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Fulfillment costs in online grocery retailing: Comparing retail store and warehouse strategies

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Abstract:

This study develops a framework that structures the operational costs of online grocery retailing in order to identify which is the most suitable e-fulfillment strategy. The cost framework was designed by applying time-driven activity-based costing (TDABC) and is based on the insights of two large European grocery retailers, which operate retail store and warehouse e-fulfillment strategies respectively. Cost information was collected, and activity-oriented process modeling was carried out in the field to identify the most relevant e-fulfillment cost drivers. For the retail store strategy, picking costs were the highest among e-fulfillment activities and up to twice as high as for the warehouse strategy. For the warehouse strategy, delivery costs were the highest and 50% higher than for the retail store strategy. Less studied logistics activities such as unpacking and reverse logistics all together accounted for up to one third of total expenses for both strategies. In omnichannel, operations and logistics managers must still ensure the profitability of the online channel if they want to succeed in the grocery business. This framework will help managers identify and estimate the most relevant cost drivers, and to allocate them to the main operational activities.

Key words:

Cost Analysis, online fulfillment, fulfillment costs, online grocery retailing, omnichannel retail.

1. Introduction

In the early days of the e-grocery industry, most bricks-and-mortar grocery retailers remained cautious and started operating retail store fulfillment strategies (the picking of goods was made in-store) to fulfill online orders. This allowed them to find synergies with their existing networks of stores and to lower the initial investments for the online channel (Wollenburg et al., 2018). In recent years, a second, more sustainable rise of grocery online sales has brought back attention to the industry as omnichannel retailing emerges, with worldwide online sales continuously increasing more than 15% annually (Kantar, 2022). In addition, the COVID-19 crisis has accelerated the growth of the e-grocery market sector, as consumers become more comfortable purchasing online (Keyes, 2020). However, it has been online-only grocery retailers who took the lead on the race for online sales (Kantar, 2019).

Under these conditions, many bricks-and-mortar grocery retailers have found themselves in a position where they needed to expand their online channels (Hübner et al., 2016a) and also develop the right omnichannel strategies (Davis-Sramek et al., 2020). Thus, retailers have started moving from retail store strategies towards warehouse strategies in order

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to fulfill their online orders (Marchet et al., 2018; Buldeo et al., 2019).

As of today, the fulfillment of online orders from both retail stores and dedicated online warehouses are still the two most common logistic strategies among bricks-and-mortar retailers (Eriksson et al., 2022). However, the economic implications of adopting one or another strategy has remained a critical gap on e-grocery operations research (Wollenburg et al., 2018; Rodríguez García et al., 2022), and bricks-and-mortar retailers stay in limbo when deciding what might best suit their online sales strategy. Analysis of all different factors points to the need for specific cost systems that also fit into the different e-fulfillment strategies adopted by omnichannel retailers. Should bricks-and-mortar grocery retailers leverage their existing retail store networks to fight against the rise of online-only players? What are the implications of moving towards high-cost, high-risk warehouse e-fulfillment strategies?

The aim of this paper is to develop a framework that helps structure the operational costs of both retail store and warehouse e-fulfillment strategies; allowing bricks-and-mortar grocery retailers to see the pros and cons of each of them. From a Cost Transaction Economics (TCE) perspective, the cost framework is developed applying time-driven activity-based costing (TDABC) methodology, and it is based on the insights from two large European supermarkets, which operate retail store and warehouse e-fulfillment strategies respectively. In addition, the authors test the framework by using real cost information from the same two grocery retailers that aided in its development. This reveals the differences in the main e-fulfillment cost drivers and the way these costs should be estimated and allocated for each strategy.

The paper is organized in six main sections, in addition to the introduction. In the first section, the authors review TCE theory and TDABC methodology to set the basis for their application to the online grocery retail industry. In the second section, we focus on the main research on retail store and warehouse e-fulfillment strategies with relevant contributions in terms of operational costs. This highlights a research gap in cost analysis. The third section describes the research methodology. In the fourth section, the cost framework is developed based on previous literature and insights from these case studies. The fifth section presents the application of the framework: real cost information collected from both retailers was used to compare retail store and warehouse e-fulfillment strategies in terms of operational costs. Finally, the authors conclude by describing the main contributions of the article from academic and managerial points of view and propose a future research agenda.

2. Theoretical background

According to Transaction Cost Economics (TCE) theory, the total cost of any economic activity can be divided into two types: production costs and transaction costs (Kirchner and Picot, 1987). When analyzing any industry from a global perspective this includes all the elements of its supply chain (manufacturers, wholesalers, retailers, and consumers), and every activity performed, except for the production of the goods sold, represents a transaction cost. These transaction costs add up to the initial production costs in every step of the supply chain until they reach the consumer (Wigand, 1997), who covers the total cost added. Additionally, the final retail transaction consists of an exchange between the retailer and the consumer that costs something to each, and in which the two parties obtain something in compensation.

In electronic market transactions, many transaction costs previously incurred by the customer in the final retail transaction such as price-type costs (parking fees, travel costs, etc.), and time-type costs (travel time, search time, overall shopping time, etc.) have now frequently been absorbed by retailers, wholesalers, and manufacturers (Chircu and Mahajan, 2006). In particular, grocery retailers have had to absorb most of these costs due to the fact that they now perform the picking and the delivery of goods, putting in jeopardy the viability of the business. In an industry with low profitability margins (Fisher and Kotha, 2014), the facts presented above have turned making online sales profitable into a brainteaser for bricks-and-mortar grocery retailers. Logically, this disruption in the business environment has therefore imposed requirements for bricks-and-mortar grocery retailers' responsiveness in its operational choices such as make-or-buy decisions.

On the one hand, dedicated online warehouses are aimed at optimizing internal operations at the cost of requiring larger investments on fix assets. This favors insourcing for being less labor intensive compared to retail store e-fulfillment strategies (Foerstl et al., 2016). On the other hand, the use of one single location from where to fulfill online orders (such a warehouse) will dramatically change the cost of distribution compared to a network of stores.

For all these reasons, it is clear that the cost structure of both retail store and warehouse e-fulfillment strategies will differ significantly, and that the addition of new processes to retailers' daily operations such as the cost of picking and the cost of delivery brings a great challenge for online sales cost management. Thus, as the retailer is at the center of our investigation, we will study the costs that bricks-and-mortar grocery retailers encounter when interacting with the online channel, with a focus on the differences found depending on the e-fulfillment strategy adopted. To achieve this, we choose Time Driven Activity-Based Costing (TDABC) as the methodology for cost analysis.

Time Driven Activity-Based Costing (TDABC), has arisen as one of the most common methodologies to analyze cost structures (Schulze et al., 2012). Originally created by Kaplan and Anderson to find out which products are more profitable against those that might incur losses, this methodology expresses the practical capacity of any activity as the amount of time that employees and machines can work (Kaplan and Anderson, 2004). Then, the total cost of each activity is divided by the practical capacity so the cost per time unit can be calculated. Finally, costs are assigned to orders and customers by multiplying the cost per time unit by the time needed to perform each specific activity.

TDABC has been successfully applied in many environments in which the time needed to perform an activity is driven by multiple drivers, such as manufacturing (Gylling et al., 2015), wholesaling (Everaert et al., 2008), and retailing (Varila et al., 2007). As an example, the picking process in e-grocery varies significantly for every single online order: as the number of items per order increases or decreases, so will the time required to pick the products. In a similar way, the typology of the items has a relevant impact too, since, timewise, it is not the same to pick up a box of cookies from a shelf than to prepare fresh-cut beef.

3. Related literature in retail store and warehouse e-fulfillment strategies

Currently, there are two main types of e-fulfillment strategies: retail store and dedicated online warehouse e-fulfillment (Eriksson et al., 2022). Retail store strategies, often referred as store-based fulfillment or simply store fulfillment, refer to the preparation of online orders by picking the products by hand from the shelves of a traditional retail store, from which they are delivered to customers' homes. Stores are not designed to optimize picking efficiency, but to make products more appealing to customers, and yet most bricks-and-mortar chose this option to carry out their e-fulfillment operations (Hübner et al., 2016b). This low-cost, low-risk operating strategy allowed grocery retailers to be more flexible when facing uncertain demand and to find synergies through the use of existing stores' assets and staff (Vazquez-Noguerol et al., 2021).

In store fulfillment operations, Vazquez-Noguerol et al. (2022) found that the allocation of online orders to specific stores in the network is critical, and it could lower total e-fulfilment costs by 21%. More recently, Dethlefs et al. (2022) proved that the integration of retail stores into an e-fulfillment system for rapid deliveries can achieve cost savings of of 7% compared to networks with the exclusive use of online warehouses, and of 4% for networks with stores only.

In warehouse strategies, online orders are directly supplied to customers from specially designed warehouses, also referred as online-dedicated warehouses, online distribution centers (online DCs) or online fulfillment centers (Buldeo et al., 2019; Kembro and Norrman, 2022). These facilities are optimized to work with smaller logistics units (items vs pallets) and lower shipment sizes when compared to traditional warehouses that supply retail stores (Baker, 2008). Online-dedicated warehouses are know for having high levels of automation and technologies that support data management, connectivity, and real-time analysis, compared with traditional warehouses (Kembro and Norrman, 2022). However, in these warehouses, picking can still go from being highly manual, with pickers moving around warehouse aisles, to fully automated, with both the order and the products being sent to a human picker or with robots directly picking the whole order (Hübner et al., 2016b; Eriksson et al., 2019; Rimélé et al., 2021).

In terms of the operational costs for warehouse fulfillment, Yrjölä (2001) developed a detailed analysis of the costs of operating one of these facilities when warehouse strategies were something new and only associated with online-only grocery retailers. Nonetheless, the model does not reveal the main logistics processes of the warehouse and lacks an integrated view of the total costs of operating the facility. In this regard, Kämäräinen et al. (2001) developed a decision model for this kind of facility that showed how much money e-grocers can invest in automation depending on how much faster the picking process can become, which is directly related to the number of orders that can be processed. More recently, Eriksson et al., (2019) described how certain factors such as the order characteristics create different requirements and impact the cost of these activities when compared with traditional distribution centers.

Transportation is another of the most important e-fulfillment cost drivers of the grocery business, which is why it has been the key focus of the literature over the years. Boyer et al. (2009) presented an analysis for warehouse strategies only and found there is a sales point where it is not feasible to make delivery cheaper. Agatz et al. (2011) focused on the impact of time windows on the cost of e-grocery delivery, concluding that using 2-hour time windows (very common among grocery retailers) increased the total delivery cost by 25% compared to time intervals that covered either all morning or all afternoon. Siawsolit and Gaukler (2021)

Other alternatives to reduce last-mile costs include offering pick-up points in stores or at specific places, known as Click&Collect (C&C), Click&Drive (C&D), or curbside fulfillment models (Rodríguez-García et al., 2016; MacCarthy et al., 2019; Siawsolit and Gaukler, 2021). In addition to traditional alternatives, innovative solutions such as mid-route shipment consolidation, which considers shipment exchanges (transfers) between different vehicles at certain customer locations (Cortes and Suzuki, 2020), or parcel lockers and crowdsourcing logistics (Rodríguez García et al., 2022) are beginning to appear in e-grocery in order to reduce the impact of the demand for more fragmented time-windows and faster deliveries.

Other complementary studies not only focused on transportation but also discussed many of the factors that could trigger last-mile expenses regardless of the e-fulfillment strategy, including high orders' frequency levels (Belavina et al., 2016), sub-optimization of delivery trucks (Kämäräinen and Punakivi, 2002), failed deliveries (Vanelslander et al., 2013), low consumer density (Kämäräinen and Punakivi, 2002) and overly demanding time windows (Kämäräinen and Punakivi, 2002). More recently, Zissis et al. (2018) analyzed the collaboration in e-grocery distribution between two retailers, concluding that important savings in both time and distance travelled could be achieved. Moreover, Paul et al. (2019) analyzed synergies in omni-channel distribution, when stores are visited to replenish offline inventories and to supply online orders that will be picked-up by customers.

So far, literature on grocery e-fulfillment costs has mainly focused on specific logistics aspects, particularly the delivery process and, to a lesser extent, the picking process. In addition, comparing e-fulfillment strategies from a cost perspective remains as one of the main gaps in recent e-grocery research (Hübner et al., 2015; Wollenburg et al., 2018; Rodríguez García et al., 2022). Based on the above discussions, two research questions were formulated:

RQ.1 How can bricks-and-mortar grocery retailers structure their operational costs to calculate the profitability of their e-fulfillment strategies?

RQ.2 What are the main differences in the operational costs incurred between retail store and warehouse e-fulfillment strategies?

To answer to our first research question, we develop a cost framework that includes all e-fulfillment activities. The framework is aimed at helping bricks-and-mortar retailers structure their operational costs, so cost information is presented in the form of cost centers for each e-fulfillment strategy. The second research question is answered by testing the framework in two grocery retailers, each of which operates a different e-fulfillment strategy. This will show how the main cost drivers vary depending on the e-fulfillment strategy, and important differences on how operational costs should be estimated and allocated to the main operational activities.

4. Methodology

As the field of grocery e-fulfillment costs remains under-researched, the authors followed a mixed method that included both deductive and inductive research. By collecting and organizing data from the literature and the case studies, the authors seek to elaborate theory, i.e. to structure, specify, and contrast theoretical constructs and relations so as to dive deep into the existing knowledge of grocery e-fulfillment costs (Gammelgaard, 2017; Fisher and Aguinis, 2017). Theory elaboration differs from both theory-testing and theory-generating as a general theory is used to approach the empirical context, yet it does not require detailed premises to deduce certain hypotheses in conjunction with this general theory (Ketokivi and Choi, 2014). The development and application of the cost framework, which falls in the context of a general theory (TCE) and was developed by applying a well-established methodology (TDABC), required the combined deductive-inductive research approach inherent to theory elaboration. Ultimately, this was achieved through an in-depth investigation of both the literature and the case studies. Figure 1 summarizes the complete research process and shows how it was structured to answer the two research questions presented by the authors.

Research on e-grocery operational costs for retail store and warehouse e-fulfillment strategies was conducted before carrying out fieldwork involving the companies under study. As well as bringing into light the most important research gaps within the field, this review of the literature was done with the purpose of identifying the main activities of e-fulfillment and exploring the main e-fulfillment cost drivers, providing the first global view on the topic. This review process was done in two main steps. The first probe was performed using combinations of terms such as "e-grocery", "online grocery", "e-fulfillment", "logistics", "supply chain", "operations", and "costs". In this step, we focus on the contributions from leading journals on Supply Chain and Operations Management research. In the second step, we used the "snowballing" technique and traced citations to other articles that significantly contributed to the field of grocery e-fulfillment costs. In addition, literature on TDABC had to be reviewed after laying the basis for the study with the theoretical background on TCE. In this case, we focus our probe on cost modeling research with relevant contributions in similar industries such as wholesaling and retailing and with a single-case-study approach. This helped the authors identify important aspects for the development of the cost framework.

To carry out the field analysis, general information for the design of the cost framework was collected from two main grocery retailers in Spain and the UK. According to Yrjölä (2001), both examples had to be representative in premises of currently operating stores and warehouses that sell groceries online. The Spanish seller is one of the largest supermarket chains in the country, and the authors used one of its most relevant multichannel physical stores as an example for the retail store strategy. The UK retailer is one of the largest online-only grocery retailers in the world, and its facilities are equipped with state-of-the-art warehousing technology, so it was selected as an example of the warehouse strategy. Nonetheless, the facility analyzed for the warehouse strategy could be used perfectly by either bricks-and-mortar or online-only retailers. The use of one single case study for each strategy is supported by Siggelkow's (2007) research, who concluded that

RQ	Research Goal	Methodology	Research Process	Contribution
RQ1	Cost Framework Design	Literature Review	Review of research on TCE and TDABC theories	Cost modeling knowledge
			Review of research on E-grocery Operations and E-grocery Operational Costs	Knowledge of important operational activites and logistics cost-drivers
		Field Analysis	Questionnaires sent to retailers	Development of an initial version of the framework
				Identification of main operational activites and collection of retailers' cost data
RQ2	Application of the Cost Framework		Semi-structured interviews with retailers	Adaptation of retailers cost information to the framework
			Visits to retailers' facilities	Estimation of the most relevant variable costs
				Allocation of all items of expenditure to the main operational activities identified
			Final interviews with retailers	Review of the framework and its application. Final version of the framework

Figure 1. Research methodology.

this methodology can be very useful when rich, longitudinal research is needed to provide details of how internal processes work. When applying cost theory, this is of high importance for the modeling of activities and the cost allocation, therefore single case studies have been commonly used in some the most relevant studies within the field (see e.g., in Everaert et al., 2008; Varila et al., 2007; Wouters and Stecher, 2017).

In our field analysis, several data collection methods were applied to meet the reliability criterion to which case studies must respond (Bryman et al., 2007; Siggelkow, 2007). Qualitative research, which we used as a combination of observation-based research and semi-structured interviews, has been proved by literature to be of great usefulness for business process modeling in the retail industry (DeHoratius and Rabinovich, 2011; Trautrims et al., 2012). In addition, interviewees from both retailers were experts in their fields: Supply Chain Director (retail store) and Project Design Manager (warehouse). Both their experience in the design of the main logistics operations and their understanding of the capital expenditures and operational costs of running the facilities bring the maximum level of knowledge to the quantitative data gathering process (see e.g., in Hübner et al., 2015). The field analysis took place over the course of 5 months, and both case studies were performed at the same time.

As a first step, a questionnaire was developed and sent to the retailers with the purpose of developing an initial version of the cost framework and to collect real cost information from both retailers. The main activities performed in each facility and the main items of expenditure were identified in this initial phase. Each questionnaire was an Excel file that included a list of the most common activities and expenses that can be found at stores and warehouses respectively, and were developed based on the literature review and complemented with data from additional sources such as companies' websites and reports (see e.g. Cichosz et al., 2020). To fill the Excel files, the interviewees had to select which of those activities were performed at their facilities and add other activities in case they were not included earlier in the original file. In the same way, the interviewees had to select the most relevant expenses of their facilities and indicate a possible cost estimator for each of them.

Once the questionnaires were received and internally discussed, a set of working sessions was conducted the retailers to give context and complete the data from the questionnaires. Four working sessions were conducted with each retailer, with each session being a semi-structured interview lasting an average of 4 hours and being conducted either face-to-face or via Skype. The first session was used to review the initial cost framework and to discuss the answers to the questionnaire provided by each retailer in-depth. At the beginning of the second session, a revised version of the framework was presented to the interviewees. At this point, each case study would advance at a different path depending on the availability of each interviewee, since the basis for the cost framework was already laid. For the rest of the second session, the authors discussed how retailers' cost data should be adapted from the retailers' internal cost structure to our framework's design. The cost information was collected from two main sources: the income statement of each retailer for 2018 and internal cost management tools. The income statement was used as a basis for calculating most of the fix costs incurred by the retailers, while internal cost management tools brought information about how these and other costs were split into items of expenditure. During sessions three and four, the authors focused on collecting information about the operating features of the facilities and to connect all cost data collected to each activity performed (cost allocation).

The final step of the field analysis was to visit each facility, both the physical store and the dedicated online warehouse. These visits were aimed at analyzing all logistics processes to complete two important parts of the framework: the estimation of relevant variable costs and the allocation of each item of expenditure to the different activities. A final semi-structured interview was also conducted with each retailer at the end of the visit to discuss the selection of cost estimates, the correct allocation of costs, and to review the framework as a whole.

5. Designing the cost framework

In this section, the authors describe the cost framework in-depth. The framework is an adaption of a Time Driven Activity-Based Costing (TDABC) model that focuses on the first two steps of its application: the identification of the main e-fulfillment cost drivers and the allocation of costs to activities from a process-oriented point of view (Hofmann and Bosshard, 2017). As explained previously, the aim of this cost framework is to answer the first research question presented by the authors, helping bricks-and-mortar grocery retailers structure their operational costs so they can ultimately calculate the profitability of their e-fulfillment strategies. Six steps were followed in order to develop the framework.

The first step was choosing the right business unit (BU) for the analysis of each strategy, as all costs would be allocated to this business unit. An individual multichannel store was chosen as the BU for the retail store analysis, while a dedicated online warehouse was chosen as the BU for the warehouse analysis. General and operational parameters such as demand information and daily operating hours of the facilities are defined in this first phase. These parameters will have a direct impact on the estimation of variable costs as well as sales data, which is required to ultimately calculate the profitability of the strategies.

Second, the activities performed or managed at the business units are identified for both strategies, with special attention to which operations are performed within each activity, so the future cost allocation can be done correctly Schulze et al. (2012). The activities completely managed or performed in each facility might differ, as in each strategy some of them will be completely or partially centralized, i.e. managed or performed from headquarters. Moreover, the store operates both channels, which means processes related only to in-store sales, processes related only to online sales, and those shared by both channels had to be separated. Our focus will be on the last two. The warehouse is a dedicated online facility, so all costs can be allocated to the online channel. In addition, the authors identify the main and auxiliary activities based on their own knowledge, as well as previous literature on e-grocery operations.

The main activities are those directly related to the physical flow of the products. First, Scott and Scott (2006) studied in detail many e-fulfillment processes such as storage, picking, packing, outbound operations, and delivery services. Then, Hübner et al. (2015) highlighted the impact of the unpacking process (replenishment) on e-fulfillment costs, while Hübner et al. (2016b) showed the importance of returns in order to achieve excellence in omni-channel grocery logistics. Later, Wollenburg et al., (2018) included processes such as inbound operations and the preparation of ultra-fresh products (e.g. products prepared at a fish or a butcher's counter) in their study of e-grocery logistic networks. Also, Kembro et al. (2018) summarized all main logistics activities of omnichannel warehouses in their literature review.

Auxiliary activities are twofold, including activities aimed at supporting the main logistics processes, e.g. IT support, maintenance, or cleaning; and other activities such as financial activities or legal affairs. These non-logistics activities are mainly centralized (performed and managed at retailers' headquarters) and will ultimately be classified in another group called "central operations" in the framework.

In the third step, all items of expenditure originally allocated to the BUs under analysis are included in the framework. Expenses are categorized according to their main type (labor, amortization, etc.) and their variability. Fixed costs were set according to the real annual cost information provided by the e-grocers. However, variable costs were estimated according to different external and internal parameters, so profitability can be calculated for different demand and operational scenarios. The design of these cost estimates (the fourth step of the model) were based on the insights of the experts interviewed and the business process modeling conducted by the researchers during the visit to the facilities. According to TDABC methodology, these cost estimates can be also referred as cost drivers, which together form a comprehensive unit of workload for each process (Schulze et al., 2012). At this point, standard times for carrying out different processes such as the picking of one item or the unpacking of one pallet of goods had to be established. Once this is done, cost drivers can be calculated by multiplying the time needed for carrying out one unit of the process by the unit cost of the resources incurred in this process (as in Everaert et al., 2008).The fifth step is the allocation of all expenses to the different activities. This allocation is done in two well-defined sub-steps. As explained before, activities were separated between main logistics-operational and auxiliary activities. Thus, all expenses are first allocated to all activities, including the main and the auxiliary activities. This first allocation (from expenses to activities) is based on the real cost drivers of each activity and can be classified in three different categories:

- The first group is those expenses that could be directly allocated to certain activities since the cost driver is fully dedicated to a certain activity. Nonetheless, most costs had to be allocated indirectly based on different criteria (as in Wouters and Stecher, 2017).

- For cases where it was impossible to easily allocate a certain item of expenditure to an activity, the knowledge of the interviewees was used. At this point, it is important to remember that the interviewees where highly experienced on the design of the facilities, which allowed us to follow this process.
- Finally, other items of expenditure were allocated to activities according to a specific quantitative criterion.

After estimating and allocating all costs to activities, and as part of the sixth and final step, the second allocation of costs is done from the auxiliary activities to the main activities. This cost allocation is supported by TCE and TDABC theories, and it is used for those activities that provide services to the main activities of the retailer, rather than directly supporting a company's products or services (Varila et al., 2007). In this case, only specific quantitative criteria were used.

Finally, all cost data gathered up in the framework are compared with sales data in order to analyze the profitability of the business. As explained before, sales data was incorporated at the beginning to connect all pieces of the framework, since variable costs are linked to them. Both the cost of goods and the total revenue per family of products are information included in the framework, as well as extra income that comes from charges for delivery. When incorporating the rest of the costs included in the framework, the profitability of each strategy can be calculated. Figure 2 summarizes the complete framework described above step by step.

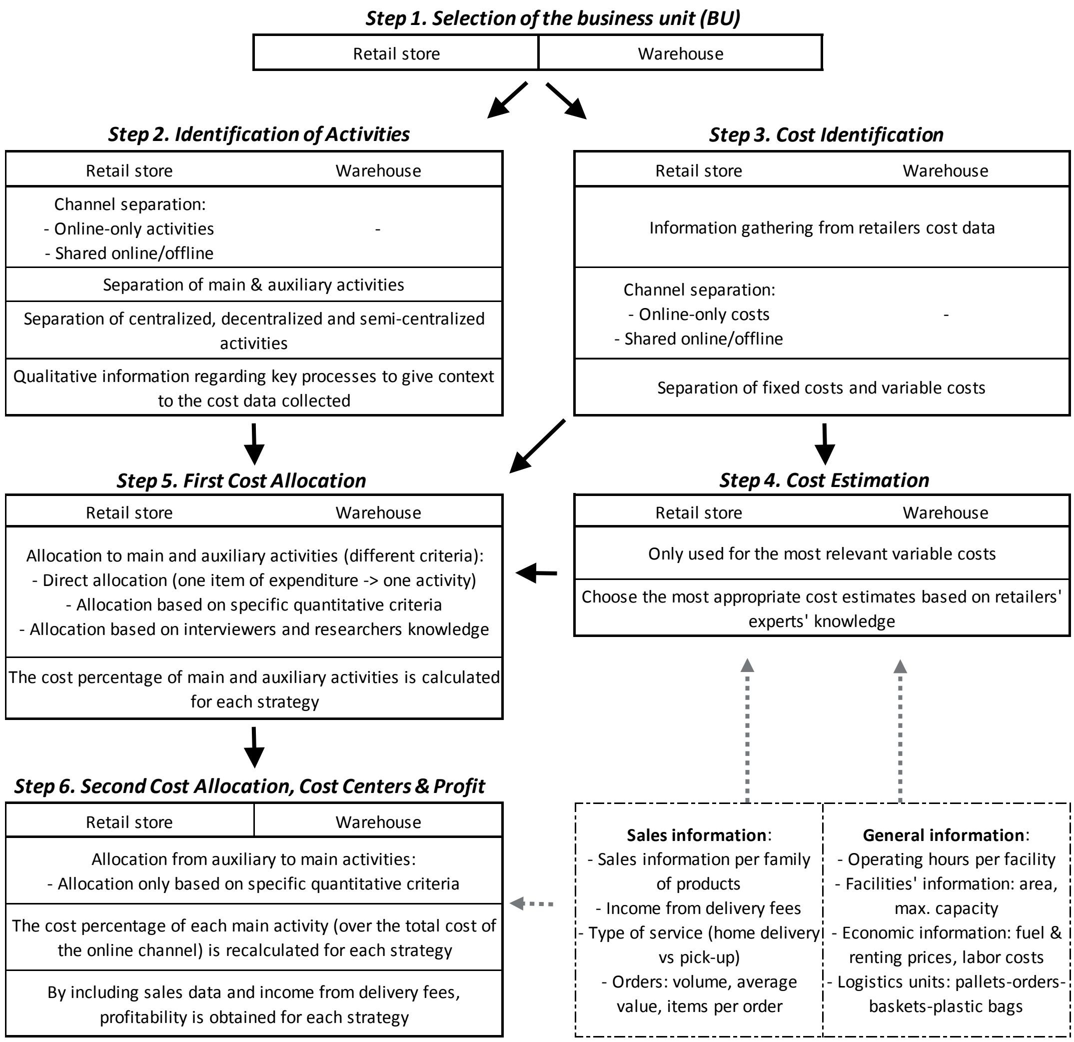

Figure 2. The cost framework.

6. The cost framework in action

In this section, an application of the cost framework is presented by using both companies' e-fulfillment strategies and cost data as examples. By doing this, the authors address the second research question of this study by comparing retail store and warehouse e-fulfillment strategies from an operational-cost point of view. When doing this, and in order to compare the cost results of both e-fulfillment strategies in a rigorous way, researchers and retailers worked together to adapt the cost information collected to present the break-even scenarios of each strategy, which could be done through the adaptation of cost estimates that impact on variable costs.

Steps 1 and 2: Selection of the Business Unit and Identification of Activities

The multi-channel store for the analysis is an average store of 15,000-ft^2 size and annual in-store sales of approximately €6,000,000. For this type of store, a maximum of 100 online orders per store per day was established to avoid pickers disturbing customers while shopping, even though most orders are prepared before the store opens. The online picking is performed with a normal cart that only allows single-order picking. This means that orders are completed one at a time by one single picker. Products are collected from the main shelves where they are exhibited for traditional shoppers who visit the store. The store also contains fish, deli, bakery, and butcher's counters where specialists prepare the products on the spot for the customers. Online delivery is outsourced to owner operator van drivers that also carry out home deliveries for in-store shopping (buy it in store, receive it at home). This way, synergies on this service are found between both channels. Reusable, insulated baskets are used to deliver the orders. Outbound operations happen in batches to match delivery time windows and, between the end of the picking process and the loading of delivery vans, online orders are stored in dedicated rooms that include refrigerators and freezers to keep the products at the right temperature.

The warehouse facility has a plot area of around 270,000-ft^2 and a floor area of more than 650,000-ft^2. It's able to deliver 25,000 orders per day, which makes it a dedicated online warehouse appropriate to fulfill the demand of large cities, including metropolitan areas. In this case, baskets containing online orders are routed using conveyor belts to specific pick stations, where pickers transfer goods from designated shelves to the baskets. Once the products of an order from a specific pick station are in the basket, the picker gives the order to the conveyor to send the basket to the next picking station and then receives a new basket. In addition, there are two special sections within the facility that prepare fresh-cut meat and fish respectively.

Also, other processes such as bagging (placing plastic bags into the baskets) and the incorporation of returned baskets to the conveyor are specialized and standardized to assure optimization. Delivery to customers is done in two steps by using a company-owned fleet of vans and trucks. Since such a large warehouse supplies large areas, there are spoke-sites located in many strategic points where cross docking is done from large trucks to smaller vans. From these spoke-sites, vans deliver orders to customers.

With this in mind, Table 1 shows the list of all the main and auxiliary activities performed in both facilities, as well as providing the information as to whether or not those activities are decentralized, i.e. managed or performed at the facilities under study. For both strategies, all main operational activities are decentralized even if important differences exist regarding the logistics processes themselves. Regarding the rest of the activities, more were completely performed in the warehouse strategy than in-store, which is entirely understandable due to the volume of sales of the facility and the number of employees working in it.

Steps 3 and 4: Cost Identification and Cost Estimation

Once all activities are identified, all online operations costs that would be allocated to the business units are presented. First, Table 2 shows how all items of expenditure are classified according to their variability and the weight of each item over the total cost of operating the online channel. As explained at the beginning of this section, in order to compare the cost data of both strategies in a rigorous way, these percentages are the values obtained for the break-even scenarios of each strategy. In addition, Table III shows the cost estimates used to calculate the most relevant variable costs.

Labor costs (direct and indirect) account for more than 70% of retail store e-fulfillment costs compared to less than 40% for the warehouse strategy. This can be easily explained since automation barely exists in stores when it comes to the preparation of

Table 1. Activities completely or partially perform at the main BUs.

		Warehouse	Retail store
Main Activities	Inbound Shipping	DE	DE
	Inbound Operations	DE	DE
	Unpacking	DE	DE
	Storage	DE	DE
	Order Picking	DE	DE
	Counters (Butcher's, Fish, Deli…)	DE	DE
	Packing	DE	DE
	Outbound Operations	DE	DE
	Delivery	DE	DE
	Reverse Logistics / Returns	DE	DE
Other Activities	Recycling & Waste Management	DE	DE
	Cleaning	DE	DE
	Maintenance	DE	CE
	Continuous Improvement	DE	CE
	Human Resources	SC	CE
	IT Support	SC	CE
	Operations & Logistics Management	SC	SC
	Quality, Environmental, and Occupational Health	SC	CE
	Marketing & Sales	CE	SC
	Finance/Accounting	CE	SC
	Purchasing	CE	CE
	Technology/R&D	CE	CE
	Legal & Business Affairs	CE	CE
	Strategic Management	CE	CE

Note: DE: Decentralized; SC: Semi-centralized; CE: Centralized

Table 2. List of all costs allocated to the facilities.

		Warehouse		Retail store	
Cost Category	Item of Expenditure	Type of Expense	%	Type of Expense	%
Direct Labor	Drivers' Salaries	Variable	25.04%	Variable	24.83%
	Pickers' Salaries	Variable	5.42%	Variable	32.92%
	Specialist Areas Salaries (Counters)	Variable	3.63%	Variable	4.32%
	Warehouse / Store Operatives' Salaries	Variable	2.67%	Variable	4.88%
Indirect Labor	Other Indirect Labor	Fixed	0.77%	Fixed	1.35%
	Warehouse / Store Managers	Fixed	0.60%	Fixed	3.69%
Depreciation	Machinery & Equipment	Fixed	7.91%	Fixed	0.19%
	Fridges & Freezers	Fixed	2.76%	Fixed	1.25%
	Facility	Fixed	1.84%	Fixed	1.00%
	Hardware	Fixed	0.92%	Fixed	0.25%
Amortization	Software	Fixed	2.76%	Fixed	1.15%
Renting	Vehicles (Trucks/Vans)	Semi-Variable	3.47%	-	0.00%
	Facilities	Fixed	0.46%	Fixed	0.00%
	Land	Fixed	0.46%	Fixed	0.00%
Utilities & Similar Expenses	Petrol (vehicles)	Variable	7.59%	-	0.00%
	Gas, Electricity, Water & Other Utilities	Fixed	4.37%	Fixed	1.32%
	Electricity (refrigeration of fresh & frozen products)	Fixed	2.76%	Fixed	1.36%
Expenses	Maintenance & Repairs	Semi-Variable	2.76%	Fixed	1.36%
	Insurances	Fixed	1.84%	Fixed	0.00%
	Logistics Supplies (Pallets, baskets, plastic bags…)	Variable	1.04%	Variable	1.70%
	Other External Services	Fixed	0.92%	Fixed	0.57%
	Other Supplies	Fixed	0.46%	Fixed	0.34%
Expenses (Special)	Central Organization Expenses	Fixed	15.41%	Fixed	7.17%
	Loss - Perishability & Theft	Variable	2.43%	Variable	6.82%
	Loss - Returns	Variable	1.74%	Variable	3.41%

Note: % represents the cost percentage over the total cost without the cost of goods

Table 3. Cost estimates for the most relevant variable costs.

Cost Category	Item of Expenditure	Cost Estimates	
		Warehouse	Retail store
Direct Labor*	Warehouse / Store Operatives' Salaries	- Logistics units handled / hour (different for each process) - Relation between logistics units (orders / baskets / pallets /…) - No orders per year	
	Pickers' Salaries	- Items handled / hour - Average items / order - No orders per year	
	Specialist Areas Salaries (Counters)	- Items handled / hour (different for each section) - Average items of each section / order - No orders per year	
	Drivers' Salaries	- Drops per van per week - Average time between drops - Vans / Trucks capacity	
Renting	Vehicles (Trucks/Vans)	- Min No of vehicles by contract - Drops per van per week - Average time between drops - Vans / Trucks capacity	-
Utilities & Similar Expenses	Fuel (vehicles)	- Vehicles distance covered - Vehicles fuel consumption - Fuel price	-
Other Expenses	Maintenance & Repairs	- Min (preventive maintenance) - % based on No of orders per year processed by the conveyors	-
	Logistics Supplies (Pallets, baskets, plastic bags…)	- Fixed % of total revenue based on interviewees knowledge	
	Loss - Perishability & Theft	- Fixed % of total revenue based on interviewees knowledge	
	Loss - Returns	- Fixed % of total revenue based on interviewees knowledge	

Note*: the estimation of labor costs required additional legal information such as national insurance contributions

online orders. Among direct labor costs, pickers' salaries at stores account for almost half of the cost, representing the highest item of expenditure. As it is shown in Table 3, this and other direct labor costs were estimated for both strategies based on operational parameters linked to performance.

Drivers' salaries were the second highest cost incurred for retail store online fulfillment, which surprisingly represent a smaller percentage than in the warehouse strategy. Although drivers that worked for the retail store e-fulfillment retailer were owner operators, which means their payments should cover all costs of operating the trucks in addition to their regular salary (Rodríguez García et al., 2018), the cost of online distribution from stores appeared to be much lower than delivering from a centralized warehouse that requires the use of spoke-sites to ultimately reach customers. As shown in Table 3, other delivery costs such as vehicles renting and fuel expenses also had to be estimated due to their importance over total costs and its variability to volume of sales.

Indirect labor was also found to have much more importance for the retail store strategy. This was probably because the proportion of middle-level managers to regular workers needs to be higher since store employees dedicate time to many different activities due to the coexistence of the online and the offline channels.

Regarding the retail store strategy costs, we only take into consideration extra costs incurred due to online sales when allocating fixed costs to the online channel. For example, the depreciation and amortization costs of tangible and intangible assets that were already in stores to support offline sales are not allocated to the online channel. Nonetheless, the depreciation of fridges and freezers specifically used to store online orders and the depreciation of the extra room refurbished for storing online orders are fully allocated to the online channel. This, together with the fact that dedicated online warehouses are highly automated facilities that require important initial investments, is one of the reasons why depreciation costs account for more than 13% in the warehouse strategy compared to only 2% in the retail store strategy.

Finally, the amount of central organization costs allocated to the facilities is much higher in the warehouse strategy. The levels of advanced technology implementation and process optimization required to run this type of facility led this online-only supermarket to establish a strong central organizational structure. Contrary, stores are the main assets of bricks-and-mortar grocery retailers. Also, it is important to mention that the levels of loss due to perishability of the products, theft, and returns are lower for the dedicated online warehouse. According to the interviewees, this might be due to two reasons: first, in-store inventory management becomes difficult due to operating two channels, which might in turn cause stock-outs and unwanted substitutions; and second, theft mainly happens during customers visits to stores.

Step 5: First Cost Allocation

In order to show how the allocation of costs to the different activities was done, Table 4 summarizes the individual criterion followed to allocate each item of expenditure.

Regarding direct labor, it is worth mentioning the difficulties found when, as in the case of the retail store e-fulfillment strategy, employees dedicate their time to multiple activities. These required using historical data, to correctly allocate their hours to different activities. Contrarily, in the dedicated online warehouse, direct labor costs such as the cost of the pickers could be directly allocated since these workers are specialized and dedicated full time to a certain activity.

The knowledge of the interviewees was also required in other cases such as machinery and equipment that were used in several processes. An example of this is the depreciation cost of the carrousel used in the warehouse to move the baskets containing customers' orders. As well as being used in the picking process, the carrousel carries all the waste generated during the decanting and the picking processes. Thus, part of the cost of the carrousel was allocated to the waste management process based on an estimation of the interviewees of the cost of the waste conveyor integrated in the main carrousel. Specific quantitative criteria were used in cases such as the depreciation costs of the facilities, which were allocated to activities according to the warehouse floor area dedicated to each of those activities.

Step 6: Second Cost Allocation, Cost Centers, and Profitability

Finally, Table 5 shows the specific criterion used to allocate the costs of each auxiliary activity to the main activities (2nd allocation). Then, the cost percentage of each main and auxiliary activity prior and after the allocation is presented in Table 6.

The allocation of costs from each auxiliary activity to the main activities was done based on specific criteria, and it mainly impacted labor intensive activities. In the case of the warehouse strategy, recycling and waste management was the most relevant auxiliary activity (1.3% of the total cost) apart from the central expenses, and it was almost fully allocated to the unpacking process, since a lot of packaging material from suppliers has to be removed during this activity. For retail stores, operations and logistics management activities, which are mainly composed of indirect labor costs (middle-level store managers), represented the highest cost among auxiliary activities (4.2%), which shows the importance of hierarchy costs related to insourced activities from a TCE perspective. Since this cost was allocated to main activities based on the total labor cost of each of them (prior to this allocation), the picking process absorbed most of it.

The data shows how much the most important costs differ between both strategies. Delivery activities represent the highest cost for the warehouse strategy, accounting for more than 36% of total costs prior and after the allocation of auxiliary activities costs. Even though the retailer with the warehouse strategy could achieve an important degree of route optimization due to the number of trucks that leave from the facility, distributing from a single location that implies longer distances to customers and requires the use of spoke-sites has a tremendous impact on delivery costs. In contrast, the economies of scale regarding truck loading that can be achieved in a centralized facility can be seen in the cost of outbound operations, which only represent 2.5% of the total cost of the warehouse strategy compared to a 4.2% for the retail store. Nonetheless, delivery expenses still have high importance for stores, accounting for 25.7% of the costs, which confirms the fact that last-mile costs are, inevitably, one of the most important cost drivers in e-fulfillment.

Table 4. Criteria for the allocation of all costs to main and aux activities.

Cost Category	Item of Expenditure	Criteria Allocation	Warehouse	Retail store
Direct Labor	Warehouse / Store Operatives' Salaries	Direct / Arbitrary Criteria	Workers' hours are tracked and allocated to specific activities	Workers perform different activities. Allocation based on knowledge
	Pickers' Salaries	Direct / Arbitrary Criteria	Workers are dedicated full time to a certain activity	Workers perform different activities. Allocation based on knowledge
	Specialist Areas Salaries (Counters)	Direct	Workers are dedicated full time to a certain activity	
	Drivers' Salaries	Direct	Workers are dedicated full time to the delivery process	
Indirect Labor	Warehouse / Store Managers	Direct	Workers are dedicated full time to management activities	
	Other Indirect Labor	Direct	Workers are dedicated full time to a certain activity	
Depreciation	Facility	Specific Criteria	Allocated to activities according to floor area	
	Machinery & Equipment	Arbitrary Criteria	Most machines and equipment are used in several processes. Allocated to activities based on knowledge	
	Fridges & Freezers	Direct	Only dedicated to store goods	
	Hardware	Arbitrary Criteria	Allocated to activities based on knowledge	
Amortization	Software	Arbitrary Criteria	Allocated to activities based on knowledge	
Renting	Vehicles (Trucks/ Vans)	Arbitrary Criteria	Trucks costs were fully allocated to delivery	-
	Facilities	Specific Criteria	Spoke sites renting costs were fully allocated delivery	-
	Land	Specific Criteria	Allocated to activities according to land plot area	-
Utilities & Similar Expenses	Fuel (vehicles)	Direct	Fuel costs were fully allocated to delivery	
	Electricity (fresh & frozen products)	Direct	Only used to keep refrigerated and frozen products on storage. Fully allocated to the storage activity	
	Gas, Electricity, Water & Other Utilities	Specific Criteria	Allocated to activities according to floor area	
Other Expenses	Maintenance & Repairs	Specific Criteria	Allocated according to the machinery & equipment depreciation costs previously allocated to each activity	
	Insurances	Specific Criteria	Allocated according to the total depreciation costs previously allocated to each activity	
	Other External Services	Arbitrary Criteria	Allocated based on the knowledge of the interviewees to different auxiliary activities at managerial levels	
	Logistics Supplies (Pallets, baskets…)	Arbitrary Criteria	Allocated to operational activities based on knowledge	
	Offices Supplies	Arbitrary Criteria	Allocated to auxiliary activities at managerial levels based on knowledge	
Expenses (Special)	Central Organization Expenses	Direct	Fully allocated to central activities	
	Loss - Perishability & Theft	Direct	Fully allocated to the storage activity	
	Loss - Returns	Direct	Fully allocated to reverse logistics activities	

In line with the above, reverse logistics was more expensive for the warehouse strategy (4% vs 3.5%). According to the interviewees, substitutions are less common in warehouse strategies due to more reliable inventory information, which reduces returns of unwanted items. However, route re-programming due to returns becomes much more complicated due to longer distances to customers and less flexible delivery scheduling, which in turn makes reverse logistics costs higher than for retail store strategies.

Table 5. Criteria for the allocation of the costs from aux to main activities.

		Criteria for Allocation to Main Activities	Warehouse	Retail store
Other Activities	Recycling & Waste Management	Specific Criteria	Kg. of waste per main activity	
	Cleaning	Specific Criteria	Area (m^2) designated to each main activity	
	Maintenance	Specific Criteria	Depreciation costs of each main activity	
	Human Resources	Specific Criteria	Labor costs of each main activity	
	IT Support	Specific Criteria	Software amortization costs of each main activity	
	Operations & Logistics Management	Specific Criteria	Direct labor costs of each main activity	
	Quality, Environmental, and Occupational Health	Specific Criteria	Direct labor costs of each main activity	
	Continuous Improvement	Specific Criteria	Total cost of each main activity prior to this 2nd cost allocation	
	Marketing, Sales & Merchandise	Specific Criteria	Fully allocated to central expenses	
	Finance & Accounting	Specific Criteria	Fully allocated to central expenses	
	Central Expenses	Specific Criteria	Fully allocated to central expenses	

Table 6. Cost centers of each strategy prior and after cost allocation from aux to main activities.

		Warehouse		Retail store	
		Cost % prior to 2nd allocation	Cost % after 2nd allocation	Cost % prior to 2nd allocation	Cost % after 2nd allocation
Main Activities	Inbound Shipping	0.2%	0.2%	0.0%	0.0%
	Inbound Operations	0.9%	1.0%	0.4%	0.4%
	Unpacking	2.1%	2.8%	4.0%	5.4%
	Storage	14.7%	15.0%	6.7%	8.2%
	Order Picking	15.1%	16.0%	29.9%	33.1%
	Counters (Butcher's, Fish, Deli…)	4.5%	4.6%	5.9%	6.1%
	Packing	1.9%	1.9%	4.6%	5.1%
	Outbound Operations	2.4%	2.5%	3.7%	4.2%
	Delivery	36.1%	36.7%	24.9%	25.7%
	Reverse Logistics / Returns	3.6%	4.0%	3.4%	3.5%
Other Activities	Recycling & Waste Management	1.3%	-	0.5%	-
	Cleaning	0.1%	-	0.6%	-
	Maintenance	0.2%	-	1.4%	-
	Human Resources	0.2%	-	0.0%	-
	IT Support	0.6%	-	0.0%	-
	Operations & Logistics Management	0.6%	-	4.2%	-
	Quality, Environmental, and Occupational Health	0.1%	-	0.4%	-
	Continuous Improvement	0.1%	-	0.0%	-
	Marketing, Sales & Merchandise	0.0%	-	1.4%	-
	Finance & Accounting	0.0%	-	1.0%	-
	Central Expenses	15.4%	15.4%	7.2%	8.1%

In comparison, picking costs are low in the dedicated online warehouse, accounting only for 16% of the costs thanks to specialized picking stations and process optimization. For the retail store, picking activities represent the highest costs of preparing online orders, accounting for more than 33% of the total costs after the second allocation, and being this cost almost entirely coming related to direct labor.

The same process optimization that reduces picking costs for the dedicated online warehouse can be found in other activities such as packing and unpacking, which reduces their cost percentages to approximately half when compared with the multichannel store's. For example, the unpacking process represented up to a 5% of the total cost of online orders for the retailer with the retail store strategy, and only 1.9% in the case of the warehouse strategy. This cost is incurred due to stock-replenishment operations in a store that were allocated to the online channel due to the increased levels of inventory that web sales required, confirming the need to allocate costs to both channels separately in order to better analyze the profitability of any of them in the case of multichannel retailers.

Counters' costs were higher in the store too, but this might be easily due to the fact that the retailer's stores prepared, not only fresh cut meat and fish, but also bread and deli products. The labor force required (specialists) would then be inevitably higher, regardless of the cost-synergies that counters in stores might find when preparing both offline and online orders due to reductions of idle time is another example.

Another significant difference was found in storage expenses, which accounted for almost twice as much in the warehouse strategy (15% vs 8.2%). This can be explained by two main reasons. First, the highly automated warehouse (excluding the conveyor that transports the baskets) represents a huge cost that was almost fully allocated to storage activities. Second, as explained before, depreciation of fixed in-store assets that were not specifically bought to support online sales and whose depreciation was not really subjected to daily use, such as in-store shelves, were not allocated to the online channel and were considered costs synergies. Ultimately, as it could already be seen when all items of expenditure were shown in table II, central expenses were found to be much higher in the warehouse strategy.

7. Conclusion

In this study, the authors answered two research questions: first, how can bricks-and-mortar grocery retailers structure their operational costs to calculate the profitability of their e-fulfillment strategies? Second, what are the main differences in the operational costs incurred between retail store and warehouse e-fulfillment strategies? The first question was answered by developing a cost framework based on TDABC methodology, so retailers can analyze the feasibility of different e-fulfillment strategies. To address the second question, the authors tested the cost framework in two grocery retailers, one of which fulfills its online orders from retail stores, while the other one does it from a dedicated online warehouse, which represents the two most common strategies adopted by bricks-and-mortar grocery retailers.

7.1. Theoretical Contributions

The contributions of this article to the extant literature are twofold. Firstly, this study expands the current knowledge of the costs of grocery e-fulfillment, which was mainly limited to the delivery and picking processes, by showing the importance of less-studied activities. Together (this includes all activities but picking, delivery, and central expenses) accounted for approximately one third of all expenses in both cases. From a TCE perspective, this is highly relevant, as retailers cannot just see e-fulfillment as the combination of two activities (picking and delivery), but a sequence of processes each of which should be considered as a make-or-buy decision. Moreover, the cost framework developed brings important insights for the e-fulfillment activities thanks to the use of cost estimates and the different criteria applied in the cost allocation process, and contributes to the extant literature on cost modeling. Thus, the novelty of the cost framework lies on the detailed view of grocery e-fulfillment costs that can allow bricks-and-mortar to calculate the profitability of their business more accurately.

Secondly, this study fills one of the most important gaps in e-grocery research by comparing the two most common e-fulfillment strategies, the retail store and the warehouse strategies, from a cost-performance perspective. Regarding the picking and delivery processes, important differences were found when compared each activity between strategies. The picking activity accounted for twice as much cost in the retail store strategy when compared to the warehouse strategy, reaching up to one third of the total cost of e-fulfillment. In contrast, delivery expenses, which also accounted for approximately one third of all expenses of the warehouse strategy, still have high importance for stores, accounting for approximately one fourth of the costs.

Among the less-studied activities, storage was twice as expensive for the warehouse strategy, while labor intensive activities such as inbound and outbound operations, fresh food counters, packing and unpacking were more expensive in the retail store. This, in turn, affected managerial costs directly related to coordinating direct labor, which turned out to be almost eight times higher for the retail store. Reverse logistics was the only exception and, in line with delivery costs, was slightly more expensive for the warehouse strategy. This can be used as a starting point for further, more detailed studies of all these activities. Finally, major differences were found in central expenses of both strategies, being approximately half important for the retail store strategy.

7.2. Managerial Implications

Our study has important managerial implications as well. The framework developed serves as a guide for e-grocery logistics and operations managers to structure the operational costs of their business, regardless of the strategy they use to fulfill online orders. If managers decide to apply the cost framework to their particular cases, the quantitative results obtained will provide managers with crucial information of the real cost of each activity, which will improve outsourcing decisions to an important degree.

Also, continuous improvement can be better focused on the most cost-intensive activities, allowing the best opportunities for cost-savings. Ultimately, the estimation of the most important variable costs shown for both strategies, including the cost estimates chosen by authors and interviewees, will also be helpful for managers looking forward to analyzing the operational costs of their activities. Even though specific e-fulfillment processes will likely vary among retailers, most parameters used to calculate how variable costs change will remain similar.

The specific results obtained when applying our framework can help managers before adopting any e-fulfillment strategy by allowing them to see which are the core operational activities of each of them. Nowadays, this could be of great relevance for retail store e-fulfillment grocery retailers planning to adopt more advanced warehouse e-fulfillment strategies.

7.3. Research Limitations and Further Research

We considered the single-case study approach to be the best methodology for our analysis, since significantly rich research was required to provide details of retailers' internal processes and real cost data. Still, the most important limitation of this study is that the cost information presented comes from just two grocery retailers. Thus, the quantitative results obtained by applying the cost framework to two specific cases of retail store and warehouse strategies could be corroborated by including multiple e-grocers in the study, in order to see if the main cost drivers remain the same.

Further research could also focus on comparing complete e-fulfillment networks that need to fill the same demand, since a dedicated online warehouse would fulfill the aggregated online demand of a bricks-and-mortar grocery retailer's network of stores in a certain area. In this regard, stores with different sizes and warehouses with different capacities and levels of automation could be included in the analysis, as well as hybrid e-fulfillment strategies that combine both dedicated warehouses and stores in the retailer's network. Finally, sensitivity analyses could show if the main cost drivers remain the same under different market conditions. To further expand the use of our cost framework, e-fulfillment strategies should be analyzed according to different demand scenarios.

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