transport from the manufacturer to the retailer

This module only includes the items that are transported via the manufacturer's DC. In some cases, items are transported directly from the factory to the retailer's DC. In that case the transport is included in the module 'manufacturer transport'. The length of the round trip is divided by the number of items in the truck, in a similar way to the module 'retailer transport'.

8.2.10 Manufacturer DC

This module is similar to the 'retail DC'. Because all retail models that make use of the manufacturer DC use the same DC, only one type of DC is included in the model. It is assumed that the inventory level at the supplier's premises is not directly influenced by distribution channel (i.e. online as opposed to conventional retail channel).

8.2.11 Manufacturer transport

The distance travelled and number of items in the truck can be specified for transport from the factory to the manufacturer DC or from the factory to the retail DC. The output value is weighted by the percentage of items flowing through each channel. The manufacturer transport includes the transport from continental Europe to the United

Kingdom and covers therefore a long distance. In 2011 international freight transport in Europe covers an average distance of 596 km while freight to and from the United Kingdom was slightly lower (Eurostat, 2012b). Therefore 500 km is assumed.

8.2.12 IT operations

As suggested by Fichter (2003), Matthews et al. (2001b) and Yi and Thomas (2007) the first order effects are included in the LCA model. Although there are many ways to order products remotely, only products ordered over the internet are included in the LCA. PCs, Smartphones, or tablets can be used to access the internet and to shop online and the fractional use of each device is specified. Environmental impacts of network access devices are also included in the calculation and are based on the EcoInvent Database. It is assumed that no online search, apart from the selection of a product in a particular web-shop, is performed before buying FMCG products online or in-store. No ICT impacts are therefore included for traditional shopping.

8.2.13 Packaging

The packaging considered here is packaging needed to ship the items to the consumer, e.g. last mile packaging. Frequently used types of packaging are included in the model: low-density polyethylene (LDPE), corrugated board, polystyrene, and starch. The formulas used to calculate the environmental impact of the packaging used in online shopping, and the formulae of all other modules, can be found in appendix F.

8.3 LCA switchboard to model specific retail models

The model has a modular structure. Depending on the retail / e-tail typology, different modules can be switched on / off (parameterised) to represent the supply chain of a specific retail / e-tail approach. Although many combinations are possible, only the main retail / e-tail typologies will be discussed below.

8.3.1 The traditional retail model

In the traditional model the products are shipped from the factory via the manufacturer's DC to the DC of the retailer. In the manufacturer's DC the products are consolidated with products from other factories. However, when volumes justify, large orders are directly send from the factory to the DC of the retailer, bypassing the manufacturer's DC.

From the retail DC, the products are further transported to the shop. The consumer will make a shopping trip to the supermarket to buy the products and transport them to his or her home. This is visually represented in figure 8.5.

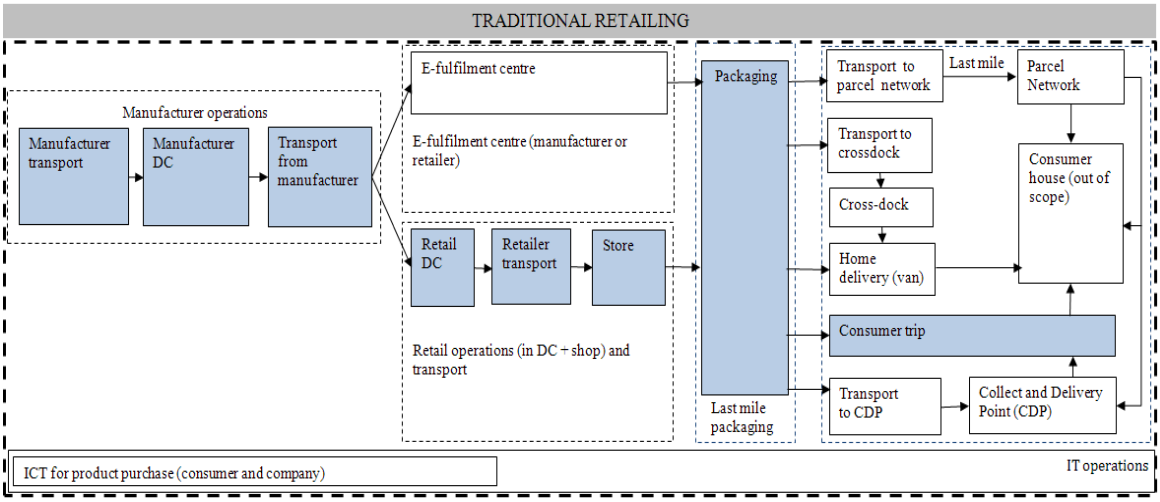


Figure 8.5: Selected modules for traditional retailing

8.3.2 Pure player 1

Pure player 1 describes the situation of a centralised retailer which fulfils the online orders with an in-house van delivery service.

In the pure player 1 situation the products are shipped via the manufacturer DC to the centralised DC of the retailer. From the retailer's DC the products are transported either directly to the consumer or transported in a consolidated load in a truck to a cross-dock station. In the latter case, the orders are split at the cross-dock locations for further home delivery with a van. The selected modules are shown in blue in figure 8.6.

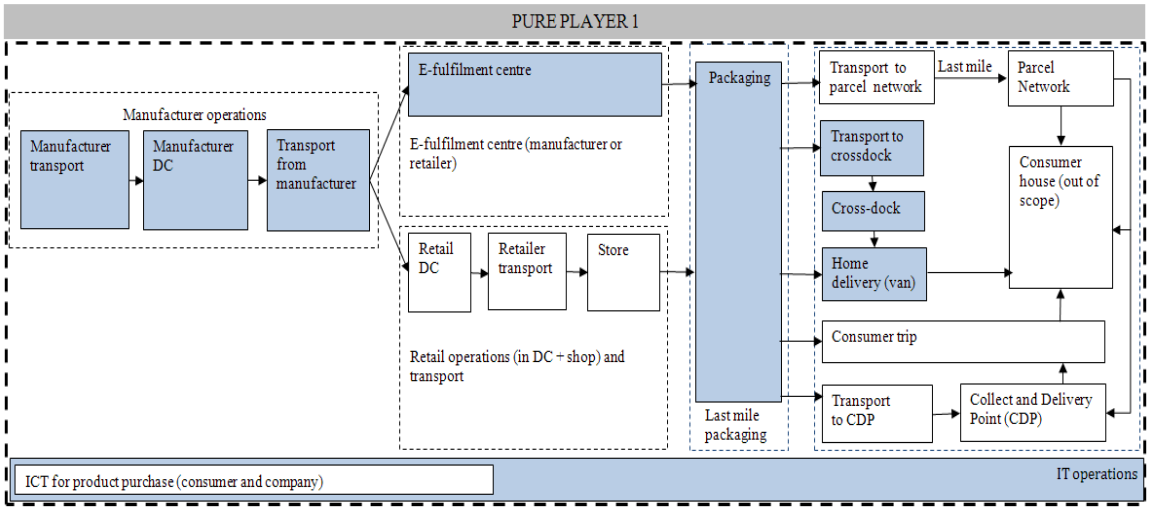


Figure 8.6: Parameterised modules for the model pure player 1

Because pure player 1 has no shops, returns are collected from the consumer's house by a van-driver. Also failed deliveries are re-delivered to the consumer's house.

8.3.3 Pure player 2

The second pure player model can be differentiated from that of pure player 1 at the last mile level. From the e-retailer's DC the products are transported to the consumers' homes through a parcel delivery network. This is shown in figure 8.7.

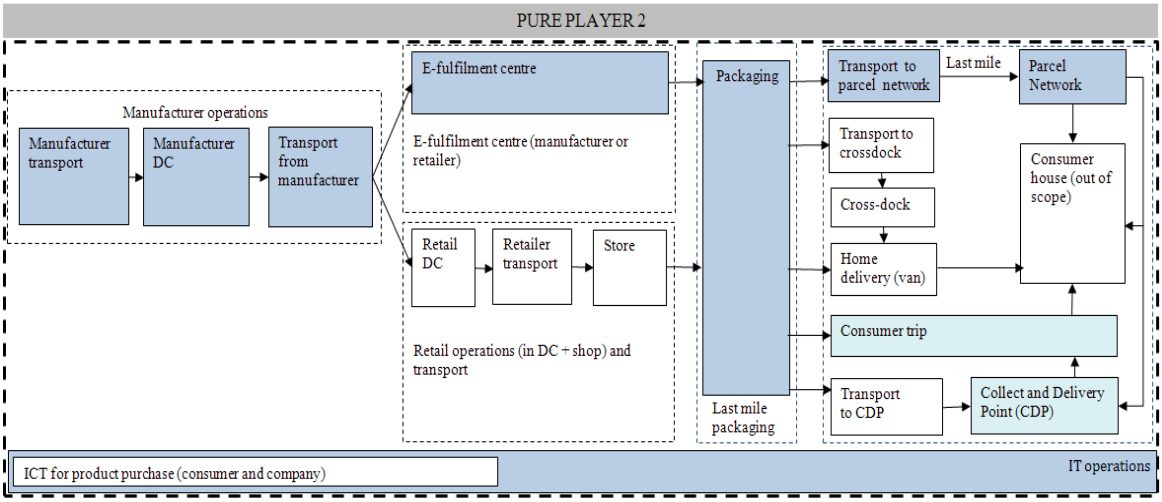


Figure 8.7: Modules selected for pure player 2 (optional modules in light blue)

In some cases, consumers do not want to have their order delivered to the home, but opt for a delivery to a Collection and Delivery Point (CDP). In that case, the parcel network will deliver the order to the CDP, where the consumer picks it up at a convenient time. CDPs can also be used for returning unwanted items or to pick up failed deliveries. However, returns and failed deliveries can also be dropped off / picked up by the consumer at the carrier's depot, or can be dropped off / picked up from the consumer's house by the parcel company.

8.3.4 Pure Player 3 (drop-shipping)

In the third pure player model the orders are accepted and processed by the online retailer but not transported from its DC. Instead it is distributed directly from the manufacturer's DC (shown in figure 8.8).

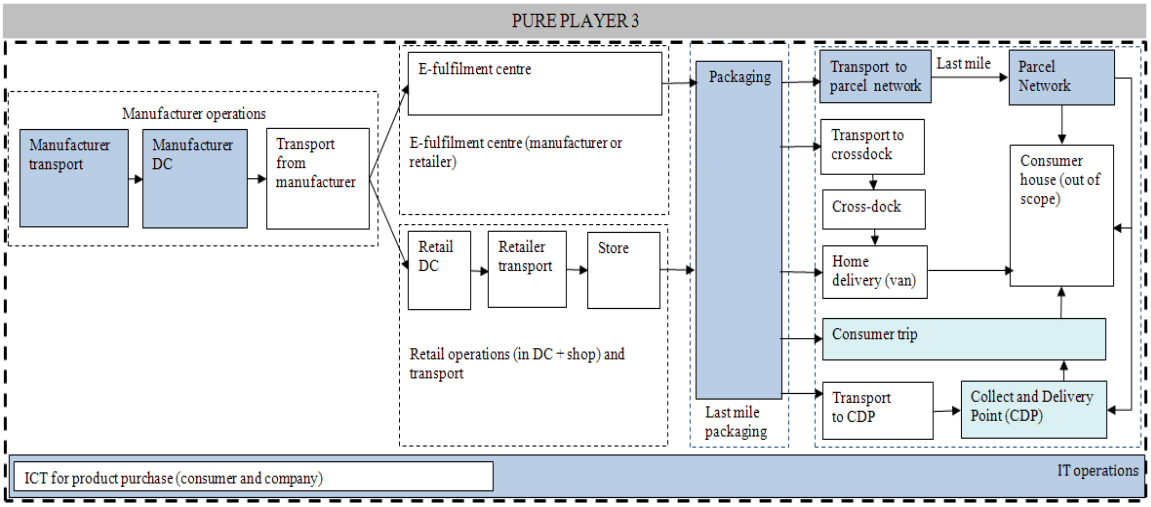


Figure 8.8: Modules for pure player 3, the drop-shipping model

Also in this case, the products can be transported to a CDP. Returns and failed deliveries can be dropped off / picked up at the consumer's house, at the carrier depot or at the CDP.

8.3.5 Brick & Click 1

Brick & Clicks retailers fulfil the online orders from a local supermarket. Like in the traditional model, the products are shipped from the manufacturer's DC or factory to the retailer's DC. From there the products are distributed to the local supermarkets from which the home deliveries are made. The relevant modules are shown in figure 8.9.

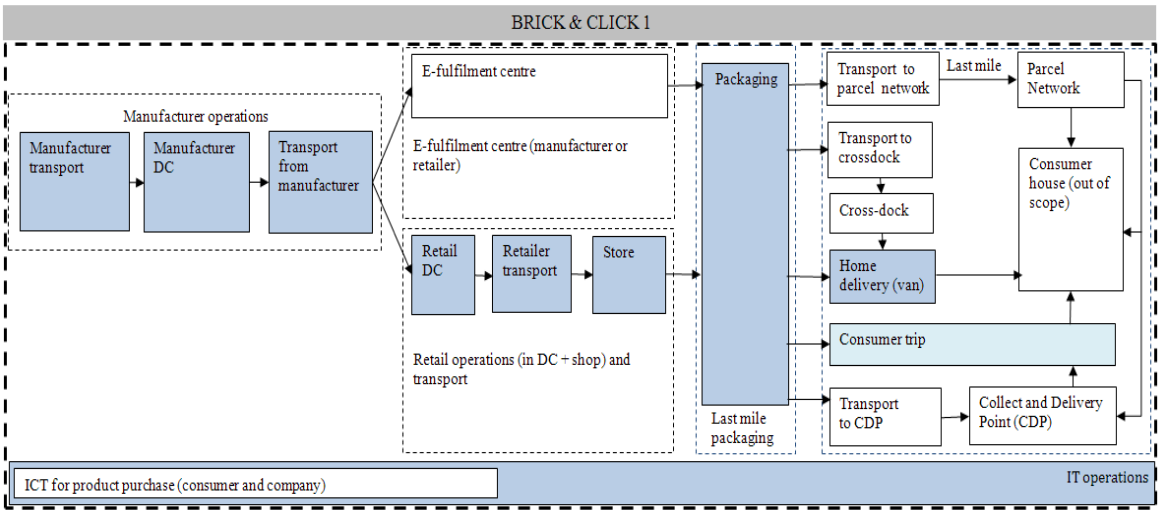


Figure 8.9: Modules selected for the retail model Brick & Click 1

Unwanted items are normally returned to the supermarket by the consumer. Failed deliveries can also be picked up in the supermarket by the consumer or can be re-delivered by a van.

8.3.6 Brick & Click 2 (click & collect in store)

Online orders received by Brick & Click retailers can be picked up at the supermarket. This is called the click & collect situation and is shown in figure 8.10.

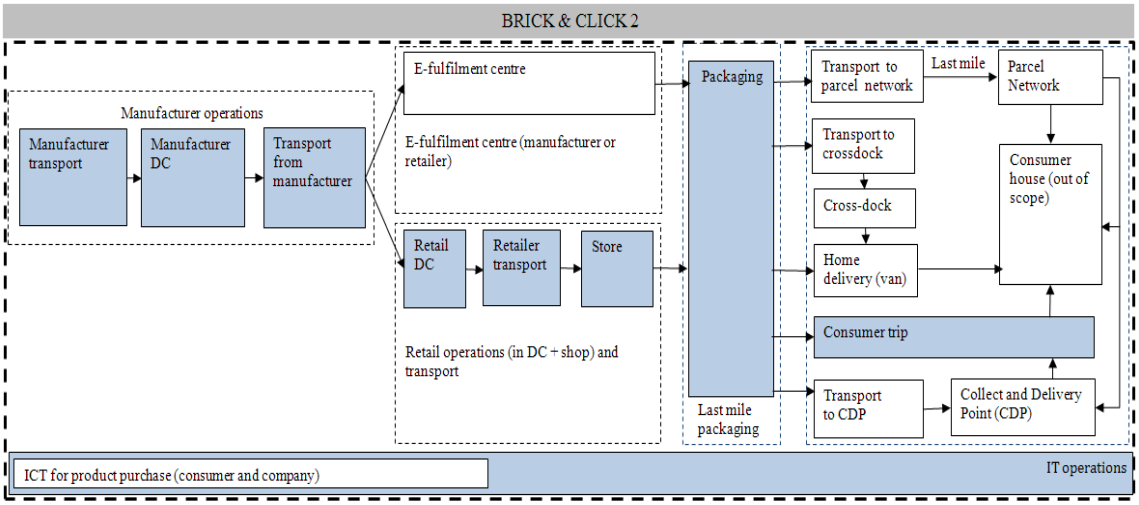


Figure 8.10: Selected modules for Brick & Click 2

In the Brick & Click 2 situation, all returns and failed deliveries involve a consumer trip to the supermarket.

8.3.7 Direct to Consumer

Manufacturers can bypass the retailer and deliver directly to the consumer via the parcel network (shown in figure 8.11). In this case the orders are prepared in the manufacturer's DC, which functions as the e-fulfilment centre.

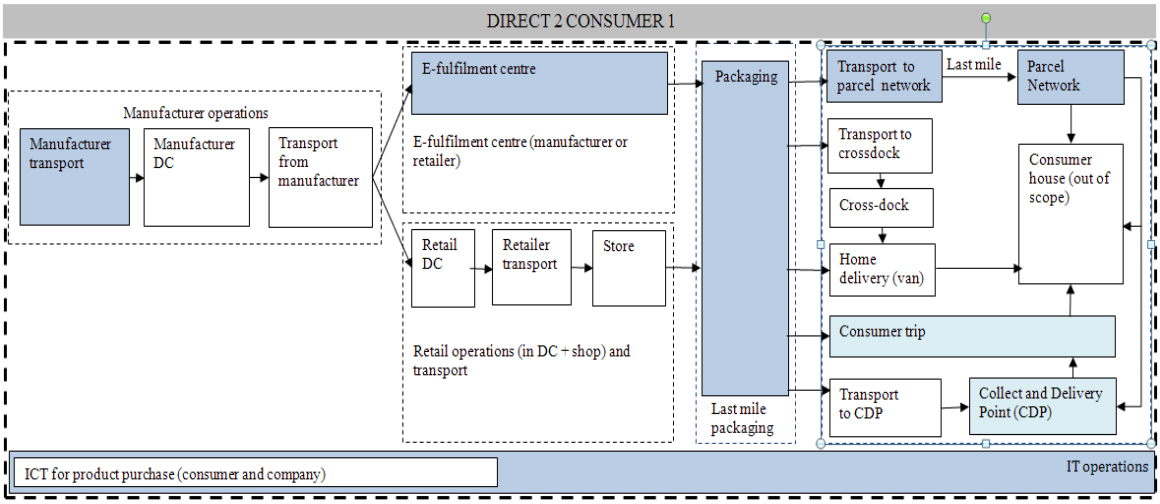


Figure 8.11: Modules selected for Direct to Consumer 1

Like other e-fulfilment models making use of the parcel network, in this scenario products can be delivered to a CDP where the consumer picks up his package. Also

returns and failed deliveries can be handled via the CDP. Alternatively returns and failed deliveries can be arranged for pick-up / drop off at the home or at the carrier depot.

An overview of the models and their abbreviations are shown in table 8.2 below.

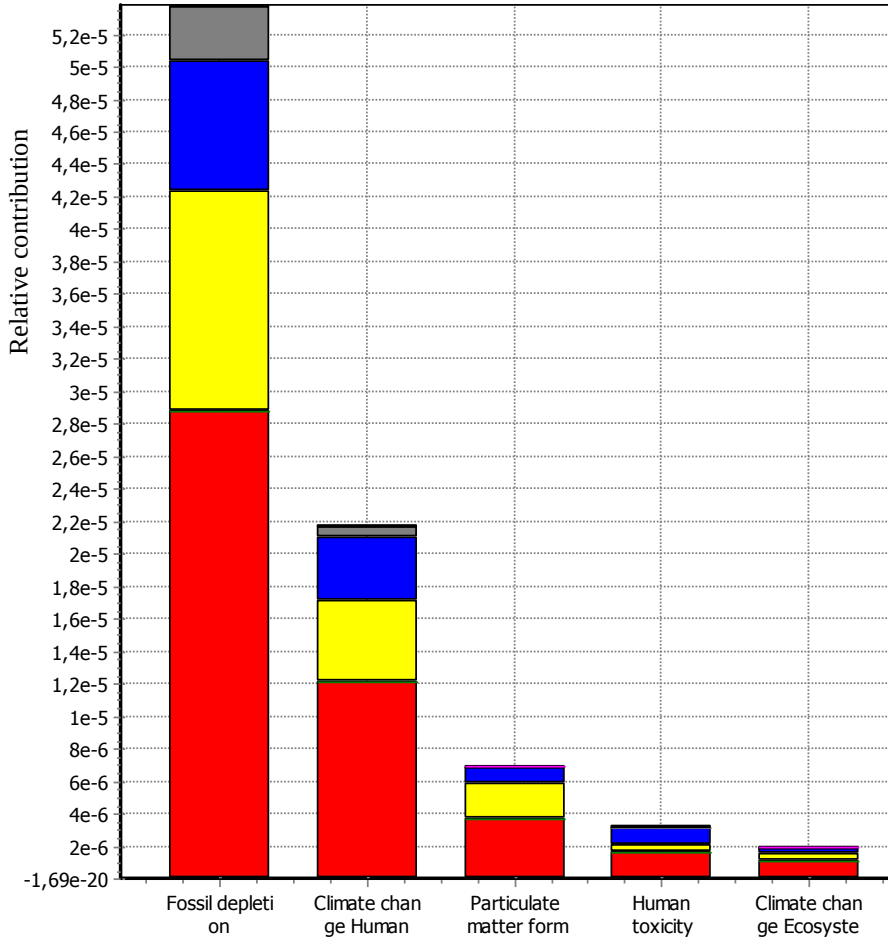
Model	**PP1**	**PP2**	**PP3**	**B&C1**	**B&C2**	**D2C1**	**B&M**
Explanation	Centralised pure player with van delivery	Centralised pure player through parcel delivery network	Drop-shipping from supplier through parcel delivery network	Van delivery from local shops	Click and Collect in local stores	Bypass retailer and use parcel delivery Network	Conventional retailing in local supermarkets

Table 8.2: Explanation of retail models

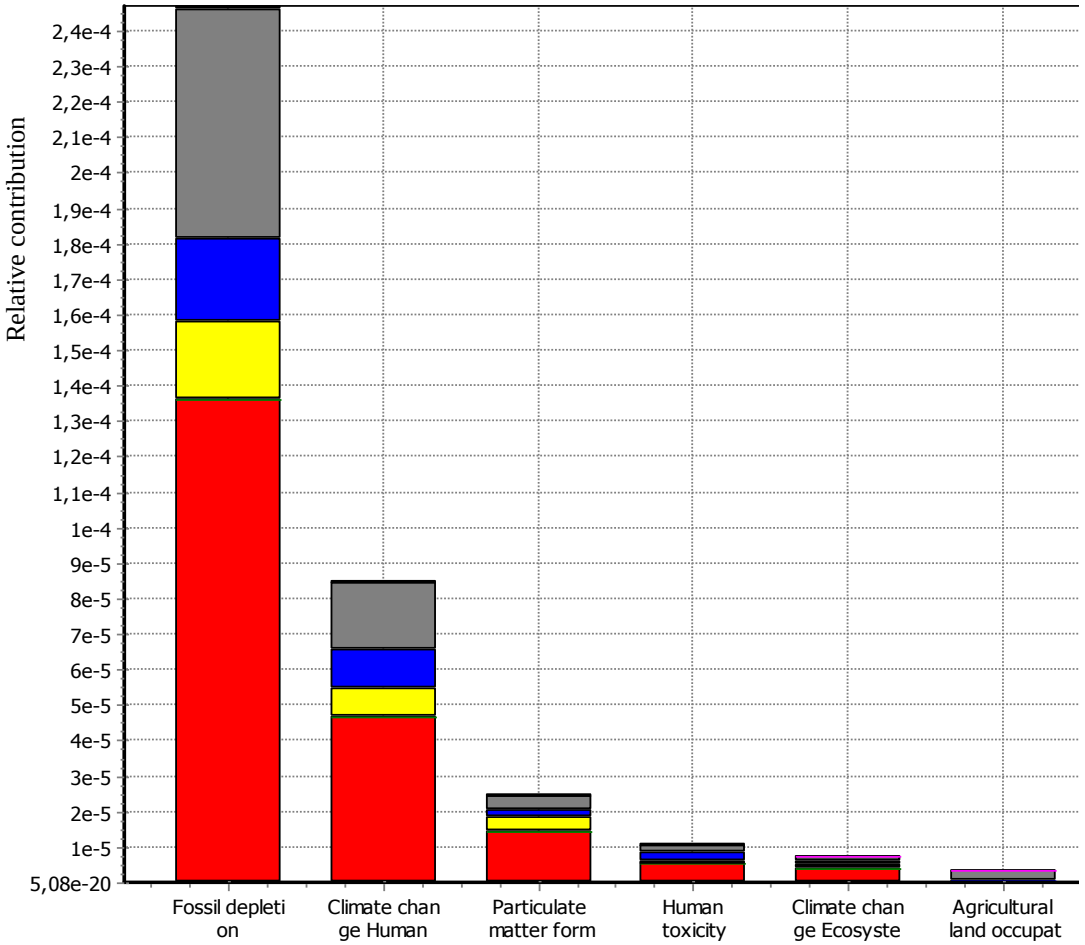
8.4 Impact assessment

The LCA will focus on climate change potential as the single environmental impact category. From the start of the study, it was expected that climate change would be the most relevant environmental indicator for this study considering the relative high energy use in most of the processes involved in retailing (transport, electricity consumption in the buildings, etc.) and the generation of much of this energy from fossil fuels.

In order to confirm this assumption, a normalisation step was carried out to assess the relevance of the environmental impacts from the system as described above. For example, it is possible that toxic material used in the production of PCs has an important influence on impact categories other than climate change. Via the ReCiPe impact assessment methodology (ReCiPe Endpoint H, Goedkoop et al., 2009) the relative contribution to worldwide damage (e.g. endpoint indicators) of 17 environmental midpoint indicators were analysed. In the normalisation step the contributions of the fulfilment of one item to a certain impact category are translated into high or low contributions relative to a certain benchmark. High contributions can be considered relevant (van Hoof et al, 2013). The results of the normalisation step for four retail models can be found below in figure 8.12. Other scenarios show a similar result. The results show the relative impact of the fulfilment of one item compared to the same impact caused normally by one person in Europe in one year. The results are sorted on value, and only results with a value above 1^{-6} are shown.



A) Pure Player 1



B) Pure Player 2

Last mile | Retailer operations | manufacturer operations | e-fulfilment centre | packaging | ICT process

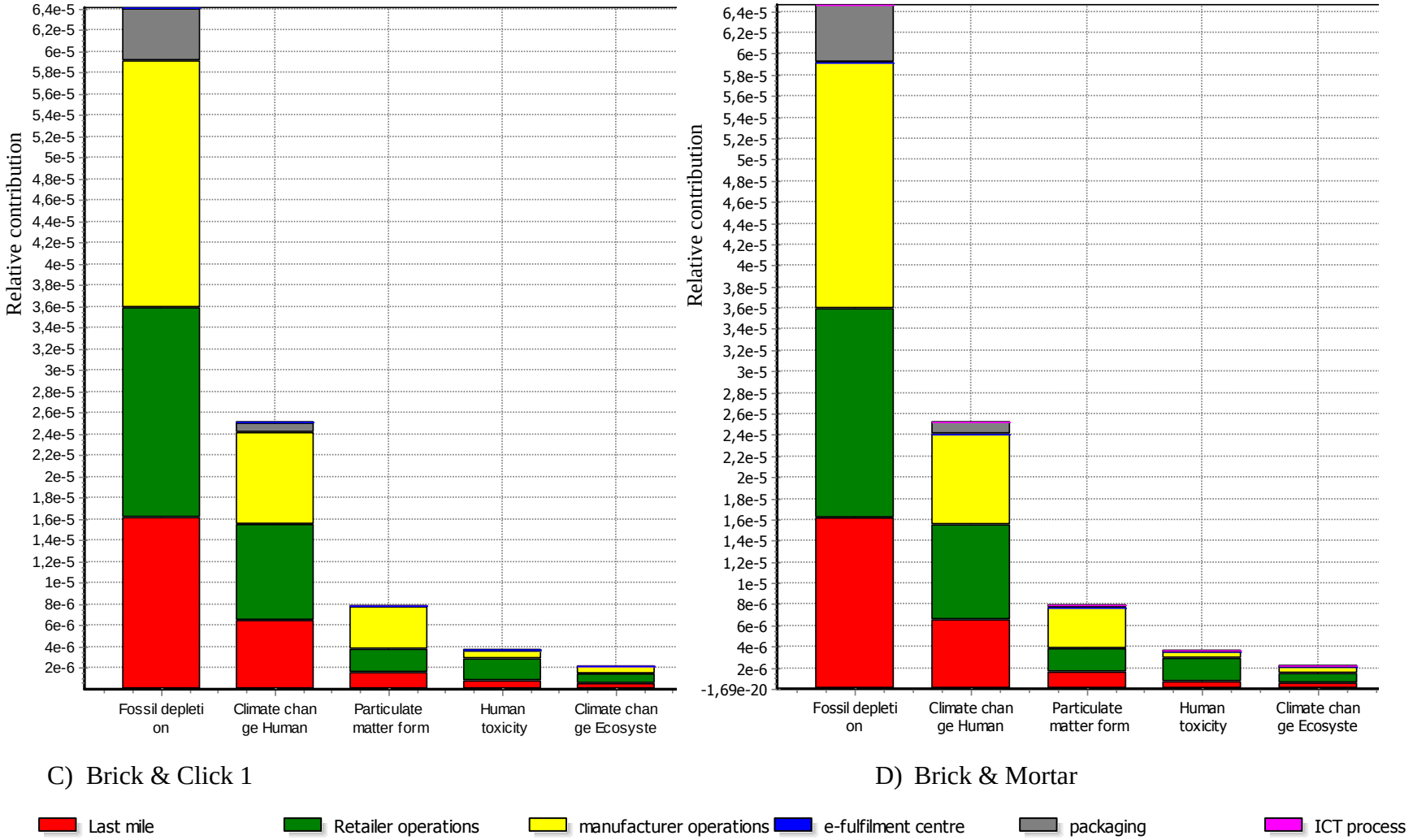


Figure 8.12: Normalisation results for PP1, PP2, B&C1 and B&M

From figure 8.12, it can be concluded that the fulfilment on 1 item contributes relatively high, compared to the average emissions of one person in Europe in one year, to 1) fossil resource depletion, 2) climate change potential, 3) particulate matter formation and 4) human toxicity potentials. Considering its relevance in the life cycle system modelled in this study[31], and the external relevance of climate change potential, the further results and discussion will be reported in this indicator only (expressed as CO_2-equivalents).

Since the "IPCC 2007 GWP 100a V1.02" methodology (developed by the Intergovernmental Panel on Climate Change, Solomon, 2007) is still the most widely recognised impact method for measuring climate change impact potentials (over 100 years), this method is further used for producing results.

8.5 Interpretation

This section presents estimates of the CO_2-eq emissions at item level for the average situation for each e-retail and conventional retail model. This means that both the supply chain and the consumer behaviour differences between the different retail models are included. For example, when buying FMCG products from an online grocery retailer an average of 45 (B&C1) to 55 (PP1) items are bought, while an average of two FMCG products are ordered at a pure player with parcel delivery (PP2). The result below (figure 8.13) include these typical basket sizes for each fulfilment model. In figure 8.13 and table 8.3 a complete substitution of consumers trips to the supermarkets due to online shopping is assumed.

[31] Following normalization, climate change is the second most relevant indicator and is contributing to two damage categories (ecosystem loss and human health). Also, fossil resource depletion (first most relevant indicator) is a result from the same unit processes in the life cycle systems, and will therefore lead to the same conclusions.

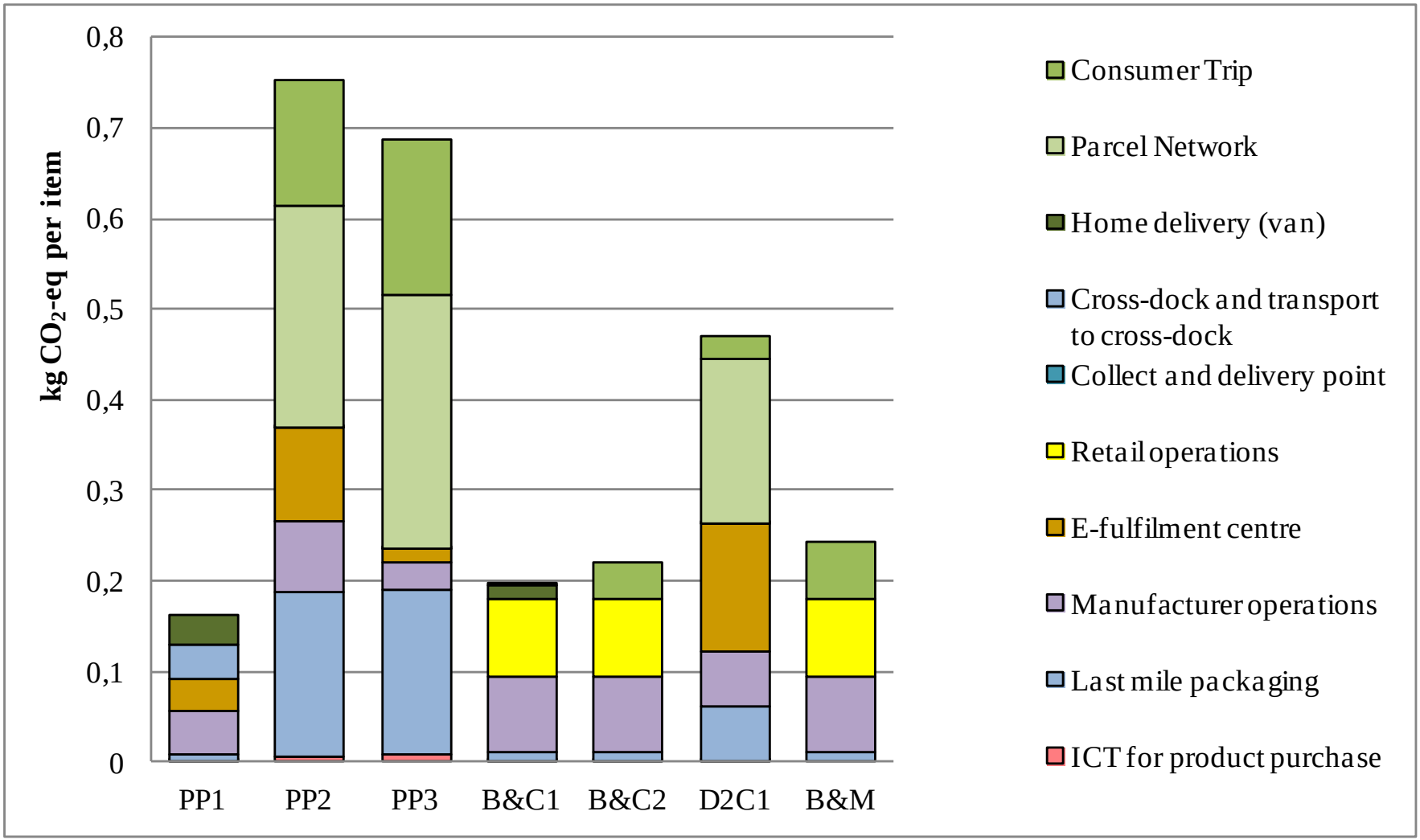


Figure 8.13: CO_2-eq emissions for different retail models, assuming 100% trip substitution

From figure 8.13 it can be concluded that the major impacts are coming from the last mile (consumer transport and home delivery), the supermarket and the transport between the factory and the manufacturer's DC. As expected from previous research (for example Weber et al., 2011), the ICT operations have a minor impact. Also the DCs, CDP and the cross-dock facility have a limited impact on the total carbon footprint of the fulfilment models. The contribution of the different modules to the total climate change potential in the industry average scenario (assuming 100% trip substitution) is shown in table 8.3.

	PP1	PP2	PP3	B&C1	B&C2	D2C1	BM
Last mile	**42.9%**	**51.6%**	**66.8%**	**8.1%**	**18.9%**	**44.1%**	**25.6%**
• Consumer trip	0%	18.3%	24.7%	0.3%	18.9%	5.5%	25.6%
• Parcel Network	-	33.3%	42.1%	-	-	38.5%	-
• Home delivery (van)	19.8%	-	-	7.8%	-	-	-
• Transport to cross-dock	21.4%	-	-	-	-	-	-
• Cross-dock	1.8%	-	-	-	-	-	-
• Collection and delivery point	-	0.01%	0.02%	-	-	0.02%	-
Retail operations	**-**	**-**	**-**	**44.2%**	**39.0%**	**-**	**35.7%**
• B&M Store	-	-	-	39.4%	34.7%	-	31.7%
• Retailer Transport	-	-	-	4.5%	3.9%	-	3.6%
• Retail DC	-	-	-	0.4%	0.3%	-	0.3%
E-fulfilment centre	**22.8%**	**13.6%**	**2.2%**	**-**	**-**	**30%**	**-**
Manufacturer operations	**29.9%**	**10.3%**	**4.2%**	**42.5%**	**37.5%**	**12.7%**	**34.3%**
• Manufacturer transport	21.8%	3.9%	4.2%	33.7%	29.8%	12.7%	27.2%
• Manufacturer DC	5.0%	1.1%	-	3.1%	2.7%	-	2.5%
• Transport from manufacturer	3.1%	5.2%	-	5.7%	5.0%	-	4.6%
Last mile packaging	**4.1%**	**23.7%**	**25.6%**	**4.9%**	**4.4%**	**12.8%**	**4.4%**
ICT for product purchase	**0.2%**	**0.7%**	**1.1%**	**0.2%**	**0.2%**	**0.4%**	**-**

Table 8.3: Contribution analysis of different e-retail models (with industry average data)

A sensitivity analysis was carried out on the most relevant modules. It is important to note that even though the parameters were selected based on the contribution analysis and the expected variation in their values, the results are sensitive to the input values. If the input values change, for example the percentage of orders moving via CDPs, the relative contribution of the output variables will also change. When an uncertainty assessment is not possible due to a lack of data, it is considered good practice to conduct

a sensitivity analysis on the parameters identified as important in the contribution analysis (Guinée et al., 2002). For this purpose an Excel tool was built which made it possible to vary parameters and interpret the results of the different e-retail models simultaneously.

8.5.1 Consumer trips

As can be seen from figure 8.13 and table 8.3 the consumer trip contributes significantly to the total climate change potential of certain retail models. Consumer trips arise due to the need to return unwanted goods, pick up failed deliveries or collect deliveries at a CDP. In parcel deliveries, the failed deliveries result in 62 to 89 g CO_2-eq per item (PP2 and PP3 respectively), assuming that 40% deliveries fail with 90% subsequently redelivered and 10% is collected by the consumer at a local CDP or carrier's depot. Another 66 g CO_2-eq is emitted due to consumers returning unwanted items in 3.5% of the cases.

In van-based models the incidence of consumer trips is much lower. Due to the 2-hour delivery windows, the proportion of failed deliveries is much lower. Also when failed deliveries occur, the consumer can pick up their items at a local shop, resulting in the distance travelled being shorter (12.5 km dedicated roundtrip) than when the consumer has to pick up their items at a carrier depot (19.95 km) as is the case with parcel deliveries. In the van-based delivery scenario (B&C1), failed deliveries lead to just 0.004 g CO_2-eq, assuming that 99% can be redelivered and 1% of the failed deliveries are picked up in the local store. The short distance and lower return percentage (0.04%) also leads to lower greenhouse gas emissions for returns in the van-based models, emitting only 0.5 g CO_2-eq. The lower return percentage in the van-based models can be explained by the different nature of the products. Although all models include FMCG products, van-based models mostly deliver grocery products, which have typically a very low return rate (Cairns, 2005), while parcel models deliver proportionally more high value FMCG products, like consumer electronics, which have higher return rates.

As argued earlier, a complete substitution of the consumer trip to the store by home deliveries is not realistic (see appendix B). Home delivery of groceries can reduce the shopping trips to the supermarket by as little as 25% (Forrester 2001 cited by Foley et al., 2003). For other online retail models this is likely to be even lower. To include this moderating effect on existing shopping trips, the percentage of remaining or complementary shopping trips is included in the environmental impact calculations of

online retailing. Depending on the retail model, 75% or 90% of the consumer trip to a physical store is included on top of the online retail emissions. Figure 8.14 shows a comparison including complementary consumer shopping trips.

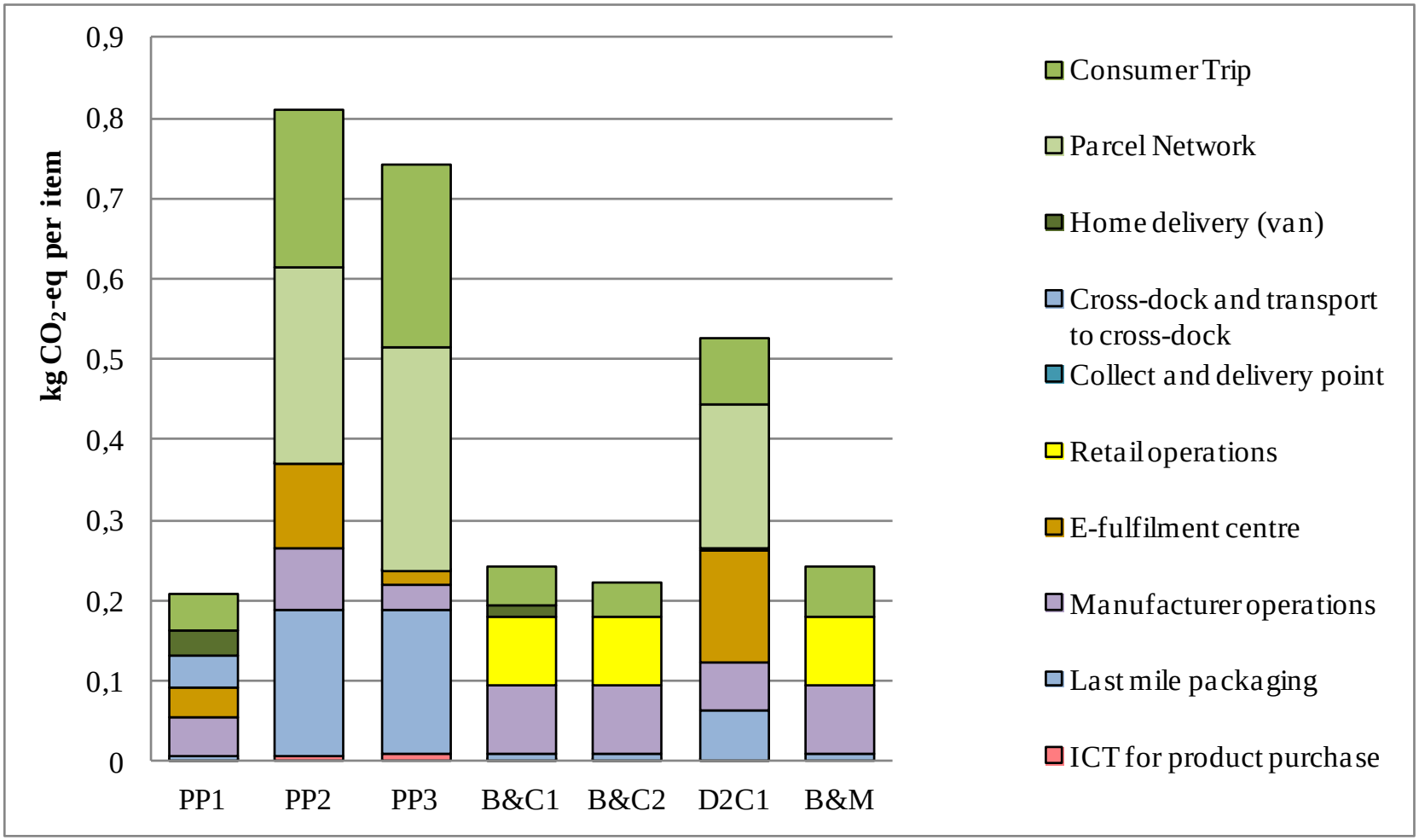


Figure 8.14: Climate change potential of different e-retail models based on industry average shopping basket sizes, trip substitution, returns and failed deliveries

A trip to the local store emits on average 62 g CO_2-eq per item, assuming a dedicated round-trip distance of 12.5 km and 30 items in the shopping basket. However, only 75% or 90% of this trip is included in the e-retail models to take into account the limited reduction in the shopping trips due to online shopping. Depending on the online retail model, the additional consumer shopping trips add between 28.7% (PP1) and 7.3% (PP2) to the total climate change potential. Including these complementary shopping trips to the supermarket leads to a shift in the environmental ranking of the various retail models. Brick & click (B&C1) no longer shows a lower carbon footprint than the click and collect option (B&C2) and conventional retailing (B&M). To analyse the effect of complementary trips in more detail, five scenarios were modelled (see table 8.4). Note that the volume is deliberately held constant in all scenarios[32].

Scenario	**Pure online**	**Online shopping and increased physical shopping**	**Online shopping but no change in-store shopping frequency**	**Online shopping & 25% reduction in shopping trips**	**Only in-store**
Number of online orders	4	4	2	1	0
Number of physical shopping trips	0	10	8	6	8
Number of items in each online order	55	45	45	55	0
Number of items per trip to store	0	4	16.25	27.5	27.5
Total number of items	220	220	220	220	220

Table 8.4: Trip substitution scenarios (based on data from Hartman Group, 2013; Ocado, 2012)

[32] Online grocery prices are equal to in-store prices and therefore it is not possible to have more volume with equal spending for this product type. Further, no evidence is found that online grocery shoppers buy more items. Chu et al. (2008) found in the household panel of a Spanish retailer that the number of items bought in a year is equal for non-online shoppers as combined online and in-store shoppers. Therefore those two scenarios, volume and spending, as suggested by Mokhtarian (2004) are not included in this study.

As discussed in Chapter 3, the effects of online shopping on consumer travel behaviour remains highly uncertain. In the first scenario, online shopping is assumed. In the second scenario the shopping trip behaviour reported by the Hartman Group (2013) is modelled; four online orders and ten physical shopping trips in a month. The assumption is made (in line with the findings of Pozzi, 2009) that the online orders are used for stock-up purchases while the physical shopping trips are 'quick trips' to get items that are running out of stock. Third, the situation is modelled where online shopping has no effect on traditional shopping. It is found that non-online shoppers go on average eight times a month to the supermarket (Hartman Group, 2013) which is supplemented with two online purchases a month in this scenario. In the fourth scenario, a 25% reduction in shopping trips is modelled as suggested by Forrester (2001, cited by Foley et al., 2003). The last scenario describes a 'non-online' shopper who remains totally reliant on conventional shopping. Online grocery orders can be fulfilled by a centralised pure player (PP1) or by a brick & click retailer (B&C1), which have a different carbon footprints. To illustrate this difference, separate graphs have been constructed for these two e-fulfilment options (figure 8.15 and 8.16).

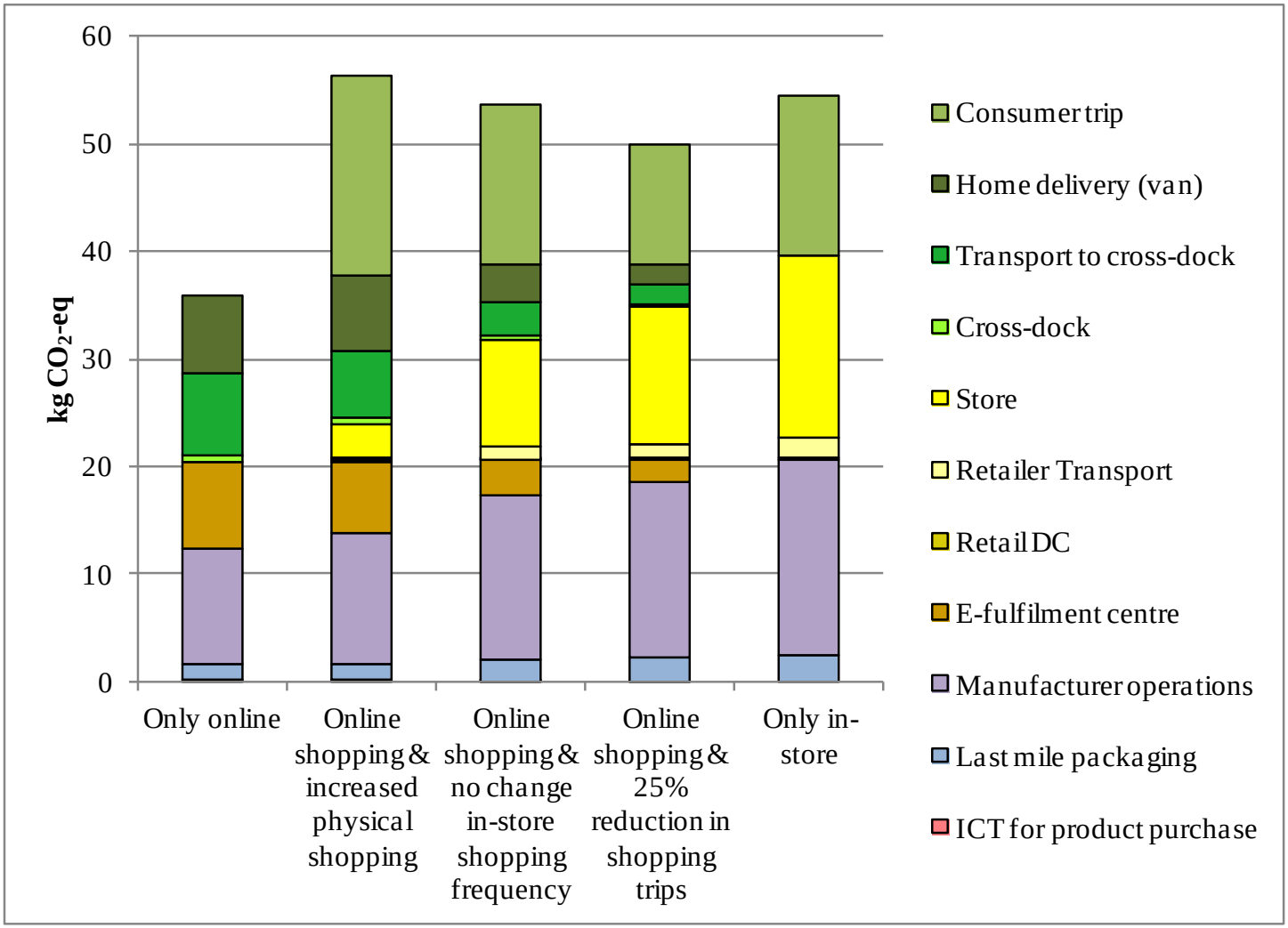


Figure 8.15: Kg CO_2-eq for the acquisition of 220 items, assuming centralised pure player (PP1)

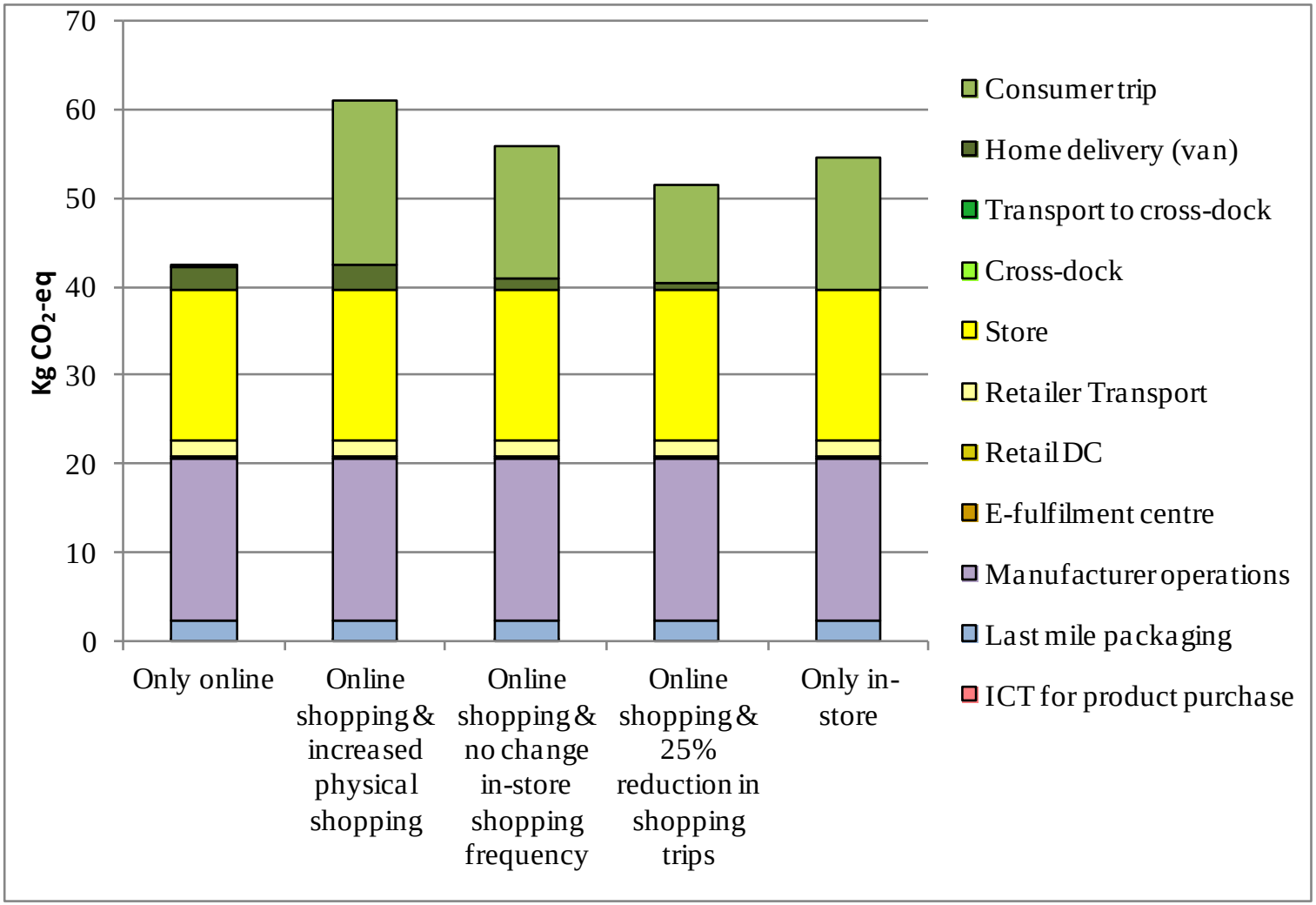


Figure 8.16: Kg CO_2-eq for the acquisition of 220 items, assuming Brick & Click retailer (B&C1)

Not surprisingly, the second scenario, in which online shopping is combined with an increase in physical shopping, is the worst scenario emitting between 256 and 278g CO_2-eq per item depending on the e-fulfilment option adopted. The high frequency of consumer trips is reflected in a high level of total CO_2-eq emissions. However, the basket size of these trips is much smaller than in the other scenarios, increasing the chance that these trips will be performed without car. This will be further assessed below.

Shifting some products to online shopping while retaining exactly the same number of physical shopping trips (scenario 3) results in a benefit to the environment when assuming PP1 for online shopping. In the case of online shopping with a brick-and-click retailer (B&C1) the results show slightly higher emissions than for conventional retailing (increased by 2.6%). This is interesting because earlier research argued that reducing personal shopping trips is needed for online shopping to become beneficial for the environment (see for example Hesse, 2002). This research shows that online shopping can reduce the impact on the environment even without reducing personal travel. The greater energy efficiency of the PP1's e-fulfilment centre relative to that of a supermarket outweighs the increased emissions from the home delivery and ICT operations. When online shopping reduces the number of physical shopping trips, even larger carbon savings can be achieved.

Consumer transport modes

The carbon footprint of the various fulfilment options is also sensitive to the consumer's choice of travel mode. The impact of this modal choice is shown in figure 8.17. In this calculation, a basket size of 30 items is assumed for conventional retailing, 55 for PP1, and 45 for B&C1.

An assessment was made of the combined effect of trip frequency and modal choice on the level of greenhouse gas emissions. This compared the situation where online shoppers also make more physical shopping trips on foot to shops within walking distance than non-online shoppers (figure 8.18).

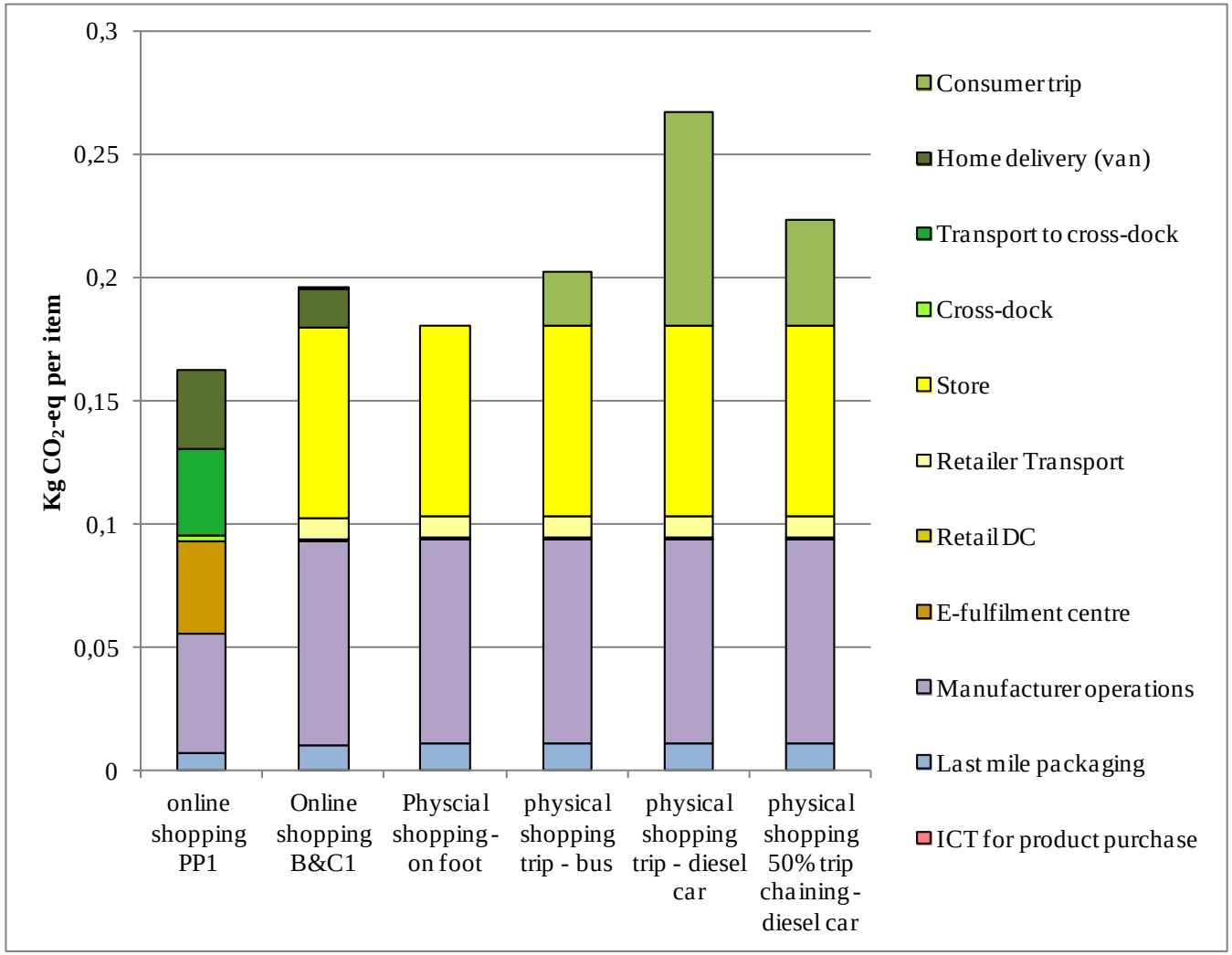


Figure 8.17: The environmental impact of consumer transport modes on conventional shopping

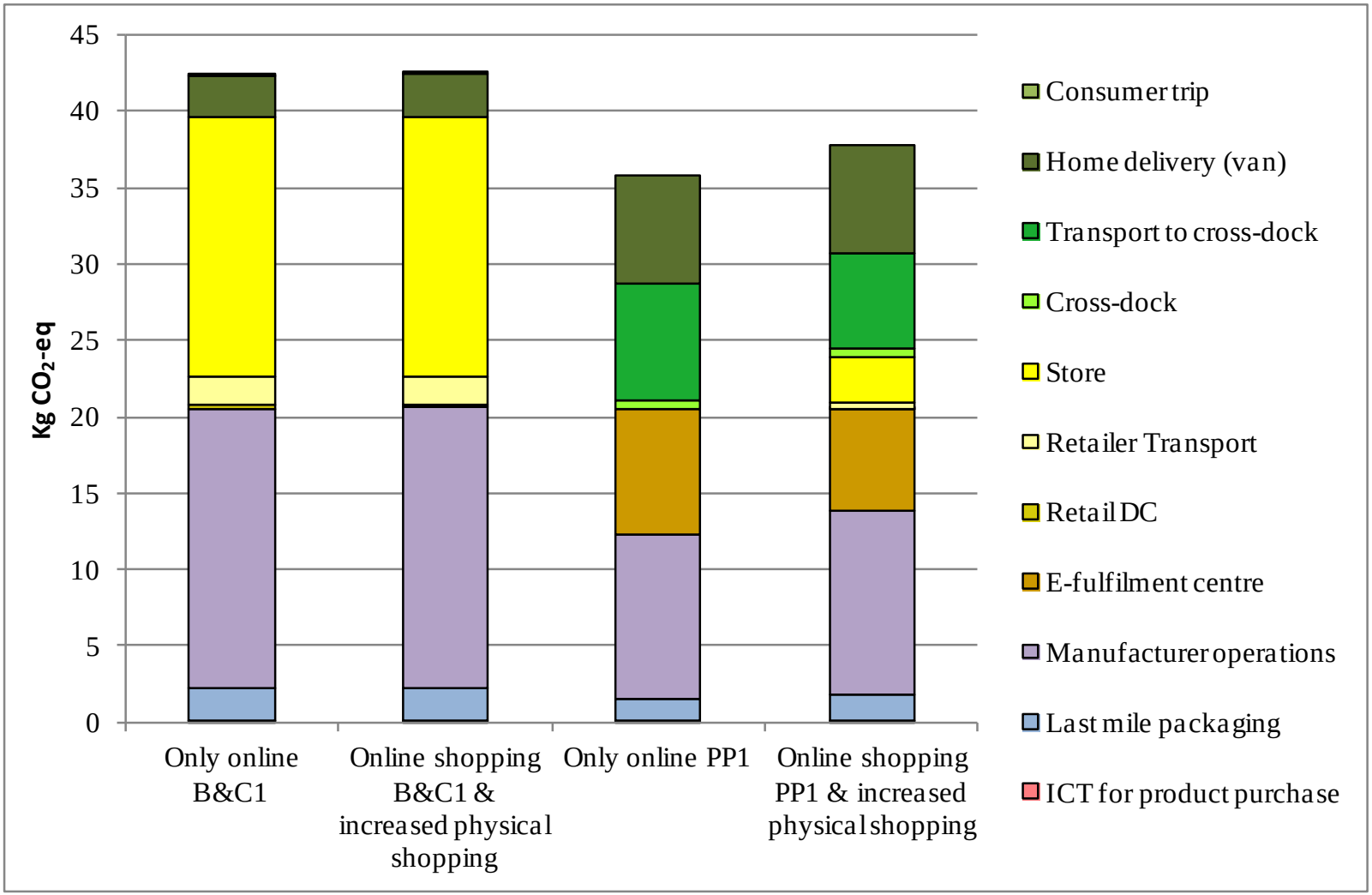


Figure 8.18: Kg CO_2-eq for the acquisition of 220 items, assuming online shopping PP1 and B&C1 and on foot physical shopping

The analysis revealed that the total environmental impact of conventional retailing is significantly influenced by the choice of personal transport mode with the total environmental footprint varying between 180 and 274 g CO_2-eq per item, depending on the mode chosen. When the consumer normally shops on foot, replacing the shopping trip with a van home delivery (B&C1) will result in a negative environmental impact. The energy efficiency of the centralised pure player's (PP1) supply chain exceeds however that of traditional shopping, even if the consumer shops on foot (163 versus 180 g CO_2-eq per item). Depending on the nature of the e-fulfilment operation, either only online shopping (at PP1) or only walking to the store (instead of online shopping at B&C1) result therefore in the lowest footprint.

8.5.2 Basket size

A critical parameter in the LCA model is the number of items in the shopping basket (Browne et al., 2006). The results shown above compared the different retail models based on the average basket sizes typical for each particular model. However, when buying a single product, which is more often the case with high value FMCG products, different levels of greenhouse gas are emitted (figure 8.19).

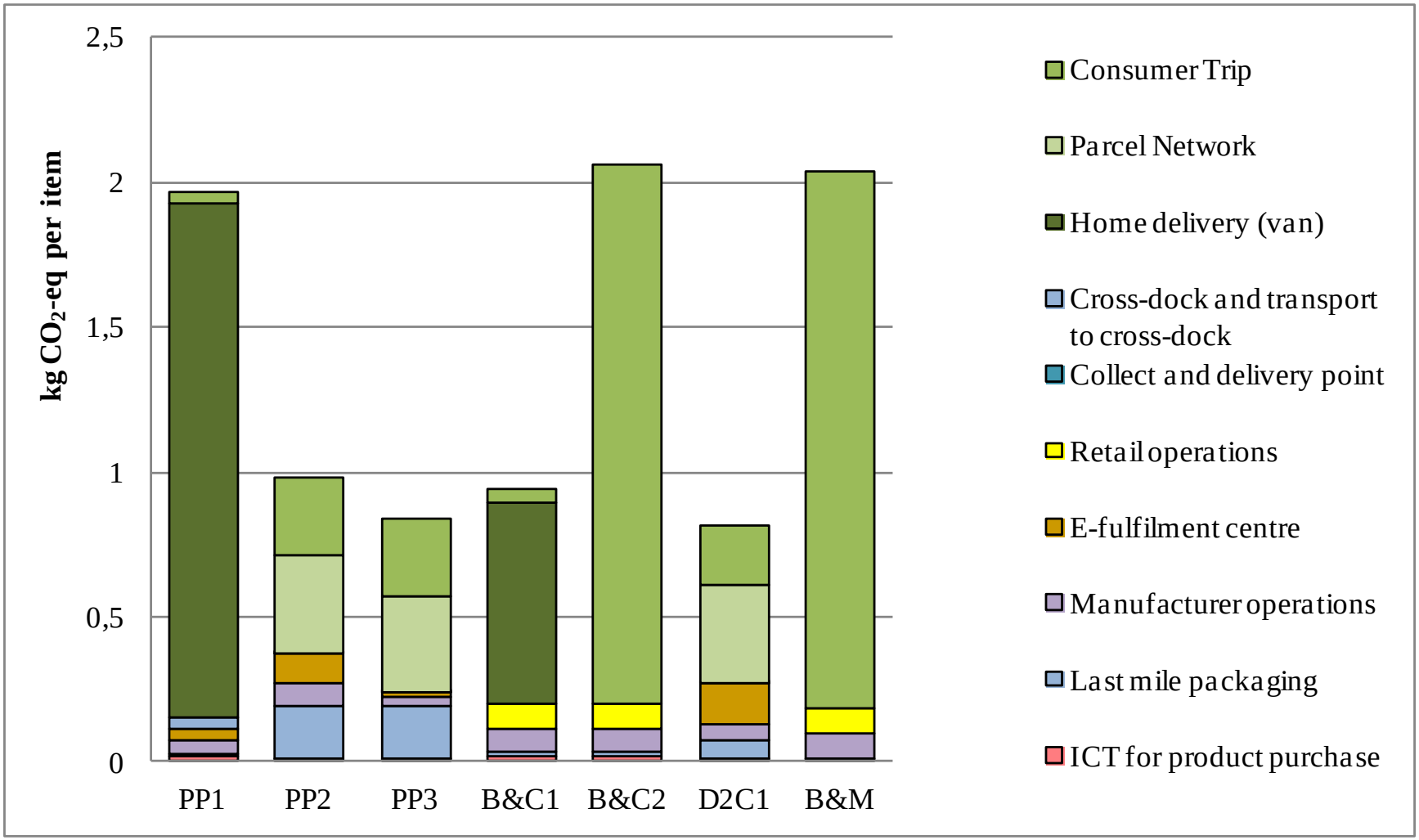


Figure 8.19: CO_2-eq emissions for the acquisition of one single item in different retail models

An average personal trip to the supermarket and a van-based delivery over a long distance (from a centralised warehouse, such as that of Ocado) result in the emissions of around 2 kg CO_2-eq. Retail models where the consumer order is consolidated with other orders / deliveries for a long period of time, e.g. parcel deliveries and deliveries from local stores, seem to be preferred from an environmental standpoint in the situation of ordering one item. The basket size determines the environmental ranking of the various e-fulfilment models. A certain cross-over point exists. The total environmental impact of the different retail models with different basket sizes was calculated and results are summarised in figure 8.20.

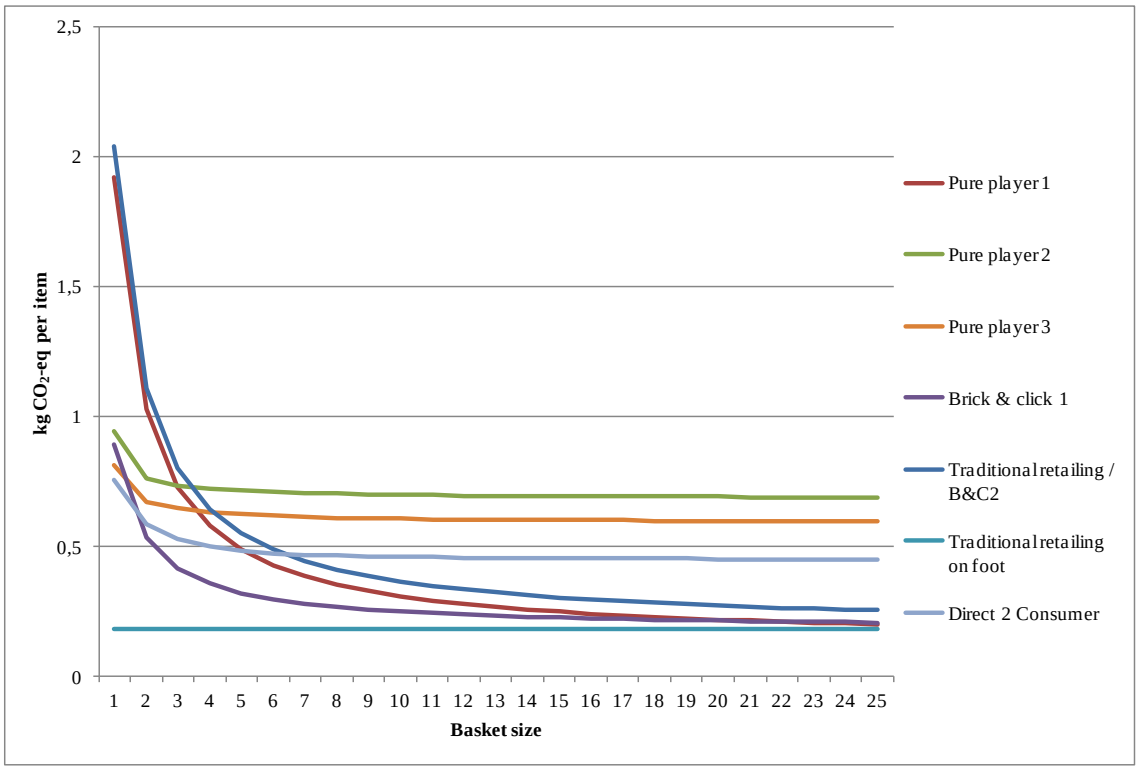


Figure 8.20: Influence of basket size on the environmental impact of retail models

From figure 8.20 it can be concluded that retail models relying on parcel networks are more suited for the delivery of specialised items which are not part of a larger basket. This is because of the greater potential for consolidating these small orders on the last mile delivery to the home. Larger orders are sometimes split into separate consignments to allow some of them to be delivered more rapidly to the consumer. This effectively reduces the average basket size and makes this kind of orders less suited to parcel delivery.

Van-based deliveries from local shops are preferable when ordering a few items. This allows products to be consolidated on the trunk haul from DC to shop and then grouped on the local delivery round to the home. It gives the B&C1 option an environmental

advantage when ordering between 2 and 22 items. Van-based deliveries from centralised e-fulfilment centres (PP1) are preferred for larger shopping baskets (22 items or more). The efficiency of the e-fulfilment centre is then offsetting the additional emissions from the longer last mile distance. However, the difference with conventional shopping is very small in this case.

Under the circumstances assumed here, with an average mix of transport modes and distances to the stores, traditional retailing is not the lowest carbon method for the home distribution of FMCG products for any basket size. However, when the consumer shops on foot, CO_2-eq per item is around 181g, regardless of to the basket size, making this the lowest carbon option up to a basket size of 37 items, at which point PP1 starts to outperform brick & mortar retailing.

Regardless of the retail model, the carbon footprint of the purchase per item varies inversely with the basket size. Therefore maximising the shopping basket size is always beneficial. The largest carbon benefit can be achieved when the right business model is chosen for the maximised shopping basket.

8.5.3 Retailer's operations and e-fulfilment centre

The retailer operations comprise handling activities at the DC and shop as well as connecting transport. The LCA suggest that the retail DC and transport emits only a small amount of CO_2-eq, respectively 0.8 and 8.7 g, accounting together for less than 5% of the total CO_2-eq emissions. The supermarket's utility consumption contributes 77 g CO_2-eq per item, of which the majority comes from the production of electricity.

The e-fulfilment centre for groceries (PP1) is estimated to emit on average 37 g CO_2-eq per item. This difference with the supermarket's emissions was expected due to the higher efficiency and throughput rate that can be reached in e-fulfilment centres, requiring less energy per item (Romm et al., 1999; Kämäräinen, 2003).

8.5.4 Packaging

Packaging can account for a significant proportion of the greenhouse gas emissions. 100 grams of corrugated cardboard plus limited amounts (less than 33g in total) of filling material, results in 0.181 kg CO_2-eq. On the other hand, plastic shopping bags, used in van-based home deliveries and consumer shopping trips, have a relatively limited impact in terms of climate change potential (less than 0.011 kg CO_2-eq). This is because

the amount of packaging is much lower. An average of 9 to 15 bags, weighting 8 grams per bag, are used for a typical order of 30 items (Barrow, 2010; Green, 2008).

8.6 Environmental impact of subscriptions

In this section the environmental impact of fixed and automatic subscriptions will be discussed. Unfortunately, due to a lack of empirical data, it has not been feasible to run an LCA on these subscription services. In the absence of this data many of the 400 parameters in the LCA model, including critical ones like the average basket size, would have had to be 'guestimated', leading to highly uncertain results. However, the LCA results have provided insights that would be relevant to the distribution of FMCG products to the home using subscription services. Therefore, the LCA results have been used to discuss the potential environmental impact of subscriptions, based on the findings of the design of such service (Chapter 5), the consumer requirements and wishes of the subscription services (Chapter 6) and the most likely supply chain impacts of subscriptions (Chapter 7).

8.6.1 Fixed subscriptions

Fixed subscriptions are currently offered by several companies. Most of these companies, with the exception of Amazon, provide only a limited assortment of products such as newspapers, magazines, coffee, wine, vegetables, etc. Consequently, the basket size of these subscriptions services is very small (see table 8.5).

Subscription service	Assortment	Most likely basket size	Delivery method
Amazon Subscribe & Save	Around 30 000 items	1 to 2	Parcel delivery
Vegetable box Abel & Cole (www.abelandcole.co.uk)	Boxes including 6 to 12 different kinds of vegetables / fruit	6-24[33]	Van home delivery directly from farm – sorted on postcode
Wine M&S wine club (www.marksandspencer.com/Wine-Club-Wine-Food-Wine/b/163787031), essentially wine (www.essentiallywine.com), Waitrose wine direct (www.waitrosewine.com)	Selection of different wines, delivered in one case of 12 bottles	12	Parcel delivery
Coffee Coffee Real (www.coffeereal.co.uk), Has Bean Coffee (www.hasbean.co.uk)	Selection of different coffees, delivered per pack	1	Mail delivery

Table 8.5: Basket sizes and delivery method of FMCG fixed subscription services in the United Kingdom

The focus group discussions showed that most consumers would use fixed subscription for a subset of the grocery basket. Most participants would prefer to have the possibility to cancel deliveries and make adjustments to the order for some products within a fixed subscription arrangement. From the suppliers' standpoint, such flexibility would reduce the predictability of the upcoming orders, reducing the possible benefits (of reduced inventory and efficient production planning, see Chapter 5) that could be achieved in the upstream supply chain if subscriptions were truly fixed.

The small basket size and the limited possibilities in the upstream supply chain reduce the chance that fixed subscriptions would lead to a lower carbon footprint than for normal online shopping. Separating a part of the grocery basket and having it home delivered by a parcel company would increase the total footprint. Overall, as can be concluded from figure 8.20, having a large grocery basket delivered in a single van delivery will be more efficient. However, the vegetable box which is delivered directly from the farm to the consumer, thereby bypassing the retailer, has the opportunity to be

[33] The same way is used here as online supermarkets use to count the number of items in the basket, meaning that one kilo of potatoes in a bag is counted as 1 item.

more sustainable than normal (offline or online) shopping (Jones, 2002). An efficient home delivery round in combination with the elimination of conventional retail operations can result in a lower footprint per item delivered than conventional shopping (see figure 8.21).

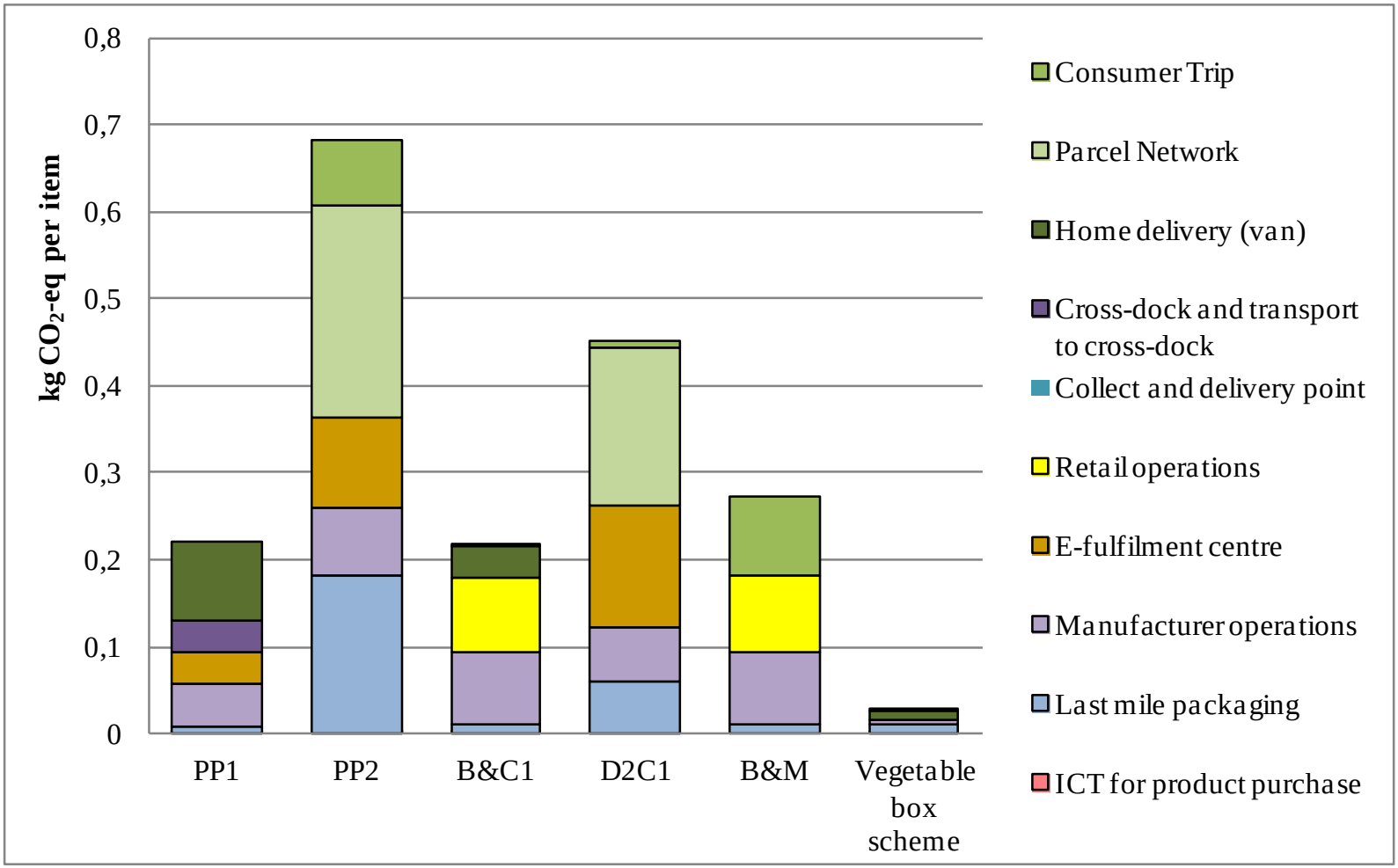


Figure 8.21: Kg CO_2 per item for vegetable box deliveries of 20 items assuming 100% trip substitution (based on data from Tinham, 2011 and Punakivi and Saranen, 2001)

8.6.2 Automatic subscriptions

According to the consumer research, automatic subscription is likely to be used only for the heavy and bulky items and not for the whole grocery basket. It also appears that consumers are willing to accept automatic subscription for a larger part of the grocery basket than fixed subscriptions. The average basket size in an automatic subscription service is therefore likely to be larger than in fixed subscription service but smaller than typical online grocery shopping basket currently ordered by UK consumers. Consumers' concern that automatic and fixed subscription services might burden them with too much inventory, might constrain basket sizes and thus limit the possibility to combine future shipments. Furthermore, a short delivery time window of 1-hour is needed to make the deliveries convenient for the group of time-poor consumers most likely to adopt a subscription service. Providing such a time-definite service would reduce delivery efficiency and hence increase carbon emissions per item. In the medium to long term future the use of reception boxes may make it possible to offer this consumer-friendly service with minimal loss of efficiency.

Except for possible improvements in the efficiency of last mile miles through consolidation in time (e.g. more items in each delivery) and / or space (combined delivery of orders in same neighbourhood, assuming unattended delivery), automatic subscriptions would be unlikely to lead to direct carbon savings across the supply chain. As discussed in Chapter 7, it is unlikely that automatic subscriptions would have much impact on production efficiency and inventory levels mainly because it would not reach the necessary critical mass and because the complexity of the individual household consumption data would make it very difficult to incorporate into upstream supply chain planning processes. Any environmental benefits resulting from automatic subscription, would therefore have to come from the last mile delivery.

If automatic subscription is executed with unattended delivery a substantial saving in delivery emissions can be expected, most likely more than five times greater than next day delivery with one hour time slots (see Chapter 7). If the delivery emissions can be reduced by a factor of five as a consequence of unattended delivery, the total emission will be reduced from 163 to 137 g CO_2-eq for the centralised pure player (PP1) and from 196 to 183 g CO_2-eq for deliveries from the local store (B&C1). This assumes average basket sizes of 55 and 45 items respectively. If five items are assumed, the total emissions will be reduced from 489 to 205 g CO_2-eq for the centralised pure player and

from 322 to 212 g CO_2-eq for the brick & click retailer. From this it becomes clear that a centralised pure player can benefit the most from this subscription service.

8.7 Conclusion

Previous research on the environmental impact of online retailing has regularly omitted important effects of online retailing, for example failed deliveries, returns and trip chaining. The LCA undertaken for this study, which includes these effects, shows that the consumer trip contributes significantly to the total climate change potential especially where the online retailers use a parcel delivery service (18.3% for PP2 and 24.7% for PP3). The relatively high percentage of failed deliveries and returns typically experienced by PP2 and PP3 results in relatively more consumer trips. Besides that, failed deliveries and returns in a parcel delivery system leads to trips to either a carrier depot or a CDP. A trip to the CDP is more efficient, in terms of greenhouse gas emissions, than going to the local store (relatively 0.25 and 1.86 kg CO_2-eq per trip). However, a typical trip to a carrier depot emits on average 3.84 kg CO_2-eq substantially increasing the impact of failed deliveries in the case of this fulfilment model. It should also be recognised that online ordering does not eliminate personal shopping trips. One recent study has even suggested that online grocery shoppers are likely to go even more often to the supermarket than those who do not shop online (Hartman Group, 2013). Obviously this would lead to increased emissions. However, benefits could be achieved if consumers move a part of the grocery shopping basket to a centralised pure player (PP1) while retaining the same number of physical shopping trips as before shopping online. Even larger savings could be reached if online shopping leads to a reduction in physical shopping trips.

Individual consumer behaviour will have an important impact on whether online shopping is more environmentally favourable than physical shopping for that particular person. For example, when a consumer walks to the supermarket, the greenhouse gas emissions of brick & mortar shopping is 25.6% lower than in the average case (see table 8.3). This shows how sensitive the carbon footprint calculation is to the nature of the transport operation between shop and home.

Another crucial factor is the shopping basket size. Maximising the number of items in the delivery decreases the environmental impact per item substantially in most cases. Large online retailers (in categories PP2 and PP3) distribute their products from different supply points and often split large consumer orders into several packages,

thereby losing some of the potential benefits of maximising basket sizes. A better strategy here would be to maximise the utilisation of the space in the packaging of the parcel. Besides that, choosing the right retail model can reduce the environmental impact further. Parcel deliveries are especially efficient for delivering products that are not part of a large shopping basket, while van-based deliveries are more suitable for larger baskets. However, the difference with traditional retailing is small.

To be able to make claims about the most sustainable fulfilment models, the uncertainty in the data and model must be assessed. In the course of assessing the carbon intensity of the different retail models this study has identified the key parameters affecting the level of greenhouse gas emissions from online and conventional retailing. A sensitivity analysis was performed on the key parameters identified in the contribution analysis.

The LCA of online and conventional retail models for FMCG in the United Kingdom has also been used to assess the possible sustainability impact of subscriptions. One particularly relevant issue here is the basket size. The consultations with consumers showed that relatively small basket sizes are more likely in subscription services. This will lead to splitting the grocery basket, which in most cases is likely to have a negative impact on the environment. Nevertheless subscription schemes for fruit and vegetables, which allow the distribution channel for these products to effectively bypass the retailer, have the potential however to reduce significantly the transport distance and utility emissions of the supermarkets. They might therefore yield a net carbon saving.

Automatic subscription also offers the opportunity to improve the efficiency of van-based home deliveries through the consolidation of orders. Especially the centralised pure player can benefit from this due to the longer last mile distances. Consumers would, however, not see automatic subscriptions as suitable for the total FMCG basket. They would need to be supplemented by other shopping trips and / or deliveries. This is currently also the case with normal online shopping. Overall, the effect on physical shopping trips of both normal online shopping and automatic subscriptions is highly uncertain and will require more research on the variability of travel behaviour at the individual consumer level.

CHAPTER 9: CONCLUSION

Online retail sales are growing rapidly and have captured a significant proportion of the retail market in many countries. As discussed in Chapter 2 and 3, little research has so far been done, however, on the environmental impact of this form of e-commerce. This while the public and government put increasing pressure on companies to reduce their environmental impact of their operations (McKinnon, 2012). This research quantified and compared therefore the environmental impact of different e-fulfilment models.

This concluding chapter is divided into four sections. The first section outlines the main findings. The second section reviews the theoretical and practical contributions of the study. The limitations of the research are discussed in the third section, while the fourth and final part considers where research in this field might be extended in future studies.

9.1 Summary and key findings

The main aim of the research was to examine the sustainability of different e-fulfilment models for supplying FMCG products to the home. In line with the research questions defined in Chapter 1, the first part defines the e-fulfilment models and summarises their supply chain implications, focusing on the possible role of subscriptions in selling FCMG products directly to consumers. In the second part of this section the environmental impact of each of these models will be assessed.

9.1.1 E-fulfilment models for FMCG

The existing e-fulfilment models for FMCG in the UK were examined. A classification proposed by de Koster (2003) to distinguish between the different types of e-fulfilment models was followed, differentiating them by 1) the location of order picking and packing, 2) whether or not they involve logistics outsourcing and 3) the nature of the home delivery process. Based on this classification, the retail models shown in table 9.1 were selected for further environmental analysis.

Model	Location order picking	Outsourcing	Home delivery process	Explanation
PP1	E-fulfilment centre	No	Home delivery via cross-docks	Centralised pure player with van delivery
PP2	E-fulfilment centre	Yes	Parcel home delivery	Centralised pure player through parcel delivery network
PP3	Manufacturer DC	Yes	Parcel home delivery	Drop-shipping from supplier through parcel delivery network
B&C1	In-store	No	Home delivery	Van delivery from local shops
B&C2	In-store	No	Collect in store	Click and Collect in local stores
D2C1	Manufacturer DC	Yes	Parcel home delivery	Bypass retailer and use parcel delivery Network
B&M	In-store	No	Collect in store	Conventional retailing in local supermarkets

Table 9.1: E-fulfilment models in the United Kingdom

In the early stages of online grocery retailing in the UK, most providers, with the exception of Tesco, set up e-fulfilment centres to pick orders for home delivery. Most of this first generation of centres were closed down as most retailers moved to a store-based picking model. Tesco has now achieved a sufficient volume of online grocery sales to operate e-fulfilment centre (what it calls 'dot com centres') economically in some areas. Ocado, the only large pure player in the UK online grocery market, has fulfilled orders from dedicated DC from the start and is now expanding its distribution system. In most cases online grocery retailers deliver to the home but some 'multi-channel retailers' now also offer a click & collect option for grocery products. Pure players have only an online presence and deliver from specially built e-fulfilment centre or directly from the manufacturer DC (called 'drop-shipping'). As yet there are few examples of producers bypassing the retailer and selling directly to the end-consumer, though this form of e-fulfilment may expand in the future. All these fulfilment models were included in the environmental analysis.

Previous research has shown that the last mile is the most emission-intensive link in the supply chain (Weber et al., 2008; Edwards and McKinnon, 2009; Gevaers et al., 2009). This is mainly caused by the nature of the transport operation, involving the use of small vans running on local roads, the narrow time windows and short order lead times that consumers now expect. If, however, consumers could be encouraged to make online grocery purchases on a subscription basis, it might be possible to improve the economic and environmental sustainability of home deliveries.

Although several ‘fixed subscription’ companies advertise that consumers would never be out of stock any more with subscriptions, a fixed subscription does not actually eliminate the risk of running out of stock at home. ‘Automatic subscriptions’, on the other hand, monitor the inventory at the home and deliver an appropriate amount satisfying the wish of certain consumers to outsource the replenishment process for grocery products. The consumer research, involving focus group discussions and personal interviews identified a group of households, mainly of time-stressed consumers who feel that they do not have enough free time to go shopping and do not enjoy grocery shopping, that would be prime candidates for automatic subscriptions.

Fixed subscriptions, where products are shipped at regular intervals, allow the possibility to consolidate deliveries in one delivery round due to the wide delivery time windows. Companies can sort the deliveries by postcode and only deliver in a particular neighbourhood on certain days in the week or month (so-called ‘nominated day’ delivery system). The consumers surveyed, however, found the fixed subscription offering unattractive arguing that without the possibility to cancel deliveries and products, they would probably not use it. The upstream production and supply chain benefits would also be very limited.

Automatic subscriptions can also improve the efficiency of delivery operations on the ‘last mile’. The subscription provider, or its carrier, gains the flexibility to deliver anytime, as long as the products are replenished before running out, creating greater opportunities for load consolidation and delivering in off-peak periods. Upstream supply chain benefits, on the other hand, are likely to be minimal for automatic subscriptions, as for fixed subscriptions. The study examined the literature on vendor managed inventory (VMI) in B2B settings and consulted several supply chain experts, most with experience of VMI in action, to see if lessons could be learned about the supply chain effects of B2C automatic subscriptions. The conclusion of this part of the research was fairly negative. The complexity of the individual household consumption data and the need to achieve a high critical mass of households participating in automatic subscriptions, makes it very unlikely that the additional insights gained in the actual pattern of product use would permit significant improvements in upstream production planning. Subscription providers would therefore most likely only benefit of increased sales and improved last mile delivery efficiency. These benefits could, nevertheless, be significant, particularly in the case of deliveries, for the environment.

9.1.2 Environmental performance of FMCG e-fulfilment models

The environmental impact of each of the e-fulfilment models was estimated by means of a Life Cycle Assessment (LCA). This focused on emissions of greenhouse gases (GHG) expressed as CO_2-eq. The findings showed that a substantial proportion of the CO_2-eq emissions is emitted in the last mile, from consumer transport and home deliveries (ranging, on average, from 8.1 to 66.8%), the supermarket (typically responsible for 31.7 to 39.4% in brick & click and conventional retail operations) and transport between factory and manufacturer DC (ranging from 3.9 to 33.7%). Also packaging can contribute significantly if cardboard packaging is used. Each of these parameters were further analysed to examine their impact on the environmental performance of the various retail models.

One crucial parameter that influences the environmental impact of several supply chain stages is the basket size. The number of items in the delivery / purchase influences the emissions per item of the home delivery (van and parcel), consumer transport and ICT. From the results it appeared that the basket size has a direct influence on which retail model is the most environmental-friendly. Small baskets can be better delivered by a parcel company due to their consolidation with other deliveries in the neighbourhood while larger baskets are more suitable for van-based delivery from a centralised warehouse (PP1). With basket sizes larger than 37 items, this latter e-fulfilment model even outperforms in environmental terms traditional shopping on foot due to the greater energy efficiency of the centralised e-fulfilment centre compared to the supermarket. However, to be able to make claims about which retail models are more sustainable (at a particular basket size) an uncertainty assessment is needed. Lack of empirical data resulted in many statistical distributions of the 3000 variables in the LCA having to be subjectively estimated, creating too much uncertainty to permit an accurate ranking of the e-fulfilment models by carbon intensity.

The environmental performance of parcel deliveries could be improved if failed deliveries and returns could be reduced. Failed deliveries and returns lead in many cases to a consumer trip to the carrier depot. With an average distance of 20 km for the consumer to drive to pick-up or return the items, this has a significant impact on the environment. Using collection points (so-called CDPs) for failed deliveries and returns, which are located much closer to the consumer (on average 2.64 km), reduces CO_2-eq

per item by between 125 and 101 g, depending on whether the consumer walks or drives to the CDP, compared to the average situation for retail model PP2.

Another possible source of environmental improvement in parcel deliveries is packaging. The use of cardboard packaging for last mile delivery adds on average 181 g CO_2-eq per delivered item. If parcel companies can move away from cardboard packaging and use reusable crates as in brick & click retailing, it would reduce the level of CO_2-eq by 19-30%.

Online retail models that bypass the e-fulfilment centre can save 137 g CO_2-eq. This environmental benefit of the drop–shipment situation (PP3) is slightly reduced by the increased emissions per item in the last mile, due to the smaller basket size. The direct to consumer retailing (D2C1) model assumed in this study has on average a larger basket size, which reduces the last mile emissions significantly (from 384 and 452 g CO_2-eq for PP2 and PP3 respectively to 208 g CO_2-eq for D2C1), improving the total environmental performance. Direct to consumer online retailing has therefore the lowest GHG footprint out of the three parcel delivery models.

Brick & click retailers experience some disadvantages in delivering from local supermarkets. Professional order pickers may impair the shopping experience of in-store consumers, as most supermarkets are not designed for online order picking. Therefore fewer items are picked per hour while the energy consumption of a supermarket is higher than of an e-fulfilment centre. Moving the fulfilment of online orders to specially built e-fulfilment centres, will reduce the greenhouse gas emissions of orders delivered by the B&C retailer. The opening of drive-throughs located at commuter routes can also potential improve the environmental performance of the brick & click e-fulfilment models. In that case, the performance will however be significantly influenced by the consumer travel behaviour and additional travel should be kept to a minimum.

The LCA assumed that carbon benefits of subscriptions would come solely from last mile delivery consolidation and not from any upstream supply chain efficiency improvements. According to the literature, removing time windows can improve the last mile delivery efficiency by more than five times, especially benefitting a centralised pure player with long last mile delivery distances (PP1).

9.1.3 Environmentally sustainable e-fulfilment models

The strengths, weaknesses and possible environmental improvements of each e-fulfilment models is shown in table 9.2.

E-fulfilment model	Strengths	Weaknesses	Possible improvements
Centralised pure player with van delivery (PP1)	Efficient e-fulfilment centre. Large average basket size. No consumer transport due to failed deliveries and returns.	Long last mile distance.	A further expansion of market share enables opening of more e-fulfilment centres, reducing last mile distances which improves overall environmental impact[34].
Centralised pure player with parcel delivery (PP2)	Consolidation with neighbourhood deliveries, which makes this retail model more efficient for small basket sizes compared to van-based deliveries.	The percentage of failed deliveries and returns, which lead to consumer trips. Separation of larger shopping baskets. Last mile cardboard packaging.	Give the choice to the consumer to have the package delivered directly to a CDP, without any home delivery attempt (reduces failed deliveries). Increase basket sizes; delivery fee based on number of parcels. Reduce last mile cardboard packaging.
Drop-shipping from supplier with parcel delivery (PP3)	Elimination of e-fulfilment centre and transport to the e-fulfilment centre (compared to PP2).	Same disadvantages as PP2. Further an even smaller basket size.	Increase basket size; incentive to order more products in delivery fee or with offers as buy 2 for the price of 1. Reduce last mile packaging and choice to have package delivered directly to CDP.
Van delivery from local shops (B&C1)	Short last mile distance, long consolidation of products with store deliveries. Low return and failed delivery percentage.	Electricity usage in supermarket is high (compared to e-fulfilment centre).	Opening of drive-throughs on commuter routes, with a low incremental distance for the consumer.
Click & Collect in local stores (B&C2)	Pick-up can be combined with shopping trip to the store, reducing last mile impacts.	Same as B&C1. Further the consumer trip to the store is likely to emit more than home deliveries (assuming online shopping substitutes physical shopping).	Reduce the impacts of consumer transport as much as possible; advice to combine trips or to take more sustainable transport modes.
Bypassing retailer with	Elimination of e-fulfilment centre / retailer DC	Small average basket size compared to	Same opportunities as centralised pure player with

[34] Distance from manufacturer to e-fulfilment centre would however increase.

parcel delivery (D2C1)	and shop and transport to it. In combination with consolidation in parcel network makes this the most efficient e-fulfilment model for very small basket sizes.	van-based delivery models.	parcel delivery (PP2) and drop-shipping model (PP3).
Subscriptions	Possibility to control last mile to larger extent, reducing consumer freedom in delivery date without reducing customer service.	Small basket sizes are likely.	Subscription offered in a pure player with own van delivery (PP1) lead most likely to largest environmental benefits, assuming larger basket are possible. Separation of basket in subscription delivery and online delivery or physical shopping trips lead to increased last mile distance and should be avoided in most cases.

Table 9.2: Environmental strengths, weaknesses and possible improvements of e-fulfilment models for FMCG products.

In summary, each e-fulfilment model has its own particular strengths and weaknesses and their relative environmental sustainability largely depends on the size of the shopping basket. In the end it is the consumer who decides on the basket size. From a consumer point of view, maximising the shopping basket and reducing the trip / delivery frequency result in the largest carbon footprint reduction.

9.2 Contribution of the research

The thesis has made both theoretical and practical contributions to research on the development of e-fulfilment models that are sustainable in environmental terms. It has done this by examining the opportunities for using subscriptions to improve the sustainability of the online retailing of FMCG products, a topic that had previously received very little attention from academic researchers. The study has also included the first LCA of a range of e-fulfilment models, requiring the environmental calibration of a new set of business activities.

9.2.1 Contributions on subscription services

Although subscription is not a new concept and subscription services are quickly emerging in the online retail market, research about the effect of subscriptions on the supply chain is still very limited. This research classified subscription services into three categories (flexible, fixed and automatic), examined their supply chain implications and considered their possible effects on the environmental performance of online retailing.

Due to the novelty of this research topic, knowledge from other areas was utilised to assess the effects of subscriptions on the supply chain and the environment. Findings from the VMI literature were extrapolated to the automatic subscription where consumers would outsource their household inventory management to the subscription provider. Based on this, possible benefits of automatic subscriptions were identified; improved customer service, increased sales and last mile consolidation due to flexible delivery times.

The research also gained a consumer perspective on the relative attractiveness of subscriptions to those shopping for FMCG products online. This involved focus group discussions and personal interviews in the UK and Belgium. It reviewed what consumers see as the potential advantages and disadvantages of this form of subscription and determined the characteristics of the market segment most likely to use online FMCG subscriptions in the future.

9.2.2 Contributions on the environmental assessment of online retailing

The comprehensive literature review identified key variables that influence the environmental impact of online retailing (see table 3.2). These key variables were mapped into a framework that can guide future researchers and practitioners conducting LCAs on online retailing (see figure 8.1). This framework includes important variables that, although generally omitted in previous research, can significantly influence the environmental outcome. For example consumer trips due to failed deliveries and returns or complementary trips to a shop for top-up purchases can significantly influence the environmental sustainability of online shopping, but have not been adequately addressed in previous environmental assessments. The study also confirmed that the number of items in a basket / order is a key determinant for the sustainability of an e-fulfilment model.

The LCA framework was then used to calculate the environmental impact of different retail models for FMCG in the United Kingdom. Based on the contribution analysis and an estimation of the range of parameter values, key parameters were selected for further assessment with a sensitivity analysis. An excel tool was made which made it possible to vary each key parameter and to analyse the results for the different retail models simultaneously. Practitioners can use this tool for a quick assessment of the different retail models and to get an understanding of the underlying factors in the environmental sustainability of each fulfilment model.

This is the first research to examine the environmental impact of different e-fulfilment models (both pure player and brick & click models) at the same time. Even though no definitive conclusions can be drawn about the ranking of e-fulfilment models in environmental terms, the impact of key parameters on the different retail models can now be evaluated simultaneously. This led to the identification of the strengths, weaknesses and possible environmental improvements of each e-fulfilment model (see table 9.2).

9.3 Limitations of research

The aim of this research was to try to determine a sustainable design for the e-fulfilment of FMCG products to the home. Even though strengths and weaknesses of the main e-fulfilment models are identified and conclusions are drawn about the suitability of the e-fulfilment models in specific circumstances, it was unfortunately not possible to make claims about which model was the most sustainable. In order to state whether a retail

model is better than another an uncertainty analysis is needed. A full uncertainty analysis requires the specification of the uncertainty of each entry point. Each retail model is specified by more than 400 parameters which would require the profiling of almost 3000 statistical distributions to determine the degree of environmental variability for the e-fulfilment models. Collecting the necessary empirical data on each of these parameters to conduct this analysis would require a substantial amount of resources and time. It was therefore not possible to conduct an uncertainty analysis as part of this research project.

A second limitation of the research is the scope of the environmental assessment. The environmental impact of the retail models is calculated for the UK, based on the fact the online shopping is within Europe most developed in the UK and other countries will most likely follow. However, this does not mean that the environmental findings for the UK are also applicable for other counties. The different characteristics of online retailing in other countries could lead to different results. For example, in the Netherlands 23% of consumers cycle to shops and 21% walk (Schwanen et al., 2004), much higher proportions than in the UK. Here the environmental impacts of conventional shopping will be much smaller and the relative environmental benefit of using a centralised pure player (PP1) will be smaller (assuming all other things equal in the UK scenario). This, as well as other differences between the countries, must be evaluated carefully before generalisations about online shopping elsewhere can be made.

9.4 Future research directions

During the research on subscriptions, several interesting research questions and ideas emerged which were unfortunately out of scope in this dissertation.

The environmental assessment could be used to develop an app to guide the consumer in assessing the sustainability choices for online shopping. Based on inputs from the consumer on distance, trip-chaining, transport mode etc, the environmental impact of both online shopping and physical shopping could be calculated. At the moment such project would be limited to a few scenarios based on user profiles but it could be extended in the future to include a wide range of consumer behaviours. In that way guidance can be given that reflects individual consumer behaviour and is easy to use.

An experiment could be set-up[35] by a FMCG manufacturer to test the subscription model developed in this thesis in the real world. Selected consumers would be able to subscribe to products in either fixed or automatic subscriptions for a couple of months to identify the supply chain impact and consumer behaviour in the subscription setting, and to investigate the suitability of subscriptions for the mass-market. The experiment could draw upon the findings in this thesis. For example, in the case of automatic subscriptions participants could be supplied with a handheld barcode-scanner, which they could use to capture their consumption data. After the first supply, consumers would scan the package each time they opened a new one. The consumption would be monitored by the subscription provider and household inventories maintained at an agreed level. By observing changes in consumer behaviour, the result impact on the sustainability of this e-fulfilment option could be monitored.

Several other subjects researched in this thesis also require further investigation.

1. Determining the critical mass within VMI and B2C automatic subscriptions. The literature review on VMI showed that while the theory suggests large savings on inventory and production efficiency, empirical work disagrees with this finding. It seems that the disagreement is caused by a need to achieve critical mass before the data gathered in VMI can be used to synchronise production and inventory with demand. Further research is needed to prove the existence of critical mass and to see what lessons can be learned for the application of the VMI principle in online B2C fulfilment.

2. A related issue is the possible improvement of inventory management at a household level. The current stockpiling behaviour during promotions and regular stock-outs suggest that the inventory management performed by consumers is not optimal for the upstream supply chain. Several researchers have argued that the bullwhip effect can be reduced if the consumer is included in supply chain collaboration practices. To examine the efficiency of the 'inventory management' performed by the consumer and to analyse if the subscription provider can improve this, a large database containing the purchases and inventory levels of several products at household level is needed. This would permit an analysis of whether individual point-of-sale data becomes more stable due to subscriptions and if this can lead to any improvements in distribution efficiency for the subscription provider.

[35] The original plan was to use the findings of this experiment in the thesis. However, due to start-up problems with this experiment, the project got delayed and is now following from rather than being part of the thesis.

3. More research is required on the effect of subscriptions on sales. Offering subscriptions does not only introduce an additional service to the consumers which does not yet existed on large scale, it also establishes a long-term relationship between the consumer and the subscription provider. This relationship can prevent the consumer from switching to other brands. Increased sales might be the largest benefit for the subscription provider. The exact relationship between the different types of subscriptions and sales needs to be further researched. For example, it is currently unclear if consumers would still shop for products during promotions while having an automatic subscription for this type of product.

4. During the environmental assessment of the e-fulfilment models some questions arose which could unfortunately not been answered as part of this research. The main question is the effect of online shopping on the travel behaviour of consumers. This effect is difficult to estimate as it varies from person to person (Edwards et al., 2011; Rizet et al., 2010; Hesse, 2002). The previous studies performed in this area did find different results, varying from a reduction to even an increase in supplementary shopping trips for top-up purchases due to online shopping. More research is needed in this area to permit a wider assessment of the environmental impact of the changes in travel behaviour resulting from online shopping.

APPENDIX A: STUDIES ON ENVIRONMENTAL IMPACT OF ONLINE RETAILING

	Study	Product type & Geo-graphical area	Method	Included within system boundaries	Objective/ dependent variable	Assumptions	Outcome
High value / large items	Caudill et al. (2000)	Computers USA	LCA study comparative	Second order effects: production including space, waste reduction and over-production, warehouse and retail space, transportation, secondary packaging and materials such as office paper.	Energy and CO_2-eq emissions	1) Direct shipment from manufacturer to consumer is assumed for the e-commerce scenario, bypassing at least one stage of bulk shipment. 2) Consumer trip to the shop is by car with a dedicated distance of 11.2 miles. 3) In e-commerce scenario combination of air and truck transport is used, while the traditional system only includes truck transport.	Air transport in e-commerce results in a negative impact on the environment. If no air-transport is used, a very small environmental benefit is reached (1% energy saving). When e-commerce is utilised to reduce overproduction, inventory and end-of-life waste, an energy saving of 11% can be reached (when no air transport is used).
	Reijnders and Hoogeveen (2001)	Computers Netherlands	No clear method mentioned. Estimation of energy requiremen	Second order effects limited to the transport to the consumers and consumer trips and a third order effect	Energy implications of e-commerce at the micro level, including increased buying	1) Average consumer roundtrip of 10 km. 2) Direct shipment from wholesaler to consumer, bypassing the retailer in the e-commerce scenario. 3) 10% lower prices online leading to	E-commerce results in lower energy per item sold. However, including the rebound effect of lower prices (i.e. increased buying power) has the opposite effect and gives lower results for traditional retailing.

			ts.	(rebound effect) of lower prices online.	power of the consumer due to e-commerce.	increased buying power of Dfl. 200-400 per purchased PC.	
	Gay et al. (2005)	Computers USA	EIO-LCA study comparative and simulation with excel tool	Second-order effects: computer manufacturing, warehousing, distribution, transportation, and storage in retail stores.	Critical EPA pollutants: carbon monoxide, nitrogen dioxide, hydrocarbons, and carbon dioxide.	1) Direct shipment from manufacturer to consumer is assumed for the e-commerce scenario, bypassing the central warehouse and retail store. 2) Four different percentages of air shipment in the e-commerce model: 10%, 25%, 50% and 75%. 3) Consumer travels 11.28 miles roundtrip to buy a computer.	E-commerce produces lower levels of CO_2 than traditional channel when air transport is limited (below 50%). When air transport accounts for 75%, nitrogen dioxide and CO_2 are higher than in traditional retailing. 60% less energy needed in e-commerce scenario due to lower inventory levels. Consumer travel is responsible for 38% of hydrocarbons and 22% of CO_2 emissions.
Medium value / small packages	Weber et al. (2008; 2011)	Flash drive USA	LCA study comparative with Monte Carlo uncertainty analysis	First and second order effects: transportation, packaging, energy use in retail store and in data centre and at the consumer house used for ordering online. Also included is part of the	Energy and CO_2 emissions	1) E-commerce scenario ships product from distributor warehouse to the consumer with a parcel service that can be either truck or airplane. 2) In all scenarios only cardboard packaging is included 3) Consumer transport is assumed to be with a car (14 miles round distance). 4) Placing an online order takes 15-30 minutes (Weber et al., 2008) and 11-20 minutes in Weber et al. (2009).	Consumer transport in traditional retailing is responsible for 65% of the CO_2 emission. Therefore e-commerce shows a lower footprint even though the packaging material and ICT impacts are higher. Wholesale warehousing emits 31% of the CO_2 emission in the e-commerce scenario. 20% probability that traditional retailing lead to lower CO_2 emission than e-commerce when e-commerce shipments are by truck, 50% when shipment is made by airplane.

Weber et al. (2009)			production energy of the home computer.			Likely that e-commerce is favourable. Digital delivery performs better than physical distribution. Transport is a major contributor, accounting between 25% (last mile delivery in e-commerce scenario) and 52% (consumer transport to the retail store) of the total CO_2 emissions.
Sivaraman et al. (2007)	DVD rental United States	LCA study comparative	First and second order effects: production of DVD and packaging, transport from factory to the consumer, the energy usage in the buildings, placing an order online, and playing the DVD	Energy, CO_2, carbon monoxide, oxides of nitrogen, sulphur dioxide, hydrocarbons, lead and particulates.	1) Consumers drive a roundtrip of 8 km to the store. 2) Placing an online order involves the use of a PC, lights and space heating / air conditioning. A burden factor is used to allocate the impacts of production and disposal of the PC to the single order. Consumers spend 7 minutes online to order the first and 5 minutes for next movie. 3) The DVDs are delivered by first-class mail.	E-commerce is comparatively better than traditional network (except for particular matter). 67% of this difference is due to the different packaging in the e-commerce scenario (a paper sleeve instead of a plastic case). Also the transportation results in lower emissions in the e-commerce scenario than transport in the traditional scenario.
Velasquez (2009)	DVD rental Canada	EIO-LCA study comparative	First and second order effects: placing online order, transportation, real	Energy and CO_2 emissions	1) Consumers drive 2 times (to pick-up and to return the movie) to the store with their car in the traditional scenario with a roundtrip distance of 8 km. 2) Movies are delivered and picked up	E-commerce results in significant lower energy consumption and CO_2 emissions.

			estate and packaging.		by the postman who walks between the consumer's house and the post office. 3) 3 movies are hired per visit/order. 4) Placing an online order takes 30 minutes. 5) Packaging in traditional method includes a plastic case, in e-commerce scenario a plastic envelope.	
Matthews and Hendrickson (2001) and Matthews et al. (2001a)	Books USA	No clear method mentioned. Environmental calculations and sensitivity analysis.	Second order effects: production, packaging, transport and fuel production.	Energy, greenhouse gas emissions, hazardous waste and emissions of conventional air pollutants.	1) In the traditional scenario 35% of the books are unsold and returned, in the e-commerce scenario 0%. 2) The consumer makes a roundtrip of 16 km to the store of which half can be allocated to the purchase of 1 book. 3) The e-commerce scenario makes use of a parcel delivery which includes air transport.	Depending on the returns percentage, online retailing is comparable or superior to traditional retailing, except for greenhouse gas emissions which might be higher in the e-commerce scenario (compared to the traditional retail network without returns) due to the air transport and packaging.
Matthews et al. (2001b)		EIO-LCA with sensitivity analysis				Assuming 35% returns in traditional retail, e-commerce is favourable for all environmental impacts studied. The elimination of passenger trips offset the increased impacts of air transport used in e-commerce. However, the results are sensitive to the input values: when increasing the air freight distance from 500

						miles to 750 miles or the distance to the stores drop to 2.5 miles, traditional retail become more favourable than e-commerce for greenhouse gas emissions.
Matthews et al. (2002)	Books USA & Japan	EIO-LCA (USA) and traditional LCA (Japan)	Including second order effects: distribution, packaging, personal transport. In the USA study book production is also included.	Energy	1) The USA study includes the implications of switching between truck, rail and air transport and uses same assumption as in the studies Matthews et al (2001a;b). The Japan study focuses on population density, mode of consumer transport and residential energy consumption. 2) Three different areas are used in the Japan study, with a consumer roundtrip distance of 1, 5.2 and 13.4 km. 3) Within the Japan e-commerce scenario the books are shipped from the distribution centres to the e-commerce firm from where it is send with a courier to the consumers.	Whether e-commerce of traditional retailing is the most energy efficient depends on the conditions of implementation and a certain crossover point exists. If no air transport is used and consumer car travel is substituted with courier home delivery e-commerce is more efficient. In Japan the more densely population and the shorter distances together with the lower reliance on cars result in a much lower energy requirement per book than in the USA.
Reichling and Otto (2002)	Books Germany	Screened LCA	First and second order effects: including electricity for placing online	Primary energy	1) Consumers go to the bookstore either by car or public bus and travel for multiple purposes (20% of energy allocated to purchase).	Personal car transport accounts for 88% of the total energy consumption in the traditional supply chain. Both the car travel as public transport travel lead to a higher energy

			order and transport		2) To place an order online, consumer would need 30 minutes. 3) E-commerce scenario assumes delivery via two freight mailing centres and a delivery base.	requirement than e-commerce. However, when the consumer takes the bike or walks, conventional retailing might be environmentally superior. Personal computer operations were responsible for 59% of the total energy consumption in the e-commerce scenario.
Williams (2002)	Books Japan	Estimation of energy use.	First and second order effects: transport, building consumption, packaging, and energy use in house including the use and share of the life cycle energy of computers and direct effects of lighting, heating and cooling.	Energy	1) No air transport used. 2) 1.5 trips per courier delivery is assumed. 3) Returns are not included. 4) Consumer shop 15 minutes online per book and 5 minutes per subsequent book.	In urban areas the additional e-commerce packaging and courier fuel use lead to higher energy in the e-commerce system than in traditional retailing. In suburban areas the score is even, while in rural areas e-commerce lead again to higher energy requirements than traditional retailing due to the courier fuel use. Energy in bookstores is very similar to energy in consumers' homes when placing online orders.
Williams and Tagami (2003)	Books Japan	LCA	First and Second order effects: transport, packaging, energy	Energy	1) Online order includes 1.7 books, in-store consumer buy on average 1 book. 2) Consumer transport by car, train and bus is included.	Online retailing lead in all situations (urban, suburban and rural) to higher energy per book than traditional retailing, although only the difference in urban areas is significant. This

			use in the retail store and in house including lighting, heating and cooling and the use and share of the production of a PC.		3) Different areas are included, resulting in a distance to the book store of 0.5, 2.6, and 7.7 km. 4) No air transport is used. 5) Within the e-commerce scenario the books are shipped from the distribution centres to the e-commerce firm from where it is send with a courier to the consumers. 6) 1.5 trips per courier delivery is assumed. 7) Returns and additional spending not included.	is due to the high percentage of public transport in urban areas.
Kim et al. (2008)	Books USA	Standard vehicle routing algorithm	Only direct transportation impacts	Energy, CO_2, Hydrocarbons, Carbon Monoxide, Nitrogen Oxides, and particular matter.	1) Consumers live in a metropolitan area in the U.S. and travel with car to the store. 2) Returns are not included. 3) Sales via central online retailer is assumed for the e-commerce scenario. 4) A pick-up point in convenience stores is used for the sustainable networked delivery scenario, in this case the travel to the convenience store is allocated 100% to the groceries and	The online scenario with pick up points (sustainable network distribution) generate 47 times less energy than traditional retailing, and 7 times less than online retailing with home delivery. Traditional retailing lead to higher emissions for all type of air emissions considered than the other two online retail situations.

					0% to the book pick up.	
Edwards et al. (2009b)	Non-food items United Kingdom	Excel spreadsheet carbon audit model	Only transport related to failed deliveries is included.	CO_2 emissions	1) Home delivery is assumed to include 120 drops in 50 miles distance. 2) Second attempt (after failed delivery) has a failure rate of 50%. 3) After two failed deliveries consumers travel to the local depot, the majority of the cases with car. When a bus is used, an average of 9.2 passengers is assumed.	In the worst case, when consumers have to drive 40km for picking up the missed delivery, 8300 g CO_2 is emitted which is the equivalent of 26 re-deliveries attempts by a delivery van. This can be massively reduced when van deliveries round are extended with a trip to a CDP to deposit first time failed deliveries.
Edwards et al. (2010a)			Transport between consumer and point of returning unwanted goods, or in case of CDP also the transport between CDP and parcel carrier local depot.		1) Home delivery is assumed to include 120 drops in 50 miles distance. 2) Distance to local shop is 6.4 miles for car travel and 4.4 miles for bus travel in the UK, one-way trip. 3) Roundtrip to local post office is 1.5 miles in the UK. 4) Only 50% of the consumer trip is included due to trip-chaining.	Returning unwanted goods with van-based parcel carriers lead to the lowest emissions, followed by return to the local post office. However, this conclusion is based on 50% trip-chaining. Combining return trips with more other activities greatly reduces the marginal CO_2 impacts.
Edwards and McKinnon (2009)			Only transport, van-based delivery and consumer transport.		1) Home delivery is assumed to include 120 drops in 50 miles distance. 2) Distance to local shop is 6.4 miles for car travel and 4.4 miles for bus	A standard shopping trip (two-ways) by car emits between 12 and 31 times more CO_2 than an average home delivery drop, depending on the type of car used. A

			travel in the UK, one-way trip. 3) 1 item is bought. 4) 0%, 10%, 30% and 50% failed deliveries assumed and in 50% of the cases the consumer travels 15, 25 or 40km to the local depot to collect the item 5) No trip-chaining and 50% trip chaining assumed. 6) No returns in first scenarios, then scenarios with 100% returns via carrier collection, shops or depot.	shopping trip by bus emits on average 7 times more than the home delivery. Both based on 0% failed deliveries and returns and no trip-chaining or browsing trips. However, when failed deliveries, returns, trip-chaining and browsing trips are included the results show no absolute environmental advantage for either online shopping or conventional shopping.
Edwards et al. (2010b)			1) Three failed deliveries rates included, 25%, 12% and 2%. 2) Consumer roundtrip travel is 12.8 miles for car travel and 8.8 miles for bus travel for non-food purchases. 3) No other transport modes for consumer travel is included. 4) Home delivery round consist out of 120 drops over 50 miles.	Conventional retailing, where a consumer purchase 1 item, emits 24 times more CO_2 than home delivery of the item, assuming no failed deliveries. Consumers who travel with the bus emits 7 times more CO_2 than e-commerce.
Edwards et al. (2009a)			1) Three failed deliveries rates included, 25%, 12% and 2%. 2) Consumer roundtrip travel is 10.4	Generally, home delivery emits less CO_2 per item delivered than conventional shopping by car. However, in certain situations

					miles for car travel and 8 miles for bus travel for non-food purchases. 3) No other transport modes for consumer travel is included. 4) Home delivery round consist out of 120 drops over 50 miles on average, but in urban areas 110 drops over 25 miles are more likely while in rural areas 70 drops over 80 miles is used. For groceries other values are used.	conventional retailing is favourable, for example a shopper who buys several items and travels by bus in peak times.
Liyi and Chun (2011)	Garment China	Mathematic model	Only transport, van-based delivery and consumer transport.	Energy and CO_2 emissions	1) No failed deliveries or returns. 2) Only consumer transport by car is considered, consumers travel 1.6 km to the store. 3) 2.5 items are bought in one purchase.	E-commerce worse (2.5 MJ & 0.39kg CO_2 compared to 0.04MJ and 0.08kg CO_2 for the traditional model)
Collins & Aumonier (2002)	Men's cotton briefs and polyester trouser United Kingdom	Streamlined LCA	First and second order effects: transport, energy in the retail store, packaging and ICT impacts.	Energy	1) Consumer spend 10 minutes on a PC per product ordered, and 1 minute PC time is needed for the company to process the order. 2) Additional packaging (2 bags for a pair of trousers) is required in e-commerce scenario. 3) A consumer trip of 7 miles to the store is assumed.	E-commerce leads to 1.56 kWh energy savings per pair of trousers, mainly due to savings in high street stores and consumer transport which are partly off-set by additional packaging and last mile transport.

Groceries / FMCG	Rizet et al. (2010a; 2010b; 2012)	Yoghurt France	Survey method assessing the energy used from producer to consumer, including a websurvey for consumer trip	Second order effects: production, transport and buildings energy usage.	greenhouse gas emissions = global warming potential = CO_2-eq.	1) Decoupling point e-commerce is retailer distribution centre, from here the products are transported to an e-fulfilment centre and then transported to the consumer via another distribution centre. 2) Yoghurt is transported in refrigerated vehicles. 3) Home delivery round is 40 km for 13.5 deliveries, each delivery contains 35 kg of items (Rizet et al., 2010a). 4) Consumers buy the yoghurt in a hypermarket, supermarket or local shop. 75% of the consumers drive their car (14km) to the hypermarket to buy 30kg. 50% of the consumers drive 9km to the supermarket to buy 15kg, and 7% drive 3km to buy 5 kg in a local shop (Rizet et al., 2010a). 5) Consumers get the yoghurt home delivered (95%) or it is delivered to a service point where the consumer picks it up (5%)	E-commerce seems to be more efficient for greenhouse gases. The online fulfilment centre is more efficient than shops and the last mile delivery is more efficient than consumers.

	Siikavirta et al. (2003)	Groceries Finland	Case study: simulation with routing software based on 1639 orders.	Only transport is included.	CO_2, CH_4, N_2O	1) The routing is limited by the time-windows, vehicle characteristics (maximum 3000 litre per route, and 5 hours of working time per route) and maximum of 60 orders per route. 2) Consumers drive 6.9 km by car for a grocery shopping roundtrip, although in reality only 55% of the shopping trips are made by car in Finland.	Home delivery more environmental friendly than physical consumer shopping trips. 1-hour time-windows lead to a total distance of only 46% of the distance that would have been driven by consumer shopping in the supermarket. In the most attainable situation, where orders are sorted by postal code, a 93% reduction in distance driven can be reached. In terms of greenhouse gas emissions this means a reduction from 18% to 87% compared to traditional shopping. However, in terms of total GHG emissions in Finland online grocery shopping lead (theoretically) to a maximum reduction of 0.3 to 1.3%.

Table A.1: Overview of environmental studies on online retailing of physical products.

APPENDIX B: STUDIES ON CONSUMER TRAVEL BEHAVIOUR AND ONLINE SHOPPING

Study	Method	Geographical area	Product category	Outcome
Ferrell (2004)	Aggregated activity diary records	San Francisco	Shopping in general	Modification effect: Online shopping is positively related with physical shopping trips. However, the consumer shopping distance did not significantly increase, implying that online shoppers make more frequent but more combined trips than non-online shoppers.
Farag (2006)	Aggregated travel data	Netherlands	Shopping in general	Complementary effect: shopping trip frequency increases if people buy frequently online.
Ferrell (2005)	Individual travel behaviour	San Francisco	Shopping in general	Substitution effects: online shoppers make fewer physical shopping trips and travel shorter distances.
Dixon and Marston (2002)	Survey	UK	Shopping in general	About two thirds of the respondents saved at least some purchase in a town centre due to online shopping. However, they did not ask it online shopping also saved any trips.
Krizek et al. (2005)	Survey	USA	Shopping in general	Substitution effect: 80% of respondents stated that they would have gone to the store if they would not have been able to purchase the product online. However, they also found that the majority were not willing to eliminate the complete physical shopping trips for online shopping.
Cao et al. (2010)	Survey	USA	Shopping in general	29% of the respondents said that the online purchase would substitute a physical shopping trip.
Weltevreden (2007)	Survey	Netherlands	Different products including jewellery, PCs, books, shoes, and	The majority of frequent online shoppers (83 to 98%) did not change the trip frequency to the stores due to online shopping. He found that most substituted trips were for the product category CDs and DVDs with 11% of the respondents stating that they go less often to the shop

			household products	due to online shopping. However, it is also in this product category where the highest percentage of frequent online shoppers is reached that state to travel more to the shops due to searching information online (6%).
Keyzers and Wagenaar (1989)	Survey, 6-day travel diary	Netherlands	Groceries	Substitution effect: Online shoppers[36] go less to the shop than the average in the country (respectively 0.36 and 0.88 shops per person per day).
Forrester (2001 cited by Foley et al., 2003)	Survey	USA	Groceries	Slight substitution of shopping trips: online grocery buyers make 10.4 physical trips per month while non online shoppers make 13.9 trips.
Farag (2006)	Survey, 2-day travel diary	Netherlands	Groceries	Frequent online shoppers make more physical shopping trips. Also the other way around is found, people who buy frequently in store also buy more frequent online. She conclude that it is difficult to determine the direction of causality due to a lack of data about shopping frequency before starting to shop online.
Hartman group (2013)	Survey	USA	Groceries	Online grocery purchasers will not visit the physical store less often. They found that 56% have not changed the number of physical trips since they shop online, 32% make fewer trips, and 13% make more trips. On average, the online shoppers bought 4 times a month online and 10 times a month at a store, while non-online shoppers visit the store only 8 times
Hand et al. (2009)	Focus groups discussions	UK	Groceries	Online grocery shopping is often complementary rather than substituting shopping trips. The participants argued that they could more easily browse for new items and promotions in the store than online and therefore prefer the two next to each other.

[36] This includes orders placed by a PC, telephone or post followed by a home delivery of the groceries.

APPENDIX C: LITERATURE REVIEW PROTOCOL

This appendix describes the literature review protocol, including the goal and scope of the literature review, the scoping study, the inclusion and exclusion criteria and the search strategy with the keywords.

C.1 Goal and scope

Goal: investigate supply chain options available to manufacturers wishing to market their products online and deliver them to the consumer's home.

Specific areas of interest:

- Disintermediation, bypassing the conventional retail channel
- E-fulfilment of Fast Moving Consumer Goods (FMCG)
- Outsourcing versus creation of own logistics infrastructure
- E-fulfilment in combination with inventory levels
- E-fulfilment in combination with costs / profit
- Delivery failure rates / proportion of returned orders
- Environmental impact home delivery channel
- Service level perceptions of home delivery

Other areas / decision points which influence the success of the home delivery service:

- Fulfilment centres versus store-based fulfilment
- Attended versus unattended delivery
- Packaging (single versus pallet)
- Warehouse operations (e.g. additional packaging)
- Delivery times and time slots
- Home delivery in relation with product types
- Customer preferences home delivery

C.2 Scoping study: size of literature

The size of the literature in this topic is determined with an unconditional search in the large academic search engine 'Business Source Premier'. The first 20 articles of each search were viewed to determine if the search strings provided relevant results or if the search strings should be changed to find articles on the above specific points of interest.

The search strings entered, the number of articles found, and the findings of the first 20 articles are presented in table C.1.

Search string	Number of hits	Findings
E-fulfilment	11	
E-fulfillment	54	
E-commerce	20 663	Includes also German and French articles
“Electronic Commerce”	72 050	Broad definition
E-business	6496	Includes also B2B articles
“Electronic business”	6911	Includes B2B
“Home delivery”	1611	Refers also to 200 childbirth articles
E-tailing	352	
E-tail	336	
Last mile problem	22	Refers to broadband connection problems
“last mile”	719	
“Online shopping”	3356	Mainly on customer behaviour
M-commerce	583	
“mobile commerce”	1807	
“Electronic shopping”	57 371	
Business-to-consumer	4053	Not directly related to e-commerce
“online retailing”	510	
“online retail”	1051	
“home shopping”	1915	

Table C.1: first scoping study: size of literature

From this it can be concluded that many articles exist about the online market, for example on customer preferences, marketing and technologies supporting online shopping. There is less literature available on the logistics of e-commerce (last mile problem or e-fulfilment).

To find articles about the logistic aspect of e-commerce a second scoping study is performed which combines the keywords of e-commerce with the logistics keywords. E-fulfilment refers (per definition) to the logistic aspect of e-commerce and is therefore included without the combination with a logistic search string. Only articles with the search strings in the abstract are included to find the most relevant articles. The search is performed in a larger database ‘EBSCOhost’.

	"E* commerce"	"Online retail*"	E-tail*	"E* business"	"Online shopping"	"Electronic shopping"	"Home shopping"
Logistic*	546 (117)	73 (10)	14 (5)	349 (95)	41 (9)	5 (0)	31 (14)
"Supply chain"	959 (240)	38 (4)	9 (3)	681 (236)	17 (1)	3 (1)	24 (5)
Distribut*	952 (200)	208 (24)	33 (12)	729 (154)	68 (18)	13 (4)	65 (6)
Transport*	355 (76)	30 (8)	4 (3)	459 (80)	19 (3)	4 (1)	31 (8)
"Home delivery"	35 (3)	27 (10)	3 (1)	8 (3)	23 (1)	4 (3)	37 (4)
"Last mile"	5 (3)	7 (2)	1 (1)	2 (1)	2 (1)	1 (0)	4 (2)

E-fulfilment	6 (3)
e-fulfillment	31 (8)

Table C.2: Second scoping study: e-commerce and logistics (between brackets are peer-reviewed articles)

Total number of articles: 5956

Total peer reviewed 1383

It is very likely that the above number of total articles includes duplicates. However, there is a reasonable amount of literature available on the logistics part of e-commerce which can provide the basis for a literature review.

C.3 Inclusion / exclusion criteria

The next step in the systematic literature review process will be to determine if the founded articles discusses the specified area of interest. In the first round, the title of the articles will be reviewed against pre-determined exclusion criteria. In the second round the abstract of the remaining articles are reviewed against the inclusion criteria.

The focus of the literature review will be on **the logistics of online retailing in a Business-to-Consumer (B2C) environment**. Articles which are focused on a Business-to-Business (B2B) or Consumer-to-Consumer (C2C) environment will be excluded from the systematic review. Also articles which are not discussing the logistic aspects of e-commerce will be excluded from the review. Examples of topics excluded are payment methods, customers trust in e-commerce, website design, or marketing strategies. The service, costs and environmental aspect of e-fulfilment will be

considered in the literature review. To be able to examine the service of the delivery, customer preferences and attitudes towards the delivery will be taken into account. Customer attitudes not related to logistics, but to marketing and safety aspects, will be excluded. Examples of excluded topics are customer attitudes towards websites, home shopping, payments methods, and customer service in general.

Articles before 1995 will be excluded. Although electronic commerce can refer to transactions via computer networks, telephone lines, post, etc., this literature review focus on online retailing, by Internet or other online services. The first World Wide Web server is created in 1990, and in 1994 the first online pizza ordering came online. The year after that, secure online payments became possible and soon there followed more online companies. In the UK home delivery of groceries began in 1997 (home service of Iceland) (Cairns, 2005). Articles on e-commerce before 1995 are therefore likely to refer to the traditional mail order retailers and not to the modern form of e-retail.

Included	**Excluded**
Business-to-Consumer (B2C) environments	Business-to-Business (B2B) and Consumer-to-Consumer (C2C) environments
Logistic aspects of E-commerce from a service, costs and/or environmental perspective	Marketing and Safety aspects of E-commerce
Customer perception of home delivery	Customer perception of home shopping
	Online Market size (including customer profile, drop density)
	Pre 1995

Table C.3: Overview inclusion / exclusion criteria:

C.4 Search Strategy

To minimise the bias, an exhaustive literature search will be performed which include not only published journals but also conference proceedings, industry trials and the internet (Tranfield et al., 2003).

Scientific articles will be searched with the search engines ‘EBSCOhost’ and ‘Emerald’. ‘Emerald’ gives access to more than 225 high quality business and management journals and to 50 book series with topics such as transportation and the environment. ‘EBSCO’ includes ‘business source premier’ and ‘greenFILE’ among other psychological and business related search engines. ‘Business Source Premier’ gives access to more than 2300 business journals, and ‘greenFILE’ covers articles on the

aspects of human impact to the environment. 'Business Source Premier' includes 11 of the top 19 ranked logistics and transportation journals, including the top 8 (see table C.4 below).

Ranking on normalized scores		Normalized score	Ratio (S/T)
1	*Journal of Business Logistics*	1.00	36.12
2	*International Journal of Physical Distribution & Logistics Management*	0.99	33.93
3	*Transportation Journal*	0.96	54.10
4	*Production and Inventory Management Journal*	0.58	64.71
5	*Journal of Supply Chain Management*	0.57	74.29
6	*International Journal of Logistics Management*	0.57	34.92
7	*Transportation Quarterly*	0.42	95.79
8	*Transportation Science*	0.40	89.68
9	*Journal of Transportation Research Forum*	0.34	11.13
10	*Proceedings of the Transportation and Logistics Educators Conference*	0.29	40.00
11	*Transportation Research: Part E: Logistics and Transportation Review*	0.24	12.31
12	*International Journal of Logistics*	0.22	11.72
13	*Journal of Transportation Law Logistics and Policy*	0.16	66.12
14	*CLM Annual Conference Proceedings*	0.15	0.00
15	*Logistics Management and Distribution Report*	0.12	0.00
16	*Supply Chain Management Review*	0.06	0.00
17	*Journal of Transportation Management*	0.06	16.67
18	*Supply Chain Management: An International Journal*	0.04	43.67
19	*Logistics Information Management*	0.02	0.00

Notes: S = total self-weighted score from Table II; T = total weighted score from Table II

Table C.4: Journal ranking (Source: Kumar and Kwon, 2004)

Books can be found using the library catalogue of the Heriot-Watt university and amazon.com. Searched in the library catalogue of the Heriot-Watt University uses ? to truncate instead of *. Further, the only content based search option they provide is search in title. For the search in Heriot-Watt University catalogue the above search strings are therefore not searched in abstract but only in title.

Relevant PhD theses can be found with 'ProQuest Dissertations' giving details of doctoral dissertations and master's theses from over 1,000 graduate schools and universities in North America and around the globe. 'DART-Europe' gives access to over 100,000 full text research theses from various European countries and is also included in the search.

Trade publications can be found with the fulfilment and e.logistics magazine and webpage. Their goal is to guide retailers, wholesalers, carriers, and fulfilment companies with publications about multi-channel fulfilment. The searches at this website are performed in the whole texts as this is the only option available.

Academic Articles	EBSCOhost	961
	Emerald	53
Books	Heriot-Watt library	0 (hits for other combinations)
	Amazon.com	101
PhD theses	ProQuest Dissertations and theses abstracts	11
	DART-Europe	2
Trade publications	Elogmag.com	240

Table C.5: Type of documents, the search place and the number of hits found for "e*commerce" and supply chain.

C.5 Quality criteria

The next step in the systematic review process will be to examine the remaining articles on their quality, using a critical analysis tool. An example of a critical analysis tool is shown in table C.6.

Elements to consider	Rating				
	0 - Absence	1 – Low	2 – Medium	3 – High	Not applicable
Contribution to understanding	The article does not provide enough information to assess this criteria.	The paper contributes little to an understanding of people and organisations at work.	Build on others ideas and makes some contribution to the body of knowledge in this area.	Significantly develops existing knowledge filling and important theory gap.	This element is not applicable to this paper.
Implications for practice	The article does not provide enough information to assess this criteria.	Not relevant for practitioners or only relevant to the population studied.	Transferable only to organisations with similar characteristics. Some useful ideas for practice but little comment made.	High level of transferability to a different context, providing useful and applicable ideas for practice with author comment on how this may be so.	This element is not applicable to this paper.
Methodology	The article does not provide enough information to assess this criteria.	Flawed research design with inadequate explanation of data analysis.	Justified research design but could be improved. Study not fully executed.	Methods chosen appropriate to the research question. Clear rationale for sample including size. Clearly outlined analytic framework with auditable analysis trail.	This element is not applicable to this paper.
Theory	The article does not provide enough information to assess this criteria.	Of little theoretical interest with inadequate literature review.	Acceptable theoretical basis with clearly defined concepts but data not entirely consistent.	Excellent review of existing literature with strong theoretical basis. Theory development consistent with data presented.	This element is not applicable to this paper.

Table C.6: Critical Analysis Tool (Anderson, 2004 cited in Atewologun, 2008)

The critical analysis tool will however eliminate many, or even most, non-academic articles. Together with other business descriptions trade publications can provide valuable insights. The following minimum requirements are used to assess the quality of the literature:

Criteria	**Quality indicator**
Contribution to understanding	Overall description of extent of knowledge and strength of argument.
	Clear indications of contribution to field.
Implications for practice	Clear representation of what the paper proposes.
Methodology	Justified research design, if applicable.
	Data supports the arguments
Theory	Valid statement of purpose of the paper and its intended contribution.
	Clear discussion of the issue, the background and its relationship to theory and practice, if applicable.

Table C.7: Quality criteria used in this thesis (adapted from Bown-Wilson, 2008 and Pittaway et al., 2004)

APPENDIX D: CONCEPT DESCRIPTIONS OF DIFFERENT SUBSCRIPTION TYPES

D.1 Concepts descriptions used in the first series of focus group discussions

Concept 1 – Fixed subscriptions

Deliver to me regularly

Newspapers and magazines can be bought in stores but these only have a limited supply. Your favorite magazine can be sold out by the time you get to the store. Therefore many people already today appreciate having their favorite magazine automatically home-delivered every day or every week or every month.

Imagine a similar automatic supply of your favorite products! Without having to reorder - you regularly receive a box delivered to your home - with the guarantee of having the products you want at a low price. You decide what products to include and we'll ship you a box of products at regular intervals. For these different products you can choose to include them in the delivery every 2 weeks, every monthly or only every 2, 3 or even 6 months. Combining products in regular deliveries saves on delivery costs and allows us to offer lower prices. You can pay after each delivery or at the end of each month – as you prefer.

Concept 2 – Fixed subscriptions with emergency shipments

Backup included

Imagine an automatic supply of your favorite products! Without having to reorder - you regularly receive a box delivered to your home - with the guarantee of having the products you want at a low price.

You decide what products to include and we'll ship you a box of products at regular intervals. For these different products you can choose to include them in the delivery every 2 weeks, every month or only every 2, 3 or even 6 months. In case you fear of running out before the next delivery – you can call in the back-up solution! Give us a call, send us an e-mail or a text message on what products you are running low and we'll immediately ship the next delivery to you.

Concept 3 – Automatic subscriptions

Never run out

Do you ever worry about running out of tap water? The convenience of always available water seems an almost indispensible comfort nowadays.

Now imagine a similar worry-free supply of your favorite products being delivered to your home. You are guaranteed of always having product available and paying a low price. Each time you empty a pack of detergent, a bottle of shampoo, a jar of beauty cream or any other product you decide to include in the service, you scan the barcode on the empty pack – just like in the supermarket. This tells our inventory management system that you've emptied a package. Our system will not immediately dispatch you new product. It will first check how much you have left and will make sure you are supplied with more product before the last package runs out. This allows us to combine products, saving on delivery costs, enabling lower prices and preventing the environmental burden of unnecessary transport.

D.2 Concepts descriptions used in the second and third focus groups series

Concept 1 – Fixed subscriptions

Deliver me regularly

Deliver me regularly brings shopping convenience to the next level. With this service you can have your favorite product delivered at regular intervals. It guarantees availability and low prices. You decide what products to include and select the frequency for each product. For each product you can ask for a certain number of items, weekly, every two weeks, every month, or only for a few items per year. At regular intervals you will receive a box combining your selected items. You will be notified one week before each delivery and will be able to adjust orders until two days before the delivery. Combining products in regularly delivery saves on delivery costs and transport emissions. This allows us to combine the convenience of delivery with low prices. Your orders will be delivered to your home or at the drop-off location or collection point of your choice.

Concept 2 – Automatic subscriptions

Never run out

Do you ever worry about running out of tap water? Probably not!

Now imagine never run out, a similar worry-free supply of your favorite products. You are guaranteed to receive your preferred product in time before you run out and enjoy paying a low price. At the start of the never run out service you receive a number of packs of products, for example three tubes of toothpaste, and each time you have an empty pack that you wish to be replaced you scan the barcode from the package or your printed menu with barcodes. The product will not be shipped immediately but will be included in the next scheduled delivery. You will be notified one week before each delivery and will be able to adjust orders until two days before delivery. This allows us to combine products per delivery, enabling lower prices and preventing the environmental burden of unnecessary transport. Your order will be delivered to your home or at the drop-off location or collection point of your choice.

APPENDIX E: INTERVIEW GUIDE

E.1: Participants

Participants are ‘head of households’ responsible for grocery shopping. For the specifically selected time-poor consumers the following requirements also applied:

- I am currently employed (full-time or part-time)
- When I go household shopping I'm in a hurry due to lack of time
- I dislike household shopping and would prefer to spend my time on other activities, or I don't hate it but I don't like it either
- When I do the household shopping I always choose my regular brand, or when I do the household shopping I mostly choose my regular brand but sometimes I take another brand that's in promotion

Consumers who replied that they feel relaxed and have enough time to do grocery shopping, those who replied to like household shopping and those who spend a lot of effort looking for promotions or the newest products were not invited for the ‘time-poor’ interviews.

E.2: Questions (semi-structured)

Personal Hygiene, Cleaning and Household products

- *Time stressed*
    - How do you feel when doing grocery shopping?
- *New items seeker*
    - How do you decide what products to buy?
- *Inventory keeper*
    - How do you decide when to buy products? (How do you have you still have stock at home?)
- *Organised inventory keeper*
    - How do you build your shopping list?
- *Promotion driven shopping list*
    - Do you look out for products in promotion?

Do you use the barcode scanner in the supermarket?

E.3 Concept description

Never run out

Open package → Scan it's barcode → Item is added to next delivery (can still remove it by scanning it out) → Delivered before running out.

Probe spontaneous reaction. Would the concept suits you?

APPENDIX F: RELATIONSHIPS AND CALCULATIONS IN THE LCA MODEL

In this appendix the calculations used in the LCA model are explained.

F.1: Consumer trip

Consumer trips can be performed by several transport modes. For each transport mode the total consumer distance associated with the acquisition of one consumer item is calculated. The total consumer distance is therefore divided over the different transport modes and multiplied with the fuel consumption of the car to calculate the amount of fuel needed for the purchase of the consumer item. The formula for the transport mode "car diesel" is shown below.

$$Car_{diesel} = \frac{Diesel_{car_{consumer}}}{100} * \left(\frac{Car_{diesel}}{100} * distance_{shop} + \frac{Car_{diesel_{return_{shop}}}}{100} * Distance_{return_{shop}} + \frac{Car_{diesel_{return_{CDP}}}}{100} * Distance_{return_{CDP}} + \frac{Car_{diesel_{return_{carrier}}}}{100} * Distance_{return_{carrier}} + \frac{Car_{diesel_{return_{shop}}}}{100} * Distance_{failed delivery_{shop}} + \frac{Car_{diesel_{return_{CDP}}}}{100} * Distance_{failed delivery_{CDP}} + \frac{Car_{diesel_{return_{carrier}}}}{100} * Distance_{failed delivery_{carrier}} + \frac{Car_{diesel_{CDP}}}{100} * Distance_{CDP} \right)$$

$Diesel_{car_{consumer}}$ = fuel consumption of diesel car for consumer transport [l/100km]

Car_{diesel} = fraction of diesel cars used by consumers to go shopping [0-100%]

$Distance_{shop}$ = distance to particular location associated with acquisition of the consumer item [km], further explained below in sections F.1.1, F.1.2 and F.1.3.

Other consumer transport modes are calculated in a similar way. EcoInvent data is then used to calculate the emissions associated with one litre of fuel in a passenger car.

F.1.1 Distance

The dedicated distance of the consumer roundtrip to the possible locations to pick up the order (shop or CDP) is included in the model. When multiply locations are visited during the round trip, a percentage of the trip is devoted to the shopping trip, e.g. the part of the trip which is incrementally made for the shopping purpose. Also the percentage of the trips which includes trip chaining is specified. The dedicated distance of the consumer trip per item is calculated with the following formula.

$$Distance_{shop} = \frac{\left(\frac{tripch}{100} * \frac{alloc}{100} + \frac{100 - tripch}{100}\right) * dist}{IT_{Order_{BM}}} * trips$$

$tripch =$ fractions of trips that are combined with other destinations (trip-chaining)

$alloc =$ fraction of trip allocated to the pick-up or return of the item(s)

$dist =$ total round trip distance in kilometres

$trips =$ number of consumer trips per order (including browsing trips) to the local store

$IT_{Order_{BM}} =$ number of items per order

The distance to the CDP is calculated in a similar way, except that “trips” is replaced by the percentage of orders via CDP, assuming that a maximum of one trip per order to the CDP is made, e.g. picking up orders at the CDP is always successful.

F.1.2 Returns

The percentage of returned items is multiplied by the distance driven for the returned items and included in the calculation. The distance is calculated in a similar way to the distance to the store or CDP, meaning that the total round trip distance is ‘adapted’ for trip chaining behaviour to the particular location. Below the formula for returns to the local store is given. Returns to a CDP or carrier depot are calculated in a similar way and therefore not shown here.

$$Distance_{returns_{shop}} = \left(\frac{tripch_{r_{shop}}}{100} * \frac{alloc_{r_{shop}}}{100} + \frac{100 - trip_{r_{shop}}}{100}\right) Dist_{r_{shop}} * per_{returns} * \frac{returns_{shop}}{IT_{return}}$$

$tripch_{r_{shop}}$ = fractions of trips that are combined with other destinations (trip-chaining)

$alloc_{r_{shop}}$ = fraction of trip allocated to the return of the item(s)

$Dist_{r_{shop}}$ = total round trip distance in kilometres

$Per_{returns}$ = percentage of items returned of total items ordered [value between 0-1]

$Returns_{shop}$ = percentage of returns via the local shop [value between 0-1]

IT_{return} = number of items returned per return trip

F.1.3 Failed deliveries

As argued in Chapter 8 (section 8.3.1), the distance, transport modes, and trip chaining activities for failed deliveries and returns to the same locations are assumed to be equal. Therefore the parameters used for calculating the impact of returns are also used for calculating the consumer transport impacts of failed deliveries, and is shown below.

$$distance_{faileddelivery_{shop}} = \left(\frac{tripch_{r_{shop}}}{100} * \frac{alloc_{r_{shop}}}{100} + \frac{100 - tripch_{r_{shop}}}{100}\right) Dist_{r_{shop}} * fail_{store} * \frac{per_{failed}}{IT_{Order}}$$

$fail_{store}$ = percentage of failed deliveries picked up at local store [value between 0-1]

per_{failed} = percentage of failed deliveries [value between 0-1]

IT_{Order} = number of items per order

F.2 Home delivery performed by the retailer

Like the consumer transport, van delivery can be performed with several transport modes. The amount of fuel is calculated for all transport modes in the same way as

shown below for diesel. The emissions associated with the fuel consumption are calculated with the EcoInvent modules.

$$Van_{diesel} = \frac{Diesel_{van_{delivery}}}{100} * \left(\frac{Van_{diesel}}{100} * distance_{delivery} + \frac{Van_{diesel_{r_{pickup}}}}{100} * distance_{r_{pickup}} \right)$$

$Diesel_{van_{delivery}}$ = fuel consumption of diesel van used for home delivery [l/100km]

Van_{diesel} = fraction of deliveries made by a diesel van [0-100%]

$Van_{diesel_{r_{pickup}}}$ = fraction of returns picked up by a diesel van [0-100%]

The distance calculated for the home delivery and pick up of returns, if any, is explained below.

F.2.1 Distance and number of drops in delivery round

The distance per item delivered is calculated by the total roundtrip distance divided over the number of orders delivered in the home delivery round and the number of items in the order. Because, in certain retail models, not all orders are home delivered, the distance is multiplied by the percentage of items home delivered ($1 - per_{CDP}$).

$$Distance_{delivery} = \left(\frac{Dist_{van}}{nr_{orders}} \right) * IT_{order} * (1 - per_{CDP})$$

$Dist_{van}$ = total distance of the roundtrip with the van including failed deliveries [km]

nr_{orders} = number of orders actual delivered (excluding failed deliveries) in the roundtrip

F.2.2 Returns

The distance per return is calculated as the distance of the return round trip ($Dist_{r_{pickup}}$), the number of stops ($nr_{returnstops_{pickup}}$), the number of items returned per stop (IT_{return}), and the percentage of items returned in this manner ($per_{returns} * return$).

$$Distance_{r_{pickup}} = \left(\frac{Dist_{r_{pickup}}}{nr_{returnstops_{pickup}}} \right) * \frac{per_{returns} * returns_{pickup}}{IT_{return}}$$

F.2.3 Percentage of orders delivered with van

The number of orders is multiplied by the percentage of orders delivered with the van.

F.3 Additional cross-dock options in the home delivery process

The cross-dock operations include the cross-dock facility itself and the transport (by van) to the cross-dock. Both modules are multiplied by the percentage of items delivered via the cross-dock facility.

F.3.1 Cross-dock

The utilities (electricity, fuel, natural gas and water) are calculated by dividing the total annual utility consumption by the number of items fulfilled via the facility ($thr_{retail_{CD}}$).

$$Electricity = \frac{Elec_{retail_{CD}}}{thr_{retail_{CD}}} * items_{crossdock}$$

$elec_{retail_{CD}}$ = utility consumption in cross-dock facility [Kwh/m^2/yr]

$thr_{retail_{CD}}$ = number of items fulfilled via cross-dock [items/m^2/yr]

$items_{crossdock}$ = percentage of items delivered via cross-dock [value between 0-1]

F.3.1 Transport to cross-dock

Also for transport by truck, several fuel types are included. Below the calculation is shown for diesel.

$$Truck_{diesel} = \frac{diesel_{truck_{crossdock}}}{100} * \frac{truck_{diesel}}{100} * distance_{delivery}$$

$diesel_{truck_{crossdock}}$ = fuel consumption of diesel truck to cross-dock [l/100km]

$truck_{diesel}$ = fraction of trips to cross-dock made by diesel truck [0-100]

$$distance_{delivery} = \frac{dist_{truck_{crossdock}}}{items_{in_{truck}}} * items_{crossdock}$$

$dist_{truck_{crossdock}}$ = total distance of one round trip of truck [km]

$items_{in_{truck}}$ = number of items in one round trip of truck to cross-dock

F.4 Collection and Delivery Point (CDP)

The utilities consumption related to the CDP are included. In line with the other modules, the production, maintenance and disposal of the CDP are not taken into account. The modules are multiplied by the percentage of items delivered via the CDP.

$$Electricity = \frac{elec_{consumption_{CDP}}}{throughput_{CDP}} * Per_{CDP}$$

$elec_{consumption_{CDP}}$ = utility consumption in CDP facility [Kwh/m^2/yr]

$throughput_{CDP}$ = number of items fulfilled via CDP [items/m^2/yr]

F.4.1 Transport CDP

Transport in a van to the collection and delivery points (CDP) is very similar to the earlier explained van delivery rounds, except that the number of drops are lower and the number of orders and items per drop are higher. Returns are also modelled separately to calculate the impact of returns via CDPs.

$$Van_{diesel} = \frac{Diesel_{van_{CDP}}}{100} * \left(\frac{Van_{diesel_{CDP}}}{100} * distance_{delivery_{CDP}} + \frac{Van_{diesel_{r_{CDP}}}}{100} * distance_{r_{CDP}}\right)$$

$Diesel_{van_{CDP}}$ = fuel consumption of diesel van used for delivery to CDP [l/100km]

$Van_{diesel_{CDP}}$ = fraction of deliveries made by a diesel van [0-100%]

$Van_{diesel_{r_{CDP}}}$ = fraction of returns picked up at CDP by a diesel van [0-100%]

$$Distance_{delivery_{CDP}} = \left(\frac{Dist_{CDP}}{nr_{stops} * order_{per_{stop}} * IT\_order}\right) * per_{CDP}$$

$Dist_{CDP}$ = total distance of the roundtrip with the van including failed deliveries [km]

nr_{stops} = number of stops in roundtrip of van delivering to CDP

$order_{per_{stop}}$ = number of orders delivered per stop at CDP

F.5 Home delivery via the Parcel network

The home delivery with van in the parcel network is almost similar to earlier van deliveries calculation shown above. The only difference is the parameter IT_{parcel}which describes the number of items in a parcel, which is not necessarily equal to the number of items in the order. The distance for the home delivery and delivery to the CDP is therefore calculated as follows:

$$Distance_{delivery} = \frac{\frac{dist_{order}}{nr_{orders}}}{IT_{parcel}} * (1 - per_{CDP})$$

$$Distance_{CDP} = \frac{dist_{CDP}}{(nr_{stops_{CDP}} * order_{per_{stop_{CDP}}} * IT_{parcel})} * per_{CDP}$$

F.6 Shop

The utilities consumption per item in the shop is calculated in a similar way as the utilities of the cross-dock and CDP described above. The utility consumption is then multiplied with the fraction of items fulfilled via the shops.

$$electricity = \frac{Elec_{BM}}{thr_{BM}} * fr_{BM}$$

$Elec_{BM}$ = utility consumption in shop [Kwh/m^2/yr]

thr_{BM} = number of items fulfilled via shop [items/m^2/yr]

fr_{BM} = fraction of items delivered via shop [value between 0-1]

The formula above, used in the modules ‘cross-dock’, ‘CDP’ and ‘shop’ is also used for calculating the environmental impact of fulfilling an item via a retail DC, an e-fulfilment centre and via the manufacturer DC.

F.7 Retailer transport

Similar calculations are used to calculate ‘retailer transport’ and ‘transport to cross-dock’.

$$Truck_{diesel} = \frac{diesel_{truck_{retailer}}}{100} * \frac{truck_{diesel}}{100} * distance_{delivery}$$

$diesel_{truck_{retailer}}$ = fuel consumption of diesel truck to shops [l/100km]

$truck_{diesel}$ = fraction of trips to shops made by diesel truck [0-100]

$$distance_{delivery} = \frac{dist_{retailer}}{items_{in_{truck_{retail}}}} * BM$$

$dist_{retailer}$ = total distance of one round trip of truck [km]

$items_{in_{truck_{retailer}}}$ = number of items in one round trip of truck to shops

$BM =$ percentage of items fulfilled via retail DC and shops [value between 0-1]

Similar calculations are used for the modules 'transport from the manufacturer to the retailer' and 'manufacturer transport'.

F.8 IT operations

The IT impacts of both the company and the consumer are calculated per order and then divided by the number of items in the order:

$$ICT_{operations} = \frac{company_{ICT} + consumer_{ICT}}{IT_{order}}$$

The company IT operations exists out of EcoInvent modules $Use_{computer}$, $Use_{IP_{network}}$ and $Use_{Networkaccessdevice}$. Each of these modules is multiplied with the time that the company's computer is online to process one consumer order.

$$Company_{ICT} = \left(Use_{computer} + Use_{IP_{network}} + Use_{Networkaccessdevice}\right) * Company_{hostingduration}$$

$Company_{hostingduration}$ = Time to process consumer order [hours]

The consumer can order products online with a desktop, laptop, tablet or mobile phone and all those options are included in the calculation.

$$Consumer_{ICT} = \left(Use_{computer_{desktop}} + Use_{IP_{network}} + Use_{Networkaccessdevice}\right) * \left(hours_{spentonline} * fr_{desktop}\right) + (\text{Use}_{\text{computer}_{\text{laptop}}} + \ldots.$$

$hours_{spentonline}$ = time consumer takes to place order online including searching for the web shop [hours]

$fr\_desktop$ = fraction of desktops used by consumer to place orders online [0-1%]

F.9 Packaging

The amount of material used (LDPE, carton, polystyrene and starch) is specified per item and is multiplied with an efficiency factor that has standard its value on 1.

$$Packagingfilm_{LDPE} = LDPE * Packaging_{efficiency}$$

$LDPE$ = amount of packaging (LDPE) used per item [kg]

$Packaging_{efficiency}$ = Efficiency factor [value between 0-2]

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