A multi-scenario analysis to improve layout efficiency

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Abstract

Logistics costs represent a large portion of overall costs. Companies in peripheral countries need to be additionally careful in streamlining them if they want to maintain their competitivity. This research is focussed on a plant belonging to an aerospace component supplier, and its purpose is to reduce the layout costs in one of its warehouses. Data was collected using documentation, archival records, informal interviews, and direct and participant observation. From 66 initial scenarios based on layout decisions, storage assignment policies and alternative picking routes, 44 were compared as these are the ones that fit the company reality. Findings showed that travelling distance could be reduced when the allocation of items in shelves follow their picking frequency and when Class-based storage with return routing policies is used. In parallel, it does not impact in a relevant way process time and the quality of the picking.

Keywords: Case study; Layout efficiency; Warehousing

Introduction

The ability to compete is paramount and efficiency, regardless of the organisations' overall approach, is an issue companies continuously strive for. Companies in peripheral geographies face additional challenges to compete in primary markets, as they have to overcome additional costs derived from their location. Geography cannot be overcome without relocation costs, but costs can be explored to compensate for this factor.

Although storage of products by itself does not add value to the customer (Tompkins and Smith, 1998; Carvalho, 2018), it has an immediate impact on the warehouse operation costs (Tompkins and Smith, 1998; Rushton et al., 2017).

Warehousing costs are an essential key in the overall costs a company has to support and can be streamed to compensate for the geography ones. Excluding inventory costs, the picking activity alone represents about 55% of the warehousing costs (Drury, 1998). Additionally, travelling during the picking activity is estimated to require about 50% of the time of the resources (Tompkins et al., 2010). Even small savings in this travelling time can have a generous impact on the operation costs.

This research focuses on a plant, Lauak Portugal, located in a peripheral European country. This plant is a partner factory of an aerospace metallurgic company, Groupe Lauak, that has plants in many different countries. These plants compete among themselves for company contracts. Service quality and fulfilment of due dates to customers are relevant in this industry. Although most products are developed jointly with the customers, the cost issue is a pertinent aspect for maintaining the competitiveness of the plant within the group. It is thus essential to continuously monitor costs while looking for strategies that allow reducing them, with warehousing costs, and particularly picking-related costs, playing a vital role in this search. The purpose of this research is thus to improve the warehousing costs in one problematic warehouse for the plant, contributing to its competitiveness inside the company.

This research is grounded on a systematic literature review on warehousing procedures and layout alternatives (Tompkins and Smith, 1998; Tompkins et al., 2010; Stock and Lambert, 2001; Rushton *et al.*, 2017), which support the development of theoretical scenarios. The analysis of these scenarios is based on data collected from interviews, observation, documentation and archival records. A case study approach is conducted following literature recommendations (Yin, 2018; Voss et al., 2002).

Literature background

Logistics management aims to offer the highest possible level of customer service while decreasing response time and logistics costs. To achieve the most suitable solution for each company case, a trade-off between these dimensions (service quality, time and cost) must be reached. It is based on how the several logistics activities are conducted.

Warehousing is one of the many logistics activities identified in the literature (see for instance Stock and Lambert (2001), Rushton *et al.* (2017), Carvalho *et al.* (2018)). Despite being essential to the whole chain, in most cases, this logistic activity by itself does not add any value to the final customer (Tompkins and Smith, 1998; Christopher, 2016; Carvalho et al., 2018). As Ballou mentions (2004: 470), "storage become an economic convenience rather than a necessity". Warehousing activities help companies managing their gap between supply and demand, decreasing supply chain vulnerability and decoupling demand from production capabilities (Ballou, 2004; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018).

When holding materials at a warehouse, the layout decision has a strategic impact as it will impact the trade-offs within the logistics attributes. Minimising travel distance and facilitating internal flows are the aims of the layout decisions (Carvalho et al., 2018). Its typology is usually classified based on how products are moved inside the facility and the location of the doors. Typically they are: Directional or Flow-through; Broken flow or U-shaped flow (Carvalho, 1996; Tompkins et al., 2010); L-shaped flow when the receiving and shipping areas are neither located side by side nor in opposite sides of the facility; a mixture between the three main typologies (Rushton et al., 2017).

In many situations, facility constraints lead the layout configuration; nonetheless, if it is possible to decide, there are guidelines to be considered. Flow-through layouts reduces travelling time inside the warehouse and decreases the traffic and internal congestion because the receiving and shipping areas are on opposite sides (Carvalho et al., 2018), but this typology is more suited for factory warehouses, cross-docking platforms, or facilities that deal with materials with more or less similar rotation (Rushton et al., 2017). U-shaped layouts lead to reduced average travel distance, as the start and end points of its flows are close, and reduced space allocated to the reception and shipping areas; it is more suited for the storage of products with different rotations and/or shapes and weights, which might difficult their movement (Carvalho et al., 2018; Rushton et al., 2017). Regardless of flow typology, all warehouses have the same main internal movements.

Each warehouse has its internal activities. However, all of them have the same 4 main functions (Tompkins and Smith, 1998; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018): Reception of products; Storage until they are needed; Picking to satisfy an order; and Shipping to the user that requested them.

When assigning locations to storage of products, three main ways can be identified: 1) define a fixed/dedicated location to each product; 2) randomly store products in whatever empty places are available during the reception period (which leads to a higher average travel time (Glock and Grosse, 2012)); 3) define areas for each product, but not a specific location (each product has a single associated area, yet is randomly stored inside it – class-based storage) (Hausman *et al.*, 1976).

The fixed location alternative, although simple in terms of locating products in the facility, requires that the company keeps space available for the maximum level of inventory for every stock keeping unit (de Koster et al., 2007). Random storage, although simple to conduct and leading to better space utilization (Stock and Lambert, 2001; Carvalho et al., 2018), requires computerized central registration as product location is continuously changing (Carvalho et al., 2018) and leads to greater travel distance to complete the same picking list (Stock and Lambert, 2001; Carvalho et al., 2018) if products do not have similar rotation. Class-based location tries to combine the advantages of the two previous methods (Chan and Chan, 2011; Carvalho et al., 2018). It increases the warehouse performance up to 40% when compared to the random storage (Rao and Adil, 2013) and reduces travel distances as products are located in the facility based on their rotation (Chan and Chan, 2011).

Hall (1993: 76) defined picking as "the process by which items are retrieved from stocking locations in a warehouse". The picking activity has a direct impact on the trade-off of the logistics attributes as it has to balance the efficiency of the use of resources (which impact time and cost) and effectiveness (measured usually in terms of the number of errors) produced (Carvalho et al., 2018). Depending on the defined goal, there are four main ways to pick products (Van den Berg and Zijm, 1999; Tompkins and Smith, 1998; Ballou, 2004; Rushton et al., 2017; Carvalho et al., 2018): 1): Pick by Order (the picker has the responsibility to collect every item from one order and only one at a time); 2) Pick by Line (the picker collects the quantity required to satisfy at once several different orders from each location); 3) Zone Picking (requires dividing the warehouse into areas, and the picker collects all the items stored per zone, changing to another after collecting all the products from that zone); 4) Batch Picking (a few numbers of orders are assigned to a single picker, who is responsible for collecting all the products from those orders at the same time).

Choosing between the different picking techniques should be aligned with the warehouse policy. A company should pick by order when orders have many lines to pick (Carvalho et al., 2018). Although it is simpler when the picking is paper-based, the productivity level is the lowest due to the time the picker needs to complete an order (Tompkins and Smith, 1998; Carvalho et al., 2018; Rushton et al., 2017).

Using picking by line leads to a higher number of errors but also to a faster conclusion of activities (Carvalho et al., 2018). Due to the number of errors it can lead to, it is more suited for companies with a few lines to pick per order (Carvalho et al., 2018).

Resembling picking by order is zone picking. It is most suited for companies operating different systems and equipment inside the same warehouse (Tompkins and Smith, 1998; Carvalho et al., 2018), when orders are usually too big for a single picker, or if there is any justification for physical storage segregation (Rushton et al., 2017). It leads to more errors but at the same time shows higher productivity (Carvalho et al., 2018). The same way zone picking is for picking by order, batch picking is more suited for picking by line (Carvalho et al., 2018).

Selecting the best picking method depends, among other issues, on product range, order size, and the equipment used to collect the products (Rushton et al., 2017).

Companies can foster their efficiency using picking routes policies (de Koster et al., 2007; Roodbergen et al., 2008; Çelk and Süral, 2014). Several routing strategies are possible inside a warehouse, among which: i) Transversal Strategy, in which the picker enters at one side of the aisle, crosses it, and exits on the opposite side (Goetschalckx and Ratliff, 1988; Hall, 1993); ii) Return Strategy, in which the picker enters on an aisle and picks all the products from one side and then returns collecting products from the other side of the aisle, exiting on the entry point (Goetschalckx and Ratliff, 1988) (also called Largest Gap Return Strategy, according to Hall (1993)); iii) Mid-Point strategy, which is the same as the return strategy, but the return point is the middle point of the aisle (Hall, 1993); iv) S-shape curves, which is basically a traversal strategy where the picker does not need to cross an aisle if there is no picking to do (De Koster and Van Der Poort, 1998; Roodbergen & De Koster, 2001a).

Manzini et al. (2007) studied the impact of several variables on picking cycle time and concluded that return is the best strategy when it comes to a quadratic warehouse, and transversal when a company operates a rectangular one. Due to its simplicity, the S-shaped strategy can be used by some companies, but the real savings arise when companies select an optimal algorithm as a picking method. Particularly, Ratliff and Rosenthal (1983) propose an algorithm that allows determining the optimal picking route that minimises the travelling distances inside the warehouse. According to these authors, the procedure starts by selecting the closest shelf to the entry point. After picking that product, the shelf closer to the initially selected product should be the next chosen one. The picker should follow this procedure until the order list is completed.

Whatever warehouse policy a company adopts, it must consider the type of products, their size, shape, weight and rotation, the location of the products in the facility, the picking policies and the service policies. It is only from the aggregation of these different aspects that time and cost can be reduced while maintaining service quality.

The company: Lauak Portugal

Lauak Portugal is a partner factory of Groupe Lauak, a French group that owns a set of industrial companies supplying the aeronautical market. This research is focused on one specific plant based in Setúbal, Portugal, that transforms metal sheet into a wide range of aircraft components.

This plant has four warehouses: two for raw material (thin and thick material), one for work-in-process, and one for the final product. The company considers that the picking process in the final product's warehouse is consuming an excessive amount of time and, for this reason, this research is focused in this specific warehouse.

The warehouse for final products has three horizontal aisles (hereafter referred to as A1 [bottom aisle], A2 [middle aisle] and A3 [top aisle]), organised with 44 shelves. It follows a U-flow configuration. Shelves are organised according to 3 product families:

- FAI: prototypes waiting for quality approval to be shipped to the customer;
- ESKU: products of a partner factory of the group;
- PFBE: final products owned by Lauak Portugal; it is considered the most relevant family inside this warehouse.

Independently on the product family, products are randomly stored on the shelves that are dedicated to its particular family. There are different boxes on the shelves to accommodate small and medium size products. Large items are freely placed on the shelves. Regarding the picking process, it follows a picking list organised according to the delivery date, with products that have the closest delivery date being the ones that should be picked first. This organisation clearly shows that the picking process is far from being optimal. This research thus explores alternative picking routes along with alternative allocations of products on the shelves, and the impact of these alternatives in the total travelling distance in the picking process. The savings achieved in terms of travelling distance will have an impact on the warehousing costs, thus resulting in savings in the total cost supported by the company.

Methodology

This research is based on case study approach (Voss et al., 2002; Yin, 2018), and involves several consecutive research steps:

- Step I: Characterizing the current operation in the warehouse, with emphasis on the organisation of the warehouse, on the allocation of products and on the picking activity;
- Step II: Defining a set of alternative theoretical scenarios for storage assignment of products and picking routes;
- Step III: Assessing and comparing alternative theoretical scenarios;
- Step IV: Presenting recommendations for the company.

Different tools are used in each of these steps, either to collect or to treat data.

Step I: Characterizing the current operation in the warehouse

The detailed and accurate characterisation of the current operation in the warehouse requires the collection of a wide variety of data. Following both qualitative and quantitative approaches, several information sources are used, following Yin (2018): documentation, archival records, informal interviews, and direct and participant observations.

A qualitative approach is based on unstructured informal interviews with employees with different hierarchical roles to understand in detail the warehouse organisation and internal operations. Particularly, the head of logistics, the picker and the warehouse manager are interviewed. Direct observation and official documents are also used, allowing to assure data triangulation (Eisenhardt, 1989; Voss et al., 2002; Yin, 2018).

Quantitative data is also measured using direct and participant observations, namely: i) distances travelled between and across aisles and shelves inside the warehouse; ii) data related with the picking activity in one specific period; iii) the volume of each product and shelf location in the warehouse. Additionally, the daily stock is extracted from the company's ERP (archival records), and the average stock is calculated based on this information.

Step II: Defining a set of alternative theoretical scenarios

A set of alternative theoretical scenarios for the storage assignment of products and picking routes are defined based on literature recommendations. Particularly, 66 scenarios are considered based on 22 picking routes and 3 storage assignment strategies.

- Picking routes: the Traversal, Return, and Mid-Point strategies are used (Goetschalckx and Ratliff, 1988; Hall, 1993; de Koster and Van Der Port, 1998; Roodbergen and de Koster, 2001a). The S-Shape Curves strategy is not specified because it is equivalent to the Transversal strategy in this specific warehouse. Also, the algorithm proposed by Ratliff and Rosenthal's (1983) is also considered as an alternative picking route. By examining these four different strategies, 22 picking routes are obtained, according to Table 1;

- Storage assignment: Random (SA-1), Class-Based (SA-2) and Fixed/Dedicated (SA-3) strategies are considered, following the recommendations of Hausman et al. (1976), De Koster et al. (2007), Chan and Chan (2011), Glock and Grosse (2012) and Carvalho et al. (2018). ABC analysis is used to classify products for Fixed/Dedicated and Class-Based strategies, using the picking frequency as criterion (Chan and Chan, 2011).

Table 1. Picking Routes

Picking routes	Number of routes	Strategy
PR-1 to PR-18	18	Return Strategy in one aisle and Transversal in the other two aisles, changing the aisle in which the route is started (6 scenarios starting in A_1, 6 scenarios starting in A_2 and 6 scenarios starting in A_3)
PR-19	1	Return strategy in every aisle
PR-20 & PR-21	2	Middle-Point strategy in one aisle (A_2 or A_3) and transversal in the other two.
PR-22	1	The algorithm proposed by Ratliff and Rosenthal (1983)

These 66 scenarios should be compared with the current situation in the warehouse, i.e., with a reference scenario (hereafter called *Current Scenario*) representing the picker's real movements inside the warehouse in one specific period.

Step III: Assessing and comparing alternative theoretical scenarios

The efficiency of the theoretical scenarios defined under Step II is assessed in terms of the total distance travelled inside the warehouse, according to Equation (1):

$$\sum_{i=1}^{n}\sum_{j=1}^{n} D_{ij} * T_{ij} \qquad (1)$$

in which *i* and *j* represents a location point inside the warehouse (it can be the entrance or a shelf), *n* represents the number of shelves plus one (to include the entrance), D_{ij} represents the distance between a location point *i* and *j* (with $i \neq j$), and T_{ij} represents the frequency in which the distance between location point *i* and *j* is travelled.

These scenarios are then compared with the current scenario in the warehouse (hereafter called Scenario 0), in which a specific warehouse layout, storage assignment and picking route are used in the daily operation (as described in the following section). To allow this comparison, all scenarios should be simulated with the same data used to characterise Scenario 0 (i.e., data related to the number of products received and delivered during a specific period).

Step IV: Presenting recommendations for the company

Based on the results obtained by comparing all the scenarios, managerial recommendations are presented to the company.

Case study

This section first presents the scenarios selected for analysis and then follows for the key results obtained based on the simulation of these scenarios.

Selected theoretical scenarios

Within the set of 66 scenarios defined above, only 44 are further anaysed in this research – the Fixed/Dedicated storage is not used in the analysis as it is not considered a doable policy by the company. Within this setting, only Random Storage (SA-1) and Class-based Storage (SA-2) are considered, together with the 22 picking routes (PR1 to PR22) – Table 2 presents a summary on the scenarios considered for analysis.

Table 2. Theoretical scenarios under study

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Storage assignment strategies</td></tr>
<tr><td>SA-1</td><td>SA-2</td></tr>
<tr><td rowspan="4">Picking routes</td><td>PR-1 to PR-18</td><td>PR-1/SA-1 to PR-18/SA-1</td><td>PR-1/SA-2 to PR-18/SA-2</td></tr>
<tr><td>PR-19</td><td>PR-19/SA-1</td><td>PR-19/SA-2</td></tr>
<tr><td>PR-20 & PR-21</td><td>PR-20/SA-1 & PR-21/SA-1</td><td>PR-20/SA-2 & PR-21/SA-2</td></tr>
<tr><td>PR-22</td><td>PR-22/SA-1</td><td>PR-22/SA-2</td></tr>
<tr><td colspan="2" rowspan="2">Total number of theoretical scenarios</td><td>22</td><td>22</td></tr>
<tr><td colspan="2">44</td></tr>
</table>

Class-based Storage requires classifying the different products. The following steps were conducted:

- First: Products are first classified according to the families already in use to organise the warehouse: FAI, ESKU and PFBE (classification imposed by the company). There are specific areas in the warehouse for each family, and it is not possible to mix families;
- Second: Within each family, ABC analysis is used to classify products in A, B and C items, according to the picking frequency;
- Third: Within each family and class, items are further divided into small, medium and large items. This classification is also required because the size of the products will also affect the selection of the shelf where it should be stored.

Based on such classification, 9 classes are defined. PFBE products should be first allocated to the shelves closer to the warehouse entrance, followed by ESKU products, and then by FAI products (according to company recommendations). Within each of these product families, items with a higher turnover (A items) should be stored closer to the warehouse entrance. Afterwards, within each family and class (A, B and C), products should be allocated randomly, although respecting the organisation in terms of volumes (it is not possible to mix small, medium and large items in the same shelf).

Key results

The 44 scenarios are simulated using data related to the picking activity recorded for one specific period of activity, and the current scenario was also analysed for this period. Table 3 summarises the key results of this simulation.

Table 3. Total travelling distance in the period in the picking activity per scenario

		Storage assignment strategies			
		SA-1: Random Storage		SA-2: Class-based Storage	
		Total travelling distance (units of distance)	**Reduction compared to the current scenario (%)**	**Total travelling distance (units of distance)**	**Reduction compared to the current scenario (%)**
Picking routes	**PR-1**	340 584	43,65		
	PR-2	**324 916**	**46,25**	**215 612**	**64,33**
	PR-3	**325 936**	**46,08**	**215 224**	**64,39**
	PR-4	338 622	43,98		
	PR-5	348 352	42,37		
	PR-6	341 710	43,47		
	PR-7	338 494	44,00		
	PR-8	345 782	42,79		
	PR-9	336 020	44,41		
	PR-10	348 905	42,28		
	PR-11	366 277	39,40		
	PR-12	349 659	42,15		
	PR-13	341 630	43,48		
	PR-14	340 550	43,66		
	PR-15	**324 884**	**46,25**	**215 209**	**64,40**
	PR-16	366 492	39,37		
	PR-17	372 054	38,45		
	PR-18	348 692	42,31		
	PR-19	347 546	42,50		
	PR-20	355 193	41,24		
	PR-21	367 260	39,24		
	PR-22	326 894	44,92		
Current scenario		604 443 (units of distance)			

The results obtained for the first 22 scenarios – scenarios related to the 22 picking routes and random storage (PR-1/SA-1 to PR-22/SA-1) – are summarised in the left half of Table 3. According to these results, the proposed scenarios allowed reducing the travelling distance between 38,45% and 46,25%, when compared to the currently travelled one per month in the picking activity. Within these 22 scenarios, the ones that allow obtaining the highest saving in terms of travelling distance are the ones identified in bold in the table and that are characterised by picking routes mixing transversal and return strategies (PR-2/SA-1, PR-3/SA-1 and PR-15/SA-1).

The right half of Table 3 summarises the results obtained for the four scenarios that resulted in the shortest travelling distance when random storage is considered, but now with class-based storage being imposed. These three scenarios were simulated with the same data used for the other 22 scenarios, but while imposing the new allocation of products in the warehouse according to the products' classification proposed above. Implementing these scenarios would allow reducing the travelling distance in the picking process at an even larger extent, when compared to the current scenario, with reductions of around 64%.

Discussion

Random storage theoretical scenarios showed to be able to reduce the distance travelled (and consequently warehousing costs) in every picking policy considered when compared to the current company policy. Nonetheless, it has to be taken into account that random storage may lead to a more time-consuming picking process if investments in information systems are not conducted as additional time might be required to find the items. This way, the reduction of at least 38,45% in distance travelled may not represent a similar reduction in the required picking time.

As the company has 3 different product families, each with items showing different picking frequencies, Class-based Storage was also analysed as a more organised random storage alternative. Findings showed that this storage assignment policy leads to even more reduced travelled distance. Although items are also randomly stored in a specific area and within that area they are organised on the shelves based on their size, they are nonetheless easier/quicker to find than in the Random storage alternative – this is because there is a quite limited number of alternative locations where they can be found. This alternative showed a reduction in the distance above 64%, which is likely to accommodate an eventual increase of time in finding the specific item in the shelves.

Picking quality should not be affected by any of the storage assignment policies or by any of the picking routes considered as no changes in terms of a more picking by line or picking by order orientation were considered.

It is possible to state that the company is currently using a suboptimal solution and that, without any investment, can reduce warehousing costs.

Conclusions

This research aimed at assessing picking policies to reduce warehousing costs, therefore contributing to Lauak Portugal competitive position within Groupe Lauak. Diverse different storage assignment (SA) policies and various picking routes (PR) were considered. From 66 possible initial scenarios (3 SA; 22 PR), 44 were considered (2 SA; 22 PR) as the remaining did not suit the specific case.

The 3 different product families were considered in defining zones in the warehouse. Families were divided into classes based on picking frequency; each class was further classified based on the size of the product as they require different shelving conditions.

Results show that significant savings in terms of the travelling distance in the picking activity can be achieved when alternative picking routes are considered, with even higher savings being obtained when the allocation of products in the shelves follow the picking frequency of products. Nevertheless, when comparing the results obtained when different picking routes are simulated (with the same storage assignment of products), no significant differences arise. Additionally, Class-based Storage showed to be a more organised solution than Random storage when product families exist.

This research contributes to practice, specifically to the analysed company. Additionally, this approach, with necessary adjustments, can be adopted by other companies to assess their policies and to find more efficient warehousing solutions.

A period of less than a year was considered, which might limit the usability of these findings. Analysing a full year would allow including seasonal uses of items, which might influence the frequency of use of the different locations. Nevertheless, the period considered was considered by the company as representative of its overall operation.

As further research, several topics may worth pursuing. Particularly, although not considered as feasible by the company, alternative layouts could be evaluated since it may result in further improvements in the picking activity. Also, a more in-depth analysis in the nature of products may lead to the organisation of products into different families, with an expected impact in the classification and allocation of products. Finally, exploring optimisation methods to identify the optimal scenario could also be pursued.

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