Warehouse configuration in omni-channel retailing: a multiple case study

Joakim Hans Kembro and Andreas Norrman
Department of Industrial Management and Logistics, Lund University, Lund, Sweden

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Abstract

Purpose – The purpose of this study is to explore warehouse configuration in omni-channel retailing.
Design/methodology/approach – A multiple case study is conducted with six large omni-channel retailers from three different sectors.
Findings – The study shows an increase in the number, variation and frequency of flows passing through omni-channel warehouses. Along with an increased variety of stock keeping units (including singles vs multipacks), there is an increase in the complexity of planning and coordination of order fulfillment. Retailers test a mix of different solutions for storage and picking and partly shift focus to advanced sorting operations. The companies already have or plan to invest in substantial automation systems, which emphasize the importance of capturing and using accurate master data.
Research limitations/implications – The study highlights the need to understand the interrelations and co-development of configuration elements in omni-channel warehousing. The findings also suggest that a successful transformation requires increased collaboration with upstream and downstream partners. Conceptual models are developed to illustrate strategies and development paths in omni-channel warehousing, and suggestions for future research are summarized in a research agenda. A research limitation is the focus on Swedish retailers in three sectors (fashion, consumer electronics and DIY/construction material). Future studies can include additional sectors, extend the geographical scope and explore cross-regional differences.
Practical implications – As one of the few deeper case studies on omni-channel warehousing, practitioners will find new configurations described and analyzed here. Along with conceptual models, a synthesis of challenges and potential solutions are presented to support retailers' practical analysis and decision making.
Originality/value – This is one of the first multiple case studies that go deeper into omni-channel warehouse configuration, which is of increasing importance to both scholars and practitioners in the field.

Keywords Logistics, Warehouse, Case study, Retail, Configuration, Omni-channel, Material handling, Sorting

Paper type Case study

Introduction

In omni-channel retailing, the front-end shopping experience is seamless. Inventories and order fulfillment are conflated, and customers can trigger interaction between online channels and physical stores (Galipoglu *et al.*, 2018). With the rapid development of omni-channel retailing, the distribution system is increasingly being highlighted as a critical component for meeting customer demands (Daugherty *et al.*, 2019). These demands include, for example, shorter lead times from placing order to receiving goods, flexible delivery and return options, lower costs and larger product assortments (Hübner *et al.*, 2015; Wollenburg *et al.*, 2018).

At the core of distribution systems, warehousing and a wide range of emerging material-handling nodes (e.g. online fulfillment centers) play a strategic role in meeting increasing expectations related to same-day delivery, flexible delivery options (click-and-collect, pick-up points, home delivery), and cutting overall logistics costs (Faber *et al.*, 2013; Hübner, Kuhn and Wollenburg, 2016; Kembro *et al.*, 2018). As described by Rouwenhorst *et al.* (2000, p. 515), "[t]he efficiency and effectiveness in any distribution network […] is largely determined by the operation of the nodes in such a

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network, i.e. the warehouses." One of the main challenges highlighted in research is the task of both effectively and efficiently handling the fulfillment of large store replenishment and relatively small web orders in a single, integrated warehouse (Hübner *et al.*, 2015; Kembro and Norrman, 2019). However, as omni-channel retailing evolves, the number of challenges in warehouse operations multiplies (Eriksson *et al.*, 2019).

Despite the critical role of warehousing, literature on material-handling operations is sparse, while literature on other omni-channel retail and logistics-related topics is advancing. Examples of advancing research fields include the front-end experience such as consumer behaviors and marketing-channel strategies, as well as the design of supply and logistics networks, and last-mile distribution (see e.g. Verhoef *et al.*, 2015; Bernon *et al.*, 2016; Ishfaq *et al.*, 2016; Murfield *et al.*, 2017; Saghiri *et al.*, 2017; Melacini *et al.*, 2018). Kembro *et al.* (2018) recently conducted a review and concluded that an increased research focus on omni-channel warehousing is needed to analyze the latest managerial practices and new solutions and technologies that are tested in omni-channel operations in order to expand existing understanding of current and future issues and solutions moving forward. In particular, there is a lack of detailed case studies to provide in-depth understanding and to develop the existing body of knowledge on the growing phenomenon of omni-channel warehousing. Hence, the purpose of this study is to explore warehouse configuration in omni-channel retailing. We address the following objectives:

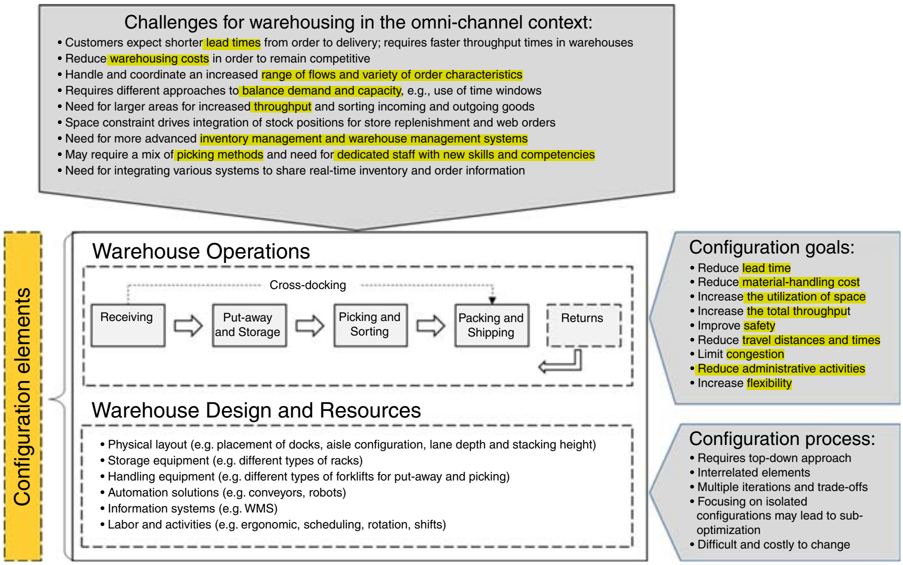
- Objective 1: Identify challenges for omni-channel warehousing.
- Objective 2: Analyze and discuss the implications for warehouse configuration.
- Objective 3: Develop a research agenda and decision support for practitioners.

Adopting a theory-elaborating case-research approach (Ketokivi and Choi, 2014), we conduct a multiple case study with six omni-channel retailers from three different sectors (fashion, consumer electronics and DIY/construction material) in Sweden. Adding to previous empirical studies, which have often focused on the UK or German markets (e.g. Bernon *et al.*, 2016; Hübner, Wollenburg Holzapfel, 2016), Sweden is interesting to study for several reasons (cf. Patton, 2002). In comparison to other European countries, Sweden was in 2017 second after the UK in terms of information technology (IT) usage (Eurostat, 2018), number four in terms of online sales, and number three after UK and Germany in terms of the share of purchases made via mobiles (tablets and smartphones) in 2016. There is also rapid growth and investments in online sales channels as well as a high degree of competition among retailers (Centre of Retail Research, 2017).

Next, we present and synthesize related literature as a basis for discussing the contribution of this study. Thereafter, we describe the multiple case study method, including research-design aspects and trustworthiness. Then, we present the observed configurations and challenges in an order that follows goods flow through a warehouse. Finally, we discuss implications and present an agenda for future research.

Warehousing theory and the omni-channel context

Building on the recent literature review conducted by Kembro *et al.* (2018), there is limited theory outlining how omni-channel warehouses should be configured. Most research that touches on omni-channel warehousing issues discusses general challenges, and literature seldom goes into detail of empirical observations to connect various issues and discuss implications for different configurations. For the purpose of this paper, we build on the general warehousing theory and place it in the context of omni-channel retailing. Figure 1 provides a synthesis of the literature review and illustrates an overview of configuration elements and goals as well as challenges mentioned in extant omni-channel literature. We use the term "configuration" for the combination of operations, design aspects, and



Source: Adapted from Kembro *et al*. (2018)

Figure 1. Overview of warehouse configuration in the context of omni-channel retailing

resources in a warehouse. The synthesis provided in Figure 1 is subsequently used to discuss the findings of our study by relating various challenges and analyzing their implications for warehouse configuration.

Configuration elements

Considered as "the points in the supply chain where [the] product pauses, however briefly, and is touched" (Bartholdi III and Hackman, 2016, p. 3), warehouses are commonly used to consolidate a range of products, match supply and demand and reduce transportation costs and lead times from order placement to delivery (Faber *et al.*, 2013). The purpose of the warehouse in the distribution network determines the characteristics of flows and the required operations (Frazelle, 2002; Gu *et al.*, 2010; Eriksson *et al.*, 2019). In retailing, it is common to use distribution centers (DC), which include operations for receiving, put-away, storing, picking, and shipping. Distribution warehouses may also have a varying degree of return handling and cross-docking flows, where goods are moved directly from receiving to shipping (Kembro *et al.*, 2017). To manage the warehouse operations effectively and efficiently, several design aspects and resources must be considered; examples of such aspects include physical layout (e.g. placement of receiving and shipping docks, aisle configuration, lane depth, and stacking height), storage and handling equipment, automation and information systems, and labor (Tompkins *et al.*, 2010; Kembro *et al.*, 2018).

Configuration goals and process

To select the appropriate configuration, it is critical to understand configuration goals. The most important goals discussed in literature are to reduce lead time from customer order to shipment, reduce material-handling cost, increase the utilization of the physical space, increase the total throughput and improve safety. Additional goals related to these configuration goals are reducing travel distances and times, limiting congestion, reducing administrative activities, increasing flexibility in terms of, for example, scaling up and down capacity or handling different product and flow characteristics (see, e.g. Cormier and Gunn, 1992; Petersen and Aase, 2004; Gu *et al.*, 2007; Bartholdi III and Hackman, 2016).

Considering that configuration elements are interrelated, the configuration process involves multiple iterations and trade-offs (Gu *et al.*, 2010). Focusing on isolated configurations may lead to sub-optimization (Baker and Canessa, 2009), and it can be difficult and costly to make significant changes at a later stage (Huertas *et al.*, 2007). Therefore, it is important to adopt a top-down approach to consider all relevant configurations and get the fundamental design choices right from the outset (Rouwenhorst *et al.*, 2000). Tompkins *et al.* (2010, pp. 292-293) add, "A facilities layout strategy should emerge from the overall strategic plan."

Challenges for warehousing in the omni-channel context

One of the reported omni-channel challenges is that web customers expect shorter lead times from order to delivery, which requires faster throughput times in warehouses (Hübner *et al.*, 2015; Marchet *et al.*, 2018). Coupled with the focus on lead times, retailers strive to reduce warehousing costs in order to remain competitive (Hübner, Kuhn and Wollenburg, 2016). Another challenge is handling and coordinating an increased range of incoming and outgoing flows as well as a variety of order characteristics for retail stores and web customers (Hübner, Holzapfel and Kuhn, 2016; Larke *et al.*, 2018).

Kembro *et al.* (2018) discuss that, in the long term, warehouse space becomes an important constraint, which requires different approaches to balance demand and capacity over time. One issue is the need for larger spaces for increased throughput and sorting incoming and outgoing goods (Hübner, Holzapfel and Kuhn, 2016; Hübner, Kuhn and Wollenburg, 2016). In addition to using time windows for handling goods, retailers may consider pooling and balancing of warehouse space and workforce (De Leeuw and Wiers, 2015). One critical aspect to free up space is the integration of stock positions for store replenishment and web orders. However, this integration will require more advanced inventory management (Hübner, Wollenburg Holzapfel, 2016; Marchet *et al.*, 2018) as well as dedicated staff with new skills and competencies (Hübner, Holzapfel and Kuhn, 2016). Integrated storage may also lead to a mix of picking methods (e.g. single vs batch picking) and the need for advanced warehouse management systems (WMS). Finally, omni-channel retailers increase the pace of implementing various automation solutions (Hübner, Kuhn and Wollenburg, 2016), and a wide range of new technologies qare being tested to make material handling more effective and efficient (Kembro *et al.*, 2017). The need for integrating various systems within a warehouse and across the omni-channel also increases with the growing importance of sharing real-time inventory and order information, both internally and externally (Kembro *et al.*, 2018; Kembro and Norrman, 2019).

Methodology

Research design and trustworthiness

To explore the challenges and implications for warehouse configuration in omni-channel retailing, we adopted a multi-case embedded design (cf. Flyvbjerg, 2006; Yin, 2009). The design of this theory-elaborating case research (Ketokivi and Choi, 2014) is aligned to what Yin (2009) proposes (see Figure 2). We applied four quality criteria to ensure methodological rigor: construct, internal, and external validity, and reliability (cf. Krause and Ellram, 2014; Da Mota Pedrosa *et al.*, 2012; Yin, 2009).

The primary units of analysis were the challenges and implications for warehouse configuration in omni-channel retailing. The secondary units of analysis were the configuration elements themselves, with two interrelated perspectives: the various

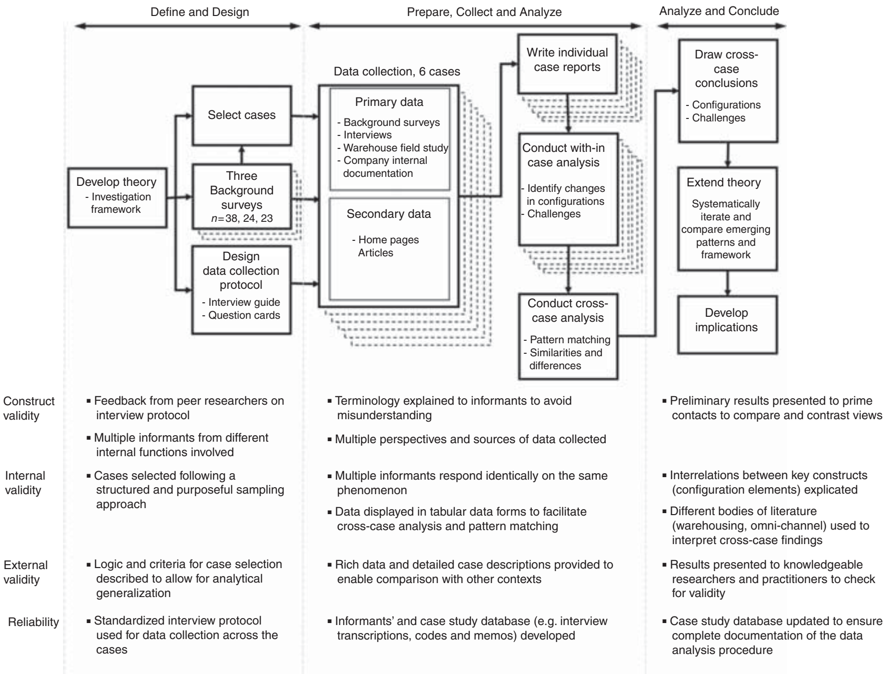


Figure 2.
Overview of research design and steps to increase trustworthiness

operations and design aspects and resources (cf. Figure 1). The warehousing nodes of six experienced and high-performing omni-channel retailers were studied. We selected the six retailers based on a series of three explorative surveys (answered by 38, 24, and 23 companies, respectively), which included self-assessed warehouse performance relative to competitors in terms of delivery service/lead time and cost efficiency, both for store replenishment and web orders. The six retailers (Table I) are among the largest in their respective sectors (fashion, consumer electronics, and DIY/construction material) in Sweden, and represent front-line development in omni-channels; many are award-winning retailers in the field. Following a logic of purposeful sampling (cf. Patton, 2002), the companies represent different contexts, from low-value to high-value products, from small to bulky products, from a fairly homogenous assortment to a mixed one, and from more international to more national market focus.

Data collection

The case-research approach enabled the triangulation of multiple data sources and perspectives. First, senior managers in SCM/logistics answered three initial exploratory web surveys, providing data on: overall background, situation and future strategy of their omni-channel logistics, current and future material handling and warehousing, and current and future IT systems and technology.

Second, in the spring of 2018, two researchers jointly visited the retailers' headquarters and main warehousing nodes (DC). Guided site visits were made, providing an opportunity to speak with operational warehousing personnel and to observe operations and configurations in practice. A total of 19 pre-planned interviews were also conducted face-to-face with decision-makers, involved in or accountable for omni-channel logistics

Table I.
Case companies and informants

Case companies	Fashion F1	Fashion F2	Consumer electronics C1	Consumer electronics C2	Consumer electronics C3	Do-it-yourself D1
Size, national rank in segment	Top-5	Top-5	Top-5	Top-5	Top-5	Top-5
Geographical scope	International	International	Nordic	Nordic	Nordic	Sweden (part of int. company)
No. of physical stores	+350	+350	+100	25–75	+350	25–75
Part online sales	~10%	~10%	Below 10%	+35%	10-20%	~75% construction-site deliveries. ~20% e-orders
Interviews (no./total duration)	2/ 5 h	1/ 5 h	2/ 5 h	3/ 6 h	4/ 8 h	7/ 8,5 h
Visit O-C WH	Yes	Yes	Yes	Yes	Yes	Yes
Titles of the informants	Supply chain (SC) developer; DC manager	Head of logistics	Logistics manager; Warehouse (WH) manager	Logistics manager; WH manager; IT manager	DC site manager; Head of distribution; Production planning manager; IT and system manager	Vice president logistics; Logistics developer; Process owner (PO) WH; PO Transport; Head of WH production; SC collaboration

and warehousing (interview protocol available on request). The number of informants and roles varied across cases (Table I), but corresponding data were collected. All main informants were responsible for their omni-channel warehouse, and all had at least 10–15 years of warehousing experience. The interviews (voice-recorded, transcribed) had an average duration of 2 h. Only one informant did not permit voice-recording; however, both researchers took detailed notes, which were validated with the informant immediately to maximize data accuracy and comprehensiveness.

Finally, secondary data were collected to corroborate and augment the evidence from the web surveys and interviews (cf. Krause and Ellram, 2014), thereby increasing internal validity. Examples include industry reports, annual reports, news articles, web pages, and other public documents. All collected data – including interview transcriptions – were condensed to comprehensive case reports for each retailer (with rich descriptions to allow for within-case and cross-case analysis) and sent to the retailers for validation.

Data analysis

To elaborate theory, data analysis proceeded through iterations between the framework and the data (cf. Ragin, 1992; Ketokivi and Choi, 2014); steps included concurrent data reduction, data display, coding, and drawing and verification of conclusions (Miles and Huberman, 1994). The collected data were coded and analyzed (first individually then jointly by the two researchers) by applying within-case analysis and cross-case analysis, structured according to the investigating framework (cf. Figures 1 and 2) to identify changes in configurations and their motivations.

We used data display to identify similarities and differences between the cases, considering both category matrices (crossing dimensions or variables to see how they interact) and category networks (a series of nodes connected by links) (Miles and Huberman, 1994, p. 239). As suggested by Miles and Huberman (1994), several tactics for generating meaning were used (e.g. noting patterns/themes, identifying plausibility, clustering, making contrast/comparisons, partitioning variables, subsuming particulars into the general, noting relations between variables). Axial coding linked the results from the within-case analysis across the cases. Manually constructed cross-case tables and diagrams (Miles and Huberman, 1994) organized, made sense of, and displayed the data, and supported generation of conclusions by comparing and contrasting evidence between the cases. Emerging patterns and results were systematically compared in iterations with the framework. Initial codes were subsequently refined based on themes emerging from the data and grouped into higher-level categories using axial coding.

Findings from the multiple case study

The findings are structured with a logic of following the goods and order flow through the warehouse (cf. Figure 1).

Goods receipt and development of supplier cooperation

Our study shows a clear increase in the number and variation of flows passing through omni-channel warehouses on a daily basis. The range of flows increases from suppliers – for example, due to an increased range of products and continuously changing assortment – with faster and more frequent deliveries to customers. There is also an increased use of drop-shipment, transshipped goods, cross-docking, and returns handling, each illustrated in Figure 3.

Drop-shipment represents goods delivered directly from the supplier to the customer/store. The case companies increasingly use drop-shipment (up to 15 percent of the total volume) as a means to offer a larger assortment without expanding storage capacity at the DC.

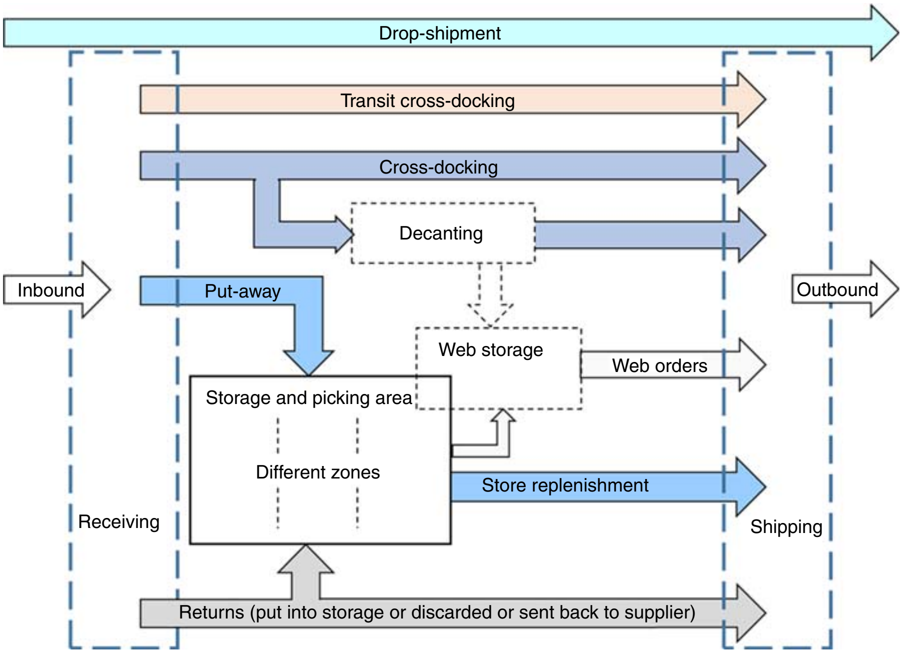


Figure 3. Overview of different flows in an omni-channel warehouse

Transit cross-docking is an alternative to drop-shipment, where goods are co-loaded at the warehouse site to increase the degree of filling per outbound truck.

Inside the warehouse, two types of cross-docking are used to move goods directly from receiving to shipping. It is typically used for seasonal products or bulky goods to reduce the need of space and labor in storage and picking. Proactive cross-docking is the most common and represents planned store replenishments that are "pushed" to the store, either as unbroken packages or via decanting where packages are opened and products are mixed among different stores. Proactive cross-docking reduces handling costs in DC, but excessively high initial allocation could risk the build-up of unsold products in stores. Therefore, case companies with short product life cycles (F1, F2) have gradually reduced the share of proactive cross-docking to 50 percent and instead developed efficient and frequent store replenishment, which is co-loaded with click-and-collect orders. Reactive cross-docking is used to quickly cover store shortages with co-loading requirements. Hence, out-of-stock items are not stored but directly sent to stores in order to reduce lead time.

Return flows have increased with online sales, but its share varies between industries (Table II). The case companies strive to minimize the number of returns because they perceive them to represent failures in customer offering and to have a negative impact on the environment. F1 and F2 prefer to handle returns in stores, as they want to drive customers there and generate additional sales. Alternatively, dedicated return nodes are used when flows can be controlled by providing return labels. Returns sent to specific return nodes are consolidated by the carrier to get regular and cost-effective delivery. Other retailers use the DC to handle returns. One flow that typically ends up at the DC is that of products that are not collected by the customer at pick-up points. Based on quality inspection at the DC, returns can either be put into storage, discarded, or – as in the case of electronics – sent back to the supplier.

Table II. Characteristics related to flows and configuration of inbound operations

Case company	Fashion (F1)	Fashion (F2)	Consumer electronics (C1)	Consumer electronics (C2)	Consumer electronics (C3)	Do it yourself (D1)
Product life cycle	Short; campaign-driven assortment changes	Short; campaign-driven assortment changes	Medium; assortment changed twice per year	Medium; assortment changed four times per year	Medium	Medium; assortment changed yearly
Supplier base	+150, mainly Asia	+150, mainly Asia	+500, both Europe and Asia	Mainly Asia	~350	~3,000, 85% national
Own brands	Main approach	Main approach	Limited	10%, growing	Limited	Seek to increase own brands
Drop-shipment (transit flows)	No	No	Some containers from Asia	No	~15%	10-12%
Proactive cross-docking	Important flow (50%)	Important flow (50%)	Used to limited extent	No	Yes, to some extent	Used to limited extent
Reactive cross-docking	No	No	Used to limited extent	No	No, but considered	No
Return flows (e-commerce)	10–15%	10–15%	Low	Low (< 3%)	Low	Low (< 3%)
Return flows, handling location	Stores, dedicated return stores, DC	Stores, dedicated return stores, DC	DC	Depends, often DC	DC	Dedicated returns, DC
Most experienced staff in receiving	Yes	–	Yes	Yes	Yes	Yes
Strict time windows	Yes	Yes	No, but see potential	No	Yes	No
Supplier cooperation in sorting	Suppliers sort, pack, and mark for different flows (e.g. cross-dock to specific stores); time-controlled deliveries	Suppliers sort, package, and mark according to four categories; time-controlled deliveries	No, but see development potential.	No, but see development potential; first need to develop internally	Deliveries scheduled according to tight time windows.	Small goods placed in plastics boxes to fit automation; time-controlled deliveries; See development potential

In receiving, goods registration must be prompt and accurate to avoid issues in later warehouse operations. Problems in receiving could result in delayed deliveries for companies that offer short lead times for customer orders. Considering that receiving often has a limited area, allowing more space for storage and outbound operations, the increasing number and variation of inbound flows is a challenge. Much sorting is needed to get goods to the right location in the warehouse. Sorting is particularly increasing for products with large variation in terms of volume or handling requirements. Sorting is also critical for products going into automation systems, where flows must be balanced to avoid releasing too many goods into the same zone in a short time. The increased complexity and importance of handling and balancing incoming flows increases process and system requirements as well as the need for advanced equipment. For these reasons, most case companies have their most experienced employees in receiving.

To improve the receiving operation, cooperation with and control of suppliers is growing in importance in omni-channels. The case companies, which have incoming goods flows from suppliers in Sweden, Europe and the rest of the world – mainly Asia (China) – work with supplier partnerships in four different areas. First, standardized packaging makes it easier to handle, stack, and store products. For the increased use of automation solutions, it becomes important that supplier packages fit the storage system (e.g. rollers, boxes/trays). In one of the cases, suppliers pack goods in trays that can go directly into the automated storage system instead of having to unpack or convert to a new handling unit. Second, how suppliers sort each box is also important, as efficient storage in an omni-channel warehouse often requires "sort-clean pallets" containing only one product (and size). For automation solutions, how many boxes and in what order the boxes are sorted is essential (e.g. in a container) to evenly balance flows to different zones and, thus, avoid bottlenecks. In comparison, boxes that are sent directly to the stores via cross-docking must be sorted differently and kitted in a "store-friendly" manner to make it easy for store staff to unpack and put on shelves. Therefore, suppliers must be familiar with the layouts of different stores.

Third, the suppliers can also facilitate the receiving of the goods by providing clear labeling and pre-notification of goods. Suppliers clearly mark to which storage zones different pallets and packages are destined to facilitate quick sorting by warehouse staff. Pre-notification implies that suppliers have already registered the delivery before goods arrive at the warehouse, so they can be scanned directly; moreover, delivery note, shipping note, seal for theft risk as well as right product, right number and right quality can be controlled quickly. Fourth, with increased volumes and flows, many of the companies have implemented strict time windows and they only receive goods that are 100 percent pre-notified. Further, the unloading order of containers is time-controlled to balance warehouse inflow. One of the fashion retailers even controls exact launch dates, and measures how time requirements are met throughout the entire supply chain. Finally, the retailers indicated the important role of suppliers in relation to increased drop-shipment.

When deeper strategic collaboration with suppliers is required, employees at different organizational levels have to meet and discuss to understand how to facilitate each other's work and thereby save time and reduce costs. Pre-sorting, labeling, and pre-notification of goods, may imply savings for the retailer's warehouse, but simultaneously introduce extra work and costs for the supplier. This requires negotiations and a certain logistics maturity in the retailer's purchasing organization. The power balance and dependence among companies also becomes increasingly important. The cases emphasize that it is easier to influence smaller companies or suppliers of own brands, for example in terms of detailed packaging and labeling that enables cross-docking. The increased requirement on supplier collaboration to improve the receiving operation also drives the retailers to work with a smaller number of suppliers. Generally, the cases aim to reduce the number of suppliers from current levels, varying from 150 to 800, to focus more on selected partner relationships.

Integrated storage and the issue of singles vs multipacks

A common challenge in warehousing is the recurring lack of space. This configuration issue is accentuated with increased e-commerce flows, a larger product range, and occasionally extreme demand peaks. One solution to the space issue is to integrate storage for store replenishment and web orders. The case companies aim to have one picking location per handled article – that is, stock keeping unit (SKU) – while there can be multiple locations in buffer storage. In addition to reducing the space need, a joint picking location can help to reduce both the number of zones and flows as well as the need for inbound sorting and consolidation of goods before shipping. The empirical data indicate that integration of picking locations is stepwise: from isolated, outsourced e-commerce warehouses (with separate WMS) that are classified as a store in the network, via separated web storage and picking zones on joint site, to integrated storage and picking areas, including joint WMS but with some separation of warehouse processes in time and logic. This integration reduces capital tied up as inventory and contributes to more efficient space use. Additionally, products do not need to be handled through multiple warehouses and, therefore, the integrated storage can shorten the delivery time for web orders.

Integrated storage and picking have advantages but may cause other issues. First, retailers must handle prioritization of different orders. The case companies give web orders priority so that products are available for web customers, who directly contribute to cash payment. Second, e-commerce requires separate activities and customization that risk interfering with effective and efficient store replenishment flows. Third, flow integration also increases the need for sorting where click-and-collect and store replenishment orders can be sorted together, while other delivery methods require separate sorting and shipping. Fourth, integration increases utilization of capacity in outbound operations, which can create bottlenecks and reduce efficiency when demand peaks. Another issue raised in all cases is whether products, particularly small goods, must be stored as singles or multipacks. While this problem may not be a surprise when integrating store and web, it is interesting to note that the retailers develop and test different solutions (Table III). All but one retailer originate from bricks-and-mortar stores, which can explain the general approach to store multipacks and then test different ways to deal with broken packages. The broken packages can cause issues in terms of storage, picking and verification of stock balance.

The decision of how to handle broken packages varies among the retailers. C3 and D1 store singles and multipacks (once a package is broken) of small SKUs in the same zone. This approach has prerequisites. One is available space, which is expanded in the two cases by using automated high-bay storage. Another requirement is packaging and labeling (done by the supplier) for both singles and multipacks. Third, an advanced information system is needed to keep track of storage locations and for direct picking to the right SKU (e.g. avoid picking multipacks when customer ordered a single). System support also ensures that required storage locations are kept to a minimum (i.e. avoid breaking new multipacks if singles are already available).

F1, F2 and C1– originating from brick-and-mortar – do not mix singles and multipacks in the same zone. F2 has an aim to integrate, but plans to create a separate zone for broken multipacks of certain products. This solution will create necessary flexibility for handling products that do not have the appropriate packaging and labeling on single units. F1 has historically tailored their packaging to include different products as a mix suitable for stores. They are considering to switch to multipacks with one type of product, and explore if it is possible to reduce the size of multipacks (e.g. packs of three socks) to suit both stores and web customers. C1 stores everything as multipacks, and moves products requested by web customers to a dedicated picking zone every day. Finally, the retailer originating as a pure e-tailer stores a larger part of the products as single packs to enable fast picking of web orders. However, this approach creates a more cumbersome handling of store replenishment orders, with more time needed to pick several single packs instead of a multipack. There is also a risk that the pallets become unstable and sub-optimal for capacity utilization in transportation.

Table III. Approaches to storing singles and multipacks of small SKUs

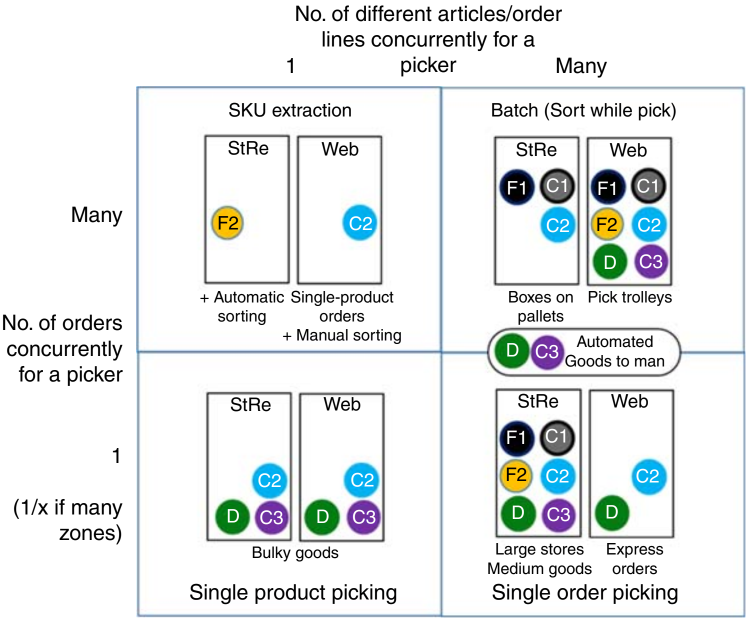
Case company	Fashion F1	Fashion F2	Consumer electronics C1	Consumer electronics C2	Consumer electronics C3	Do-it-yourself D1
Origin	Bricks-and-mortar	Bricks-and-mortar	Bricks-and-mortar	E-commerce	Bricks-and-mortar	Bricks-and-mortar
Approach to storing small SKUs	Stores singles and multipacks in different zones	Stores singles and multipacks in different zones	Created special area for daily positioning of multipacks from where singles are picked	Created separate zone where all SKUs available on the web are stored as singles. Otherwise, stored as multipacks	Stores singles and multipacks of small SKUs in same zone (when pack is broken)	Stores singles and multipacks of small SKUs in same zone (when pack is broken)
Reasoning	Has separated zones for storage and picking of web orders (singles) and store replenishment (multipacks)	Has separated zones for storage and picking of web orders (singles) and store replenishment (multipacks)	To enable flexible use of space and fast manual picking of singles	To enable fast manual picking of web orders (and particularly one-order-line orders)	Invested in an automated storage and picking solution, which enables pooling of demand and reduced inventory levels	Invested in an automated storage and picking solution, which enables pooling of demand and reduced inventory levels

Effective management of customer orders and production orders

The choice of picking strategy is critical to meet customer expectations on shorter lead times. The retailers use a range of picking strategies in different zones, which are tailored to different order and product characteristics and variation in storage and handling methods (Figure 4). The picking strategy for web orders is mostly batch-picking, using a trolley with a large number of slots. The larger the goods, the fewer the items and customer orders that can be picked at the same time. In comparison, the picking strategy for store replenishment varies depending on, for example, the size of the goods and number of stores in the network. For small goods with frequent replenishment to smaller stores, several (often two to four) stores can be picked simultaneously on a pallet. Meanwhile, for large products or large volumes to big stores with more seldom replenishment, single orders are picked using one or more pallets.

The case study revealed a configuration that, to the best of our knowledge, has not previously been described in literature. In contrast to traditional picking strategies (single, batch, zone, wave), the new picking strategy decouples customer and production orders (i.e. pick lists). We refer to this configuration as SKU extraction, which implies that a large number of customer orders are accumulated and the picker only goes to one or a few storage locations and (manually) takes out hundreds of the same SKU to a trolley or pallet. These products are then moved to a sorting system. The use of SKU extraction can partially be attributed to the development of automation and e-commerce with multiple one-order-line orders. The focus shifts to quickly getting products out of storage while avoiding bottlenecks in manual or automated picking. In addition, the travel time, which generally constitutes the largest operational cost in warehouses, is eliminated as a cart is filled within a distance of only a few meters.

Regardless of the picking strategy, good planning is required. To a varying degree, the companies plan the warehouse activities so that store replenishment orders that are known first are picked first. The timing for releasing a store replenishment order typically depends on the destination and freight mode, where long distance and transport via terminals are



Notes: StRe, store replenishment order; Web, web order

Figure 4.
Overview of picking strategies

picked first. Web orders arrive throughout the day and can be managed continuously. However, the click-and-collect flow is often coordinated with store replenishment so that these are shipped together. One solution is to release click-and-collect orders until the shipping gates for associated store destinations are closed. The systems such as enterprise resource planning (ERP) and WMS can support prioritization of urgent orders or orders for a particular destination. A related challenge is the need to reduce the lead time between receiving orders and customer delivery. Therefore, several cases have postponed the "cut-off time" for receiving orders to be picked the same or next day. Many interviewees also mentioned that the picking orders are generated overnight, making it difficult to plan next-day operations.

Another aspect is the integration or separation of physical zones, operations and resources for handling store and web orders (Figure 5). On the vertical axis, a warehouse may have more separated or more integrated operations and resources, represented by the picking process, use of time windows, system support (e.g. WMS) and staff. Meanwhile, the horizontal axis refers to how the physical picking area within each zone is more separated or more integrated for handling store and web orders. It is important to note that a warehouse can have numerous zones (e.g. large vs small goods, singles vs multipacks, manual vs automation). In fact, a retailer could choose to integrate handling of store and web orders in one zone (e.g. in automation), whereas another could be separated (e.g. seasonal, fast moving e-commerce goods). Thus, the two axes represent the overall assessment for a warehouse.

A large degree of integration of store and web is noted in C1 and C3. These cases have joint space, processes, system support and staff for handling store and web orders. One example of this integration is the combination of picking store and click-and-collect, which are merged and have the same destination. The other cases strive to increase integration in certain aspects, for example, physical space or joint WMS. It is interesting to note that integrating physical areas does not mean that the actual operation for handling store and web orders is fully integrated in terms of processes, system support and staff. Another observation is that increased integration is often coupled with implementing advanced automation.

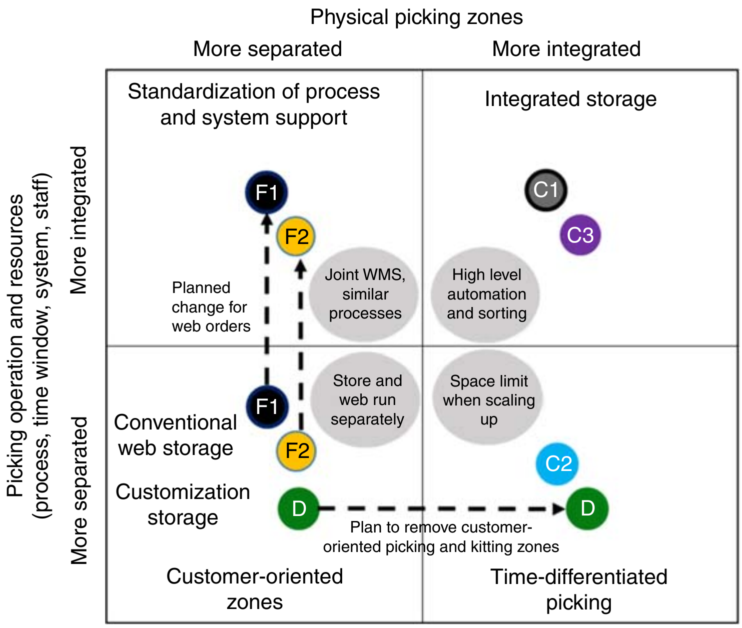


Figure 5.
Alternatives for separation or integration for picking store and web orders

Increased degree of sorting for outgoing goods

The increased amount of flows, products, zones, services and delivery points in omni-channels has led to a rapid increase in sorting activities (Table IV). An order with several order lines from different zones is typically consolidated before shipment. An alternative, used by one company, is to ship several different packages separately. The company's rationale is that unsorted goods are faster, and it is cheaper from an overall logistics perspective as the low transportation tariff for small single packages outweighs the sorting cost. Goods are also sorted by store/customer and by destination, and click-and-collect flows are increasingly being consolidated with the respective stores. For store replenishment, additional sorting may be required if picking zones are not designed according to the store's layout. This approach is becoming more common to simplify unpacking in the stores. Two important factors are lead-time requirements and transport fill rate. Tighter lead-time requirements imply narrower time windows in sorting and shipping areas. Meanwhile, the fill rate of carriers is crucial for reducing logistics costs. Therefore, additional sorting is important to maximize the utilization of space in trucks.

One company reported that they carry out over 20m sorting actions per year for outgoing goods. The case study illustrates that the increased sorting requires space and automation. In one case, 25 percent of the total warehouse area is used for sorting, including conveyor bands, scanner bows, and dynamic sorting bins. An implication is that there is less space available for other warehouse operations, such as receiving, put-away, storing, and picking. Several of the retailers also began seeking new, innovative solutions such as using video technology and/or sensors for automatic sorting, labeling, and packaging. For example, an advanced sorting system could introduce a number of different sorting algorithms where: goods from different zones are consolidated per customer, web orders are merged with replenishment orders, orders are sorted according to destination to improve capacity utilization in transportation, and each replenishment order is sorted automatically according to the store-friendly concept.

Traditionally, sorting by customer takes place simultaneously with picking. However, in omni-channel warehouses, multiple sorting points take time and create extra work. Often additional sorting is required to pack and prepare orders for shipping. One example is the consolidation of SKUs picked from different zones. Therefore, the companies postpone sorting in the warehouse, for example, by decoupling the picking and customer order. A possible solution is advanced sorting systems, which can handle multiple sorting activities simultaneously.

Considering the lack of space and need for fast outbound flows, retailers also increasingly postpone sorting outside of the warehouse. Important configuration decisions are related to when different sorting activities must be conducted, at what point in the network must sorting take place, and who should perform these activities. Each company appears to investigate different solutions. One solution is to fill the carriers' trailers in the morning instead of retaining goods inside the warehouse. Other cases push unsorted goods to the downstream network and thereby postpone sorting to external sorting hubs, which are either outsourced or managed internally. The purpose of this approach is partially to meet the increased time pressure from the customer and partially to achieve scale economies.

When postponing sorting activities in the network, several aspects must be considered. The solution must enable short delivery times while ensuring quality in terms of the right product to the right place without damage. The retailers describe extensive distribution networks with numerous trans-shipment terminals as a major risk, both in terms of time and quality. One respondent described these systems as a tombola, which increases the risk of errors in handling and goods registration and failing to meet the lead-time requirements and delivery precision. Most cases strive to shortcut at least one tier in the sorting/distribution network. For example, C2 allows their 3PL operator to use part of

Table IV.
Characteristics related to outbound flows and sorting configuration

Case company	Fashion (F1)	Fashion (F2)	Consumer Electronics (C1)	Consumer Electronics (C2)	Consumer Electronics (C3)	do-it-yourself (D1)
Product characteristics	Small goods	Small goods	Mix of small- and medium-sized goods	Mix of sizes, including bulky goods	Mix of sizes, including bulky goods	Large mix, including bulky goods
Warehouse zones (for picking)	Hanging goods; store vs web; zones for ladies, underwear, kids	Hanging goods; store vs web; zones for ladies, underwear, kids	Medium-sized goods (pallets); small goods (shelves; automated for l ow- frequency goods)	Large goods (floor storage); medium-sized goods (pallets); small goods (shelves)	Large goods (floor storage); medium-sized goods (pallets); small goods (automated)	Many zones, e.g., bulky indoors vs outside; small goods (automated)
Sorting of web orders	Sorting while picking	Sorting while picking	Sorting while picking	Postponed to packing station	Postponed to packing station	Postponed to sorting terminal
Store-friendly sorting	Yes	Yes	Yes	No	No	Yes
Click and collect (C&C) approach and delivery points	C&C for free; home delivery costs	C&C for free, home delivery in few selected countries	No C&C; home (or pick-up point) free; express delivery costs	No C&C; home delivery free; express delivery costs	C&C for free; home delivery costs	Limited C&C; delivered to site (home or construction)
Coordination store and C&C	Consolidated before shipping	Consolidated before shipping	No C&C	No C&C	Increasingly coordinated	No C&C; store and home coordinated
Regional (internal) sorting hubs	No	No, but pre-sort to skip one of the third-party logistics provider 's (3PL) sorting nodes	No, but can pre-sort to skip one of the 3PL's sorting nodes during demand peaks like Black Friday	No, but close cooperation with 3PL, sorting web orders at their premises to delay cut-off time	Yes, rent time windows at several local terminals. Small-parcel sorting done by the 3PL	Yes, rent time windows at different local terminals
Transport management	Major 3PLs and Post	Major 3PLs and Post	Major 3PLs and Post	Major 3PLs and Post	Internal control, but leveraging 4PL; chartering carriers' long-term capacity	Internal, chartering carriers' long-term capacity

their DC to sort goods, thereby cutting one terminal handling in the 3PL company's sorting network. C3 and D1 have established their own networks for sorting and distribution, using their own chartered trucks and renting timeslots at different terminals around the country for co-loading and sorting.

The decision to manage distribution networks internally appears to be linked to the size of goods and flows and the importance of increasing the fill rates in trucks. With small goods, it is difficult to fill entire trucks, particularly if retailers want a high frequency of daily deliveries and returns. Then, it may be necessary to let a 3PL operator co-load with other companies. The first destination is a regional sorting hub; thereafter, goods are broken up per store, except in cases where the store has sufficient volume to fill a truck. Some case companies mention that they can merge store replenishment flows, click-and-collect and home delivery for web orders to fill trucks out of the DC. The retailers are clearly investigating and testing new nodes in their networks. Regional distribution hubs, sorting hubs and large "XXL" retail stores are used (or planned for) to facilitate omni-channel logistics with time and cost requirements. The case companies discuss the various roles of the stores as sales and marketing points vs logistics nodes. The roles of the stores vary from traditional sales to warehouses, service and meeting points. Several retailers reason about the possibility of segmenting stores with different roles, depending on location and size. Shops in city centers are considered better suited for sales and marketing, while stores in the outskirts of cities can also function well as logistics nodes. Such nodes may specialize in the supply of city shops, co-loading and coordination of last-mile distribution and return handling.

Increased use of automation

The case study shows increased use of warehouse automation, but the current degree of automation varies. While some companies have already made extensive investments and automated large parts of the warehouse and material handling, others have automated certain operations but are continuously investigating opportunities and potential gains with new automation solutions.

The companies use automation mostly for small and more standardized products. Hence, retailers with a large variety in terms of product size often use different zones with varying degrees of automation. This in itself leads to an increased mix in handling and the need for consolidation and sorting of different flows before shipping. The most commonly automated operations are mainly linked to storage, picking, sorting, and packing; receiving and return handling are more often handled manually. As storage for store replenishment and web orders is merged, the retailers foresee that the integrated warehouses are highly automated.

Related to previous discussion on sorting nodes and network design, Figure 6 displays an overview of how the companies use automation and different types of warehouses (five years ago, present set-up and five years hence). These two aspects are combined because they have a major influence on warehouse configuration. As illustrated in Figure 6, the retailers are moving toward using more automation as well as extending their network, both with increased drop-shipment (to increase offered assortment) and more and different types of handling nodes closer to customers (to reduce lead time). These movements thus suggest big changes in future warehouse configuration.

Automation brings numerous benefits. Although it requires extensive investments, the retailers expect automation to pay off in the long run through streamlining flows and more cost-effective handling. Factors driving automation are increased sorting and packaging (e.g. folding, packing, and labeling) as well as ergonomics and safety. In particular, safety and ergonomics are important, and automation can reduce heavy lifting for pickers. Moreover, according to certain companies, automation can also provide higher utilization of space capacity in the warehouse. However, one company (D1) questioned this, claiming

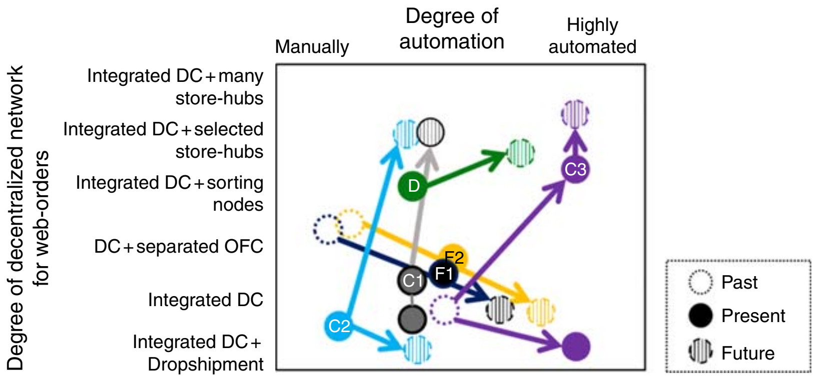


Figure 6.
Use of automation and network set-up over time

on the contrary that automation can generate a lower utilization of space capacity than manual handling.

Further, the retailers mentioned certain challenges in this regard. While automation implies more streamlined and less flexible handling of goods, omni-channel retailing requires more flexibility as it implies greater product assortment and product variation; automation can be sensitive to changes in product characteristics and size variation. Therefore, it can be difficult to adapt automated solutions for companies introducing new products with different sizes and handling requirements. Similarly, for extreme demand peaks in various seasons (e.g. Black Friday) and for handling various customer requirements and flows, such as express orders, automation could actually become a constraint. Several cases emphasize the difficulty of adapting and trimming performance for maximal capacity, considering that increasing staff does not help in a highly automated warehouse. Staffing can also become a challenge in the future, as automation partially changes the required profile of workers. Instead of handling goods, more personnel are then needed for designing and maintaining automation solutions.

A critical aspect related to automation is increased requirement of master data for articles and packaging (e.g. singles and multipacks) handled in the warehouse. Master data (e.g. product ID, dimensions, volume, and weight) are important for selecting storage location and improving utilization rate in storage areas. It is also critical for calculating capacity utilization pallets and trucks for outgoing transport. The retailers emphasize that product information must be correct from the beginning; errors in registration of product information may create issues throughout the chain. Hence, most of the companies use the most experienced staff for receiving. Additionally, investments in automation (e.g. sensors, video technology) enable prompt and accurate dimensioning. Certain retailers mention increased drop-shipments to be a related challenge, as products do not pass the warehouse but go directly to the customer and master data are never stored in their system. Another question is who takes responsibility and where master data are registered when omni-channel retailers use 3PL warehouses in their networks.

Logistics information systems

An important aspect linked to automation and master data are the development and integration of various systems within the warehouse and between different nodes in the omni-channel. The complexity of systems like ERP and WMS increases when storage for replenishment and web orders is integrated and the number and variety of flows increases. For example, the retailers indicate the increased complexity of deciding what, where, and how many of each SKU should be stored in each node and how flows as well as staff must be balanced in storage and picking. The companies also use warehouse control systems (WCS) to control, for example, robots and advanced sorting algorithms. In addition to ERP, WMS, and WCS, there are several other systems, for example, for labeling, administering, and transport administration (TAS). The retailers indicate the need for additional systems for efficient planning and control of flows and activities linked to the omni-channel warehouse. A major challenge highlighted was the need for continuous updates and increased requirement for "smart" integration of various systems. An important aspect is to avoid that a change in one system (e.g. in WCS) requires extensive changes in each of the other systems.

Moving beyond the warehouse, the companies indicate that omni-channel distribution networks become increasingly decentralized with, for example, regional sorting hubs and the use of stores as logistics nodes. Concurrently, customers' expectations of new services (e.g. click-and-collect and click-and-reserve) and expectations of updated information, such as inventory levels in different nodes and customer order visibility, are increasing. These expectations increase demand on the implementation and integration of advanced information systems throughout the network. The retailers highlight the importance of mainly three currently underdeveloped aspects. First, the retail stores' inventory information must be integrated and synchronized with the central warehouse (WMS) so that a customer can better understand how many and in which node in the network an article is stored and available for sale. Further, the systems must support real-time synchronization, for example, in terms of inventory stock levels and the possibility of customers reserving products. With shorter delivery lead times, it will be more important to offer real-time follow-up of picking and delivery information. Finally, there is an increased need to have a distributed order management system that could provide decision support for selecting the node in which a customer order is picked/shipped. Such a system is based on advanced calculations to improve lead times and reduce logistics costs.

Discussion, implications and future research

As omni-channel retailing transforms rapidly, warehousing is a critical component for meeting the increasing requirements of service, cost, and variation embedded in the dichotomy of handling store replenishments and web orders simultaneously. A focus on omni-channel warehousing is required, but the available literature is sparse. As such, this study makes an important contribution. We conducted a multiple case study to identify the challenges and discuss the implications of warehouse configuration in omni-channel retailing. The challenges described in this study can be summarized as an interrelated web of aspects to consider both inside and outside the four walls of the warehouse (Figure 7). The arrows in Figure 7 indicate that one challenge influences another. In this section, we build on Figure 7 to discuss implications for theory and practice.

Implications for theory and practice

Theory is extended with regard to internal warehouse operations, design and resources as well as the interrelation of processes and resources external to the node. Building on Figure 7, the study confirms, and further details, challenges previously discussed in literature. Important examples in this regard include an increased range of incoming and outgoing flows, greater variety of product characteristics, and handling large replenishment and small web orders in an integrated warehouse (Hübner, Holzapfel and Kuhn, 2016; Kembro *et al.*, 2018; Larke *et al.*, 2018). We also extend the discussion on implications of reduction in warehousing costs (Hübner, Wollenburg Holzapfel, 2016) and web customers' requirements driving shorter warehouse throughput times (Hübner *et al.*, 2015; Marchet *et al.*, 2018). These challenges are important to consider for the embedded target conflict

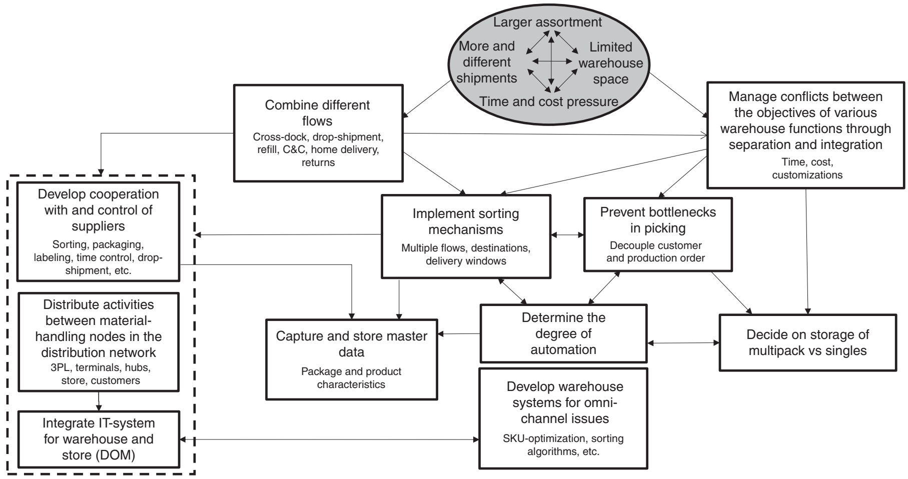


Figure 7.
Challenges for omni-channel warehousing

between store and web and the decision to integrate or separate, for example, physical space, system support, processes, and staff.

Other challenges that we contributed a greater understanding of include the issues of constrained warehouse space (Kembro *et al.*, 2018) combined with the need for a larger area for throughput and sorting of incoming and outgoing goods (Hübner, Holzapfel and Kuhn, 2016; Hübner, Kuhn and Wollenburg, 2016). Another important extension to the omni-channel warehousing discourse is with regard to the choice of singles and multipacks and different approaches to handle this decision both in terms of storage positions and requiring suppliers to label different SKU levels. We also provided additional insights to and understanding of the need for implementation of advanced WMS, advanced inventory management, automation, and other new technologies (Hübner, Kuhn and Wollenburg, 2016; Kembro *et al.*, 2017; Marchet *et al.*, 2018; Kembro and Norrman, 2019). To support automation, the ability to capture product master data may become a key competence. Then, how returned drop-shipment goods complicate master data generation in omni-channels becomes an interesting aspect.

We further extended theory by showing how different configuration elements are interrelated and how changes in one element (e.g. automation) are dependent on others, both internally (e.g. sorting, balancing flows, master data) and externally (e.g. labeling and packaging performed by suppliers and logistics service providers). With reference to Figure 7, our study supports and extends existing research, thereby suggesting that the configuration process involves multiple iterations and trade-offs and requires a holistic top-down approach to avoid sub-optimization (cf. Rouwenhorst *et al.*, 2000; Baker and Canessa, 2009; Gu *et al.*, 2010).

We also discussed the fit of picking strategies, particularly how requirements of shorter throughput times motivates the use of SKU extraction. To the best of our knowledge, this picking strategy, which can be used both for single order lines in e-commerce and to improve store replenishment, has not been described in literature before. We elaborated this discussion to include the increased requirement of postponed sorting and different alternatives for and types of sorting, both for inbound and outbound flow. The study highlights several drivers for increased sorting, including lead-time pressure, decoupling of customer and production orders, merging of store and click-and-collect, consolidation of orders picked in multiple zones, and preparation of store-friendly packaging. These insights extend previous warehousing theory, which to a large extent has been focused on picking (cf. Gu *et al.*, 2007; Davarzani and Norrman, 2015; Hübner, Wollenburg Holzapfel, 2016). A related contribution is the increased postponement of sorting activities to the network, such as sorting hubs. This study explains and describes the need to leverage external partners' resources to improve omni-channel warehousing. External partnerships become increasingly important, and retailers consider the division of activities and collaboration with actors both upstream and downstream to increase the efficiency and effectiveness of warehouse operations. The increased external integration also calls for attention to inter-organizational information systems (Kembro and Norrman, 2019).

With regard to practical application, the descriptions of challenges and their implications for warehouse configuration could inspire practitioners to address their own challenges when transforming their omni-channel retailing. By comparing a retailer's situation, motivation, and logic with the six case companies, practitioners can better decide on appropriate configuration elements. Practitioners can use the results to assess their existing warehouse operations and create a better fit with omni-channel requirements. More specifically, decision-makers can build on the overview presented in Figure 7 to: extend collaboration with suppliers to better prepare and advance warehouse operations, analyze potential bottlenecks and understand what separation or integration of different operations could bring, leverage combined use of clearly defined flows, e.g. drop-shipment and cross-docking, consider increased use of sorting in inbound and outbound operations, and analyze trade-offs with other WH operations, and analyze effects (e.g. lead time and cost) of postponing sorting and packing to handling nodes closer to consumers. A similar assessment can be done for warehouse design and resources: analyze effects of using singles vs multipacks on storing and handling equipment, evaluate different automation solutions, especially related to needed flexibility, develop capabilities for capturing and storing master data to support automated solutions, understand benefits of and challenges to more integrated information sharing between warehouses and other handling nodes, and analyze the required competencies of future WH employees, considering interface with automation, robots (e.g. drones), IoT and AI.

A "limitation" for all case study research is that the aim is not statistical generalization but analytical (Yin, 2009), where previously developed theory is compared to the empirical observations of the case study. Considering the focus on Swedish retailers in three sectors (fashion, consumer electronics and DIY/construction material), an implication is the limited external validity of the study – meaning the domain to which the study findings can be generalized. To address these limitations, future studies can include more varied companies, extend the geographical scope, and explore cross-regional differences as well. With regard to sectors, the development in grocery retail appears to be different in terms of, for example, separated warehouses and more frequent use of online fulfilment centers (cf. Eriksson *et al.*, 2019). As analytical generalization is dependent on the chosen theory, another limitation of the study is its focus on warehousing theory. This research could thus also be extended by applying other established theories. First, the dynamic-capability theory (e.g. Teece, 2007; Teece, 2018) could be used to explore capabilities needed to transform and manage omni-channel warehouses. Second, the contingency theory (Donaldson, 2001) can be applied to analyze how warehouse configuration is tailored to different contexts. Examples of interesting analysis include separation or integration of physical layout for different flows, when/where/how to collaborate with suppliers and other partners, the decision to use SKU extraction as a picking strategy, and to store singles and multipacks of different SKUs. Third, marketing theory related to sorting (e.g. Alderson and Martin, 1965; Hulthén and Gadde, 2007) could be extended to analyze different sorting processes and potential trade-offs in the omni-channel context as well as the decision to move sorting and packing operations closer to the consumer.

Building on our synthesis of literature (Figure 1) and case findings (Figure 7), we summarize practical implications and a research agenda for omni-channel warehousing in Figure 8.

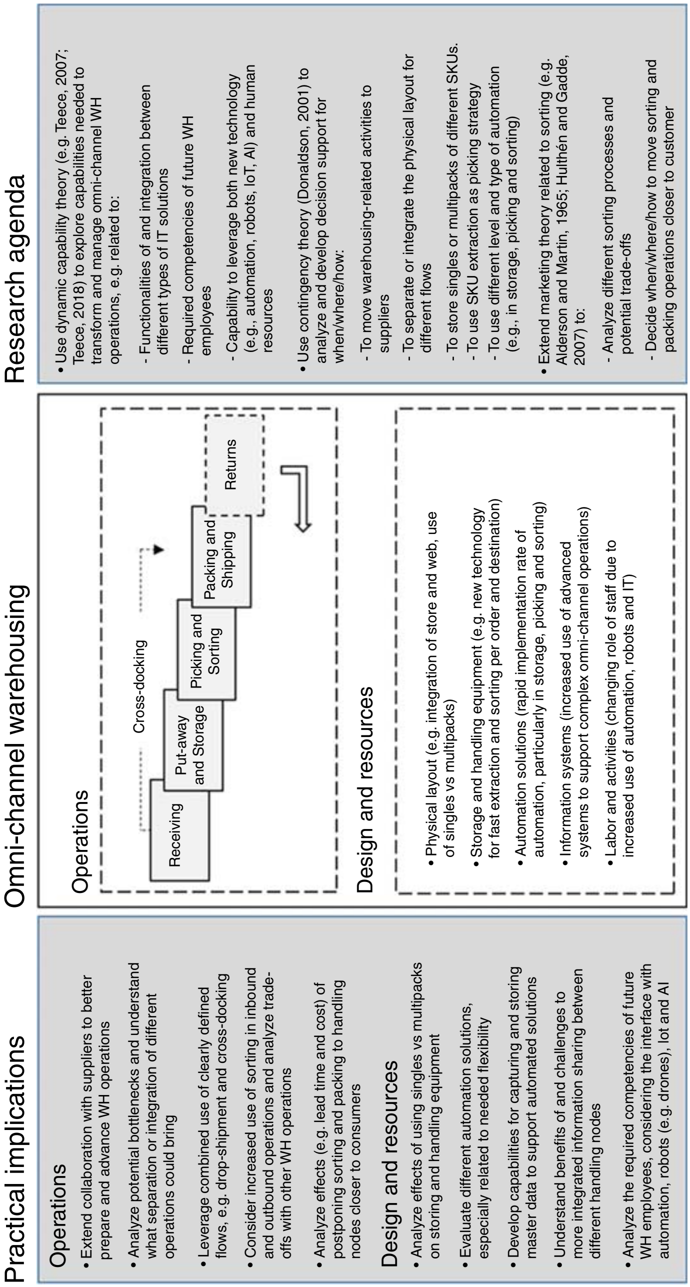


Figure 8.
Overview of practical implications and research agenda

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Corresponding author
Joakim Hans Kembro can be contacted at: joakim.kembro@tlog.lth.se