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Contextual adaptation of omni-channel grocery retailers' online fulfilment centres

Ebba Eriksson, Andreas Norrman and Joakim Kembro
Department of Industrial Management and Logistics, Lunds University, Lund, Sweden

Abstract

Purpose – The purpose of this paper is to investigate how grocery retailers configure their online fulfilment centres (OFC) as they move towards an omni-channel structure and what contextual factors influence their decisions.

Design/methodology/approach – An exploratory case study with three grocery retailers in the Nordic countries was conducted. The study investigates the current OFC configurations and identifies nine important contextual factors.

Findings – This study shows the importance of understanding the changes that omni-channel retailing entails for an OFC configuration. Nine contextual factors were identified. Several of the factors are found in previous theory, but this paper extends the knowledge of how they affect the configuration of an OFC in grocery retail. The changes in, for example, order characteristics create different requirements for picking, packing, sorting and shipping when compared with traditional distribution centres (DC). Although representing a separate flow for online fulfilment, OFC configuration depends on how the other logistics flows from the DC to stores are designed.

Research limitations/implications – To support further theory development, nine contextual factors and their relationship to OFC configurations are proposed.

Practical implications – This study provides managerial value in two ways. First, grocery retailers with one or more OFCs can benchmark existing solutions using the empirical case descriptions. Second, the findings provide grocery retailers with knowledge of how to configure an OFC.

Originality/value – The literature lacks a holistic approach towards how grocery retailers configure their OFCs and what factors affect these decisions. This study provides the first in-depth analysis of how the omni-channel context affects the configuration of all the aspects of an OFC.

Keywords Warehousing, Grocery retail, Case study, Contextual factors, Omni-channel, Distribution centre, Online fulfilment centre, E-fulfilment centre, Dark store, Sorting

Paper type Case study

Introduction

The retail industry is currently going through a digital revolution with a rapid shift towards a mix of physical store and digital online sales, an integration often referred to as omni-channel retailing (Blut *et al.*, 2018; Galipoglu *et al.*, 2018). Customers expect flexibility when and where they can shop, receive and return products while also wanting high product availability and real-time information updates (Piotrowicz and Cuthbertson, 2014; Beck and Rygl, 2015). These changes have been evident across several retail sectors since the early 2000s. An exception is the grocery sector, which has been lagging behind and only recently has started to see growth in online sales coupled with increasing customer demands for an omni-channel experience (Hübner, Kuhn and Wollenburg, 2016).

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The grocery sector has been slow to adopt omni-channel for several reasons. Particularly, the threshold for consumers to buy online seems to be higher in grocery. Customers are used to see, touch and smell the product, and buying online implies that the customer must rely on the retailer to select products of acceptable quality (Boyer and Hult, 2006). Furthermore, activities related to storing, picking and arranging home deliveries of groceries are more complex and expensive compared to other products such as fashion and home electronics (Wollenburg *et al.*, 2018). Grocery retail is characterised by large assortments with a wide range of product characteristics, such as differences in weight, size and fragility. Grocery retailers also manage goods from three different temperature zones including frozen, fresh and ambient, and must ensure that the cold chain is intact from production to final delivery (Smith and Sparks, 2004). Many of the omni-channel challenges for grocery retailers thus emerge in the logistics network where retail marketing meets operations. The challenges are especially related to material handling and distribution, i.e. the back-end logistics for getting the right products to the right place at the right cost in the right quality (Boyer *et al.*, 2009).

A critical component of logistics and for providing the omni-channel experience to consumers is the configuration of the distribution centre (DC) (Kembro *et al.*, 2018). The DC plays a key role in fulfilling customer orders and has a large influence on both logistics costs and service levels (Faber *et al.*, 2018). In the omni-channel era, many retail sectors have integrated store replenishment and online fulfilment into one DC. In grocery, however, retailers (e.g. in the UK and Nordic countries) have decided to separate the handling of online orders in a new type of DC called an online fulfilment centre (OFC) (Marchet *et al.*, 2018; Wollenburg *et al.*, 2018), which, in practice, is often called "dark stores". The reasons behind using separated OFCs in the grocery sector are, for example, the differences in terms of order lines, order volume, handling units and customer requirements between store replenishment and online shopping.

The idiosyncrasies of grocery retail create specific requirements regarding the configuration of an OFC. However, there is little research on this topic (cf. Kembro *et al.*, 2018). Research has mainly focused on the network perspective (De Koster, 2002; Wollenburg *et al.*, 2018), and the few studies that discuss the configuration of an OFC primarily consider the picking operation (cf. Kämäräinen *et al.*, 2001; Fernie *et al.*, 2010; Hübner, Kuhn and Wollenburg, 2016). This knowledge gap is of concern for grocery retailers considering the difficulty in transferring the findings from research on non-food retailers to grocery retailers (cf. Wollenburg *et al.*, 2018). OFCs also differ from traditional grocery DCs in terms of demand patterns, order structure and customer expectations, which increases the difficulty in applying studies' findings on the configuration of DCs.

The purpose of the current study is to investigate how grocery retailers configure their OFCs as they move towards adopting an omni-channel structure and what contextual factors influence their decisions. A contingency approach (cf. Donaldson, 2001; Kembro *et al.*, 2018) is applied in a multiple case study (cf. Yin, 2014) of three Nordic grocery retailers to explore the relationship between contextual factors (e.g. customer demand and order characteristics) and OFC configurations. Based on our theoretical background and conceptual framework, we analyse the collected data and discuss the implications for grocery retailers. Finally, we present conclusions and suggest avenues for future research.

Related literature

Omni-channel logistics in grocery retail

Grocery retail is an industry characterised by low product margins and a large product range (Holzapfel *et al.*, 2016). The product range, which often requires larger warehouses (Wollenburg *et al.*, 2018), comes with different physical characteristics (size, weight and fragility) that have a great influence over storage and picking strategies (Chabot *et al.*, 2017).

Another idiosyncrasy of grocery retail is the different temperature requirements (e.g. frozen, chilled and ambient), which can be defined by law (e.g. for frozen products) or applied to increase quality (e.g. for longer shelf-life) (Ostermeier and Hübner, 2018). Critical perishables require a high number of store delivery frequencies and short replenishment lead times, while other segments, such as slow-moving ambient products, can have longer lead times and lower delivery frequencies (Kuhn and Sternbeck, 2013).

Knowledge about omni-channel logistics in grocery retail is limited. One reason for this is that omni-channel retailing in general is often explored from a marketing and strategic perspective, seldom from a logistics perspective (Galipoglu *et al.*, 2018; Kembro *et al.*, 2018). Further, the specific characteristics of grocery retail hampers a direct transfer of results from non-food retailing (cf., e.g. Agatz *et al.*, 2008; Hübner, Wollenburg and Holzapfel, 2016). Third, few studies have examined omni-channel logistics in the grocery sector; only five of the articles (de Koster, 2002; Boyer *et al.*, 2009; Enders and Jelassi, 2009; Colla and Lapoule, 2012; Hübner, Kuhn and Wollenburg, 2016) reviewed in Galipoglu *et al.* (2018) examine this specific topic and context.

The literature on omni-channel logistics in grocery retail mainly addresses two aspects. One is the final delivery destination (home, store or pick-up point) and the alternatives for last-mile distribution (cf., e.g. Punakivi and Saranen, 2001; Boyer *et al.*, 2009). The other aspect relates to where in the logistics network the online customer order will be picked (cf., e.g. Enders and Jelassi, 2009; Colla and Lapoule, 2012). The main alternatives of where to pick online orders include: existing retail stores, existing DCs or new OFCs (Hübner, Kuhn and Wollenburg, 2016; Wollenburg *et al.*, 2018). However, unlike non-food retailers (Cao, 2014; Hübner, Wollenburg and Holzapfel, 2016), grocery retailers avoid using integrated DCs and instead invest in a new OFC to handle increased e-commerce (Wollenburg *et al.*, 2018).

Comparison between DC and OFC

DCs typically have high turnover rates and fast throughput (Kembro *et al.*, 2017). An OFC differs from the traditional retail DC in that it only fulfils orders from consumers (Higginson and Bookbinder, 2005). This difference is important because customer characteristics have implications for the configuration of the warehouse (Faber *et al.*, 2018). As an example, traditional European grocery DCs are used for store replenishment (Broekmeulen *et al.*, 2017) and commonly apply roll-cage sequencing, meaning that trucks are loaded according to the receiving store's layout (Hübner *et al.*, 2013; Kuhn and Sternbeck, 2013). Therefore, the layout of such a DC must mirror the store's layout, which typically is designed for displaying products, not for the efficient picking of an online order (Hübner, Kuhn and Wollenburg, 2016). In contrast, an OFC caters to online customers, meaning that the layout can ignore marketing perspectives and instead focus on maximising picking efficiency (Kämäräinen *et al.*, 2001).

Another difference between a DC and OFC relates to the order characteristics. There are differences between store replenishment and online shopping in terms of order volume, number of order lines and demand uncertainty (Hübner, Wollenburg and Holzapfel, 2016; Wollenburg *et al.*, 2018). Related products are commonly picked in their secondary packaging in a DC and in their primary packaging in an OFC (Kuhn and Sternbeck, 2013; Broekmeulen *et al.*, 2017). Hence, the secondary packages are broken up in the OFC, and the items are stored in their primary packages (Wollenburg *et al.*, 2018). Furthermore, store replenishment orders are delivered according to a predefined delivery pattern (Sternbeck and Kuhn, 2014), whereas shipping to the consumer's home is more complex (Higginson and Bookbinder, 2005). The planning of the shipping route in an OFC must take a larger number of final destinations and delivery times into consideration (Kembro *et al.*, 2018).

Contextual adaptation of OFC configuration in grocery retail

The differences between a DC and OFC, as well as the idiosyncrasies of grocery retailing, are important to consider for the configuration of warehouse operations and design. The importance of context has gained increased attention in recent years (cf., e.g. Faber *et al.*, 2018; Wollenburg *et al.*, 2018), and research has discussed factors such as market, product and order characteristics (cf., e.g. Rouwenhorst *et al.*, 2000; Faber *et al.*, 2018). We build on the conceptual framework presented by Kembro *et al.* (2018) to present a framework for the analysis of OFC configuration, as shown in Figure 1. Typical warehouse operations include receiving, put-away and storage, picking and sorting and packing and shipping (Bartholdi and Hackman, 2016). Design aspects include the physical layout, for example, aisle configuration, lane depth and stacking height (Huertas *et al.*, 2007); storage and handling equipment, for example, different types of racks and forklifts (Rouwenhorst *et al.*, 2000); automation solutions, for example, conveyors and robots (Baker and Halim, 2007); information systems, for example, warehouse management systems (Kembro *et al.*, 2017); and decisions related to labour management, for example, scheduling, rotation and shifts (de Leeuw and Wiers, 2015).

Methodology

Case selection and overview of the case companies

To address the purpose of the current study, we conducted an exploratory case study (cf. Voss *et al.*, 2002; Flyvbjerg, 2006; Yin, 2014) with three grocery retailers in the Nordic countries. From a sampling perspective (cf. Patton, 2002), the Nordic countries are interesting to study because they represent a homogenous market context with a high degree of competition among retailers, as well as rapid growth and investments in online sales channels (PostNord, 2017). Furthermore, the three retailers (referred to as Alpha, Beta and Gamma to ensure confidentiality) are among the largest brick-and-mortar grocery retailers in the region and represent the frontline development in Nordic grocery omni-channels.

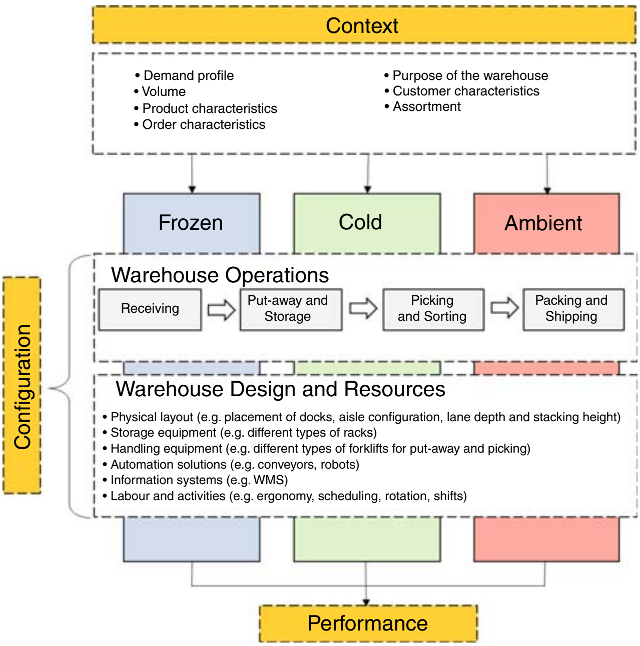


Figure 1. Conceptual contingency framework for warehouse configuration

The selected retailers (Table I) are similar in the sense that they have multiple stores that are dispersed over a large geographical area. The consumers in all of the cases are demanding the addition of online stores that have full-scale assortments, they prefer to be able to choose which products they want to purchase (i.e. not predefined dinner solutions), and they want to have the option to get their products delivered to their homes. Hence, all the retailers recently introduced OFCs to their distribution networks. The three cases describe OFCs where the total volume handled through the warehouse is still low and where the development of the warehouse operations and design is characterised by trial-and-error approaches. Meanwhile, the three cases represent different contexts in terms of, for example, organisational setup, geographical location, market coverage and the development stage of the online sales platform. For example, Alpha decided to separate its online brand from its existing range of retail chains, while Beta and Gamma have fully integrated online and existing (single) store brands. Alpha has operated its OFC for five years, Beta has conducted its OFC for one year and Gamma's OFC has been up and running for less than six months. Furthermore, Alpha serves its entire market from its OFC and does not utilise its stores for online fulfilment. Beta and Gamma use their OFCs to cover urban regions and utilise their store networks for order fulfilment in other regions. The described similarities and differences between the selected cases are thus interesting for understanding the relationship between the various factors and design requirements of OFCs in the grocery context.

Data collection and analysis

The case study approach allowed for the triangulation of multiple data sources. First, an exploratory survey was conducted focusing on the following: current and future logistics

	Alpha	Beta	Gamma
Organisation and strategy			
Ownership structure	Cooperative	Cooperative	Independent stores that own core functions together
Retail chains and store formats	Several different retail chains and store formats	One retail chain and several store formats	One retail chain and several store formats
Online brand	Online brand is separated from the store brand	Online brand is integrated with the store brand	Online brand is integrated with the store brand
OFC categorisation in internal organisation	Store	Store	Store
Logistics network			
Online order fulfilment	From OFC	From OFC and from selected stores	From OFC and from all stores that choose to offer online
Number of OFCs	One	One	One
Market coverage for OFC	The entire market	Urban region	Urban region
No. of years with an OFC	Five years	One year	Less than six months
Major supplier for OFC	Internal DC (80–90%)	Internal DC (80–90%)	Internal DC (80–90%)
Last-mile delivery responsible	External transporter with regular trucks	External transporter with temperature-controlled trucks	The retailer with temperature-controlled trucks
Delivery options	Attended and unattended home delivery	Attended home delivery	Attended home delivery and delivery to store for pick-up

Table I.
Overview of the case companies

network configuration; material handling and warehousing; and their performance and challenges. The surveys were answered by senior case representatives in charge of designing and managing the OFCs. Second, during the spring of 2018, each of the OFCs was visited with the respondents to observe the facility design and operations. Third, during the on-site visit, the respondents participated in 90–120 min semi-structured interviews. The interview questions focused on the previous and current configurations of the OFC, as well as plans for the future. The interviews, which were all recorded and transcribed, made it possible to understand how and why changes had been initiated and how different contextual factors had influenced decision making in this process. Finally, to corroborate the findings – thereby increasing the internal validity – industry reports, annual reports, news articles and other public documents were consulted.

Each case was thereafter written up with rich descriptions to allow for a within-case analysis. The collected data were structured according to the developed framework (see Figure 1) to identify the themes and contextual factors that would be salient for the design of the OFC. Next, through a cross-case search for patterns (cf. Eisenhardt, 1989; Yin, 2014), the findings from the individual analysis were compared to identify the similarities and differences between the cases. The emerging patterns and results from the analysis were systematically compared with the conceptual framework in an iterative process.

Description of the three OFCs

In terms of OFC configuration, there are similarities between the three cases (Table II). All cases showcase a high degree of manual work, and temporary workers are used to handle demand peaks. Customer orders are batch-picked (three to ten customer orders at a time) using carts and hand scanners. A customer order typically includes twenty to fifty order lines, representing products from all temperature zones, with only one or a few items per line. Furthermore, all the studies OFC cases pack and sort customer orders according to shipping time and final destination.

There are also differences among the cases, particularly between Gamma and the other two. First, regarding storage, Gamma keeps products from the same category close together. Gamma experiences issues with high levels of product substitutions and wants to aid the order picker in the substitution decisions. Alpha and Beta do not explicitly store per category. Instead, they arranged storage in a way that best optimises picking routes, considering, for example, picking frequency, bottlenecks, weight and fragility. Second, regarding picking, Gamma has one worker moving through the different temperature zones to pick customer orders in their entirety. Alpha and Beta instead apply zone picking, meaning that one worker only picks products from one zone, so customer orders eventually are consolidated before shipping. Beta even picks fruit and vegetables in a wholesaler's facility nearby with the aim of increasing the level of freshness.

Third, regarding packing and sorting, Beta has automated the consolidation and sorting activities and ships the customer orders in paper bags. After the orders have been picked, they are placed on a dynamic conveyor belt that sorts the orders pre-shipping. Alpha and Gamma manage their sorting activities manually, repacking the picked orders in reusable plastic boxes (Gamma) or in reusable styrofoam boxes (Alpha), both of which require additional activities and space. The styrofoam boxes are used to allow for both attended and unattended delivery with regular trucks that do not have refrigeration. To various degrees, all cases experience the packing, sorting and shipping areas as bottlenecks during peak hours. The studied OFCs offer next-day delivery to all customers (Beta and Gamma) or to customers in certain regions (Alpha). This increases the need for flexibility in picking and shipping, and the capacity requirements may fluctuate.

Online fulfilment centre: Operations and layout

		Alpha	Beta	Gamma
WH Context	Assortment	Full grocery assortment	All grocery retail categories, except fruits and vegetables	Full grocery retail assortment
WH Context	Order characteristics	Average number of order lines per online order: twenty to fifty	Average number of order lines per online order: twenty to fifty	Average number of order lines per online order: twenty to fifty
WH Operations	Receiving	Manual	Manual	Manual
WH Operations	Put-away and storage	Manual, according to picking routes Buffer zone behind flow racks	Manual, according to picking routes	Manual, according to picking routes
WH Operations	Picking and sorting	Optimised picking of end-customer order Manual batch picking (three to ten orders) per zone. Sorting while picking	Optimised picking of end-customer order Manual batch picking (three to ten orders) per zone. Sorting while picking Fruits and vegetables from a closely located wholesaler	Minimising product substitutions Manual batch picking (three to ten orders). Sorting while picking
WH Operations	Packing	Manual consolidation Orders packed in reusable styrofoam boxes	Automatic consolidation Orders packed in regular paper bags	Manual consolidation at customer delivery Frozen items in plastic bags, with cold and ambient items in reusable plastic boxes
WH Operations	Shipping	Manual sorting pre-storage	Automatic sorting pre-storage	Manual sorting pre-storage
WH Design and Resources	Layout	Different areas for temperature zones Areas are organised to optimise picking efficiency	Different areas for temperature zones Areas are organised to optimise picking efficiency	Different areas for temperature zones Areas are mainly organised by product categories and optimal packing
WH Design and Resources	Storage equipment	Flow racks for high frequency picking zones and racks for low frequency picking zones	Flow racks for high frequency picking zones and racks for low frequency picking zones	Products are stored on racks
WH Design and Resources	Handling equipment	Cages for put-away and carts for picking Hand scanner and pick-by-voice to support pickers	Cages for put-away and carts for picking Hand scanner to support pickers	Cages for put-away and carts for picking Hand scanner to support pickers
WH Design and Resources	Automation solution	None	Dynamic conveyor belt for consolidation and sorting	None
WH Design and Resources	Information systems	WMS and an ERP with ATP calculations	WMS	Basic system developed in-house, no WMS
WH Design and Resources	Labour and Resources	High level of manual work and temporary workers to handle peaks	High level of manual work and temporary workers to handle peaks. More experienced workers pick fruit and vegetables	High level of manual work and temporary workers to handle peaks

Table II.
Overview of OFC configuration

Analysis and discussion

Based on the case study, we identified several contextual factors that affect grocery retail OFCs in an omni-channel setting. The factors will be discussed in two steps. First, we analyse the similarities and differences between traditional DCs and grocery retail

OFCs (Figure 2). Second, we compare similarities and differences between OFCs within grocery retail (Figure 3).

Comparison between traditional DC and the studied OFCs

To analyse the configuration of grocery retail OFCs, it is important to understand the similarities and differences between an OFC and a traditional DC; the similarities can highlight existing knowledge that can be utilised in the configuration of the OFC, while the differences can be used to understand how factors influence the configurations differently (Figure 2).

First, an OFC serves the end consumer, which has different expectations for delivery compared with stores. The end consumers in the studied OFCs expect home delivery and next-day delivery. The home delivery option means that shipping route optimisation increases in complexity because a large number of final destinations and shipping times must be taken into account in short time frame. Second, similar to the DC, the customers of the studied OFCs require full grocery assortment. The full product range includes a variety of product characteristics that create specific requirements on the warehouse configuration (cf. Kämäräinen *et al.*, 2001; Chabot *et al.*, 2017). One important aspect is the need for different temperature zones with unbroken cold chains from receiving – via storage – to shipping. In addition, some product characteristics, such as fragility and weight, are more important in an OFC. Online consumer orders typically contain single items with a wide range of characteristics, and the retailer must ensure that all the items are undamaged when handed over to the customer. Therefore, it is crucial for an OFC to consider the order in which fragile products are picked, packed and shipped.

Another important aspect identified is the difference in terms of size and annual growth of total volume handled through the warehouse. The relatively low volumes in the studied OFCs affect several configuration decisions. Specifically, the volumes handled through the OFCs are regarded as too low to justify investments in automation, which is otherwise perceived to improve effectiveness and efficiency in grocery DC picking operations (cf. Hübner, Kuhn and Wollenburg, 2016). Therefore, the OFCs rely on manual handling and focus on optimising picking routes by configuring storage locations. Meanwhile, the potential volume growth in grocery OFCs makes for high uncertainty regarding investments and what the optimal processes will be in the future.

Moreover, DCs and OFCs serve different types of customers, and as a result, order characteristics differ. The studied OFCs handle orders with fewer items and order lines compared with DCs but still have a large number of order lines per order, which results in

Contextual Factor			Configuration of operations, design and resources Implications on OFC in comparison with DC	
			Similarities	Differences
External context	Customer characteristics	Delivery →		• Home delivery, increases complexity in packing and shipping • Next-day delivery, increases complexity in picking and shopping
		Assortment →	• Holding inventory for full assortment	
	Product characteristics	Temperature	• Different temperature zones needed	
		Fragility Weight →		• Fragility and weight have to been considered in picking and shipping
	Volume	Size →		• Low, cannot require optimised shipments from supplier • Low, has to focus on storage location to optimise picking • Low, cannot justify automation of picking
		Growth →		• Very high, uncertainty about investment and optimal processes
	Order characteristics	Order structure →		• High number of order lines but fewer items/line, increased complexity in picking
Network context	Delivery and shipment	Consumer home delivery →		• Higher number of final destinations and shipping times, increases the need for sorting of picked orders • Received secondary packaging has to be broken up and stored in primary packaging
		Speed →		• Short lead time, requires extra buffers for pre-picked orders • Short lead time requirements, create bottlenecks in packing/sorting areas

Figure 2. Comparison of contextual factors and configuration for grocery DC and OFC

many picks per order. In combination with the large assortment of products, different temperature zones and a low level of automation, picking costs and order lines are comparably higher in an OFC than DC (cf. Hübner, Kuhn and Wollenburg, 2016; Wollenburg *et al.*, 2018). Finally, in the distribution network, a DC often ships to stores according to a predefined shipping schedule, whereas demand uncertainty is higher for an OFC. Combined with the high number of final destinations and shipping times that home delivery entails, this results in an increased need for sorting activities pre-shipping, requiring both additional resources and warehouse space. As volumes grow, the increased need for sorting pre-shipping creates a bottleneck in the OFC's outbound operations.

Comparison of the studied OFCs

By comparing and analysing similarities and differences between the studied OFCs' configuration decisions and the reasoning behind these decisions, knowledge of what contextual factors have influenced configuration and how they influence OFC decisions regarding operations and layouts can be generated. Because there are no distinct differences in customer characteristics between the three studied OFCs, no additional analysis in this area will be made. In Figure 3, the similarities and differences between the OFCs are compared and analysed. The emerging patterns in Figure 3 contribute to the understanding of the relationship between contextual factors and configuration decisions in an OFC.

Contextual Factor			Implications on OFC configuration of operations, design and resources	
			Similarities	Differences
External context	Product characteristics	Temperature	• Different temperature zones	Beta and Gamma: • Selecting temperature controlled trucks to ensure unbroken cold-chain in delivery Alpha: • Selecting packaging solutions to ensure unbroken cold-chain in delivery
		Fragility Weight	• Fragility and weight considered in picking and shipping	
		Category		Alpha and Beta: • Splitting some product categories to optimise order picking routes Gamma: • Storing product category together to minimise substitution
		Frequency		Alpha and Beta: • Including picking frequency in picking optimisation to a large extent Gamma: • Including picking frequency in picking optimisation to less extent
	Volume	Size	• Low volumes • Low degree of investments in automation • Cannot require optimised shipments from supplier • Focus on storage location to optimise picking instead of automation	Alpha and Beta: • Higher volumes compared to Gamma • Picking optimisation increases in importance • Zone picking increases in importance • Larger degree of bottlenecks during peak hours Gamma: • Lower volumes compared to Alpha and Beta • Does not achieve the same gains of picking optimisation and zone picking • Less degree of bottlenecks during peak hours
		Growth	• Uncertainty about investments and optimal processes	
	Order characteristics	Order structure	• Large number of order lines but with fewer items/line	Alpha and Beta: • Applying zone picking with batch picking Gamma: • Applying batch picking
Network context	Categorisation in internal network	Warehouse or store	• Issues with received goods optimised for in-store logistics, requires additional manual handling	
	Delivery and shipment	Consumer home delivery	• Breaking secondary packages, store primary packages • Large number of final destinations and shipping times	
		Speed	• Requires extra buffers for pre-picked orders, creates bottlenecks in packing/sorting	
		Last-mile transportation		Beta and Gamma: • Temperature controlled trucks for last-mile delivery to maintain cold-chain • Infrastructure, e.g. power outlets for trucks, is required Alpha: • Non-temperature controlled trucks for last-mile delivery, instead focus on packaging material to maintain the cold-chain
OFC context	Picking strategy	Optimisation focus		Alpha and Beta: • Configured storage area to optimise picking efficiency Gamma: • Configured storage area to minimise order substitutions
		Picking method	• Batch-picking requires sorting per customer order	Alpha and Beta: • Decision to have zone picking requires consolidation activities Gamma: • No zone picking, no additional consolidation required
	Shipping route optimisation	Destinations and shipping times	• Degree of additional sorting of order before shipping	Alpha and Gamma: • Manual consolidation and sorting pre-shipping of picked orders Beta: • Automated consolidation and sorting pre-shipping of picked orders

Figure 3.
Comparison of configurations for the different grocery OFCs and the factors influencing them

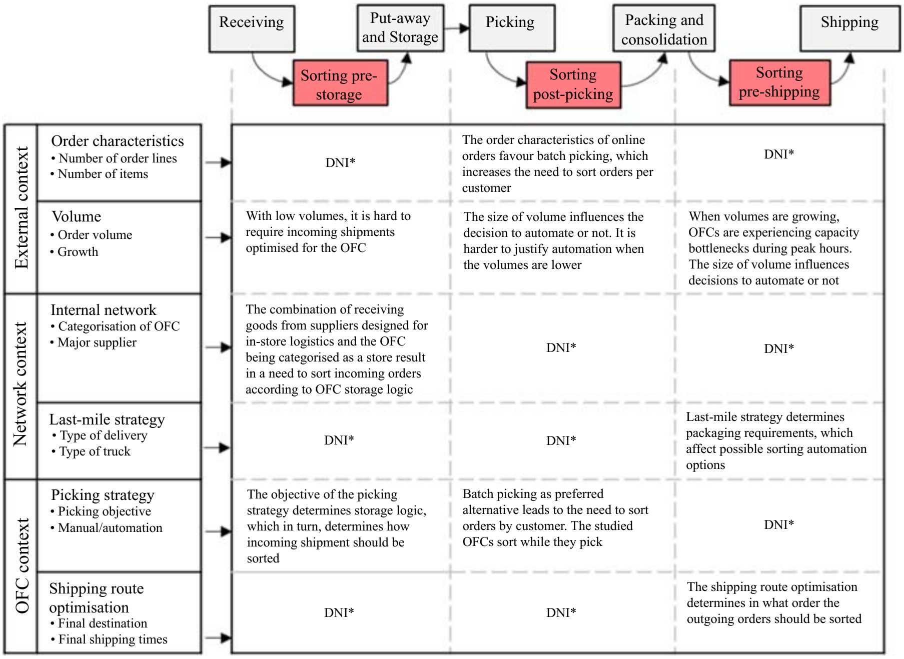
To begin, product characteristics have a major influence on OFC configuration. First, all of the studied OFCs have different temperature zones that must cater to the different temperature requirements in the grocery assortment. However, the three OFCs have chosen different last-mile strategies to ensure an unbroken cold chain. Beta and Gamma use temperature-controlled trucks, while Alpha uses special packaging material. Further, all the studied OFCs consider the products' weights and fragility when deciding where products are located. Alpha and Beta also consider picking frequency to improve picking optimisation; they also seek to minimise the risk of bottlenecks by not placing the most frequently requested items close together. Meanwhile, Gamma experiences issues with product substitutions but lacks the system support, routines and experience to manage this issue well. To minimise the negative influence of substitutions on consumer satisfaction, Gamma has prioritised storing products from the same category together rather than optimising picking routes; this approach guides the picker in the substitution choice without needing system support for substitution management. Gamma believes that many of the issues they currently face are related to being in the start-up phase and having low e-commerce volumes. The current low volumes handled through the Gamma OFC would not give efficiency gains in, for example, picking optimisation; however, Gamma believes that with growing order volumes, an approach similar to Alpha's and Beta's will be unavoidable. All the studied OFCs have a high degree of manual work throughout the warehouses, and a main contextual factor behind the low degree of investment in automation is the current low volumes handled through the OFCs. All case respondents believe that manual work and pick-route optimisation will reach a limit in terms of efficiency, and future automation will be inevitable with growing volumes. When and at what levels are still uncertain for the participating companies.

Moreover, the order characteristics greatly influence the picking strategy used. There are both similarities and differences in the picking strategy among the studied OFCs. The small total volume per order allows workers to meet several orders at the same time. All three OFCs apply batch picking, and they all sort products per customer order while picking. Alpha and Beta combine batch picking with zone picking, meaning that one worker picks several orders at the same time but only in one zone. Gamma does not apply zone picking yet, pointing to the lack of experience and current low volumes handled through the OFC as the main reasons. With zone picking, additional handling is required to consolidate customer orders before shipping.

Further, all of the studied OFCs offer delivery to the end-consumer's home. This approach has implications for different configuration decisions. First, all the studied OFCs break up secondary packages and store the primary packages to serve the end consumer. Moreover, home delivery entails a large number of final destinations and shipping times, which increases the complexity in the shipping route optimisation. All the studied OFCs offer, to some extent, next-day delivery, and the speed required in outbound operations contributes to bottlenecks in packing and sorting.

In addition to the traditional warehouse operations, there is an increased need for sorting in different stages of the OFC (Figure 4). Three types of sorting operations are identified, sorting pre-storage, sorting post-picking and sorting pre-shipping. The contextual factors influence these additional sorting operations differently. As shown in Figure 4, the contextual factor "volume" influences all three sorting operations, while, for example, last-mile strategy, only influences sorting pre-shipping. The relationships between contextual factors and the three types of sorting operations are discussed in more detail below.

First, all the studied OFCs are categorised as stores in their internal networks and receive most (80–90 per cent) of their goods from internal DCs. This approach creates a challenge for the OFCs because outgoing flows from the DCs are tailored for efficient unpacking in a



Note: *Contextual factor does not influence (DNI)

Figure 4.
Contextual factors influence on sorting in different stages of the OFC

physical store layout (cf. Sternbeck and Kuhn, 2014). The layout of the stores is typically designed with a focus on, for example, marketing and increasing sales rather than increasing picking efficiency. As a result, the OFCs included in the current study describes how they must break up received DC shipments from secondary packaging to primary packaging and sort and distribute them according to the OFC's own storage logic, which is determined by optimised picking routes. An increased need for sorting pre-storage thus arises (Figure 4). Ideally, the DCs would put an effort to sort goods uniquely for OFCs, but the current volumes handled through the OFCs are too low to motivate such special configurations.

The picking strategy decided by the OFCs influences other configuration decisions in the OFCs. The focus on picking optimisation sets requirements on the configuration of the storage area and, in extension, creates an increased need for sorting pre-storage. In addition, the configuration of the picking operation increases the need for additional sorting in conjunction with the picking itself. All of the studied OFCs apply batch picking, which requires sorting orders per customer during picking or post-picking (Figure 4).

Finally, among all the studied OFCs, there is an increased need for a focus on sorting activities pre-shipping. The reasons for increased sorting are the customers' requirements for rapid deliveries and the increasingly complex shipping route optimisation. Thus, customer orders need to be sorted according to shipping time and final destination and lined up in preparation for shipment. However, there are some differences in how the studied OFCs manage their pre-shipping sorting (Figure 4). To handle the increased sorting and consolidate picked orders, Beta has installed an automated solution with a dynamic conveyor belt. Alpha and Gamma both carry out the entire sorting and consolidation manually. Alpha and Beta experience space limitations during peak hours when the handled volumes are high.

Both OFCs are struggling with long-term solutions to the bottleneck situation in sorting in the pre-shipping stage. In the short and medium term, Beta is planning to install an increased number of electrical power outlets for the temperature-controlled trucks. Beta can then load the truck with the ready orders and store them in the car, freeing up space inside the OFC. This approach is, however, seen as a temporary solution. Gamma has lower volumes than Alpha and Beta but already utilises the shipping area to the fullest during peak hours. In summary, it can be assumed that the area dedicated to packing and sorting prior to shipping will become a constraining factor for the OFCs when volumes grow. Even though all three case respondents argue that larger order volumes are required to justify investments in picking automation, none of them present any clear ideas of how to manage growing volumes in packing and shipping operations.

Important contextual factors for configuring OFC operations

Building on the previous analysis of the similarities and differences between the DCs and OFCs, as well as among the studied OFCs, the contextual factors that have an influence on the configuration of an OFC can be identified. The following discussion represents a first attempt at structuring the relationship between contextual factors and the configuration of an OFC in omni-channel grocery retail. However, as discussed by Kembro *et al.* (2018), it is important to note that the complexity of the interactions in an omni-channel environment makes it difficult to describe a one-to-one relation between one contextual factor's influence on one warehouse configuration aspect.

The present study shows that the identified contextual factors affect different warehouse operations. To sort out the interdependencies and implications, we propose analysing the contextual factors and their influence on OFC configurations based on three levels defined from the perspectives of the OFC managers (see Figure 5). The first level – external contextual factors – includes customer requirements, product characteristics, volume handled through the OFC and order characteristics. These factors are, to a high degree, dependent on external market development although retailers can attempt to change order volumes and customer requirements with marketing and sales activities. The second and third levels are internal to the retailer. The second level – corporate retail contextual factors – can be influenced by the strategic decisions made by the retail chain's corporate management but may not be directly affected by the OFC manager. This level includes the categorisation of the OFC's role in the internal network, the OFC's major suppliers and the last-mile strategy. The third level – internal OFC contextual factors – relates to the decisions made internally by OFC management,

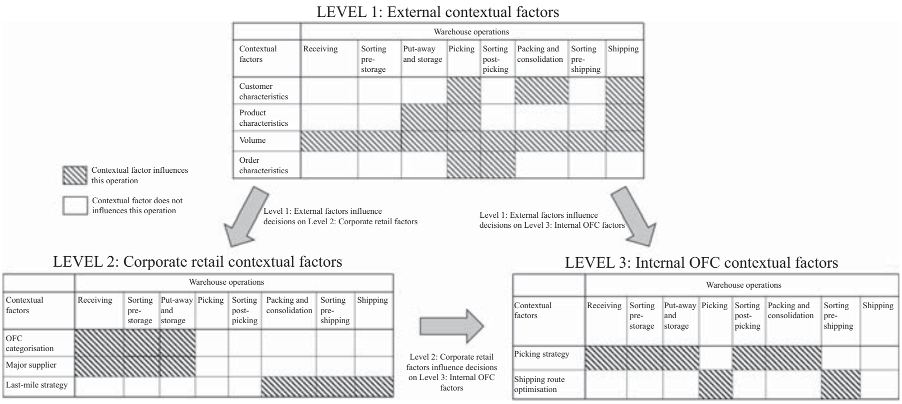


Figure 5.
Contextual factors influencing the configuration of OFC operations

including picking strategy and shipping route optimisation. These factors influence other configuration aspects, such as how incoming shipments from the DC and outgoing consumer orders should be sorted. The different levels are connected; decisions made on Level 1 may affect contextual factors on other levels. For example, customer characteristics influence the choice of picking strategy, while picking strategy itself is a Level 3 contextual factor (Figure 5). Arrows connecting the levels in Figure 5 visualise these relationships. To highlight the need for additional sorting activities throughout the warehouse, three additional operations are specified in Figure 5, as follows: sorting pre-storage, sorting post-picking and sorting pre-shipping.

The main factor affecting the OFC's configuration seems to be the total order volume. In line with previous research (e.g. Hübner, Kuhn and Wollenburg, 2016), volume handled through the OFC, for example, influences the decision to automate operations or not. Our study, however, shows that the volume factor affects many more configurations related to various warehouse operations. Particularly, the current low volumes handled through the OFC in combination with low power in relation to their main supplier (the internal DC) leads to the OFCs having to accept incoming shipments optimised for in-store logistics. Another aspect is that the warehouse area dedicated to sorting, packing and storing pre-shipping seems to be where a capacity shortage is first noticed with growing volumes, and none of the participating retailers have yet to find a sustainable solution.

As discussed in previous literature (cf., e.g. De Koster, 2002; Wollenburg *et al.*, 2018), product and order characteristics entail challenges for a grocery OFC overall. However, product characteristics and the change in characteristics that omni-channel entails create different requirements on operations in an OFC. With the high level of manual handling in the studied OFCs, there is an immense focus on optimising the picking operation. Product characteristics play a vital role in the configuration of the picking operation. The temperature requirements create the need for different temperature zones, making zone picking a convenient alternative. Further, the full grocery retail assortment includes a wide range of product characteristics, such as large differences in weight, picking frequency and fragility. The assortment of products in combination with the order characteristics of an average consumer order creates the need to plan the picking route based on these factors. Additionally, the characteristics of grocery consumer orders affect the configuration of the picking strategies in other aspects as well. The large number of order lines but small volumes per order has made batch picking the preferred alternative.

The choice of picking strategy has a great influence on the configuration of other aspects in the warehouse (Gu *et al.*, 2007). The current study shows how the picking strategy itself affects the other aspects of the OFC's configuration. First, the picking strategy has an influence on the configuration of receiving, put-away and the increased need for sorting pre-storage (see Figure 4). Because the studied OFCs prioritise optimising order picking, the incoming shipments must be broken up and sorted according to this logic. However, the combination of the internal DC as a major supplier and the OFC internally being defined as a store that is specific for omni-channel uses creates a trade-off when it comes to the picking strategy. Second, the OFC's internal decisions, such as the combination of zone and batch picking, create the need for post-picking sorting and consolidation of picked customer orders. Because picking is the most time-consuming operation in the OFC, efficient picking is prioritised, while other operations must adjust.

The last-mile setup, combined with omni-channel customers' requirements for rapid deliveries, increases the complexity of the shipping operation. Because the shipping route optimisation must consider a large number of final destinations and shipping times, additional sorting (Figure 4) of the order pre-shipping, which must consider shipping time and destination, is needed.

The present study identifies an increased significance for sorting activities throughout an omni-channel grocery retail OFC in pre-storage, post-picking and pre-shipping.

The current sorting configuration approaches among the studied OFCs and their relationships with contextual factors are summarised in Figure 4. Although Beta has automated one of these additional storage activities, the level of manual handling in all of the studied OFCs is still extensive. The capacity for sorting pre-shipping is a significant and specific challenge for an OFC. Although the studied OFCs depend on increased volumes, they are already experiencing bottlenecks.

Conclusion

Contributions

Our study explores OFC configurations in omni-channels that emerge in the intersection between grocery retail marketing and operations. Specifically, the purpose was to investigate how grocery retailers configure their warehouse operations as they move towards using an omni-channel structure and what contextual factors influence the configuration decisions. We connect research on warehouse operations and design with omni-channel grocery retail to structure the contextual factors that affect the configuration of grocery retail OFCs. Hence, the current study responds to recent calls for more research on omni-channel logistics and warehousing (Kembro *et al.*, 2018), particularly in grocery retailing (Galipoglu *et al.*, 2018; Wollenburg *et al.*, 2018). The present study can be seen as a first effort to explore the configuration of grocery retail OFCs, hence responding to the increased importance of warehouse operations (cf., e.g. Faber *et al.*, 2018) and the fact that omni-channel grocery retailers struggle with profitability (Kestenbaum, 2017).

The current study confirms the conclusion of Kembro *et al.* (2018) that certain factors have a varying array of implications for warehouse configuration in an omni-channel environment. Meanwhile, the findings indicate that there are multiple interdependencies between these contextual factors. One factor (e.g. product characteristics) can affect another factor (e.g. selection of a picking strategy), which, in turn, can influence a third aspect (e.g. sorting post-picking). Emphasising the unique context of the rapidly growing omni-channel grocery sector, we identified nine factors that can affect the configuration of OFCs. The factors represent three contextual levels: external contextual factors (customer requirements, product characteristics, total volume handled through the OFC, order characteristics, etc.); corporate retail contextual factors (OFC categorisation in the retail network, major suppliers, last-mile strategy, etc.); and internal OFC contextual factors (picking strategy, shipping route optimisation, etc.). In addition to confirming the factors that have been discussed in previous research, we identify new factors, including OFC categorisation in the retail network and major supplier and shipping route optimisation, which have previously not been highlighted in the literature. We also extend the knowledge on how all nine factors affect different operations and design aspects, such as receiving, storage, picking, packing and shipping, in a grocery retail OFC in practice. Our study thereby moves beyond the previous discussion focusing only on the different aspects of picking (cf. Kämäräinen *et al.*, 2001; Hübner, Kuhn and Wollenburg, 2016). As an exploratory case study of how three OFCs configure their operations and layouts in practice, the present study's insights and findings identify several relevant and interesting aspects to investigate in future research.

Implications for theory

One of the most important factors for the configuration of an OFC is the volume handled through the OFC. As discussed in previous research (Hübner, Kuhn and Wollenburg, 2016; Wollenburg *et al.*, 2018), volume is a key factor when it comes to several OFC decisions. We want to highlight three warehouse aspects that are particularly affected by the volume handled through the OFC. First, the volume has a great influence on the decision to automate warehouse operations or not. Grocery retail OFCs in general struggle with profitability in the operations (cf., e.g. Boyer *et al.*, 2009), and automation is often viewed as the solution (Hübner, Kuhn and Wollenburg, 2016). The case companies view increased automation as inevitable but argue that the volumes are too low today to justify such decisions. This raises interesting questions for future research concerning the relationship between investments in automation and volume. For example, what volumes are needed to justify automation in different warehouse operations, and will it be possible to operate an OFC for a longer time at the current volume levels without investments in automation?

Second, the volumes handled by the OFCs are small compared with the volumes handled by the companies' internal DCs. Our study indicates that low volumes in combination with the internal categorisation of the OFC leads to a mismatch between how the OFC should be viewed by the internal supplier and how the OFC is viewed today. Because the OFC internally is categorised as "a store", received shipments are far from optimal when it comes to designing efficient warehouse operations. The low volumes handled through the OFC, however, make it difficult to demand shipments composed in other ways. Thus, our study shows that although an OFC represents a separated logistics flow for online consumers, there is an interrelation with the overall logistics system, and the configuration of the internal DC influences the structure of incoming shipments into the OFC. Future research should investigate if larger volumes can increase the OFC's power when it comes to handling internal suppliers, and if so, what volumes handled through the OFC are needed for the OFC to be recognised differently from a store in the distribution network. It is also worth investigating in what other ways an OFC can work to change incoming shipments. A third area that volume affects is the bottleneck in capacity experienced in the outbound operations. Even though the volumes handled through the studied OFCs are argued to be too small to justify investments in automation, the studied OFCs are already experiencing capacity shortages in packing, sorting pre-shipping and shipping during peak times. Given that continuously increased volumes are viewed as a necessity for an OFC, addressing the capacity bottleneck becomes increasingly important as well. An important question for future research is how a grocery retail OFC should manage the capacity shortage in outbound operations as the volume handled through the OFC continues to grow.

Another critical contextual factor is customer characteristics. In contrast to a DC, an OFC caters directly to the consumer. Online orders, which are characterised by a large number of lines but with few items per line, represent a significant cost driver for picking operations and are one of the main challenges for efficient picking in OFCs. The order characteristics have made batch picking a preferred alternative among the studied OFCs and, in line with the literature (Kämäräinen *et al.*, 2001; Hübner, Kuhn and Wollenburg, 2016), our study supports the notion that picking is the most time- and resource-consuming operation. Therefore, considering that all the studied OFCs apply a high level of manual handling, much focus has been on optimising picking and routing. Configurations in picking, however, affect other operations, and our study shows the importance of balancing the focus of optimising the picking operation and the influence it has on other aspects of the warehouse. An important point is that the studied OFCs believe they will almost certainly automate picking operations in the future. Therefore, future research should investigate how this change influences the configuration of other OFC operations, not only picking. An important question is what requirements the automation of picking activities has on other OFC operations. Additionally, considering that order characteristics differ between online and store replenishment, the automation solutions previously used by grocery retailers may not be suitable for an OFC. Therefore, future research should also investigate automated OFCs to explore what requirements the order characteristics set on an automation solution and how an automation solution should be designed to fit the characteristics of online orders.

Another aspect of customer characteristics is the expectations of the last-mile delivery from OFCs. Our study shows that the last-mile strategy and its related shipping route optimisation have several implications for OFC operations and layouts. Short delivery windows and home delivery increase the number of final destinations and possible delivery times, which affects the planning of in what order to pick customer orders and the increased need for sorting pre-shipping. Furthermore, the decision to either deliver with temperature-controlled vehicles or not influences the packaging requirements. Without temperature-controlled vehicles, specific types of packaging material are required to ensure unbroken cold chains. The use of reusable packaging material requires additional package activities and additional storage space.

Finally, the current study reveals the increasing importance of sorting activities throughout the OFC (see Figure 6). Sorting works as a buffer that can balance out the more complex requirements that different contextual factors impose on the OFC. We identify three different types of sorting: pre-storage, post-picking and pre-shipping. These sorting activities increase as the OFC seeks to balance the trade-offs between: handling the shipments from the DC, the focus on optimised picking operations and the requirements from customers on outbound shipment. Specifically, additional sorting is required in the receiving operation because incoming goods (from the DC) have been arranged to fit a retail store layout, not a storage layout optimised for picking online orders. The configuration of the picking operation not only increases the need for additional sorting pre-storage, but also in combination with the picking itself. All of the studied OFCs apply batch picking, which requires the sorting of orders per customer during picking or after. Meanwhile, in outbound operations, there is an increased need for sorting because of the consumer's changing requirements for rapid home deliveries. The large number of final destinations and delivery times means that the OFCs must sort orders pre-shipping. As sorting increases in importance for OFCs in general, there is a need for more research. Previous research on sorting in different types of warehouses is underdeveloped (Gu *et al.*, 2007; Davarzani and Norrman, 2015). Relevant questions for future research include the following: what the different requirements are on different types of sorting and how different types of sorting in an OFC should be designed to improve performance. Other aspects worth investigating include when and why different types of sorting should be automated and what types of automation solutions fit different types of sorting.

As with most research, the current study has its limitations. Particularly, the use of only three cases from the Nordic grocery retail market can be addressed in future studies by

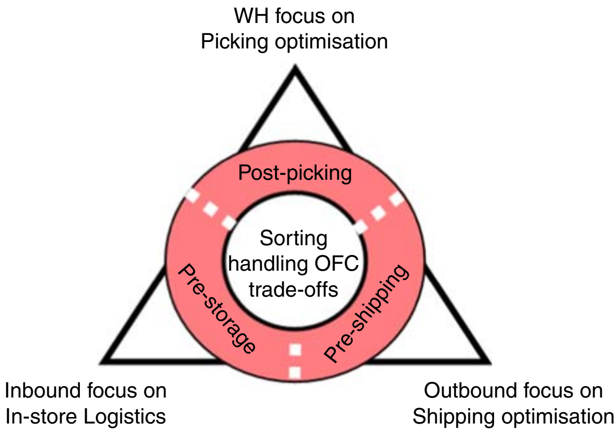


Figure 6.
Sorting balancing trade-offs in OFCs

adding more cases and extending the geographical scope. Future research could explore cross-regional differences as well. With more cases, the influence of maturity and development could be better studied. Further research could also compare OFC configurations and contextual factors for pure online grocery retailers with omni-channel retailers.

Implications for practice

Although OFCs have been a reality in practice for over a decade, research on their operations and design is still limited. The current study can support practitioners in the configuration of an OFC in a start-up phase with low volumes. First, the purpose and customers of an OFC differ from traditional DCs, and practitioners should understand the changes this entails for the warehouse design. The focus for a grocery OFC configuration should be to fulfil the demand of the end customer, with other order characteristics, demand patterns and delivery requirements to take into consideration when designing the OFC's operations and layout. This means that the OFC's storage logic should be planned with online order characteristics in mind.

Second, we show the importance of having a holistic perspective to avoid sub-optimisation to an excessive degree. Although a main focus on cost optimisation of the picking operations is reasonable for an OFC with a high level of manual handling, we suggest that OFCs should balance the picking optimising with trade-offs to other warehousing aspects. In general, sorting mechanisms could be used and further developed to bridge the gaps between different functions and logics. If management of the OFC cannot change how incoming shipments are organised, additional sorting activities pre-storage can help create a better flow through the warehouse.

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Corresponding author
Ebba Eriksson can be contacted at: ebba.eriksson@tlog.lth.se