An innovative multivendor warehouse in e-grocery: an activity based model to assess different configurations

Mangiaracina R.*, Perego A.*, Siragusa C.*, Tumino A.*

** Dipartimento di Ingegneria Gestionale, Politecnico di Milano, Via Lambruschini, 4B 20156 - Milano – Italy (riccardo.mangiaracina@polimi.it, alessandro.perego@polimi.it, chiara.siragusa@polimi.it, angela.tumino@polimi.it)*

Abstract: Despite e-grocery is growing in Italy, its penetration on the overall grocery sales is still low if compared with other European countries (e.g. UK, Germany, France). Afterwards the incoming of new players in the e-grocery landscape, traditional retailers are attempting to enter the online market. Though, this decision introduces some challenges. On the one hand, the initial volumes of e-grocery are not big enough to justify a dedicated warehouse. On the other hand, the in-store picking, which is more suitable for low volumes, is not efficient enough to assure the economical sustainability of the initiative; moreover, it results to be not effective, especially when volumes increase. In order to overcome these barriers, this study investigates an innovative collaborative logistic solution that could reduce the overall cost per order. It considers a multivendor warehouse with inventories and deliveries shared among three different retailers. First, the warehouse layout is defined. Second, the main activities performed in the warehouse are identified and the related costs estimated through an activity-based approach. Third, the total cost per order is computed and compared to the base-case of the single merchant warehouse. The solution is tested in seven picking scenarios, obtained varying the products allocation and the batching policy, aiming at finding the most efficient configuration. Finally, a sensitivity analysis on selected parameters is performed. If compared to the traditional one-vendor warehouse, the multivendor solution implies a cost reduction per order between 14% and 20%. This work can be considered the starting point for an innovative logistic solution the retailers can rely on to enter the e-grocery business. In particular, the developed model may represent a useful tool in the definition of the online channel strategy: the study clearly shows the potential benefit of sharing the logistic infrastructure instead of building a stand-alone warehouse.

Keywords: E-grocery, Multivendor, Picking

1.Introduction

In Italy, e-grocery is significantly growing (+40% per year), but if compared to other sectors and countries in which e-commerce is more diffused, its penetration on the overall retail sales is still very low (i.e. 0.35%) (Italian Observatory on B2c eCommerce, 2017). Though, new players, characterised by high potential for investments and significant experience in e-commerce, are entering the e-grocery landscape. In 2015 Amazon launched Prime Now in Milan, Italy, assuring a one-hour delivery with a fee of 7.99 € or a same-day delivery for free. Also start-ups started launching grocery delivery services. Supermercato24 allows customers to do the grocery shopping among a set of retailers and to select the delivery time window – among the available ones – with a fee of 4.90 €. Therefore, new players are sweeping in an underdeveloped market at the expense of traditional grocery retailers, which fear to loose sales. Hence many vendors are facing the challenge to enter the online channel. In particular, they need to understand how to make their ecommerce profitable, starting from the economical sustainability of their logistics. An effective logistics is fundamental for any successful e-grocery venture (Punakivi and Saranen, 2001). Retailers entering this market face some challenges: on the one hand, the initial volumes of e-grocery are not big enough to justify the adoption of a dedicated warehouse; on the other hand, the alternative solution in-store picking, which is a more suitable option for low volumes, is not efficient (Hübner *et al.* (2016)). The relevance of the logistics theme is strengthened by e-grocery peculiarities, i.e. large orders of multiple single-piece lines and a wide product range including dry, frozen and fresh perishable items. Moreover, in Italy 95% of the e-grocery sales comes from home delivery, while only 5% is related to click-and-collect service: the home delivery is thus a preferable option for the retailers who decide to enter the e-grocery sector, but it is definitely more expensive and more complex to be managed. Trying to overcome the entry barriers for grocery vendors, the scope of the present study is to develop a horizontal collaborative logistic solution among three e-grocery players, aimed at reducing the overall cost per order. The general aim of the study is declined into two research questions, which are detailed in §3. The developed model will result to provide a reduction in the cost per order if compared to a base-case configuration, i.e. a dedicated warehouse of a single retailer.

The remainder of the paper is organized as follows. The next section provides the literature review: focus is on logistics activities, in particular warehousing and last mile delivery, and on pooling as a way to reduce operating costs. The methodology adopted within the study is described in Section 3. The Section 4 reports the main findings. First, the definition of the considered processes and picking scenarios, as well as the warehouse layout are reported. Second, analysis of cost results for the multivendor warehouse, sensitivity analysis on selected parameters and comparison with the one merchant costs results are displayed. In the final section, conclusions are drawn and research limitations are identified.

2.Literature review

Logistics costs are the main obstacles for the expansion of the e-grocery sector. E-grocery is characterised by huge differences in the operative system with respect to the traditional grocery. Murphy (2007) defined logistics as the "killer costs" of e-commerce. Specifically, two main areas in the e-grocery logistics play an important role in the efficiency of this sector: *last mile delivery* and *warehousing*. According to Vanelslander *et al.* (2013), last mile delivery is the main cost factor (i.e. about 50%), followed by picking and storage activities costs. A big effort should be spent to increase the efficiency of both last mile delivery and warehousing in order to make the e-grocery sector profitable. Moreover, Tadei *et al.* (2016) reported that the additional costs in the e-grocery sector related to last mile delivering and picking are generally higher than the fees customers are willing to pay for delivery at home.

With regard to the last mile delivery, some solutions have been identified to increase the efficiency. Kamarainen *et al.* (2001) proposed a reception box in the household of customers in order to reduce the delivery costs for the e-grocers by arranging transport operations in the most efficient way, and to increase the service level as long as customers become independent from the delivery timetable. Emeç *et al.* (2015) and Carrabs *et al.* (2016) addressed the routing problem to increase service level and decrease the transport costs. Ghajargar *et al.* (2016) identify two main potential solutions: automated pack station, where parcels are retained until the customer is able to pick them up, and a network of local stores, which act as pickup points to store customers' items.

Considering the warehousing, many authors highlight the inefficiency of the in-store picking, underlining the advantage of developing a dedicated warehouse: the main problem is the elevated initial investment (Melacini *et al.*, (2017)) and the operating costs that can be recovered only with a high and constant utilisation rate (Kamarainen *et al.* (2001), Hays *et al.* (2005)). A solution proposed by some authors is the hybrid model, which combines both the previous models. Yrjola (2001) provides a theoretical framework for a solution based on current supermarkets that may be redesigned in order to more effectively fulfil online orders but, at the same time, keeping the conventional store. Tanskanen *et al.* (2002) identify instead the hybrid model as an intermediate solution before building a dedicated warehouse.

In general terms, a solution aimed at reducing part of the operating costs could be the inventory pooling. Inventory pooling refers to an arrangement in which different companies share their inventories; lateral transhipments are used to satisfy a demand at a company that is out of stock, from another company with a surplus of on-hand inventory (Wong *et al.*, 2007). The spare parts sectors seems to be the most frequent application for inventory pooling (Wong *et al.* (2005), Karsten *et. al.* (2012)). The reduction of the inventory holding costs is considered the main benefit arising from the application of inventory pooling (e.g. Braglia and Frosolini (2013), Reaidy *et al.* (2014), Abdelaziz and Mejri (2016)). However, this is not the only type of cost impacted by inventory sharing: Bauso *et al.* (2006) stress the reduction of transport costs for the retailers involved. Hays *et al.* (2005) mentioned the advantages of pooling for a grocer – but limited to its own locations – in order to better manage the inventory, reduce inventory holding costs and increase inventory turnover rates. Anyway, no research deepened the possibility to apply inventory pooling to the e-grocery sector, among different players, in order to optimise the logistics operations. Most of the papers addressing this sector consider the cooperation between the different players with the form of lateral transhipments and not keeping the inventory in the same warehouse. Considering both physical and virtual sharing type, many researchers argued that inventory pooling enables to cope with the logistic inefficiencies and to increase the performances (Braglia and Frosolini, (2013), Van Le *et al.*, (2013)). What emerged from the literature is that inventory pooling is advantageous for the increase of logistic performances even if the coordination between the different players is critical as well as the sharing of information. In this regard, a third-party acting as pooling provider is fundamental to assure the maximization of the performances of the entire system (Yan and Zhao, 2015).

Previous papers combining e-grocery and collaborative logistic were not found in the extant literature. In particular, three main gaps can be identified: (i) absence of inventory pooling among competitors in e-grocery sector; (ii) absence of papers qualitatively proposing physically shared warehouse with shared inventory in a general industry; (iii) absence of quantitative papers proposing horizontal collaboration logistics solutions in e-grocery.

3.Objectives and methodology

Given the identified gaps, the present study aims to contribute to the extant literature on e-grocery by proposing a collaborative model among the e-grocery players. The main objective is to provide an innovative solution for entering the e-grocery market considering its peculiarities and complexities. The approach proposed by this study is to exploit the advantages of the dedicated warehouse (e.g. higher efficiency in the picking process) and, at the same time, mitigate the investment and the operating costs by sharing the structure, the inventory and the transport with other companies serving the same sector. In order to reach the mentioned goals, the following research questions will be addressed:

RQ1 – How can the horizontal collaborative logistic solution be designed in the e-grocery sector?

RQ2 – Is the logistic solution beneficial with respect to a single player's dedicated warehouse? Which are the impacted costs and how do these costs vary?

The core of the research is represented by an Activity-based model developed according to a three-step methodology:

Phase I – Definition of the research configurations. The baseline configuration is a dedicated warehouse to the online orders for each single player. The present work develops the alternative configuration of a multivendor warehouse. The most significant difference is the share of the structure and the resources. At this stage, the general context and the main assumptions have been investigated.

Phase II – Model development. The main processes performed in a e-grocery warehouse and the related elementary activities have been identified, as well as inputs and parameters feeding the model were identified. The warehouse layout has been simultaneously designed.

Phase III – Model application. The model has been applied to the different scenarios by calculating the operating costs per order. Key parameters affecting the overall results have been identified in order to perform a sensitivity analysis. In addition, a comparison of each scenario with the correspondent baseline case (i.e. one merchant dedicated warehouse) has been implemented.

The main methods adopted in the Research are:

- Literature review to investigate potential horizontal collaboration solutions.
- Interviews with specialised e-commerce operators and express couriers in order to collect data for the model. Interviews were conducted following a semi-structured scheme, which could allow the rising of ideas and data the authors were not able to think about in advance.
- Analysis of secondary sources, such as case studies and e-commerce websites to triangulate data coming from both the extant literature on the topic and the interviews.

4.Findings

The collaborative solution designed is a warehouse shared by three retailers that serves a province or suburban area in Italy. The level of collaboration in this multivendor configuration is total: the players share their inventories, the labour resources and the vehicles for the delivery with the other retailers. Dry food, no food and fresh food products are stocked in the shared warehouse. Clothing, gardening, stationery, multimedia products and small appliances were excluded from the analysis. A home delivery service is considered for both the one merchant's warehouse and the multivendor case: home delivery seems to be the most suitable solution for the Italian e-grocery market – indeed, in Italy, 95% of the e-grocery sales comes from home delivery. Moreover, "click & collect" is not appropriate in the multivendor case due to competitive reasons between the players operating in the same infrastructure.

Four main processes have been taken into account:

• Picking process: it consists in a set of activities aimed at collecting all the items ordered by the customer;

• Refill process: the activities in the refill process are all those needed to replenish the shelves, including the unloading of the goods received from the suppliers. Products addressed to close locations are refilled in the same tour, in order to minimize the path: replenishment tour is assumed to visit only one aisle.

• Products packaging process: this process is necessary to prepare the fresh food (i.e. fruits and vegetables, meat, fish and dairy products) in pre-defined packages. Indeed, the customer is not free to choose whatever quantity and weight of these products. The assumption characterising this activity is that the suppliers for fruits, vegetables, meat, fish and dairy products will be basically the same.

• Delivery process: it is composed by all the activities aimed at bringing the ordered items to the customers. This process includes both the activities performed in the warehouse to recompose the final order and the activities performed outside the warehouse to physically deliver the order to customer's home.

The inventory holding cost has been included in the model even if it is not related to any operating activity, but it is differential to assess the benefits of the inventory sharing.

The warehouses of the two models (one merchant's warehouse and multivendor warehouse) have different sizes because of the different volumes managed within the warehouses. Nevertheless, the layouts are similarly shaped.

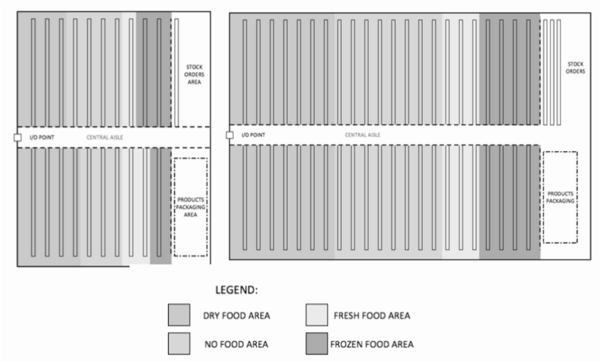

Figure 1: One merchant's warehouse layout (left) and multivendor warehouse layout (right)

Each warehouse is divided into three main areas: (i) picking area, (ii) stock orders area (i.e. the shipping area) and (iii) products packaging area, where the super fresh food (i.e. fruits, vegetables, meat, fish and dairy products) is prepared in predefined packages with a specific weight. The picking area is shaped according to the type of adopted batching policy. In case of batch picking, particularly batch picking within picking zones, the overall area is divided into subareas, according to the categories of product (i.e. dry food, no food, fresh food and frozen food).

In order to answer to the second research question, the multivendor warehouse should be compared to the baseline case (i.e. one merchant's warehouse); the relevant trade-off is between the picking and the delivery costs. Inventory sharing implies a warehouse of bigger dimensions, resulting in longer picking time and consequently higher picking costs. For these reasons, considering the importance of the picking process, seven different scenarios have been investigated, aiming to optimize the final picking cost per order. The different scenarios are characterised by different assumptions in terms of batching policy (i.e. order picking or batch picking) and storage policy (i.e. random based storage or access index based storage), while the routing policy is always the traversal one. The batch picking requires the division of the picking area into picking zones, according to the products categories (i.e. dry food, no food, fresh food and frozen food); in order to find the best solution, two layouts have been considered: the first one characterised by 4 picking zones and a second one characterised by 6 picking zones. The seven scenarios are explained in detail below:

1. *Order picking, random based storage*: it represents the baseline solution for the picking process. In the order picking policy, a single picker completes the entire picking tour needed to gather a single complete order. The products are randomly stocked in the warehouse; it is assumed that there is the same probability to visit the different areas of the picking system;

2. *Order picking, access index based storage*: the picking tour is aimed at fulfilling just one order, while the adopted storage policy is the access index one. The products are divided– within each product area – into three classes (i.e. A, B and C) according to the ratio between their picking frequency and their dedicated space; class A of products are located closer to the I/O point since they are the most frequently picked;

3. *Batch picking, random based storage (4 picking zones)*: the third proposed solution is the zone picking in combination with a batch order picking policy. The whole picking area is divided into four areas according to the products categories (i.e. dry food, fresh food, frozen food and no food) and the orders are picked in batches composed by multiple orders. In each zone the random storage has been adopted as storage policy, so each aisle has the same probability to be visited;

4. *Batch picking, random based storage (6 picking zones)*: it is similar to scenario n.3, but the picking zones are six instead of four. "Dry food" and "no food" areas, which are the biggest areas in terms of sizing – because of the higher number of stocked items – have been both divided into two sub areas. This fourth scenario is considered in order to verify whether there is an improvement in the final picking cost;

5. *Batch picking, access index based storage (4 picking zones)*: the fifth scenario is a zone picking combined with a batch picking policy, but with an access index based storage in each of the four zone. A single picker is dedicated to a specific zone and he has a high probability to visit a lower number of aisles – if compared with scenario n.3 – thanks to the different storage policy;

6. *Batch picking, access index based storage (6 picking zones):* it is similar to scenario n.5, but the picking zones are six instead of four. "Dry food" and "no food" areas have been both divided into two sub areas to verify whether there is an improvement in the final picking cost.

7. *Alternative batch picking, access index based storage (4 picking zones)*: it is a variation of the scenario n.5. Pickers will be dedicated to a portion of a zone corresponding to a class of products (e.g. "Dry food" zone, A-class products) instead of being dedicated to the entire zone (e.g. "Dry food" zone).

The following section is committed to the picking cost per order computation. For each scenario, first the daily picking cost is calculated as the product between (i) the number of pickers per shift, (ii) the number of shifts in a working day (i.e. 2 shifts), (iii) the number of hours per each shift (i.e. 8 hours) and (iv) the hourly cost of labour.

In particular, the number of pickers per shift depends on the *picking time per order*, the number of orders to be fulfilled in a day, as well as the number of shifts in a day and the working hours for each shift. Second, the obtained overall daily picking cost is allocated to each fulfilled order.

Picking time per order is made up of three elements: (i) set-up time, (ii) travel time and (iii) retrieval time.

Set-up time, which is a fixed parameter, includes the time for downloading the picking list and for preparing the picking cart.

Retrieval time is calculated as the sum of the fixed time for retrieving each product line and a variable time to retrieve all the single pieces. Retrieval time varies while considering either an order picking policy or a batch policy.

Travel time is instead calculated as the ratio between the travel distance and the travel speed. While travel speed, which refers to the speed of walking of the pickers, is considered a fixed parameter, the travel distance varies according to each picking scenario. In each case, travel distance is computed as the sum of (i) the travel within aisles and (ii) the travel across aisle:

- *Travel within aisles* depends on the length of the aisles, the width of across aisles and the number of visited aisles. In particular, the number of visited aisles varies according to the storage policy (i.e. random based storage or access index based storage).
- *Travel across aisles* depends on some layout elements (i.e. width of an aisle and rack width) and on the furthest couple of aisle to be visited. The furthest couple of aisle varies according to the storage policy (i.e. random based storage or access index based storage).

Similarly to the picking cost, the refill cost and the delivery cost are calculated starting from the computation of the daily costs for performing these sets of activities, which are then allocated to each product. For what the inventory holding cost is concerned, it is affected by the average value of the stocks, their values and a series of cost items (i.e. cost of capital, cost of space, cost of obsolescence).

Processes and different scenarios have been displayed. The model application is organised into three main steps: (i) analysis of cost results for the multivendor warehouse, (ii) sensitivity analysis and (iii) comparison with the one merchant costs results.

4.1 Analysis of costs results

The difference between the seven scenarios is due to the picking cost, as long as all the other costs do not change according to the picking solution considered. The alternative batch picking access index based storage with 4 picking zones (scenario n.7) is the most efficient solution: compared to scenario n.1 (i.e. order picking random based storage), which is the worst scenario, there is a saving of 2€/order, which corresponds to a 15% reduction of the overall cost per order. This cost reduction is the result of an iterative optimization process (from scenario n.1 to scenario n.7) that was performed in order to make the multivendor warehouse picking activity as competitive as possible.

Table 1: Picking cost per order comparison between the different multivendor picking scenarios

Scenario		Picking cost per order
1	Order picking, random based storage	€ 4.74
2	Order picking, access index based storage	€ 3.47
3	Batch picking, random based storage (4 picking zones)	€ 3.47
4	Batch picking, random based storage (6 picking zones)	€ 2.95
5	Batch picking, access index based storage (4 picking zones)	€ 3.16
6	Batch picking, access index based storage (6 picking zones)	€ 2.95
7	Alternative batch picking, access index based storage (4 picking zones)	€ 2.74

In figure 2, the incidence of the different cost items on the total cost per order in scenario n.7 is illustrated. The overall cost is mainly affected by the delivery cost, whose incidence is around 64%. Thus, delivery cost accounts for more than half of the total cost per order. In addition, the main delivery cost component is represented by the drivers' labour cost (79% of the total). The picking cost impacts for the 22% of the whole cost per order, while refill, products packaging and inventory holding cost account for the remaining 14%.

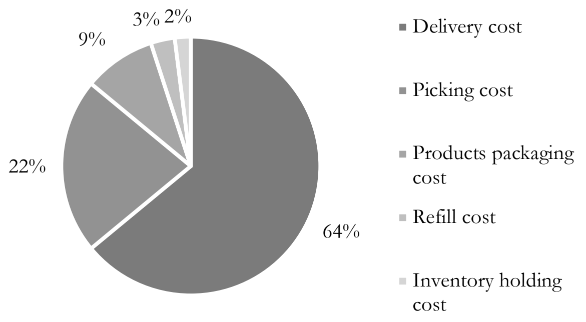

Figure 2: Cost items impact in scenario n.7

In the other scenarios, the situation is very similar: the delivery cost impacts from 58% (in case of order picking, random based storage) to 64%; the picking cost represents, on average, the 23% of the total cost per order. Although the main effort in developing the model has been spent on finding the best picking solution, the most impacting process resulted to be the delivery. For this reason, a simulation tool has been used to identify the optimal number of deliveries that can be completed in a timeslot: the result is 12 deliveries every four hours. Basing on this obtained number of deliveries and considering the picking cost findings, the total operating cost varies between 12.37 € per order – in scenario n.7 – and 14.35 € per order – in scenario n.1. Figure 3 shows the operating costs in each considered scenario.

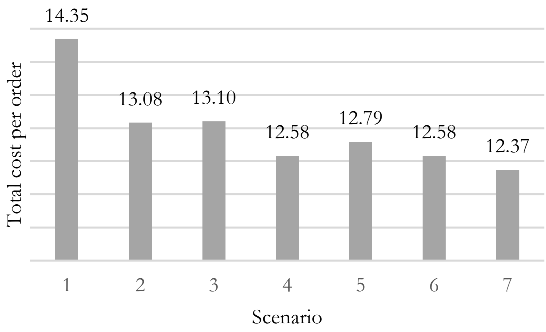

Figure 3: Total cost per order in multivendor scenarios

4.2 Sensitivity analysis

In order to further understand the impact of some key parameters, two sensitivity analyses were developed by varying (i) the number of deliveries to be performed in a time slot and (ii) the order composition.

As already underlined, the delivery cost has a strong impact on the total cost per order due to the drivers' labour cost. The delivery cost per order was calculated by varying the number of deliveries from 1 to 22 (which is considered the upper bound due to fixed times, i.e. the time lapse between the time the courier arrives at the customer's home and the time in which it is ready to leave to the next customer). By increasing the number of deliveries in a tour, the delivery cost decreases. In particular, the trend of the cost curve is hyperbolic: it decreases rapidly until 10 orders per delivery tour and then it decreases with a lower slope. For example, in order to obtain a total cost per order around 10€, which could be acceptable given 40 pieces per order, each driver should deliver 18 orders per tour. This result could be achievable by considering some variations in the assumptions, e.g. by changing the fixed delivery times or by reducing the distance between two delivery points. Finally, it is noticeable that if the number of deliverable orders is low (e.g. from 1 to 5 orders), the delivery cost slightly increases (e.g. respectively from about 80 €/order to 20 €/order), resulting to be not affordable in terms of margin for the retailer - considering an average order value of about 120€.

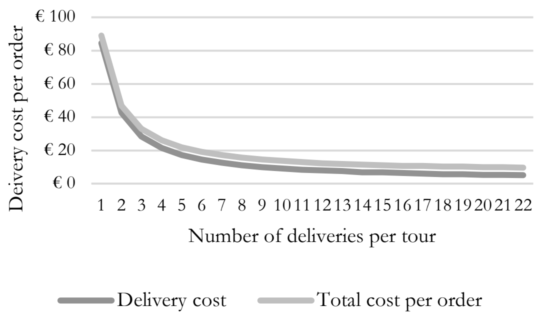

Figure 4: Delivery cost and total cost per order in scenario n.7, by varying the number of deliveries per time slot

The second sensitivity analysis was performed on the shopping composition in terms of number of lines per order and number of pieces per line. The main result is the need for the retailers to establish a minimum order value to guarantee the home delivery to their customers. Home delivery is not economically sustainable under a certain number of pieces per order: for example, if the order has less than 5 lines (with one piece per line) – considering that the average price of an item is around 3 € – there is no margin for the retailer that must sustain an operating cost around 10 € for each order. This high value is due to the cost of delivery that is not affected by the composition of the order.

4.3 Comparison with the one merchant's cost results

The final part of the analysis of results is the comparison between the multivendor model and the one merchant's warehouse. The total cost per order was calculated for the same seven picking scenarios proposed in the multivendor case. The obtained results are reported in Table 2.

Table 2: Total cost per order comparison between the different one merchant picking scenarios

Scenario		Total cost per order
1	Order picking, random based storage	€ 16.70
2	Order picking, access index based storage	€ 15.73
3	Batch picking, random based storage (4 picking zones)	€ 16.08
4	Batch picking, random based storage (6 picking zones)	€ 15.76
5	Batch picking, access index based storage (4 picking zones)	€ 15.76
6	Batch picking, access index based storage (6 picking zones)	€ 15.76
7	Alternative batch picking, access index based storage (4 picking zones)	€ 15.44

Comparing the total cost per order, the one merchant's warehouse generates, on average, around 3 € more per order (i.e. 25% more in case of alternative batch picking access index based storage with 4 picking zones). This difference is due to the picking and the delivery costs. Picking cost is always lower in the one merchant case because of the smaller warehouse dimension. Anyway, considering the best identified scenario – n.7 – the picking cost in the one merchant's warehouse differs only 0.18 € from the multivendor case. The multivendor solution, if compared to the traditional one-vendor warehouse, implies a cost reduction per order between 14% - in scenario n.1 - and 20% - in scenario n.7.

5.Conclusion

Generally, the multivendor warehouse is characterized by lower operating costs mainly due to the delivery benefits, obtained thanks to the synergies from the three players. The presented results confirmed the expectations of the cost convenience of a shared warehouse with shared inventory if compared to a single player's dedicated warehouse. A multivendor warehouse for the online grocery orders improves the logistics efficiency: it allows reaching the critical mass; thanks to the multivendor warehouse, the critical mass can be reached through synergies between the players and the total operating costs are even lower than the one merchant's warehouse.

In conclusion, the multivendor warehouse model with shared inventory and shared delivery may represent an innovative alternative to the logistics models currently used in the e-grocery sector. The model provides cost benefits if compared to a dedicated warehouse of a single retailer. The main evidences from this study are:

(i) The picking cost impacts the total cost per order with an incidence from 23% to 30%, depending on the adopted policies.

(ii) The most impactful cost in managing the multivendor warehouse is the delivery cost: the incidence of the delivery is around 58-60% of the total cost per order.

(iii) On average, the one merchant's warehouse generates an overall cost around 3 € more per order. Moreover the multivendor solution, if compared to the traditional one-vendor warehouse, implies a cost reduction per order between 14% and 20%.

The research presents some limitations. First, the model focuses only on the logistic perspective: it mainly considers the benefits stemming from the operating costs and, in particular, the ones linked to the activities performed within the warehouse and to the delivery. When evaluating whether entering the e-commerce channel, the initial investment is a relevant element to be considered. A further step could thus be aimed to analyse the investments required by each alternative available in the e-grocery sector, in order to provide a complete comparison between the different logistic solutions. Second, the retailers are not prone to share their business information with their competitors: the resistance to the full collaboration may affect the application to real cases. Third, the study is strongly based on some assumptions, which have certainly influenced the results. Above all, the decision of the number of players sharing the solution is remarkable: a different number of players would have affected the sizing of the warehouse, resulting in potential different operating costs. Another significant element is the customer density, which was taken into account by considering a determined distance between two customers. As shown by the sensitivity analysis (§4.2), the number of deliverable orders strongly affects the delivery cost per order. Therefore, changes in delivery parameters will strong affect the final results.

Even if this research work is characterized by some limitations, the present model can constitute the base for future developments that would contribute to increase the extant knowledge on the logistics efficiency in e-grocery. For what practical implications are concerned, the developed model may represent an useful tool for grocery retailers entering the online channel to define their strategy: the study clearly shows the potential benefit of sharing the logistic infrastructure instead of building a stand-alone warehouse. In the end, the proposed solution may be applied to other e-commerce sectors, allowing the possibility of new applications.

References

Bauso, D., Pesenti, R. and Giarré, L. (2006). Cooperative Inventory Control. Current Trends in Nonlinear systems and control, pp. 475-491.

Abdelaziz, F. B., and Mejri, S. (2016). Multiobjective bi-level programming for shared inventory with emergency and backorders. Annals of Operations Research, 1-17.

Braglia, M., & Frosolini, M. (2013). Virtual pooled inventories for equipment-intensive industries. An implementation in a paper district. Reliability Engineering & System Safety, 112, 26-37.

Carrabs, F., Cerulli, R., & Sciomachen, A. (2017). An exact approach for the grocery delivery problem in urban areas. Soft Computing, 21(9), 2439-2450.

Emeç, U., Çatay, B., & Bozkaya, B. (2016). An adaptive large neighborhood search for an e-grocery delivery routing problem. Computers & Operations Research, 69, 109-125.

Ghajargar, M., Zenezini, G., & Montanaro, T. (2016). Home delivery services: innovations and emerging needs. IFAC-PapersOnLine, 49(12), 1371-1376.

Hays, T., Keskinocak, P., & De López, V. M. (2005). Strategies and challenges of internet grocery retailing logistics. In Applications of Supply Chain Management and E-Commerce Research (pp. 217-252). Springer, Boston, MA.

Hübner, A., Kuhn, H., & Wollenburg, J. (2016). Last mile fulfilment and distribution in omni-channel grocery retailing: a strategic planning framework. International Journal of Retail & Distribution Management, 44(3), 228-247.

Kämäräinen, V., Saranen, J., & Holmström, J. (2001). The reception box impact on home delivery efficiency in the e-grocery business. International Journal of Physical Distribution & Logistics Management, 31(6), 414-426.

Karsten, F., Slikker, M., & van Houtum, G. J. (2012). Inventory pooling games for expensive, low-demand spare parts. Naval Research Logistics (NRL), 59(5), 311-324.

Melacini, M., Perotti, S., Rasini, M., & Tappia, E. (2017). Designing logistics in omni-channel retailing: drivers behind company distribution configurations. In 22nd Summer School "F. Turco" (pp. 47-53).

Murphy, A. J. (2007). Grounding the virtual: The material effects of electronic grocery shopping. Geoforum, 38(5), 941-953.

Osservatorio eCommerce B2c (2017). [Report]. Food&Grocery in Italia: l'eCommerce è servito? [http://www.osservatori.net]

Punakivi, M., & Saranen, J. (2001). Identifying the success factors in e-grocery home delivery. International Journal of Retail & Distribution Management, 29(4), 156-163.

Reaidy, P. J., Gunasekaran, A., & Spalanzani, A. (2015). Bottom-up approach based on Internet of Things for order fulfillment in a collaborative warehousing environment. International Journal of Production Economics, 159, 29-40.

Tadei, R., Fadda, E., Gobbato, L., Perboli, G., & Rosano, M. (2016, June). An ICT-Based Reference Model for E-grocery in Smart Cities. In International Conference on Smart Cities (pp. 22-31). Springer, Cham

Tanskanen, K., Yrjölä, H., & Holmström, J. (2002). The way to profitable Internet grocery retailing–six lessons learned. International Journal of Retail & Distribution Management, 30(4), 169-178.

Van Le, D., Huynh, L. T., Claudiu, K. V., & Achim, M. (2013). The impact of inventory sharing on the bullwhip effect in decentralized inventory systems. Logistics Research, 6(2-3), 89-98.

Vanelslander, T., Deketele, L., & Van Hove, D. (2013). Commonly used e-commerce supply chains for fast moving consumer goods: comparison and suggestions for improvement. International Journal of Logistics Research and Applications, 16(3), 243-256.

Wong, H., Cattrysse, D., & Van Oudheusden, D. (2005). Inventory pooling of repairable spare parts with non-zero lateral transshipment time and delayed lateral transshipments. European Journal of Operational Research, 165(1), 207-218.

Wong, H., Van Oudheusden, D., & Cattrysse, D. (2007). Cost allocation in spare parts inventory pooling. Transportation Research Part E: Logistics and Transportation Review, 43(4), 370-386.

Yan, X., & Zhao, H. (2015). Inventory sharing and coordination among n independent retailers. European Journal of Operational Research, 243(2), 576-587.

Yrjola, H. (2001). Physical distribution considerations for electronic grocery shopping. International Journal of Physical Distribution & Logistics Management, 31(10), 746-761.