From Bricks-and-Mortar to Bricks-and-Clicks – Logistics Networks in Omni-Channel Grocery Retailing

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Abstract

Purpose - The advent of grocery sales through online channels necessitates that bricks-and-mortar retailers redefine their logistics networks if they want to compete online. Because the general understanding of such bricks-and-clicks logistics systems for grocery is still limited, the purpose of this paper is to analyze the internal logistics networks used to serve customers across channels by means of an exploratory study with retailers from different contexts.

Design/methodology/approach - A total of twelve case companies from six European countries participated in this exploratory study. Face-to-face interviews with managers were the primary source for data collection. The heterogeneity of our sample enabled us to build a common understanding of logistics networks in grocery retailing on multiple channels and to understand the advantages of different warehousing, picking, internal transportation and last-mile delivery systems.

Findings - Bricks-and-mortar grocery retailers are leveraging their existing logistics structures to fulfill online orders. Logistics networks are mostly determined by the question of where to split case packs into customer units. In non-food logistics channel integration is mostly seen as beneficial, but in grocery retailing this depends heavily on product, market and retailer specifics. The data from our heterogeneous sample reveals six distinct types for cross-channel order fulfillment.

Practical implications - Our qualitative analysis of different design options can serve as decision support for retailers developing logistics networks to serve customers across channels.

Originality/value - The paper shows the internal and external factors that drive the decision-making for omni-channel logistics networks for previously store-based grocery retailers. Thereby it makes a step towards building a contingency and configuration theory of retail networks design. It discusses in particular the differences between grocery and non-food omni-channel retailing, last-mile delivery systems and market characteristics in the decision-making of retail networks design.

Keywords: Omni-Channel Retailing, Grocery Retailing, Retail Logistics, Logistics Networks, Typology, Exploratory Study, Contingency Factors

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Introduction

This paper analyzes logistics network structures for grocery retailing via multiple channels, i.e., where retailers offer their products not only in bricks-and-mortar stores, but also online in a "bricks-and-clicks" approach. Focusing on the product flow, the products can be picked up at the store, at pick-up stations or delivered to the customer's home. Enabling the different delivery and pick-up modes across channels is a recent phenomenon, particularly in grocery retailing. Retailers may operate all types of networks from isolated product flows – where direct-to-customer shipments and store supply are operated independently – to unified systems with comprehensively conflated front- and back-end logistics [Hübner et al., 2016c]. Bricks-and-clicks retailers therefore need to address the question of how to operate logistics networks to serve customers across channels.

Such logistics networks that enable bulk and single unit picking and delivery are more costly than traditional store fulfillment with bulk deliveries to stores, where customers themselves are responsible for order picking at the store. In grocery retailing, differing temperature zones, orders with multiple items, higher waste due to perishable inventories and rapid delivery requirements make logistics for grocery more complex than for non-food. Innovative logistics networks need to fulfill customer expectations particularly in terms of high delivery speed, high product availability and low delivery costs, while retailers need to consider the upside potential of new market segments, but also manage their own costs and complexity arising from different channels and network options. Bricks-and-mortar grocers need to find answers to how product flows for the fulfillment of online orders can be organized within their existing network or in a separate distribution channel.

Investigating the different network design options is relevant from a practical and an academic perspective. In Europe grocery retailing is predicted to surpass consumer electronics in online sales to become the second largest category after apparel by 2018 [Forrester, 2014]. In the United States a recent study shows that 41% of customers have already bought groceries online. A total of 21% had purchased groceries within the previous 30 days [Brick Meets Click, 2016]. However the fulfillment options for grocery are very different across markets. For example, German bricks-and-mortar retailers mostly supply their currently small volume of online orders through their existing store outlets, whereas most Dutch and UK retailers fulfill home delivery via specialized online distribution centers [Hübner et al., 2016b]. In France 3,325 drive-through stations for pick-up of online grocery orders are registered – nearly twice the number of hypermarkets in the country [Vyt et al., 2016]. Logistics literature mostly focuses on online grocery fulfillment (e.g., Kotzab and Madlberger [2001]; Teller et al. [2006]; Grant et al. [2014]; Dreyer et al. [2015]) and cross-channel fulfillment for non-food retailing (e.g., Agatz et al. [2008]; Hübner et al. [2015, 2016a]; Ishfaq et al. [2016]), but only on cross-channel grocery retailers to a very limited degree (e.g., Colla and Lapoule [2012]). Management literature shows that the organizational transformation to omni-channel retailers has a positive effect on firms' sales growth (e.g., Cao and Li [2015], Wollenburg et al. [2016]). Most retailers are therefore merging their channels at least to some extent [Hübner et al., 2016c]. However, the question arises as to whether this is always beneficial, especially if this applies for all retail categories, and to what extent [Verhoef et al., 2015].

We apply an exploratory study because our understanding of the logistics network for grocery fulfillment across channels is still limited [Seuring, 2008]. A multiple case study approach with grocery retailers from different contexts is therefore used to understand the advantages of different warehousing, picking, internal transportation and last-mile delivery systems. The aim of the paper is to analyze which logistics networks are used to serve customers with grocery across channels.

In the following, we provide the context of our scope of investigation into grocery retail logistics and develop the specific research question in Section before describing the methodology applied in Section . The main Section develops a typology of logistics networks and reveals the reasons why retailers use specific omni-channel grocery logistics networks. This also serves to enhance the general understanding of retail logistics network design. Finally the key findings are discussed in the light of literature in Section .

Conceptual background and research question

Many different expressions have been developed for retailing via multiple channels with "bricks-and-clicks". Terms encountered in practice include "multi-channel", "cross-channel" or "omni-channel", which are often used interchangeably and without clear differentiation [Beck and Rygl, 2015]. In omni-channel (OC) retailing, neither the customer nor the retailer distinguishes between physical store and the Internet channel anymore [Brynjolfsson et al., 2013; Bell et al., 2014; Verhoef et al., 2015]. In the context of logistics, OC retailers apply information exchange, joint operations, warehousing and inventories across channels, which leads to a conflation of the fulfillment processes [Hübner et al., 2016c]. The upcoming subsection () therefore first conducts a literature-based channel-specific analysis of *pure bricks-and-mortar* and *pure online* grocery logistics networks and describes the internal and external factors for retail logistics network design. In general, retail logistics networks – in comparison to other logistics networks – have special characteristics in their distribution structures (e.g., number of delivery points, multiple distribution centers, high picking costs). The focus of this literature review is on logistical influencing factors: further macroeconomic, political or competitive factors are neglected. This analysis builds the foundation for formulating the research question of the present study concerning the logistics networks of OC grocery retailers in Subsection .

Bricks-and-mortar and online grocery logistics networks

Briefly, the logistics network of a grocery retailer can be segmented into inbound logistics, warehousing and distribution (e.g., Bourlakis and Weightman [2007]; Hübner et al. [2013]; Kuhn and Sternbeck [2013]). The scope of our investigation is on the retailers' internal network. The internal network consists of the subsystems warehousing, internal transportation between distribution centers (DCs) and stores as well as last-mile delivery to customers [Kuhn and Sternbeck, 2013; Hübner et al., 2016b]. In grocery retailing, one additional and crucial part of warehousing is picking processes, which largely determine the configuration of the logistics network. In the following we therefore focus on the four areas (i) warehousing, (ii) picking, (iii) internal transportation, and (iv) last-mile delivery. We will first explain the general processes and setting for all four areas, and then describe the specific requirement for each channel separately. Figure 1 gives an overview of product flows from suppliers across different DCs to stores, pick-up stations and customers, and separately for bricks-and-mortar and online fulfillment.

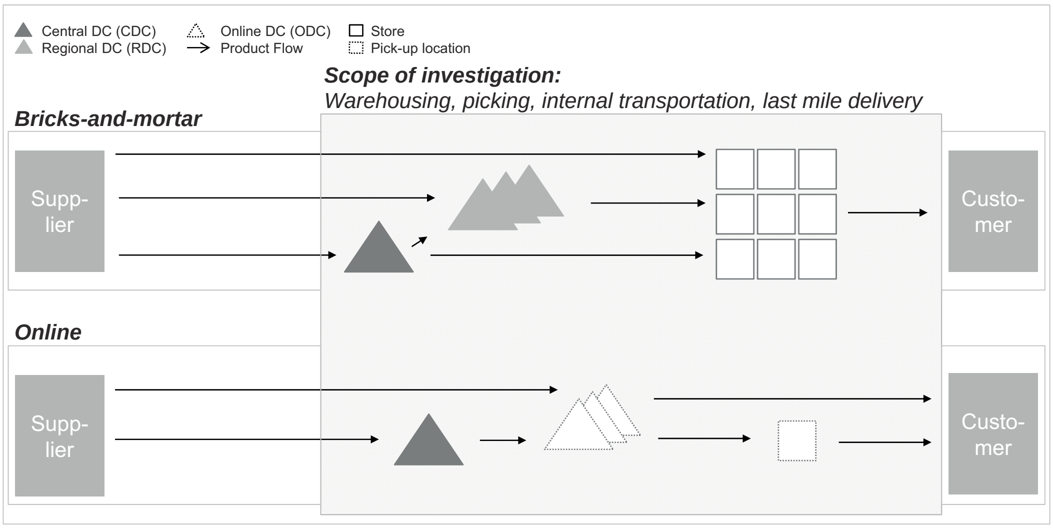

Figure 1: Network structures of pure bricks-and-mortar and pure online grocery retailers

(i) Warehousing frames all planning aspects related to long-term network configuration, e.g., sizing the number of DCs, or defining functionalities and number of layers of DCs and which DC holds which products [Ambrosino and Scutella, 2005; Holzapfel et al., 2016b]. Retailers use their DCs for inventory holding and picking, but they can additionally serve for cross-docking. Because grocery products have differing temperature requirements, grocery retailers need to operate separate facilities by temperature zone. Furthermore storage (e.g., best-before issues) and transport restrictions (e.g., arrival before store opening) allow only limited distances between stores and end-consumer. After the receipt of products from suppliers or other DCs, items are stored, picked, and distributed in different temperature zones. Retailers receive products in case packs, i.e., outer packs (secondary packaging), from their suppliers, but sell these products in customer units, i.e., eaches (primary packaging), to their customers. The suppliers' case pack facilitates the handling of multiple customer units in the supply chain and protects the products during picking and transportation [Broekmeulen et al., 2016].

Bricks-and-mortar. In grocery retail logistics networks usually a number of central DCs store slow [Hübner et al., 2013] in large facilities with a broad assortment range, whereas multiple regional DCs mostly store fast-moving items and items with short transportation lead time requirements (e.g., fresh produce) [De Koster et al., 2007]. The network is determined by size, number and type of DC. Internal consolidation of orders can take place when items from central DCs are cross-docked and bundled in an regional DC for further transportation [Kuhn and Sternbeck, 2013]. Items are usually stocked in case packs or in a larger-scale unit (e.g., a pallet).

Online. Pure online grocers operate DCs in different temperature zones. They are termed online DCs because they only fulfill online orders [Hübner et al., 2016b]. Sometimes they are also referred to as "dark stores" [Mena and Bourlakis, 2016]. Online DCs are built close to customers to shorten the transportation lead time [Hays et al., 2005]. At an online DC case packs are divided into (and stocked in) customer units. We term this point "break-open point", i.e., where case packs from suppliers are "broken" and divided into customer units for the first time (cf. De Koster et al. [2007]; Broekmeulen et al. [2016]). It determines in which subsystem of the supply chain logistics costs increase as products are no longer handled together (i.e., more efficiently) in a larger packaging unit.

(ii) Picking is the process where different items for store and customer orders are compiled. Minimizing the travel distance of pickers and consolidation effort of orders is the primary objective [Gu et al., 2007]. Picking is performed in all DC types (i.e., central DC, regional DC, online DC) and conducted by temperature zone. Product variety and availability targets throughout the network are important variables in determining picking costs which in the end also influences the network type.

Bricks-and-mortar. In most cases picking is completed in case packs [De Koster et al., 1999; Gu et al., 2007], where a picker takes an entire case pack from a storage area and puts it on a transportation unit (e.g., pallet or roll cage). Usually each transportation unit equals one picking job and contains 15 different items on average [Glatzel et al., 2012], i.e., a picker has an average of 15 different items to pick per job. The overall picking speed depends also on manual, semi-manual or automated picking procedures [Glatzel et al., 2012]. Larger quantities than case packs (e.g., entire pallets) are only picked for bulky items or if stores display items on pallets. Under certain circumstances, e.g., for low-volume high-value products, a bricks-and-mortar retailer removes the secondary packaging at the DC and then uses reusable boxes for transportation. The break-open point is in the store for almost all items. The consolidation of items from various temperature zones takes place either in the DC (if stores are delivered with multi-temperature vehicles [Hübner and Ostermeier, 2017]) or in the store.

Online. In online grocery retailing the unpacking has to be done, i.e., the secondary packaging removed, before customer orders are picked. In a first stage pallets containing items of one product type are often broken up into case packs and then in a second stage case packs are further broken up into customer units. Online picking is also more complex because the orders consist of multiple different items [Agatz et al., 2008]. Each online order contains from 60 to 100 different items [Fernie and McKinnon, 2009]. After picking, the order has to be consolidated (if split up into different picking jobs), packed and sorted by delivery region before the distribution can start. The final consolidation of an order from different temperature zones is performed by vehicle drivers at the customer's doorstep.

(iii) Internal transportation deals with deliveries between DCs or from DCs to stores.

Bricks-and-mortar. The minimum transportation unit for store supplies is a pallet or roll cage for most items. After goods have been picked on transportation units, haulage is carried out by temperature-specific trucks (or temperature-specific compartments of a truck) that deliver orders to a store from once per week (i.e., slow movers) to a couple of times per day (i.e., ultra-fresh grocery) [De Koster, 2002; Holzapfel et al., 2016a]. Repetitive delivery patterns are applied to facilitate the planning in other subsystems [Kuhn and Sternbeck, 2013; Holzapfel et al., 2016a]. The resulting replenishment frequency impacts accordingly the network design. Regional DCs may serve as transshipment points for central DC shipments. Further transshipment points (e.g., for cross-docking) may be also applied. There is an interdependence between routing and warehouse location decision which determines a logistics network as well [Ambrosino and Scutella, 2005]. Thus the main influencing factors include the number of stores, store density, delivery patterns and whether or not transhipment points are used.

Online. For online orders the only internal transportation occurs when retailers have central DCs and transport items from different temperature zones to online DCs for further picking and distribution.

(iv) Last-mile delivery defines the delivery of online orders to customers and is therefore only relevant for online retailers. After picking, online grocery retailers distribute their products from online DCs with the help of logistics service providers or with their own fleet [Rao et al., 2009]. The transportation vehicles need to either contain multiple compartments or be equipped with isolated boxes to transport products from different temperature zones. Basic differences in home delivery concepts are attended home delivery (e.g., Kämäräinen et al. [2001]) and unattended home delivery (e.g., Punakivi et al. [2001]). This describes whether a customer needs to be at home when goods are delivered to the door or not. It impacts the network design as the degree of fredoom in delivery frequencies and routing varies between both types [Hübner et al., 2016b]. Delivery in time windows and balancing demand over the day are critical factors for efficient home delivery (e.g., Punakivi and Tanskanen [2002], Boyer et al. [2009], Vanelslander et al. [2013]). Some online grocers use pick-up solutions like box systems with different temperature zones in congested areas for shortening the last mile to the customer and for bundling of orders. The returnability of items influences the logistics network as well (e.g., store density for convenient return).

Summary of general aspects of retail network design. From the literature review we can summarize for both channels the required configuration decisions, contingency factors and related costs for retail logistics network design as shown in Table 1. The contingency factors influence the configuration in each area of the logistics network and lead to different costs for locations, picking, inventory holding and transportation.

Area	*Configuration*	*Main contingency factors*	*Related main costs*
(i) Warehousing	Number of layers, number of DCs, functionality of DCs (e.g., slow/fast mover, central/regional DC), size of DCs, product assignment to DCs	Temperature requirements, transportation distances and lead time requirements, storage unit (i.e., case packs or customer units), assortment range	Location, inventory holding, transportation
(ii) Picking	Picking process, degree of automation, order batching	Assortment range, picking unit (i.e., case pack or customer unit), size of orderlines, handling and transportation units, lead time	Picking
(iii) Internal transportation	Flows between DCs and stores	Number of stores and density, delivery frequency and patterns, transhipment option	Transportation
(iv) Last mile delivery	Vehicle selection, routing	(Un)Attended delivery mode, time windows, outsourcing options, delivery frequency	Transporation

Table 1: Main criteria of retail logistics network design

Research question

The analysis of bricks-and-mortar and online grocery logistics networks reveals considerable differences between both channels. The question therefore arises as to how grocery retailers can organize their retail logistics network and operations to supply not only stores but also pick-up points and customers at home at the same time. In grocery retailing all existing OC retailers started from a bricks-and-mortar operational model. To the best of our knowledge up to now, no former pure online grocer has begun to sell grocery products in large store networks. The focus of the present study therefore lies in analyzing former bricks-and-mortar grocery network structures and product flows to serve customers in both channels. This addresses the question of how already existing bricks-and-mortar logistics structures can be used to fulfill the online channel in grocery retailing.

Whereas logistics structures for non-food OC retailing are analyzed in literature (e.g., Hübner et al. [2016c], Ishfaq et al. [2016]), OC grocery logistics networks have not yet been researched and require separate consideration. The present investigation thus conducts an exploratory study achieving a better understanding of OC grocery retail logistics by answering the following research question:

Which OC logistics networks are used by former pure bricks-and-mortar grocery retailers and why?

Methodology

This section details the research process. This study follows an exploratory approach [Flynn et al., 1990; DeHoratius, 2011]. We applied a case study design as this is particularly suitable for exploratory qualitative research [Seuring, 2005; Pagell and Wu, 2009; Yin, 2014].

Sampling. Case studies were conducted with twelve OC grocery retailers from six European countries. The selection of retailers from six different countries provides the opportunity to make firm use of the strengths of a case study approach in exploratory research by combining a sample that shares internal homogeneity (i.e., retail companies sharing common characteristics) and external heterogeneity (i.e., retailers operating from different consumer expectations, population density, infrastructure, etc.) [Wu and Choi, 2005; Seuring, 2008; Trautrims et al., 2012]. Cases were selected purposefully as recommended for exploratory qualitative studies (e.g., Pagell and LePine [2002]) based on the criteria that the retailer had a minimum sales volume of EUR 500 million p.a.

and a minimum of 50 outlets of their own, ensuring an established store logistics network before commencement of online operations. In addition to this, retailers were required to sell all grocery products from multiple temperature zones (i.e., fresh, frozen and ambient) combined in at least one channel and selling grocery products from at least one temperature zone across all channels. As a result we only included full-range grocery retailers that had started initially as bricks-and-mortar grocers and then built up an online channel over time to sell grocery goods across channels.

Interviews. We interviewed 16 managing directors and section heads from logistics, IT and e-commerce departments to obtain the broadest possible view and the most in-depth insights. An overview of participating companies by country is provided in Table 2.

Country	**Germany**				**Austria**	**France**		**UK**	**Netherlands**			**Portugal**
Case Company	1	2	3	4	5	6	7	8	9	10	11	12
Interviews	1	3	1	1	1	1	1	1	1	1	1	1
Participants	1	3	1	1	1	1	2	1	1	1	2	1
-Logistics		*2*	*1*		*1*	*1*	*1*			*1*	*1*	
-IT	*1*	*1*										
-E-commerce				*1*			*1*	*1*	*1*		*1*	*1*
Stores in country	>5,000	>5,000	<500	<500	1,000-5,000	>5,000	500-1,000	500-1,000	500-1,000	500-1,000	<500	<500
Sales in Euro	30-50bn	>50bn	5-10bn	5-10bn	5-10bn	30-50bn	30-50bn	10-30bn	<5bn	10-30bn	<5bn	<5bn
Share in country	10-20%	20-30%	<10%	<10%	>30%	20-30%	20-30%	10-20%	10-20%	>30%	<10%	20-30%
Years online	3-5	3-5	3-5	3-5	1-3	>5	>5	>5	3-5	>5	1-3	>5

Table 2: Overview of participating companies by country

The interviews were conducted face to face at the site of the OC retail companies. The interviewees were self-selected by the retailers as the relevant specialist executives for the logistics structure of their OC ambitions and can hence be considered the relevant experts for the respective retailer. Expert interviews are a suitable instrument for data collection because the knowledge of the experts interviewed stems from their position within the companies (see, e.g., in Flynn et al. [1990], Ellram [1996], Creswell [2003], Trautrims et al. [2012]). The case interviews, with one to three interviews per case company, lasted 80 minutes on average. We used theoretical sampling for our interviews, which took place over a period of six months, with ongoing data analysis after each interview. In total we researched 12 case companies as a European OC grocery retailer sample set [Eisenhardt, 1989; Glaser and Strauss, 1967]. Twelve cases are the upper end of Ellram's (1996) recommendation for the assurance of sufficient generalizability of case study research. Guest [2006] come to the same observation in a similar study on "how many interviews are enough" in qualitative and exploratory research. The interview data was enriched using market intelligence reports. These additional data sources were used for triangulation to achieve internal validity together with confirmation checks with interview partners [Jick, 1979].

An interview guide was developed over a period of two months. It was based on the product flow in the supply chain from the retailer to the customer. Questions and probes in the interview guides for the four network planning areas were informed by the literature review (e.g., Bourlakis and Weightman [2007], Fernie and Sparks [2009], Hübner et al. [2013], Agrawal and Smith [2015], Hübner et al. [2016c]) as well as from articles on OC grocery retail logistics in practitioner oriented journals (e.g., Mercier et al. [2014], Klingler et al. [2016]). Prior to collecting primary data, two pilot interviews were conducted. After both interviews, minor adaptations were made to the interview guide. All interviews were recorded and afterwards transcribed for the application of the qualitative data analysis support software MAXQDA 11. Interviews were conducted in German in the German-speaking countries and in English in the other countries. Coding of the interviews was undertaken in English. To ensure reliability of the translation, two researchers translated the responses independently from each other and compared their results before entering them into the software.

Data analysis. Transcripts of the interviews were coded and categorized [Miles et al., 2013] using MAXQDA 11 until preliminary theoretical saturation was reached [Corbin and Strauss, 1990]. Two researchers coded the data independently of each other to provide external validity of our findings. Codes were assigned to reflect interviewee descriptions. A total of 755 individual passages were coded. If a description or view did not fit a code that had already been assigned, a new code was assigned to this item [Maanen, 1979]. Each code was linked to a phrase from the interview transcript or recording. This enabled complete traceability from an individual code to the original source. Three main logistics network configurations resulting in six different types of online channel organization within an existing bricks-and-mortar logistics network are derived from the data. Additional influencing factors are grouped into two categories, namely market and consumer influences. These factors are used in the analysis to address the question of why a certain type is applied at a retailer. The following section presents and analyzes the emerging types of OC grocery logistics networks.

Empirical findings

This section presents the empirical findings of the exploratory study conducted. In section each OC grocery logistics network type identified is described and analyzed individually before section develops towards a generalization of OC retail network design.

Typology of omni-channel logistics networks in grocery retailing

In OC grocery retailing three main logistics network configurations can be distinguished. In the first network configuration ([1]) online orders are mostly fulfilled via traditional bricks-and-mortar logistics networks. The configuration therefore abstains from establishing a separate online DC for online order fulfillment. The second network configuration ([2]) is characterized by the availability of an independent online DC that fulfills at least a significant share of all online orders. In the third network configuration ([3]) all orders are fulfilled from one channel-integrated DC. The network configurations [1] and [2] can be further divided into two ([1.1], [1.2]) and three ([2.1], [2.2], [2.3]) diverse types, respectively, so that altogether six different types exist.

This subsection describes and analyzes the general setup of these types considering the respective subsystems warehousing, picking, internal transportation and last-mile delivery. This consecutively answers the research question formulated (i.e., "which OC networks exist?" and "why is a particular OC network operated?").

Network configuration [1]: Traditional bricks-and-mortar structures for online order fulfillment

Network configuration [1] is based on the traditional structures of a bricks-and-mortar grocer, as stores and pick-up points are supplied through existing networks. A separate online DC does not exist. All online orders are exclusively supplied via stores or pick-up points. Case packs are broken into customer units as late as possible in the supply chain, allowing a long continuing common flow of goods. Two different types can be distinguished whereby either all online orders are fulfilled from store (type [1.1]) or separate solo pick-up stations are built up fulfilling part of or all online orders (type [1.2]).

Type [1.1]: Fulfillment of all online orders from store

In type [1.1] all online orders are fulfilled from regular stores. Customers can choose whether they either pick up online orders from a pick-up point that is attached to a store or have their orders delivered to their home. In both cases orders are picked at the store (see Figure 2). The flow of goods goes from the supplier across different temperature and category-specific DCs and transshipment points via stores to the customer. The arrows display the granularity with which items are handled – in case packs or customer units. Case packs are divided at the break-open point for the first time (i.e., "broken open") into customer units, and from there everything is processed on a customer unit basis. At type [1.1] the break-open point is at the store.

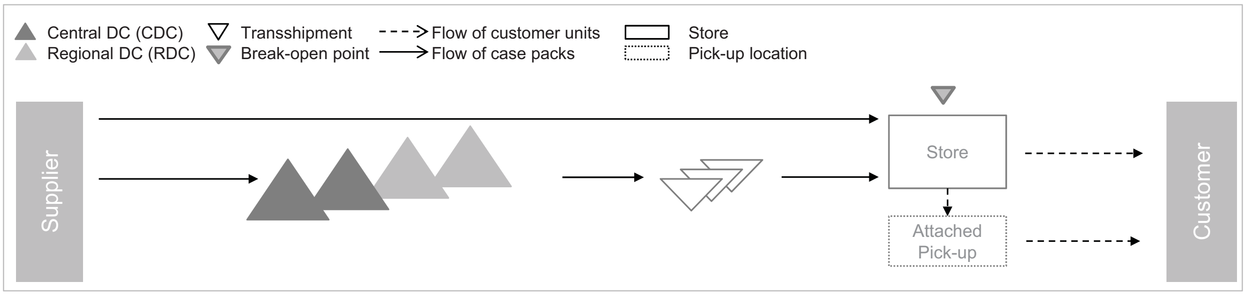

Figure 2: Type [1.1] – Fulfillment of all online orders from store

Description. Suppliers mostly deliver goods to central and regional DCs on pallets, and via transshipment points to stores in different temperature zones. Slow-moving products are stored in central DCs and fast-moving products are stored in regional DCs, which are generally located closer to the stores. Store orders are picked in central and regional DCs and online orders in stores. Picking for stores is done in large quantities in DCs and at case pack level. Afterwards, the retailer delivers goods from the DCs to the stores in different temperature zones on pallets for store replenishment. Here, the case packs are divided into customer units and online orders are picked from store shelves by store employees in a defined picking procedure.
Retailers can either only offer pick-up of products from the store or additionally offer home delivery with delivery vehicles from the store. The final consolidation of an order across temperature zones is conducted when customers pick up the order from the associated pick-up station or via home delivery when the driver reaches the customer's doorstep.

Analysis. In this type no additional online DC is necessary, so no investment costs in new warehouse locations and no additional inventory are incurred. Moreover, the identical assortment for online- and store channel leads to joint storage of online and store products in the DCs and therefore no additional space requirements for additional online items. However, no virtual shelf extension with for example slow-moving items is possible in the online shop as products come directly from store shelves. It is also difficult to provide availability information to the online channel. In general, high inventory inaccuracy exists at the store level and there is a higher out-of-stock risk as store customers can take items from shelves before online order picking. The forecasting of joint store and online demand is more complex. Purchase patterns are not the same for online and store channel customers, which can lead to mismatch of store replenishment forecasts and inventory holding.
In addition, low service levels in store can lead to a lot of product replacements. This is especially relevant in grocery retailing as an order usually contains multiple items per order, so a customer order can rarely be supplied without replacements for missing items.

> *In non-food you expect two to three different items per basket. We have 50. In the UK, which is still more advanced in terms of online grocery shopping, the average is between 68 and 72* [Company 1, Germany].

However, the acceptance level of substitutions is high for online orders.

> *Service levels at in-store picking are not a problem for us. French customers accept substitution for dry food in more than 90% of cases* [Company 5, France].

The picking in central and regional DCs of case packs on pallets allows high operational efficiency in the DCs. However, this is suspended by the additional picking step and low picking efficiency in store as the stores are not designed for order picking. Competition on products between online and store orders (i.e., allocation of products to customer or picker in the event of limited availability) in store is another disadvantage of in-store picking. As a result, retailers claim that this concept is only appropriate if online sales volume is low.

> *If you reach a figure of 5% for online sales in your store, you should switch to online DC picking to reduce the risk of impacting store customers* [Company 12, Portugal].

At the internal (temperature-specific) transportation between DCs and stores, stores can still be supplied using efficient transportation loads. No additional costs are required for internal transportation flows of online orders (e.g., from central and regional DCs to an online DC). Furthermore, the high number of shipment locations (i.e., stores instead of online DCs) result in lower transportation costs on the last mile and shorter delivery lead times to the customer. Shipment of last-mile deliveries from a high number of decentralized locations (i.e., stores) results in higher capacity investments for vehicles as there are only very limited pooling effects available across last-mile operations as each store needs to operate its own fleet. Grocery retailers prefer to keep the last-mile delivery within the company as the handling of grocery items and the final delivery and handover of items is seen as a delicate procedure by customers. OC grocery retailers therefore often invest in their own fleets for last-mile delivery.

This logistics network allows fast market coverage for grocers with a dense store network. For example, in Germany and Austria more than double the grocery stores per 1 million inhabitants are available compared to France or the UK. Consequently, in France and the UK grocery stores are larger and also further outside the city centers than in Germany and Austria [Nielsen, 2015].

> *We were losing market share, that's why we had to react quickly* [Company 8, Netherlands].
>
> *No additional pick-up points are necessary throughout the country due to the high density of our outlets* [Company 2, Germany]

From a market perspective this type is therefore best suited for regions where a broad customer base can be approached from stores within a short distance and online volume is low. Furthermore, the structure is especially suited for and used by cooperative organizations where every owner knows their local customers best and where there is only limited interest in a central and mutual online DC sharing investment costs. However, cooperative organizational structures limit the speed of implementing new network designs.

Type [1.2]: Additional solo pick-up points for online orders

Type [1.1] can be extended by adding solo pick-up points (see Figure 3).

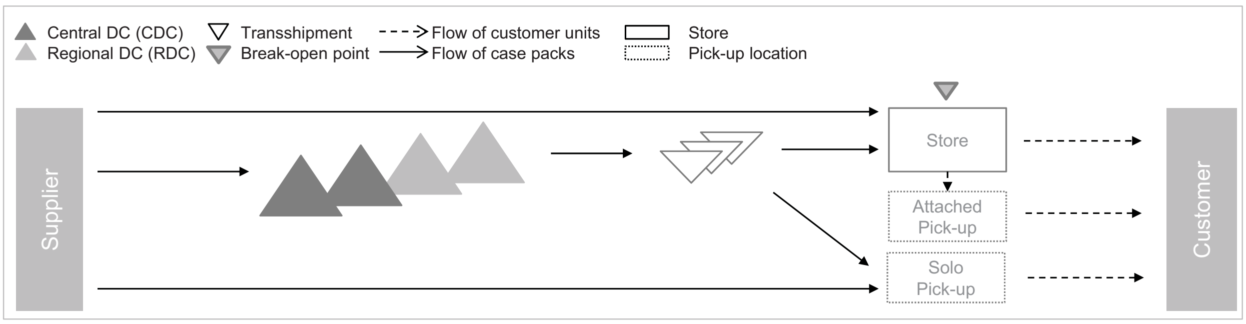

Figure 3: Type [1.2] – Pure pick-up of all online orders

Description. On top of the delivery to central and regional DCs and stores, suppliers also deliver selected product categories directly to solo pick-up points that have their own inventory. The solo pick-up points are often organized as drive-through stations and are mainly supplied from central and regional DCs with the same internal transportation systems used for store replenishment. At the solo pick-up points case packs are opened and items stored in customer units, where professional pickers take care for the order picking. Online order picking is done directly from store shelves by store employees at attached pick-up stations. Retailers can either only offer pick-up of products from pick-up points or additionally offer home delivery with vehicles from the store.

Analysis. While there is no duplicated inventory holding in online DCs, multiple inventory holding of customer units occurs at every solo pick-up station, leading to increased inventory holding costs. The inventory holding costs include capital costs, costs for the storage area, costs for overstocking (waste), and costs for understocking (out-of-stock). Only selected products are offered online because the DCs attached to solo pick-up stations do not have the facilities to offer all product categories such as ultra-fresh products like in the store, leading to a more limited assortment. However, this may not be an issue if customers only want to buy a selected assortment online for pick-up.

> *Up to 20% of total sales in unemotional categories like water, milk or other dry foods are bought via pick-up and drive-through stations. For other segments this is less than 1%* [...] *for example fresh fish or meat, because customers want to see, touch and feel the products before buying them* [Company 5, France].

Picking in DCs to supply stores and solo pick-up points is still possible in case packs, making joint transportation to stores and the pick-up points of the attached DCs concerned easier. However, the two-stage picking for single items for every online order (i.e., first in the regional DC and then additionally either in solo pick-up locations or in store) increases picking costs. The disadvantages of in-store picking remain for the pick-up stations attached to stores (see type [1.1]). Home delivery is usually unavailable with this type because solo pick-up points are set up to be close to the customer. However, retailers can also decide to deliver orders picked from store shelves or solo pick-up points to customer's homes.

> *French customers want to pick up groceries that they have bought online. We have tried home delivery but it does not work* [Company 5, France].

This concept is appropriate in markets where the pick-up of products is accepted because retailers save costs on the last mile and customers save shopping time. Whereas in the Netherlands (5.6%) or in Germany (16.8%) the percentage of households where both parents have a full-time job is relatively low, in France (41.4%) and in Portugal (66%) this number is significantly higher [OECD, 2015], leading to difficulties with attended home delivery and therefore to advantages with the pick-up option.

> *No-one is at home during the day to attend to home delivery. Women work in nearly every household, so they want to pick up online orders when they have the time for it. This is different in other countries such as Germany or the UK* [Company 6, France].

In addition, French customers are much more used to driving a longer distance to the next supermarket [Nielsen, 2015]. Even in markets where the home delivery of groceries is already widespread (e.g., the UK), retailers are thinking about steering customers towards pick-up solutions because this has major cost advantages (see also Wollenburg et al. [2016]).

> *At the moment we have 90% home delivery and 10% pick-up where online grocery orders are concerned. If we could start over, we would definitely promote pick-up more and try to bring customers to our pick-up stations and stores.* [...] *Our goal is to change these figures to 70% home delivery and 30% pick-up because this will enable us to save transportation and planning costs on the last mile* [Company 7, UK].

However, this logistics network is not appropriate when online order volume is low due to the high costs of investing in pick-up locations and the substantial inventory costs because of the risk of waste and inventory obsolescence in decentralized locations.

Table 3 summarizes the key features and the advantages and disadvantages of the network configuration [1].

Type	Main characteristics	Key advantages for logistics	Key disadvantages for logistics
[1]	• Stores supplied in large quantities and case packs by DCs • Online orders picked in store • Customers pick-up at store or receive home delivery from store	+ Efficient case picking in DCs + No investment cost for online DC + Shorter distances for home deliveries from stores	- Inventory allocation problem to online and store customers - Upscaling difficult with growing online volume - Customer and picker compete for products at in-store picking
Further features of subtypes			
[1.1]	• All online fulfillment processes start in store	+ Little investment cost for online fulfillment as logistics processes until store stay the same	- Low service levels in store may be insufficient for online orders; substitutions necessary
[1.2]	• Solo pick-ups supplied in large quantities and case packs by DCs • Online orders can also be picked in backroom of solo pick-ups • Customers can additionally receive order at solo pick-up	+ Possible synergies in joint supply of stores and pick-ups by DCs + Shorter distances to customers as solo pick-ups cover additional areas, i.e., build close to customers home	- Multiple inventory holding due to solo pick-ups - Multiple picking locations for online orders requires consolidation

Table 3: Summary of network configuration [1] ("Traditional bricks-and-mortar structures for online order fulfillment")

Network configuration [2]: Dedicated distribution center for online orders

In the second configuration an online DC is introduced to fulfill all or parts of online orders. The online DC may be used solely for home delivery orders (type [2.1]), for all online orders including the supply of pick-ups (type [2.2]), or for specific parts of an online order, whereby some product categories are added from stores (type [2.3]). In any case, case packs are divided into customer units earlier in the supply chain (i.e., in online DCs) compared to network configuration [1].

Type [2.1]: Online distribution center for home delivery orders

One or more online DCs are introduced to fulfill all home delivery orders, while pick-up orders are still fulfilled from stores (see Figure 4).

Description. On top of the supply of central and regional DCs and stores already mentioned (see network configuration [1]), suppliers also deliver directly to online DCs, which are usually smaller than central and regional DCs. Online DCs are additionally replenished from central and regional

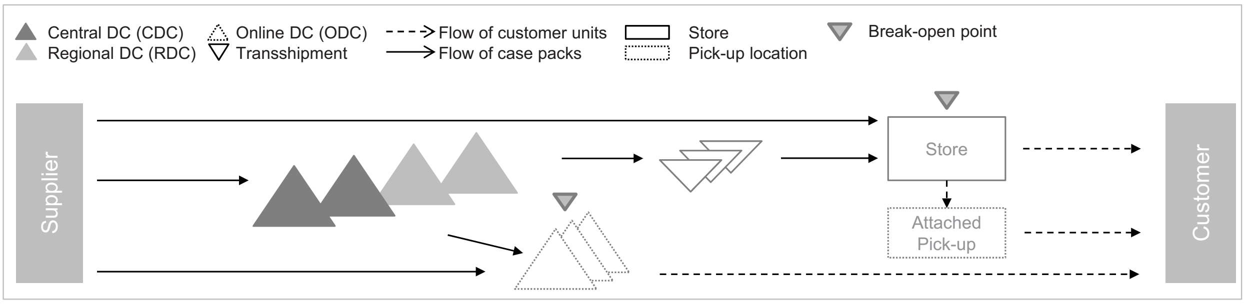

Figure 4: Type [2.1] – Online distribution center for home delivery orders

DCs like a bricks-and-mortar store using case packs, which are broken up and then stocked in customer units. Picking of online orders in customer units is completed here for home delivery. Multiple orders are stored in boxes of different temperatures and delivered in small vehicles, where the final order is assembled at the customers' home. Online orders for pick-up are still picked from store shelves and made available afterwards at the attached pick-up station.

Analysis. At online DC inventory holding, customers benefit from longer best-before dates on products ordered online because storage duration in the store is saved, while service levels due to inventory pooling effects in the online DC are usually higher than in store. However, the high initial costs for setting up the online DCs require a certain online order volume to amortize the fixed costs. Another cost factor is duplicated inventory holding to serve online orders in store for pick-up and in online DCs for home delivery. In addition, virtual shelf extension is not possible for all online orders. The store assortment limits the online assortment because pick-up orders are fulfilled from store shelves. The assortment offered online can only be tailored automatically according to the order fulfillment location in a second step if retailers retrieve the delivery information (i.e., order for home delivery or order for pick-up) from the customer in a first step of the purchasing process. Customers who order for home delivery may see a larger assortment than customers who order for pick-up. Furthermore, because the picking processes for home delivery orders are specialized in online DCs, more efficient picking of customer units can be accomplished here than in a store.
However, investments in picking technology for customer unit picking occur (e.g., automation), while in-store picking has disadvantages as pick-up orders are still picked in store. Having two picking locations for online orders at the same time, i.e., store and online DC, will lead to higher internal processing, coordination and transportation costs due to lower economies of scale.

On the last mile to customers, the capacity of delivery systems can be better utilized by capturing bundling effects across orders because the online DC serves a larger delivery area than a single store. These bundling effects may make it possible to uphold time windows for home delivery reserved by customers more economically using online DCs. However, delivery may ultimately involve greater transportation distances and longer lead times because stores are closer to customers' homes.

> *Either you are very fast with your delivery anyway, for example if you deliver direct from your stores, or you offer tight time windows for delivery* [...] *That is easier from online DCs due to better bundling of orders* [Company 11, Austria].

A higher number of online DCs allow shorter transportation distances to customers. Nevertheless, they will usually be greater than delivery from stores. A trade-off exists regarding centralization of the online DC accompanied by pooling effects and decentralization, where the proximity to customers and possible delivery of regional products has to be carefully considered, especially when regional differences of customers regarding product variety and affinity towards the products exist.

When online order volume is low, central and larger online DCs are appropriate especially on scattered markets, whereas decentralized and smaller online DCs should be set up in markets where big cities with a lot of potential customers can be approached within short distances.

> *If online order volume is low, retailers should focus on big cities with high population density for their home delivery. We only supply 30% of the country, but 70% of the population with fresh online products* [Company 12, Portugal].
>
> *The decision for or against an online DC or the decision that stores are sufficient for online order fulfillment is dependent on the density of the supermarket structure in a region and on the online order volume* [Company 8, NL].

Type [2.2]: Online distribution center for all online orders

In type [2.2] all online orders (i.e., pick-up and home delivery) are fulfilled from online DCs (see Figure 5).

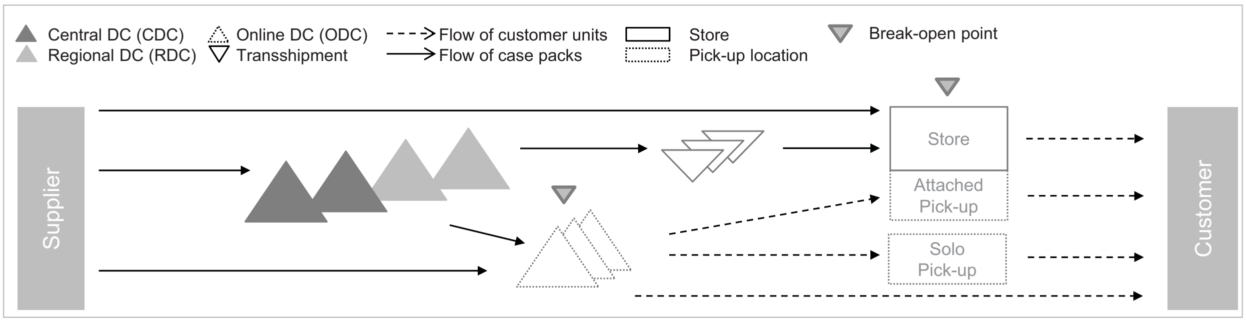

Figure 5: Type [2.2] – Online distribution center for all online orders

Description. This type is similar to type [2.1] in terms of most of the operational practices. The major difference is that the online DC also supplies all pick-up stations with online orders that are picked in customer units and transported in boxes. Multiple online orders are hence transported in boxes from different temperature zones to the various pick-up points (i.e., attached and solo pick-up) and to customers' homes. Stores do not supply any online orders anymore.

Analysis. Because inventory for all online orders is now stored in the online DC, only one stock for online items is necessary, thereby eliminating inventory holding of online items in multiple locations (i.e., stores). This increases service levels. The online channel can also provide a virtual shelf extension, offering an enlarged assortment online. There is no interaction of store customers and pickers in the store anymore. Retailers benefit from the learning and pooling effects of specialized picking for all online orders in the online DC. Despite the fact that picking in store for attached pick-up points increases picking costs (see type [2.1]), this decreases internal transportation costs. This is vice versa for the picking of every online order in the online DC, which has a positive effect on picking costs and a negative effect on transportation costs. The question is therefore whether picking efficiency in the online DC compensates for another intermediate transportation and processing step in the logistics network (i.e., regional DC to online DC to store/pick-up instead of regional DC to store/pick-up).

Type [2.3]: Hybrid store and online distribution center for online order fulfillment

In this type orders are fulfilled from both online DCs and stores together depending on the content of the online order (see Figure 6).

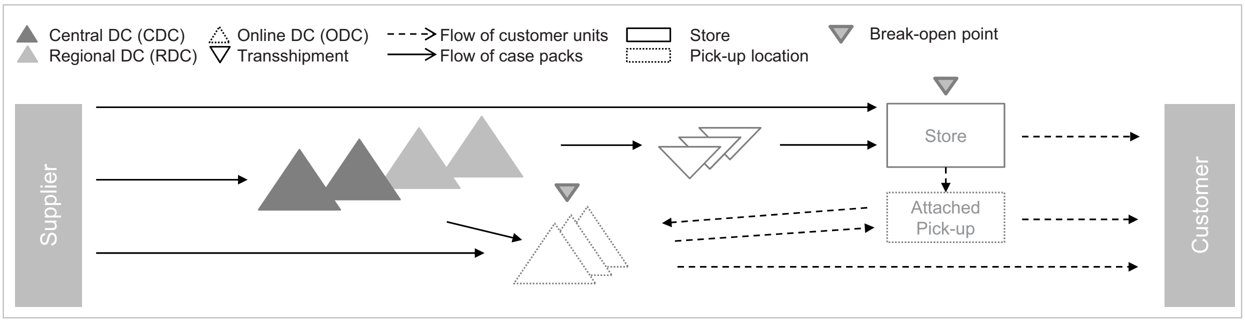

Figure 6: Type [2.3] – Hybrid of store and online distribution center for online order fulfillment

Description. Warehousing in central and regional DCs and online DCs is the same as in type [2.1], and online orders are picked in online DCs and stores. The majority of products sold online are picked from online DCs, whereas the remainder are added from stores. Ultra-fresh products in particular (e.g., unpacked fish, meat or fresh bakery goods) is picked in stores because stores are already directly supplied with this commodity group. A broad assortment range, including ultra-fresh products, can therefore be offered online.

> *In the online DC 5,000 - 7,000 fast-movers are picked, representing approximately 85% of products sold online. The remaining 15% come from store, especially counter products like fresh meat and fish. For the final assembly of an order, the products are transported from the online DC to the store* [...] *or the other way around depending on where the customer lives* [...]. *Afterwards the order is brought to the customers' home in a multi-compartment vehicle* [Company 12, Portugal].

Items ordered online are transported internally either from online DCs to stores or vice versa. The online orders are assembled either in store or in online DCs, depending on the order location, and the products ordered are then transported to the pick-up location or to the customers' home. If an online order consists solely of products stored in online DCs then the order is fulfilled in full from there. Stores therefore mainly act as hubs in city centers where specific items (e.g., ultra-fresh products) are added to complete an online order from online DC.

Analysis. This hybrid solution can achieve inventory pooling effects between stores and the online DC, leading to high service levels. There is no need for additional inventory holding of ultra-fresh products in online DCs because those products can be added to online orders from store. This significantly reduces the waste for this product category. A broad assortment including ultra-fresh products can be offered online and stored partly in store and partly in the online DC. In addition to the remaining disadvantages of in-store picking (see type [1.1]), more repacking and repicking of customer units is necessary because of the two different picking locations for online orders. Transportation costs are also higher because of the additional transportation between the online DC and stores. This logistics network can be used especially in markets with a high population and store density, where the stores can serve as hubs for last-mile deliveries. The hybrid approach is also meaningful in markets where customers do not buy prepackaged meat, fish or cheese, and also want ultra-fresh products online. While some retailers are already using this network structure, it is a future scenario for others.

In the future, about 80% of items could be stored and picked outside big cities in a highly automated manner. They are then transported to a store or another hub in the cities and the remaining 20% of an order, for example meat, fish or bakery goods, are added directly from store [Company 2, Germany].

Network configuration [2] can be summarized in Table 4 which describes the main features of type [2.1], [2.2] and [2.3].

Type	Main characteristics	Key advantages for logistics	Key disadvantages for logistics
[2]	• Introduction of an online DC where case packs are broken up and stored in customer units	+ Centralized online inventory improves service and freshness level and holding costs + Specialized picking of customer units in online DC	- Two-stage picking at regional and online DC - Disadvantages of in store picking for pick-ups remain - Longer distances from online DC to customers homes compared to delivery from store
Further features of subtypes			
[2.1]	• Home deliveries fulfilled from online DC and pick-up orders from store	+ Replenishment of stores stays the same; no other stream of products is delivered to store	- Customer and picker compete for products at in-store picking
[2.2]	• All online orders are fulfilled from online DC (including pick-up orders)	+ Possible virtual shelf extension + Better utilization of transportation capacities for home delivery	- Higher transportation costs to supply attached pick-up points
[2.3]	• Majority of online ordered products picked in online DC, remainder added in store • Transportation of products between online DC and store in both directions	+ Possible virtual shelf extension + Inventory pooling effects between stores and online DCs leads to higher customer service levels + Special products of online order (e.g., ultra-fresh) can be added in store	- Customer and picker compete on products at in-store picking - Higher transportation costs to supply attached pick-up points and for reverse flows to online DC

Table 4: Summary of network configuration [2] ("Dedicated DC for online orders")

Network configuration [3]: Integrated distribution center for all orders

Network configuration (and type) [3] integrates regional DC and online DC for fulfillment of all online and store orders (see Figure 7). This may be a future scenario for some retailers, but it is already an existing solution under certain settings and for certain regions (e.g., big cities) and retailers with small store formats (i.e., convenience stores, mom-and-pop stores, nanostores, etc.). The supply of supermarkets and hypermarkets is therefore not considered in this type.

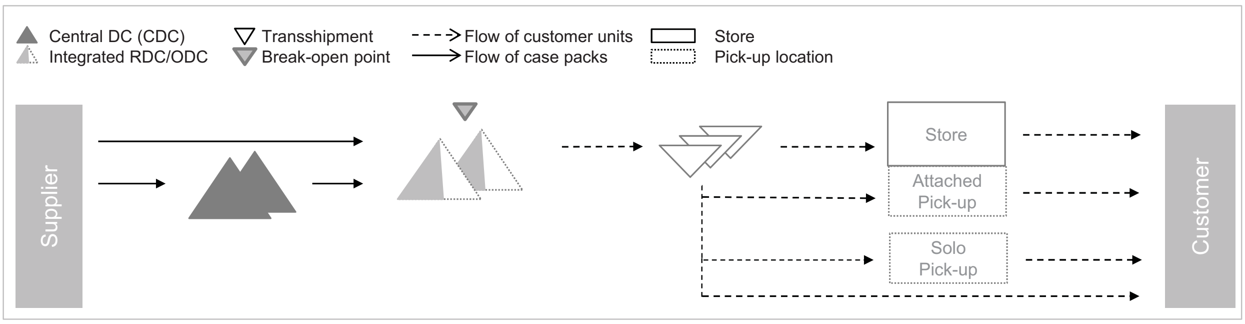

Figure 7: Type [3] – Full integration of regional- and online distribution center for all orders

Description. After reception of products from suppliers and central DCs, all items are stored on a customer unit basis and not in case packs in an integrated DC that supplies convenience stores, pick-ups and customers directly. Store and customer orders are picked in parallel or sequentially from the same inventory. Convenience stores have a selected assortment range focusing on the presentation of specific grocery products (e.g., ultra-fresh products).

> *It is possible to have only select products in smaller stores presented really well, and all products online where presentation is not important* [Company 9, NL].
>
> *Convenience stores with a select assortment will serve as a pick-up location* [...] *joint warehousing and transportation for both channels is possible.* [Company 4, Germany].

The items can be delivered jointly on one tour with the identical multi-temperature vehicle to the small stores, pick-up locations as well as to customers' homes.

Analysis. Retailers can offer a large assortment online for pick-up (or home delivery) that is stored in integrated DCs with a high service level. The joint inventory allows pooling effects for online and store items. It is also possible to replenish convenience stores in a demand-actuated manner in customer units, which reduces the waste in stores.
However for items such as dry food it is very expensive to unpack and store everything in customer units rather that in case packs for store replenishment. Investments are necessary to rebuild regional DCs or build new online DCs and set up the associated picking processes to fulfill small order sizes. On top of this, DC picking in customer units – also for stores – reduces picking efficiency. For internal transportation and on the last mile to the customer, only one kind of multi-compartment vehicle is necessary that can fulfill home delivery, pick-up and convenience store orders. Transportation costs per unit for store delivery are higher due to greater delivery frequency and small volume deliveries. Delivery times for stores and customers also differ. Stores are usually replenished in the morning while customers want their products delivered in the evening. The joint transportation of products is therefore only possible for small stores where store replenishment fits in the smaller vehicles and store and customer delivery times match each other (e.g., early delivery of convenience stores and afterwards a two-hour time slot for delivery to customers near the store). In this case it may be possible to achieve higher store delivery frequency.

Completely integrated DCs have a number of prerequisites if they are to be operated efficiently. First of all, this is beneficial in markets with a dense customer population and expensive rental fees that foster a greater number of small store formats. Secondly, the order sizes and delivery windows for stores and customers should be close. Finally, a high online order volume is required to accommodate the changes in the warehouses. For example, in the UK grocers are thinking about applying this logistics network structure in specific regions like London where the city center is congested with a dense population for home delivery. The assortment range is reduced (e.g., by 11% at Tesco, 6% at ASDA, 4% at Sainsbury's) to support smaller store formats [IRI, 2015] and supermarkets and hypermarkets are being remodeled as convenience stores (e.g., Carrefour Express, Sainsbury's Local, Tesco Express). Furthermore, in emerging markets convenience stores or nanostores are already the standard store format. Here case packs are unpacked at a DC level and products are mostly delivered to the stores in small unit sizes (see, e.g., Albán et al. [2015]).

Table 5 summarizes the main features of network configuration [3].

Contingency factors and configuration approaches for OC grocery networks

In this section we aggregate our empirical findings to articulate patterns and profiles in the design of retail networks for multiple channels. This is a step towards the generalization of our findings. However, one needs to note that the generalization is restricted to the product and logistics specifications in grocery retailing (e.g., temperature control, large orders) in comparison to non-food

Type	Main characteristics	Key advantages for logistics	Key disadvantages for logistics
[3]	• DCs supply convenience stores and fulfill online orders • All products are stored in customer units in regional DCs • Parallel or sequential picking across all channels	+ Centralized inventory improves service and freshness level and holding costs + Possibility for joint transportation of orders for convenience stores, home delivery and pick-up	- High cost for storing and picking everything in customer units and rebuilding regional DCs for online fulfillment - Delivery times and frequencies of store and online orders differ, making joint delivery complex

Table 5: Summary of network configuration [3] ("Integrated DC for all orders")

retailing. We develop the patterns and profiles from a contingency perspective (see Lawrence and Lorsch [1967], Scott and Cole [2000]) and apply additionally a configuration approach (see Miller [1986]) to go in more detail into how the different factors work together in network configuration (see Flynn et al. [2010]] for a similar approach). We aggregate the contingency factors from our empirical findings in two overarching dimensions that determine the network configuration. We also identify a development path that depends on these two dimensions. The first dimension expresses the (1) capabilities in online fulfillment. The second determines the (2) online order volume itself and in terms of OC retailing especially the shift from bricks-and-mortar towards online retailing.

(1) ***Capabilities in online fulfillment*** The required capabilities in online fulfillment are impacted by different factors. The most crucial factor is the *up- or down-stream position* of the break-open point which defines where online orders are being picked. A downstream break-open point allows operating with lower capabilities in online fulfillment, whereas an upstream position needs high process proficiencies. Setting the break-open point downstream in the supply chain means picking all or most online orders at the store. Instore picking does in general not require complex logistics systems. For last-mile delivery, vehicles and customers are allocated to a store. This simplifies routing, but results in less synergies in last-mile transportation capacities. Setting the break-open point upstream in the supply chain requires online DCs and therefore significant investments into structures and capabilities, especially in the picking processes for customer units. Secondly, the development of logistical capabilities is influenced by the *organizational structure*. For example, decentralized organizations like cooperatives have more and higher hurdles to cross when implementing centralized online solutions. Regional differences in product variety, affinity of customers and cultural differences (e.g., French customers prefer pick up while British customers prefer home delivery) limit a direct transfer of a successful fulfillment concept between markets. Another consideration in online grocery retailing is *trust in safe handling of products* is important. Most OC grocers therefore deliver their products with an own fleet instead of using logistics service providers. As a forth contingency factor *store sizes* and *replenishment frequencies* impact the logistical capabilities. In types [1.1] to [2.3], separate *picking processes* across the channels are either conducted in case packs for stores or in customer units for the online channel. This is different in type [3], where small stores and customers are supplied in customer units, which allows a combined picking and transportation. Also, the possibility of *joint forecasting* of online and store orders influences online logistics capabilities and costs. Finally, a further contingency factor is the companies' *assortment policy* and the option to extend the store assortment with a virtual shelf. This can only be operated efficiently if dedicated online DCs are implemented.

(2) ***Online order volume*** The shift from bricks-and-mortar to online sales forces retailers to reconfigure their networks. The online share depends on *geographical location* (urban vs. rural), *density and size of stores* within the region as well as *competition intensity*. Furthermore, specific customer requirements for certain product categories have to be considered (e.g., ultra-fresh products also in online channel). Customer satisfaction with the OC setup,

availability and efficiency of *different delivery services* like pick-up, tight time windows and a high delivery velocity influence online volume as well as *customers willingness to pay* for these services.

Summary of network development directions. Figure 8 shows at an aggregated level the network patterns, its dependencies and its developments. Overall, the online order volume drives the network development, and with an increased willingness of customers to buy online, investments into online fulfillment capabilities are made. In a first phase, mainly bricks-and-mortar structures are used for the fulfillment of all channels. For the final customer delivery or pick-up, product flows are kept together as long as possible (see network [1]). In a second phase, channels are separated by opening an online DCs for the fulfillment of this particular channel (see network [2]). In a third phase, when online volume accounts for a significant share of sales, retailers reconsider merging online and bricks-and-mortar logistics. Certain stores (e.g. convenience stores) can be supplied together with customers (see network [3]). The development from phase 1 to phase 3 goes along with increasing logistics capabilities and thus efficiencies. While a general development from phase 1 to phase 3 can be observed, this does not necessarily mean that all OC grocery retailers develop in any case from 1 to 3 or pass through all phases in their development cycle.

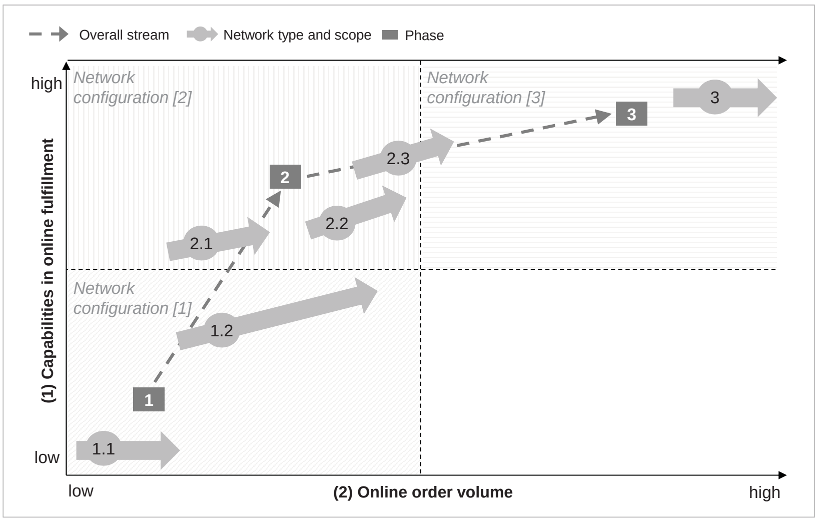

Figure 8: Patterns and development directions of retail logistics networks (conceptual view)

Discussion

In this section the main findings are discussed in the light of literature in three areas. (I) First differences in OC grocery and OC non-food logistics are highlighted. (II) Second the interrelation of different subsystems is discussed (e.g., warehousing and last-mile delivery). (III) Finally we discuss the patterns and development options identified.

(I) We identified six types of logistics networks for OC grocery retailing. Significant differences between OC grocery logistics networks and OC non-food logistics networks exist. The *implication for theory* is that characteristcs of OC non-food networks can only be applied to OC grocery networks to a very limited degree. While an online grocery order consists of more than 60 different items on average, an average online shopping basket in non-food retailing (e.g., fashion, electronics) consists of only 1 - 3 items [Fernie and McKinnon, 2009; Hübner et al., 2016c]. Additionally, the larger assortment sizes in grocery stores result in larger warehouses, larger picking distances and ultimately in higher picking costs in grocery than in non-food. Hence, picking and the associated processes, number of stages and locations play a much more decisive role in the entire grocery supply chain. While grocery online orders need to reach the customer as soon as possible (because of the perishability of items and customer expectations), next-day delivery is sufficiently in non-food retailing in most cases [Hübner et al., 2016a]. A higher number of decentralized warehouses are therefore necessary in OC grocery logistics compared to more centralized DCs in non-food retailing. Non-food orders are exclusively delivered from logistics service providers, while former pure bricks-and-mortar grocers build up their own fleet for last-mile home delivery.

Moreover, in grocery existing bricks-and-mortar logistics structures are partially used for online fulfillment but the ultimate goal for grocery retailers is not – as for non-food retailers – to have one common warehouse with one stock for bricks-and-mortar and online grocery items. This can be the case in a specific retail setup with only small stores, but is not the norm. Logistics is only integrated across channels up to the break-open point. However, existing OC literature sees the integration of both channels as the ultimate goal for retailers (e.g., Fisher [2013]; Verhoef et al. [2015]). This is seen to be necessary in terms of market presence and customer interfaces (e.g., Brynjolfsson et al. [2013]) and for operations and logistics (e.g., Hübner et al. [2016c], Ishfaq et al. [2016]). However, existing literature does not differentiate between grocery and non-food logistics, and neglects grocery specifics such as temperature zones, picking complexity, shorter lead times, etc. What is referred to as OC logistics is in fact mostly OC *non-food* logistics.
As an *implication for practice*, we identified that a more differentiated picture of logistics integration – identifying the particularities of OC grocery logistics and channel integration – is required. We show that grocery characteristics prevent the direct transfer of non-food structures to grocery retail logistics networks. Grocers are encouraged to review the different network configurations and to select the most appropriate one for their setting.

(II) All subsystems in the supply chain areas play an important role in the network design, costs and service levels. However, current literature has predominantly analyzed the subsystems individually. An *implication for theory* from our empirical findings is that warehousing, picking, internal transportation and last-mile delivery are interrelated in OC retailing and therefore need to be analyzed together. On the last mile, a higher number of shipment locations (i.e., stores instead of online DCs) enable shorter delivery lead times to the customer. This can also have a positive effect on the transportation costs due to bulk deliveries with larger vehicles to supply these shipment locations (instead of direct deliveries of customers from remote warehouses with smaller vehicles). However, if shipped from many decentral locations, there are fewer options to bundle transportation capacities for the last mile and hence lower economies of scale (e.g., vehicles are not well/fully utilized). The same holds true for inventory efficiency. Decentralized inventories with multi-stage picking processes, low picking volume in each location or less efficient picking in the store drive picking and inventory holding costs. When comparing deliveries from store with delivery from an online DC, the benefits of fulfillment from stores (i.e., mainly smaller distances, no investment costs) therefore need to be offset by higher picking costs per unit, lower bundling effects and lower utilization of delivery vehicles. To overcome the high last-mile delivery costs, some retailers only offer pick-up of online orders. However, this results in high investment costs in solo pick-up stations. The resulting multiple inventory locations (i.e., for each solo pick-up station) lead to higher inventory holding costs as well.

The existing literature gives a short but incomplete overview of how stores and DCs can also be used for online grocery fulfillment (e.g., Kotzab and Madlberger [2001]). Country specifics like the solo pick-up stations in France [Colla and Lapoule, 2012; Vyt et al., 2016] or barriers for online grocery fulfillment in Germany [Grant et al., 2014] are described without giving a holistic and supply-chain wide view on OC logistics networks. Similarly, Hübner et al. [2016b] focus predominantly on online grocery fulfillment but do not develop a complete end-to-end picture of OC logistics networks. The literature often focuses solely on the aspect of how products can be handed over to the customer in the case of online grocery retail, i.e., via attended or unattended delivery (e.g., Kämäräinen et al. [2001], Boyer et al. [2009]). In the case of attended delivery the customer needs to be available at the doorstep to receive a product. When delivery is unattended (i.e., reception box, delivery box, pick-up stations), grocery orders can be distributed according to a fixed route without running the risk of having to approach customers multiple times (e.g., Punakivi et al. [2001]). However, the total travel distance and transportation costs are also dependent on where central and regional DCs, online DCs and stores are set up, which also influences delivery speed and potential frequency. It is not sufficient to just consider the last-mile costs. A further *implication for practice* is, that a total cost perspective for OC grocery retailers is essential in evaluating their OC logistics without focussing on one aspect of their supply chain (i.e., only the last mile). Retailers can base their network choice on the analyzed (dis-)advantages of the various configurations. This will help to get a supply chain-wide view on OC structures.

(III) With this in mind, we also show that logistics networks are not only planned based on logistics parameters such as cost savings, transportation distances or operations synergies (see e.g., Teo and Shu [2004], Piotrowicz and Cuthbertson [2014]), but also by considering product, customer and market characteristics (see, e.g., Rao et al. [2009]). The *implication for theory* in OC grocery retail logistics is the identification of different network configurations, influenced by various contingency factors, as well as the evolutionary process from one network configuration to another. In an evolutionary process the fulfillment of online orders via stores (network [1]) is an entry model (see, e.g., Hays et al. [2005]). In most cases separation processes start as online order volume grows. Online DCs are then used for at least parts of the online fulfillment after online volumes exceed a certain level (network [2]). The complete integration of all warehousing, picking and distribution processes can be advantageous in specific settings as well (network [3]). Current studies related to logistics across channels are based on investigations of individual countries (e.g., Colla and Lapoule [2012], Hübner et al. [2016b]). However, regional differences in OC grocery shopping exist even within countries, driving different concepts in densely populated areas and in the countryside. Each OC grocery retailer will therefore need to apply distinct logistics networks (see types [1] to [3]) for different regions and formats. A further *implication for practice* is that grocery retailers need to be aware that there is not one clear solution similar to the integration of channels in OC non-food logistics (e.g., Hübner et al. [2016c], Ishfaq et al. [2016]). Particular market developments, diverse customers and varying online order volume need to be factored in to the network design. Our heterogeneous sample contributes to an understanding that retail network design structures in all OC grocery companies have to be adapted accordingly. The contingency factors and underlying theory of omni-channel grocery logistics network design serve as decision support for managers of retail companies to decide which logistics network to use under which circumstances.

Conclusion and future areas of research

The dynamic of the OC phenomenon means that it is "necessary to continuously investigate new developments to understand it" [Bernon et al., 2016]. We therefore apply a supply chain-wide view to OC logistics network structures in the field of grocery retailing that has not yet been explored. This paper contributes to the area of OC grocery logistics by providing a typology and contingency factors for logistics execution. Our heterogeneous sample reveals that grocery retailers use different warehousing, picking, internal transportation and last-mile delivery systems depending on product, customer, market and retailer specifics. Whereas in the field of OC non-food retailing, logistics integration is mostly seen as beneficial (e.g., Verhoef et al. [2015], Hübner et al. [2016c]), a definitive answer cannot be given for OC grocery logistics.

Although we began discussing demographic structures, i.e., customer and market differences that differentiate the application area of the different logistics networks, future research could validate our findings by incorporating more data from a market survey (such as customer perceptions from different countries and regions). A detailed cost/benefit analysis is also lacking. Future research could quantify our qualitative and exploratory findings by assigning retailers' costs and sales data from the different channels to the typology we have developed. In addition, longitudinal research could be conducted by repeating our results in five to ten years to analyze development stages in OC grocery logistics due to order volume changes and shifts from one channel to another. On that note, the contingency factors and configurations which are highlighted to serve as decision support for retail managers could be further enhanced, embedded into the general networks theory and tested in future research. However a cross-country analysis is mandatory as the fulfillment models differ significantly by region. Moreover, when former pure online grocers develop bricks-and-mortar logistics structures to become capable of providing "omni-channel" service, the question arises as to whether the logistics structures will be similar to those of former pure bricks-and-mortar grocers or different.

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