

Choosing the Minimum Order Size in Large-Scale Retail Trade Distribution

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Abstract: One of the main issues characterizing the large-scale retail trade (LSRT) distribution is the relatively high transportation costs compared to profit margins. The complexity of non-integrated supply chains worsens this problem because the actors – wholesalers, third-party logistics providers and retailers – may reasonably have different and conflicting aims. Furthermore, due to the numerous operational field-specific peculiarities, it is not possible to straightforwardly apply those consolidated operations management models which have been conceived in other industrial contexts. Among these, the classical models for defining the appropriate order size to minimize transportation costs seem not to be appropriate for the LSRT context. In this paper we propose an approach to compute the minimum order size for a network of retailers supplied by a single wholesaler, to obtain an overall transportation costs optimization through the increase of trucks saturation. Taking cue from literature review on optimization techniques in LSRT supply chain and logistics, and highlighting the context-specific constraints, we propose an heuristic approach which has been validated on the case of an Italian LSRT company.

Keywords: Logistics; Transportation Costs; Large Scale Retail Trade; Distribution

1. Introduction

Large-scale retail trade (LSRT) is an industry worth over one trillion euro worldwide in 2015, only considering the turnover of the twelve major international groups in the sector. In particular, the eight major Italian groups ended 2015 with turnovers of more than 40 billion euros and an increasing grow rate (Mediobanca 2017). However, such high levels of turnover are typically characterized by very low margins. Therefore, companies belonging to this industry should specifically focus on process efficiency at a company-wide level in order to contain operative costs as much as possible.

Because of the LSRT industry historical evolution, companies traditionally try to achieve better economic performance leveraging on commercial policies rather than applying logistic cost reduction approaches. This can be partially explained by the technical complexity of supply chain and distribution management problems in LSRT operative context: first, different goods with very different constraints in terms of handling and transport conditions must be managed. Furthermore, the retailers network typically generates further constraints on distribution problems, for example imposing different time windows for the delivery of different product categories; on top of this, the variety of store locations usually generates additional constraints on transportation modes because of the stores’ accessibility. Aiming at minimizing the distribution costs, operations research experts know that these few constraints are already sufficient to configure an NP-hard problem which – besides being typically very expensive to approach with dedicated software heuristics – may often yield far from optimal solutions due to the great distance between the real case specificity and the simplified

modelled instance. In LSRT context, traditional supply chain mathematical approaches very often require heavy simplifying assumptions and significant changes in problem setting, making some of the most well-known optimization models inapplicable.

Among these, the classical models for defining the appropriate order size to minimize transportation costs result to be inappropriate in case of a non-integrated distribution supply chain, that is one of the most common LSRT configuration. Indeed, as the business is managed by different subjects, the definition of the order quantity is left to the bargaining between the wholesaler and the retailers, who aim to optimize opposite utility functions and are often led by myopic behaviour and opportunistic attitudes. As a result, the order size is mainly determined by commercial negotiation and the logistic optimization is, eventually, pursued in a second step, leading only to minor refinement.

This paper proposes a pragmatic yet precise approach for computing a minimum order size to be applied in a non-integrated supply chain of the LSRT industry, in order to reach a sustainable transport cost level for the wholesalers, while considering retailers constraints imposed by the industry peculiarities.

2. Literature review

2.1. Supply chain optimization in LSRT industry

The optimization of supply chain costs represents a relevant topic for all companies, especially for those that operate in increasingly competitive environments (Sternbeck e Kuhn 2014) (Christopher 2005) such as LSRT companies, where logistics represent an important part of

the business activity. With reference to the interests of LSRT business, literature on supply chain costs optimization can be classified into three major approaches:

- Distribution Network Design, that aims to define the number and the best position of the storage points, in order to improve service level, while reducing the distribution costs (Wanke 2012). In the LSRT industry the main aspects that affect the distribution network configuration are related to the transportation constraints of goods, the store distribution and the related service areas, and the expected service level and logistics performance, often specified in the affiliation contracts established among the wholesaler and the retailers.
- Routing optimization, which aims to optimize shipment costs by minimizing the distance and/or the total travelled time, the number of used vehicles, and maximizing the truck load ratio. The routing optimization approaches therefore take into consideration complex cost functions to define the optimal routes given a set of orders and the fleet characteristics. In LSRT contexts, the routing optimization is often configured as a difficult Multi-Depot Multi-Type Vehicle Routing Problem with Time Windows Operation Research problem, leaving aside the complexity originating from several other specificities such as, for example, the opportunity to mix different goods categories on a subset of vehicles. The adoption of transportation management system (TMS) software, which approach the problem with customized heuristics, may generate cost reductions from 5% to 10% (Hasle, Knut-Andreas e Ewald 2007).
- Distribution planning, which aims to determine the optimal replenishment timings within a supply chain based on certain inventory control parameters. It calculates the time-phased inventory requirements considering variables such as the forecasted demand, the scheduled receipts, the on-hand inventory, the products shelf life and the eventual effects from promotional initiatives, aiming to minimize the total cost of distribution (Sainathuni, et al. 2014) or to reducing waste of goods (Mena, Adenso-Diaz e Yurt 2011). A comprehensive literature review on distribution planning and inventory management approaches for perishable goods can be found in (Karaesmen, Scheller-Wolf e Deniz 2011) while, again, Chabot et al (Chabot, et al. 2016) put in evidence the high number of operational constraints that hampers a straightforward application of distribution planning models.

In the following paragraphs, a specific focus on distribution planning in LSRT is given and, specifically, to the computation of the optimal order size in a non-integrated supply chain.

2.2. Distribution planning and order size definition

The general distribution planning process refers to the management of physical flow and storage of the products from the production phase, up to the final consumer

(Rushton, Croucher e Baker 2006), and this is still true in LSRT industry. However, within the distribution process, many actors may be involved, from the various stages of wholesaler, to the retailers. The level of cooperation among the various echelons grows with the establishment of affiliation contracts or with vertical integration. Nevertheless, in order to optimize the cost of the distribution process the best solution would seem to be to adopt integrated approaches (Sternbeck e Kuhn 2014).

In case of vertically integrated supply chains (i.e. a supply chain in which the wholesaler acts as a distributor, owning or controlling the retailer echelon), the distribution planning optimization consist in the definition of the order size that allows to reduce both transport and inventory costs in the whole chain (Mendoza e Ventura 2007) (Swenseth e Godfrey 2001) (Rieksts e Ventura 2009). The definition of the order size is based on the classical production scheduling models, of which the economic order quantity (EOQ) model developed by Harris is the first example (Harris 1913). Such models consider the trade-off between the holding costs, that increase along with the quantity, and ordering costs, which tend to be decreasing as ordered quantities increase. Despite being a milestone of the literature related to the distribution planning and inventory management, the EOQ model finds many limitations in the application to real contexts. Later in 1976, Silver proposed a model for the definition of the optimal order quantity a multiproduct replenishment (Silver 1976). The main contribution of the model proposed by Silver consists in the possibility to consider the different consumption and the different intrinsic value of the products in the definition of multi-product distribution lot. Afterwards, some authors expanded this concept by proposing a multi-product EOQ model that considers both the constraints related to the storage capacity of goods and a limited number of orders placed by the customer (Pasandideh, Niaki e Nia 2011). Recently, some authors eliminated the hypothesis of non-perishable products by proposing an EOQ model for perishable goods: some have deepened the inventory management decisions of a retailer who sells a single perishable goods in a deterministic context (Dobson, Pinker, & Yildiz, 2016), others have instead presented a stochastic mathematical model for perishable products that include costs of obsolescence and stockout (Muriana, 2016).

2.3. Limits of the current order size approaches

Although the EOQ model series are the most popular optimization models in supply chain management (Teng, 2008), the hypotheses and conditions underlying these models make them not always applicable in real industrial contexts (Pasandideh, Niaki e Nia 2011). Indeed, despite the improvements made over time to the Harris EOQ, the models developed afterwards have never succeeded in removing some overly simplistic hypotheses. One of these concerns the need to consider the supply chain as a single entity and therefore not to take into consideration the hypothesis of supply chains not vertically integrated.

Indeed, the EOQ model would seem inappropriate to define the optimal order quantity in a non-integrated supply chain, because of the different cost allocation among the

wholesaler and retailers. Indeed, in a non-integrated LSRT supply chain, the transport costs are handled by the wholesaler, that aims at minimizing the distribution costs for the replenishment of the stores and that is not interested in the holding cost of the goods at the retailer storage point. On the other hand, the retailer tries to minimize the holding cost, but is not interested in keeping transport costs under control. The result is that retailers tend to place small and very frequent orders, making it difficult to optimize the distribution for the wholesaler, because of the low saturation of vehicles. This latter, although dependent on the distribution and the number of stores, leads to strong diseconomies for the wholesaler, which in some cases could even make non-profitable deliveries.

In order to keep under control, the impact of transport costs on the value of delivery, some wholesalers need to define a minimum order quantity, which allows to regulate the purchasing behaviour of retailers. However, the definition of this value is not immediate, as:

- Stores located in different geographical areas shall not have the same minimum order size constraint, since the transport cost incidences on revenues may be extremely different.
- Stores with different sales capabilities shall not have the same minimum order size constraint, as it may be difficult to resell the goods before the expiration date for a small retailer.
- Different product categories shall not have the same minimum order size constraint, since these have different replenishment frequency.

On the contrary, the determination of the minimum order size should take into consideration the distance between the distribution centre and the store, the store size and the product category, and find an optimal balance among these factors.

3. Proposal of a model for order size definition in LSRT

In this paragraph, a model to compute the minimum order size is proposed for a network of stores that are supplied by a single wholesaler. The minimum order size definition aims at decreasing the incidence of transportations costs on the wholesaler’s turnover, computed on products sell-in prices (i.e. the wholesaler’s turnover originates from the sales to the retailers’ stores). This model is not intended for integrated supply chain contexts, in which wholesalers and stores are managed by the same company.

3.1 Main hypotheses

a) All the logistic flows start from the single wholesaler’s distribution centre. Products are boxed in packages which, in turn, are bundled on pallets; pallets may contain different products.

b) All the transportation costs are borne by the wholesaler;

c) The distribution lot is composed by different products, belonging to different categories, that are periodically reordered by the stores. Every product has a different sale rate and, thus, a different reorder frequency.

d) Road freight is the assumed as the transportation mode (i.e. trucks).

e) The stores network is relatively near to the distribution centre, so that every truck follows a multi-stop route, delivering to multiple stores located in different service areas (henceforth, provinces);

f) Let \mathcal{T} denote the reference time horizon; we assume that \mathcal{T} equals to one year since the goods seasonality has a direct impact on the sales trend.

3.2 Structure of the model

The model calculation procedure follows three phases:

1) A target value is chosen for the ratio between transportation cost and wholesaler revenue, to serve the stores in each province. Given the average value of the truck load and the average transportation cost per province, the first phase returns the minimum trucks saturation for each province.

2) The second phase defines clusters of the served stores according to their size (i.e. turnover), so that the model will yield different order sizes for each cluster.

3) The last phase merges the previous phases computing the minimum order sizes for each cluster of stores in each province.

Figure 1 graphically displays the model calculation procedure.

The following notation is used.

\bar{p}	Average sell-in price of product packages
\bar{n}	Average number of packages per pallet
\bar{d}	Average length of the distribution tour from the wholesaler distribution centre to the stores
\bar{r}	Average number of stores in one truck tour
c	Transportation cost per distance unit
q	Truck load capacity, in terms of pallet number
i	Value of the ratio between transportation cost and wholesaler revenue
i^{target}	Target value for i
i^{min}	Minimum value for i (corresponding to 100% truck saturation)

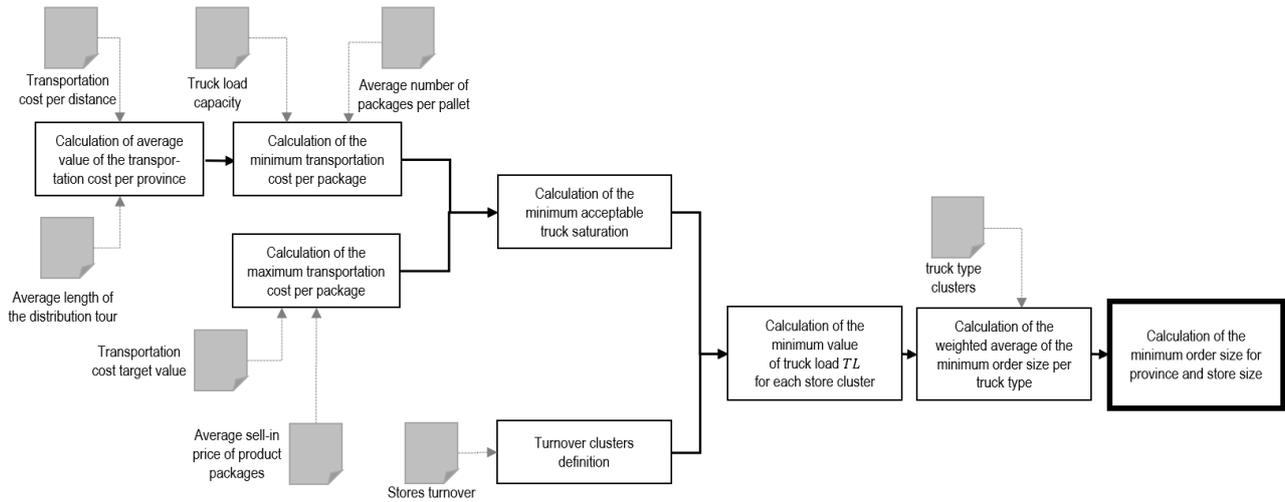


Figure 1. Model calculation procedure

3.3 Calculation procedures

Let:

- H be the set of b provinces;
- J be the set of j different types of trucks in terms of truck load capacity (i.e. in number of pallets, pl):
- $j \in \{16pl; 23pl; 33pl\}$
- T be the set of t different types of stores in terms of turnover:

$$t \in \{S(mall); M(edium); L(arge)\}$$

The first phase follows:

Step 1. We define the calculation of the minimum trucks saturation for each province b and for each truck j as follows:

Step 1.1. The calculation of average value of the transportation costs $\overline{TC}_{h,j}$ for each province b and for each truck type j , is defined as:

$$\overline{TC}_{h,j} = c_j \times \overline{d}_h \quad \forall h, j$$

Step 1.2. Considering 100% as the truck saturation, the minimum transportation cost per package \overline{PC} for each province b and for each truck type j is defined as:

$$\overline{PC}_{h,j}^{min} = \frac{\overline{TC}_{h,j}}{q_j \times \overline{n}} \quad \forall h, j$$

Step 1.3. The maximum transportation cost per package for each province b and per each truck type j , given a target ratio i , can be computed with the following procedure.

Let the input value for i be:

$$i^{input} = \max(i^{target}, i^{min})$$

then

$$\overline{PC}_{h,j}^{max} = i_{h,j}^{input} \times \overline{p}_h \quad \forall h, j$$

Finally, the calculation of the minimum acceptable truck saturation is performed for each province b and for each truck types j as:

$$\overline{TS}_{h,j}^{min} = \frac{\overline{PC}_{h,j}^{min}}{\overline{PC}_{h,j}^{max}} \leq 100\% \quad \forall h, j$$

Clearly, for those provinces where $i^{target} < i^{min}$, the computation yields a minimum truck saturation of 100% and the target value of the ratio between transportation cost and wholesaler revenue cannot be reached.

The second phase follows:

Step 2. Three classes of store turnover are defined: small, medium and large. The stores clustering is performed in order to obtain equinumerous classes.

Step 2.1. The average number of stores that can be reached during one tour \overline{r} is computed: to this extent, two different approaches are possible: if a database of all the tours is available, this number can be easily determined through the analysis of the historical time series. Differently, \overline{r} can be estimated considering the deliveries time-windows, the loading and unloading times and the travelling times.

Step 2.2. All possible turnover classes combinations are computed in order to determine the average combination of store size in one tour.

For example - anticipating some details on the case where the model has been validated – in the analysed context the average tour \overline{r} included 2 *medium/medium* sized stores.

Lastly, the third phase follows: small

Step 3. The minimum order size for province b and for each store size s is computed.

Step 3.1. The minimum value for the truck load TL for a given cluster of store size t , for each province h and for each truck types j is calculated:

$$TL_{h,j}^t = \overline{TS}_{h,j}^{min} \times q_j \times \bar{n} \times \bar{p}_h \quad \forall h, j, t$$

Step 3.3. The minimum order size can be computed with the following procedure:

Let u_j be the percentage of each truck type j , i.e. the fleet composition. In order to obtain a minimum order size MOS for each province h and store size t can be obtained through a weighted average as:

$$MOS_{t,h} = \sum_j TL_{h,j}^t \times u_j \quad \forall h = 1 \dots n$$

with

$$t \in \{S(mall); M(edium); L(arge)\}$$

and

$$j \in \{16plt; 23plt; 33plt\}$$

In this way, the minimum order size to be delivered to each store (with size t) based on his geographical location (in the province h) is obtained.

In next section, the validation of the model on the case of a LSRT company in Italy is shown.

3.4 Validation on the case of a LSRT company in Italy

The model has been applied to a real business case to verify the potential improvements in terms of reduction of the incidence of the transportation cost on the company turnover.

The analysed wholesaler company mainly operates in the south of Italy, serving 250+ stores in 10 Italian provinces (and sourcing from a single distribution centre (DC), with a 400+M€ turnover. Deliveries are performed with a truck fleet composed by: *i*) 22 16-pallet-sized trucks; *ii*) 19 23-pallet-sized trucks; *iii*) 15 33-pallet-sized trucks. Products belong to three main categories: *(i)* fruit and vegetables, *(ii)* cold cuts and cheese, *(iii)* general goods.

Aiming at measuring the performances of the company’s logistics distribution, preliminarily a transportation cost analysis has been carried out on the company’s 2017 data. The analysis reported the incidence of transportation costs on turnover for all the ten served provinces, along with the average order size and frequency.

The following Figure 2 clearly shows the effect of the distance of the province from the DC on the incidence between the transportation cost and the turnover. The figure clearly shows the inverse correlation between the order size and the frequency. One would expect that farthest stores would order less frequently, choosing larger order sizes. On the contrary, this is not true in this case, given that the stores are not bearing the transportation cost. This represented a problem for the wholesaler company.

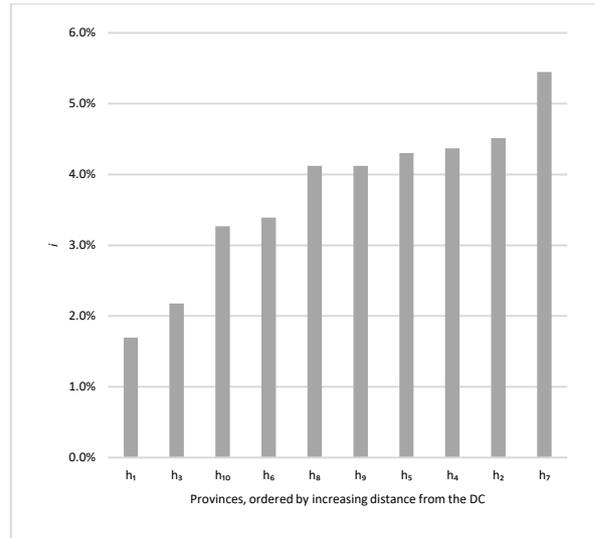


Figure 2: value of i for each province

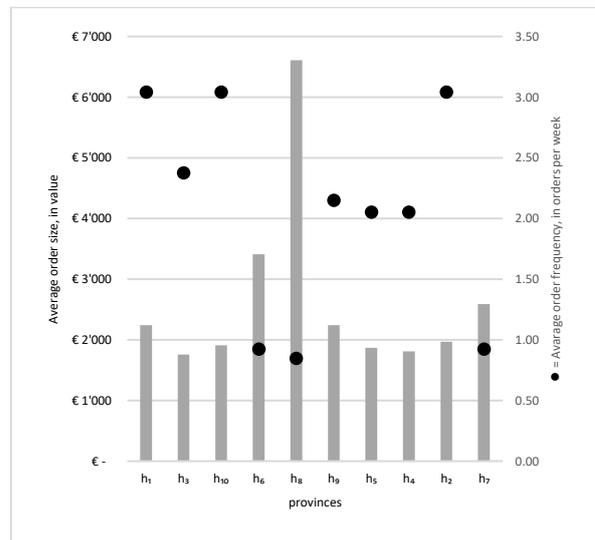


Figure 3 : A comparison between order value and order frequency, per province

The proposed model has been applied to the company case. The following Table 1 shows the minimum order sizes, expressed in Euros, for each store size and province.

Table 1: minimum order size

Province	Small size	Medium size	Large size
h_1	€ 2'310	€ 4'600	€ 6'930
h_2	€ 2'140	€ 4'300	€ 6'420
h_3	€ 2'310	€ 4'620	€ 6'930
h_4	€ 2'200	€ 4'400	€ 6'600
h_5	€ 2'300	€ 4'580	€ 6'870
h_6	€ 2'280	€ 4'560	€ 6'840

Province	Small size	Medium size	Large size
h_7	€ 2'360	€ 4'720	€ 7'080
h_8	€ 2'230	€ 4'450	€ 6'680
h_9	€ 2'600	€ 5'200	€ 7'780
h_{10}	€ 2'310	€ 4'620	€ 6'930

In order to estimate the effectiveness of the proposed model, a “to-be” scenario has been computed simulating the behaviour of the company’s distribution network with the new minimum order sizes.

In order to show the effect resulting from the application of the proposed procedure, the percentage of the orders below and above the minimum order size have been calculated and reported in Figure 4 and 5 respectively per each province and each store turnover class.

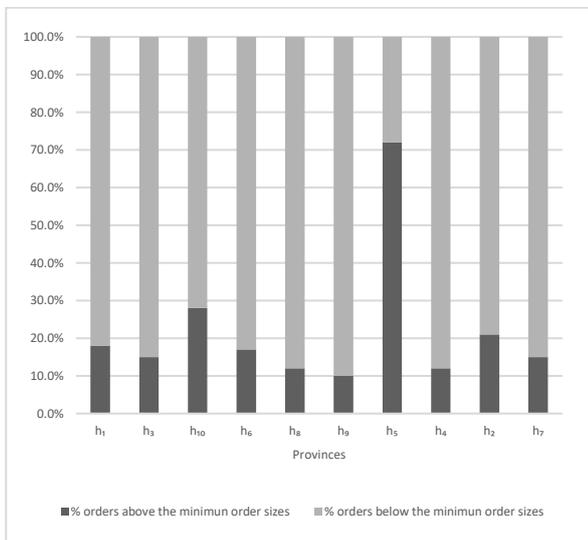


Figure 4. Percentage of the orders below and above the minimum order size per each province.

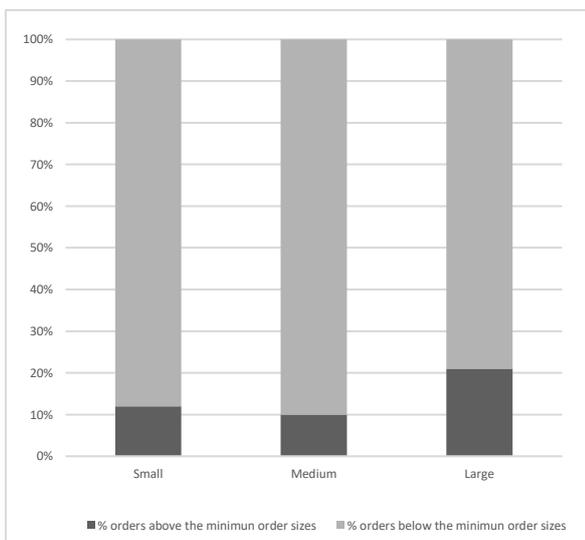


Figure 5. Percentage of the orders below and above the minimum order size per each store turnover class.

Thus, the store reorders in 2017 have been used to recompute the orders timing and re-build the distribution tours, assuming the previously reported minimum order sizes as binding constraints. Thus, the total distribution cost has been recalculated. In this way, a fair comparison between the original 2017 situation and what would have happened using the minimum order size has been possible.

The average ratio between transportation costs and the company turnover in 2017 was:

$$Incidence_{before} = 2.69\%$$

The same ration assuming the implementation of the minimum order sizes resulted to be:

$$Incidence_{after} = 1.52\%$$

Therefore, with the implementation of the minimum order sizes, the company would have been able to reduce the incidence of transport costs on turnover about 43%.

4 Limitations

Although the positive results, it seems important to point out the limitation of the presented model.

First, it has to be noticed that the order size is expressed in value and does not give any indications on the products assortment. This makes it independent from the product shelf life constraint. A large order of fresh food may generate problems in terms of storage and wastes, but this aspect is not considered in this model. Moreover, the order size does not consider any constraint on the back-of-house (i.e. the store warehouse) capacity. Very small stores may face space problems when complying their minimum order size.

Then, the store classification has been defined aiming at optimizing the transportation means saturation after the definition of the minimum order size. Therefore, turnover values per store cluster do not follow a linear scale and, moreover, are not related with any marketing or commercial consideration.

Finally, since the minimum order size has been computed per province using average data, it cannot be excluded that large stores located on the edge of each province may generate higher transportation costs than expected.

Thus, the proposed model aims to achieve an overall economic improvement on the entire distribution network but cannot guarantee the optimality of the solution per each single store.

5 Conclusion and next steps

The proposed model has demonstrated to practically find a solution, in terms of computing the minimum order size to contain transportation costs, for a LSRT company operating as a wholesaler and distributing goods to a multitude of stores in different provinces.

As one possible future development could be differentiating the delivery frequency per each product category, considering that the three typical products aggregations (fruit and vegetables, cold cuts and cheese, general goods) have at least two different delivery time

windows per store. At the same time, considering the relationship between the order size and the average inventory turns of the products assortment may lead to important considerations related to the sale potential of the order size.

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