Abstract

In order to surpass the fierce competition existing in today’s global markets, the continuous improvement of the supply chain operations is key. With warehousing and inventory control holding more than 40% of logistical costs in Europe (Mayer et al. 2009), this is an activity which optimization can lead to overall cost reductions in the operations. In this context, this paper presents the case study of Sugal Group, specialized in the production of tomato derivatives.

The main goal of this study is to develop a strategy to achieve cost reduction and to provide an alternative to solve the two main identified improvement opportunities: lack of capacity and the excess of pallets handling. The result was a MILP mathematical model which minimizes the total handling cost by allocating products to locations within the warehouses in an optimal way, together with a dashboard with a practical approach on results.

Keywords: Warehousing; Warehouse management; Optimization; Layout; Product allocation.

1. Introduction

The growing expectations from the consumer and the dynamic competition existing nowadays, lead to companies having to constantly innovate and adapt their strategies and operations while simultaneously reducing operational costs to remain competitive.

Sugal Group is one of the biggest worldwide companies specialized in the production of tomato derivatives. Their supply chain management faces the typical challenges of perishable goods such as compliance with expiration date and quality assurance from the production site until the delivery of the good.

At the Benavente production site, three warehouses are available for finished product storage. However, due to the increase in sales and production volume, the company faces a lack of storage capacity and must contract external warehousing space. In addition, the three warehouses are physically apart and, due to the current warehousing strategy and the existing physical conditions, there is a frequent transfer of pallets between warehouses, which translates into high handling costs.

The objective of this paper is to reduce the total handling costs and to propose an alternative strategy for the storage of finished product. For this purpose, a mixed integer linear programming model to optimally allocate products into warehouse locations is proposed. Simultaneously, a dashboard is built to allow an easy and fast result consultation.

The remainder of the paper is structured as follows: in Section 2 relevant literature regarding warehouse management and existing methodologies for the different warehousing activities is presented. In Section 3 the framework of the case study and the assumptions considered are described. In Section 4 the tools developed to support a decision on the case study are discussed. The scenarios analyzed, and the results obtained in each scenario are present in Section 5. As a conclusion of this paper, the Section 6 presents a few final remarks and proposals for future work.

2. Literature Review

2.1. The importance of warehousing nowadays

The adoption of new management methodologies, such as Just-In-Time and lean
Production, brings challenges for warehouse management, as they require greater inventory control, shorter response time and greater diversity of items. On the other hand, there is a growing implementation of new information technologies that offer opportunities to improve warehouse performance (Gu et al. 2010).

However, the answer to these challenges does not come free. Warehousing and inventory cost account for a large proportion of total logistics costs. In Europe, it is estimated that storage and inventory maintenance costs exceed 40% of logistics costs (Mayer et al. 2009). Any improvement in the warehousing operations which results in a cost reduction will therefore have a direct contribution in the reduction of total costs.

The role of storage has been overlooked not only by some professionals, but also by the scientific community. Only a small fraction of the literature is devoted to storage, and there is little information exchange between the scientific community and the operational reality (Gu et al. 2010).

2.2. Warehouse management

The main purpose of a warehouse within a supply chain is to intermediate the flow of material to achieve a high level of service. Some of the tasks performed in a warehouse are: receiving products from an internal or external source, storing goods, picking products to fulfill orders sending them to the respective recipient (Tompkins & Smith 1998). Of all these activities, order picking alone accounts for 65% of the total cost of the warehouse and occupies 50% of the available workforce (Broulias et al. 2005).

Warehouse design

Five main decisions are taken when designing a warehouse: determining the overall structure; calculating the size and dimensions of the warehouse and its sections; determining the detailed layout of each section; selecting the warehouse equipment to be used; and determining what operational strategies will be put into practice.

The selection of the operational strategies determines how the warehouse will be operated, for example, with regards to receiving, storage, order picking and shipping (Gu et al. 2010).

Receiving and Shipping

Receiving and shipping activities are characterized by the entry and exit of products from the warehouse, respectively.

Upon reception, the product is unloaded from the conveyor, the inventory is updated and an inspection is performed to check for quality or quantity inconsistencies (de Koster et al. 2007). This process corresponds to about 10% of the warehouse operating costs (Frazelle 2002).

During the shipping operation, it is necessary to check the orders in terms of quantity and quality, prepare the transport documents and, finally, proceed to load the customer's order on the lorry or container. Shipping is responsible for approximately 15% of the storage process costs (Frazelle 2002).

Storage

The storage activity includes the organization of goods in the warehouse to optimize the use of the space and to facilitate the handling of the products. There are three key decisions to be taken in storage management: (1) how much inventory of each SKU to keep in storage; (2) how often and at what time the inventory replenishment for a given SKU should be performed; (3) the location of the warehouse to be assigned to each SKU, both in terms of storage and movement (Gu et al. 2007).

With the purpose of improving the performance of storage, the scientific community has invested in the development and application of models, simulation and algorithms. The results obtained in the published studies can be used to support decisions, so the decision is taken in an informed and efficient way.

For the allocation of SKUs to warehouse locations, which is referred to in the literature as the product allocation problem, there are several policies. The most discussed are: (1) random storage, in which newly arrived products are assigned to unoccupied locations in a random fashion; (2) dedicated storage, where each product already has a specific location previously determined; and (3) storage by classes, where products with similar characteristics are stored in the same warehouse area (Hausman et al. 1976).

The main contribution of the literature in solving the problem of product allocation lies in the modeling the problem through linear
programming. Sanei et al. (2011) developed an integer linear programming model with various operational constraints to prevent the decentralization of products inside the warehouse. Later, this model was adapted by Guerriero et al. (2013) to a warehouse with several levels of storage height and with compatibility restrictions between the products.

**Order Picking**

Order picking, consists of the collection of articles that have been requested in an order by a customer. To make this process efficient, it is important to determine the best route that allows collecting the products, so that the distance traveled is minimized (Cormier & Gunn 1992).

Picking has gained importance since it is the activity that requires more labor and, consequently, has the highest costs. For this reason, warehouse professionals consider order picking as the highest priority activity for performance improvements (de Koster et al. 2007).

Currently there are three manual picking policies more commonly discussed in the literature: wave picking, batch picking and zone picking. Wave picking is preferred when there are orders with similar characteristics, such as having the same shipping time or being transported by the same carrier. These similar orders are then collected over a set time interval and shipped together. In a picking by batch policy an employee is assigned a set of orders to be collected only on one trip. Finally, in zone picking the storage area is divided into zones, and each employee is responsible for collecting items in a given area (Gu et al. 2010). These methodologies are also classified as picker-to-goods policies, as operators move the product to collect it. Manual picking policies are the most adopted in warehouses worldwide (de Koster et al. 2007).

Over time, there has been an increase in the number of automated collection and storage systems, which typically carry the products to a collection point. These systems are called goods-to-picker (de Koster et al. 2007). Simultaneously, information and communication technologies are installed to facilitate material handling and picking operations to reduce handling time, cost and the number of errors (Hou et al. 2009).

The choice of the picking policy is conditioned to both external and internal factors, depending on the reality of each warehouse. External factors include marketing channels, the pattern of demand, the pattern of replenishment by suppliers, the total demand for each article, and the state of the economy. Internal factors include the characteristics of each system, for example the level of mechanization, and the operational policies adopted (Goetschalckx & Ashayeri 1989). More recently, there has been concern in the literature about the influence of human factors on picking policies. Grosse et al. (2015) review the literature on picking policies with special focus on these factors, while Grosse and Glock (2015) model the effect that learning has on order picking.

### 2.3. Outsourcing of warehousing activities

Over the past few years, storage activity has been outsourced not only to reduce costs, but also to enable companies to focus on the core of their business (Rao & Young 1994). This solution is sometimes preferred to build a new warehouse or to expand the existing warehouse, which involves a high investment.

One of the main reasons for this decision is the finite capacity of the warehouses, and the companies become compelled to use external warehouses as an extension of capacity. Most companies recur to external facilities when there is an increase of production. Using this extra capacity then becomes useful to acquire high quantities of raw materials to take advantage of economies of scale (Wutthisirisart et al. 2015).

### 3. Case Study

Sugal production's site in Benavente produces tomato derivatives in four different production lines. Each production line has a different final location and uses a different packaging material: glass, plastic, tetrapak and bags.

Besides the production space, the storing space at Sugal includes five warehouses: the virtual warehouse and the warehouse 2 are used to store raw materials; the warehouse 1 stores finished product on temporarily basis; the warehouses 3 and 4 & 5 are used to store the finish product.

Currently, the operations of storage and expedition of the pallets within the Benavente facilities are characterized by the following operational restrictions:

- After production, all finished products are temporarily stored in Warehouse 1;
• Finished products intended for export are then transported into and stored in Warehouses 3;
• Finished products intended for national clients are then transported into and stored in Warehouses 4 & 5;
• Finished products stored in Warehouse 3 are shipped from Warehouse 1;
• Finished products stored in Warehouses 4 & 5 are shipped from Warehouses 4 & 5.

Figure 1 depicts the plant of the Benavente site.

This plant includes the final location of each production line, the warehouses and its relative locations and the movements related to the pallets of each type of product. It is clear there is an excess of pallets handling, which leads to high handling costs and increase of the possibility of damage to the pallets.

The strategy adopted in the storage operation is non-structured and is characterized by allocating pallets into available locations without the support of any allocation system.

There is currently no warehouse management system implemented, hence the tracking of pallets is not possible in an automatized way, and only operators are aware of the location of each lot. This results in a time waste in both storage and order picking operations, since the operators must search for available locations to store the pallets and also to look for the correct pallets when preparing an order.

Besides the internal storage spaces, Sugal currently rents external storage space since the capacity of their warehouses is complete due to an increase of production. The products stored externally are then transported back to the Benavente facilities to be shipped.

Based on the literature review and on the case study presented, two main problems which lead to a cost increase were identified: excess of pallets handling and lack of capacity. In the interest of challenging these issues, it was decided to propose an alternative storage strategy.

In order to solve the problems identified above and to propose an alternative storage strategy, a mixed integer linear programming model (MILP) was developed and a dashboard was designed in order to present and analyze the results.

4. Mathematical Model and Dashboard

The MILP model includes all the operational restrictions which characterize the case study and applies the concept presented by Sanei et al. (2011), using penalties to prevent the decentralization of products within the warehouse. The MILP model was implemented in GAMS software, through the ILOG CPLEX algorithm, to find the optimal solution.

The main goal of the model is to determine the optimal allocation of products to locations within the warehouses with the goal of minimizing the travelled distance and hence the handling costs. The concept of flow was chosen to classify the SKUs by the frequency of movements in a certain time interval (Carvalho 2018). The objectives of the model are:

• Allocate articles with higher flow to locations which require a lower travelled distance;
• Allocate the articles respecting preferential relative locations by reducing the decentralization of the same SKU in the warehouse and simplifying the order picking for the operators;
• Allocate all pallets from the same SKU to the same location.

If allocating all the pallets from a SKU to the same location is not possible due to capacity constraints, the preferred storage order will be the following: (1) store products of the same category in adjacent locations, (2) store products of the same category in opposite locations, (3) store products of the same category in backside locations, (4) store products of the same category in non-neighboring locations.

Besides the model, a supporting dashboard, developed in Microsoft Excel with resource to Visual Basic for Applications, was developed to provide input data to the mathematical model.
implemented in GAMS and to present the results in an easy and understandable way. It is important to have an output of easy comprehension, since the information contained in this file will be put into practice by the operators of the warehouse, who mostly do not have a higher education.

The dashboard will be presenting the following results in four different tabs:

- **Quantity**: the quantity of pallets of each SKU to be stored in each location is presented in tabular form;
- **Layout**: the layout of the warehouse is displayed to easily visualize where it is most efficient to store each SKU;
- **Turnover**: turnover was defined as the average number of days that a certain SKU remains in average in the warehouses of Sugal, from its production date until its shipment;
- **Results**: The total cost of the strategy is presented in the final tab of the Output file, as well as the total traveled distances, the consumption of the machines used to perform the strategy and the total man-hours needed.

### Scenario 1 and Scenario 2. The scenarios are characterized as described in Figure 5:

- **Scenario 1**
  - Finished Product
  - Warehouse 1
    - Destined to: National Clients → Warehouses 4 & 5
    - Destined to: Export → Warehouses 3
    - Capacity surplus → External warehouse
  - Storage strategy: minimize travelled distance and the decentralization of products

- **Scenario 2**
  - Finished Product
  - Warehouse 1
    - 10% Warehouse 1
    - Warehouse 3
    - Warehouses 4 & 5
    - Capacity surplus → External warehouse
  - Storage strategy: minimize travelled distance and the decentralization of products

### Figure 3 - Scenarios defined for analysis.

The main goal of studying the Current Scenario was to set a starting point for future comparisons and to analyse the current storage strategy. To evaluate the impact of applying the model on the storage strategy, Scenario 1 was developed. For further analysis of an alternative storage strategy, on Scenario 2 the Warehouse 1 is partially used for storage of finished product and all the products are allocated independently of their destination (national clients and export).

### 5. Results

The MILP was applied to each of the scenarios presented previously and the results were exported into the dashboard. The historical data from November 2015 was used as an input for the model, since it was the month with the highest quantity of stored pallets.

A comparison between the scenarios was also performed.
5.1. Turnover

The analysis of the turnover results obtained allows the identification and study of sales seasonality, which can be used for production planning. The number of lost pallets sent to destruction for being stored longer than their shelf life was also estimated. Besides these calculations, the dashboard includes the following information about each SKU produced during 2015:

- Number of productions batches;
- Average production lot size;
- Total amount of pallets of the article produced;
- Expiration date of the SKU;
- Recommended shelf life of the SKU.

The turnover results were calculated considering data for the year 2014 and 2015 and are independent of the scenario under analysis.

A detailed turnover analysis of one of the available SKUs was performed and can be consulted in the dissertation present by Carvalho (2018).

5.2. Quantity

Another of the results of the mathematical model that is displayed in the output file is the number of pallets of each SKU to be stored in each warehouse location. For the warehouse management team this result has two important applications:

- Acts as a map of directions that can be used as a guide for operators;
- It can be used for an allocation analysis by the warehouse manager, since the model discriminates how many pallets are allocated to each internal warehouse and to external warehouses.

Figure 4 presents an example of the output obtained to illustrate how many pallets of each SKU to be stored in each location. This example corresponds to the result of Scenario 2, Warehouse 3. A possible reading of this table is the following: in Scenario 2, the location 198 stores 28 pallets of SKU s34 and 1 pallet of SKU 37.

Two other indicators were calculated for each scenario on the Quantity tab of the dashboard: the occupancy rate of each warehouse and the percentage of pallets allocated to external warehouses. The results for the scenarios analyzed are shown in Table 1.

<table>
<thead>
<tr>
<th>Occupancy Rate</th>
<th>Current Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouse 1</td>
<td>-</td>
<td>-</td>
<td>95%</td>
</tr>
<tr>
<td>Warehouse 3</td>
<td>-</td>
<td>39%</td>
<td>59%</td>
</tr>
<tr>
<td>Warehouse 4 &amp; 5</td>
<td>-</td>
<td>76%</td>
<td>56%</td>
</tr>
<tr>
<td>Total Sugal Warehouses</td>
<td>-</td>
<td>52%</td>
<td>59%</td>
</tr>
<tr>
<td>External Warehouse</td>
<td>18%</td>
<td>14%</td>
<td>0%</td>
</tr>
</tbody>
</table>

In the Current Scenario, the data were provided by Sugal and since there is no pallet tracking system, it was not possible to calculate the occupation rate of each warehouse. However, it is known that 18% of the total pallets stored are in external warehouses.

In Scenario 1, most pallets are stored in Warehouses 4 and 5, totaling 76% of existing pallets. The remaining 39% of the pallets are stored in Warehouse 3. In this scenario, the occupancy rate would be 52%, which means that the storage space would not be very effective, since although there are several positions of free storage, 14% of the total pallets are stored using an external warehouse.

In Scenario 2, Warehouse 1 is used for final product storage, and its occupancy rate is 95%, which means that the space available in this warehouse would be used in a very efficient way. The Warehouse 3 occupancy rate increases from 39% in Scenario 1 to 59% in Scenario 2, while Warehouse 4 and 5 occupancy rate decreases from 76% in Scenario 1 to 56% in Scenario 2, which demonstrates that adopting a different storage strategy has obvious differences in the distribution of pallets across the different available warehouses.

In general, the occupancy rate is 52% in Scenario 1 and 59% in Scenario 2, which means that the storage space is better used in the latter, and there are more storage positions occupied. In Scenario 2 it is possible to store all the pallets in the warehouses of Sugal and it is not necessary to use the external warehousing service.

The biggest difficulty in optimizing the storage space is the fact that there is no standard storage solution for all products. Currently, most products are stacked directly on other pallets, which in
addition to not taking full advantage of existing space increases the likelihood of damaging the pallets.

One solution to maximize the use of warehouse space, and consecutively increase the occupancy rate, would be to adopt a shelf system for all pallets to maximize the warehouse capacity. This measure is already applied to the articles with tetrapak packaging.

5.3. Layout

Along with the occupancy rate, the layout is important to understand the efficiency of the strategy adopted. The resulting layouts of each scenario are compared in Figure 6. Since a localization system is not installed, the resultant layout printed in the dashboard is very useful to locate the pallets after they have been stored.

In Scenario 1 it is clearly visible that the strategy adopted does not efficiently use the storage space. Warehouse 3 has many available positions to occupy while Warehouse 4 and 5 it is necessary to use an external warehouse to store the surplus pallets. However, although it no longer has free positions, Warehouse 4 and 5 has an occupancy rate of only 75.6%, which is explained by the height in which is possible to stack the pallets, which is not maximized due to the nonexistence of a standard storage system. This disparity comes from from the separation of products destined for different markets.

A clear advantage of Current Scenario and Scenario 1 is that by separating the products destined for the national market and the export market, the storage and picking operations are facilitated for the operators since they know to which warehouse they should go just by knowing which product they are picking.

The total occupancy rate increased from 52.5% in Scenario 1 to 59.1% in Scenario 2. In this scenario, the space in Warehouse 1 is complete, but there are several unoccupied storage positions in Warehouse 3 and in Warehouse 3 Warehouse 4 and 5, which will be useful in case of stock fluctuations. Another advantage of Scenario 2 is that it is not necessary to use external storage space. This scenario also brings an additional operational challenge, since it is no longer possible for workers to assume that an article intended for a specific market is stored in a predetermined warehouse.

In any of the alternatives, it is possible to identify a symmetry in the layout of the warehouse, and the pallets of the same SKU are stored aggregated in specific areas of the warehouse, which facilitates its localization by the workers.

5.4. Impact of costs, distance and duration

The last section of the dashboard presents the operational costs of each of the scenarios. Table 2 shows the results obtained in each scenario.

<table>
<thead>
<tr>
<th>Distance, Duration and Cost</th>
<th>Current Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance - Forklift</td>
<td>1494 km</td>
<td>1375 km</td>
<td>1503 km</td>
</tr>
<tr>
<td>Distance - Tractor</td>
<td>520 km</td>
<td>221 km</td>
<td>250 km</td>
</tr>
<tr>
<td><strong>Total Distance</strong></td>
<td>2014 km</td>
<td>1597 km</td>
<td>1753 km</td>
</tr>
<tr>
<td>Duration - Forklift</td>
<td>498 h</td>
<td>458 h</td>
<td>501 h</td>
</tr>
<tr>
<td>Duration - Tractor</td>
<td>65 h</td>
<td>28 h</td>
<td>31 h</td>
</tr>
<tr>
<td><strong>Total Strategy Duration</strong></td>
<td>563 h</td>
<td>486 h</td>
<td>532 h</td>
</tr>
<tr>
<td>Total Man-hours</td>
<td>804 h</td>
<td>694 h</td>
<td>760 h</td>
</tr>
<tr>
<td>Cost - Forklift</td>
<td>1618 €</td>
<td>1489 €</td>
<td>1627 €</td>
</tr>
<tr>
<td>Cost - Tractor</td>
<td>589 €</td>
<td>250 €</td>
<td>325 €</td>
</tr>
<tr>
<td>Cost - External warehouse</td>
<td>6835 €</td>
<td>5384 €</td>
<td>-</td>
</tr>
<tr>
<td>Cost - Labor</td>
<td>4424 €</td>
<td>3819 €</td>
<td>4181 €</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>13465 €</td>
<td>10941 €</td>
<td>6134 €</td>
</tr>
</tbody>
</table>

Figure 5 shows the percentage distribution of each cost parcel for each of the scenarios under study. The analysis of this figure facilitates the perception of the weight of each parcel in the total cost of the strategy.

In the Current Scenario, the number of hours of operation were provided by the company, while the other results were calculated from these values.

![Cost Distribution](image)
Figure 6 - Comparison of the layouts obtained in each of the Scenarios.
The Current Scenario has the highest travelled distance, hence the duration of the strategy is also the longest of the three situations. In terms of costs, this scenario has the highest cost allocated to the renting of external storage space, which accounts for 51% of the total costs for this scenario.

The total cost of Scenario 1 is 19% inferior than the cost of Sugal's current strategy. The reduction is mainly due to the optimized allocation of the pallets, which allowed the reduction of the travelled distance and the optimization of the storage capacity, since it would be necessary to rent less external storage space. Once more, in this scenario the rental of storage space represents the biggest share of the costs, representing 49% of the total cost, followed by the cost of labor, which represents 35% of total cost.

Scenario 2 presents a significant cost reduction when compared to the previous two. The total costs of this scenario would be 6,133.80€. This amount is 67% lower than the total cost of the Current Scenario and 44% lower than the total costs for Scenario 1.

The improvement of the result was due not only to the optimization of the allocation of SKUs within the warehouses but also due to the removal of the restriction that allocated products destined to different markets to different warehouses. In this scenario it was not needed to rent external storage space. On the other hand, since all the pallets were stored at the premises of Sugal, there was an increase in the travelled distance and, consecutively, the duration of the strategy and the number of hours of labor required also increased.

For all three scenarios, five full-time workers would be required to execute the strategy.

Comparing all parameters, quantity, layout and costs, Scenario 2 is the preferable solution for Sugal, having a higher occupancy rate, a layout that can accommodate possible stock fluctuations and a lower operational costs result. One disadvantage of Scenario 2, important to consider, is that products destined for the same market are not necessarily in the same warehouse, feature present in the Current Scenario and Scenario 1. This detail will bring some additional difficulty to the operators when it is necessary to perform the order picking. However, this difficulty would be easily eliminated by installing a locating system that would allow the location of each of the pallets to be queried.

6. Conclusions

In this paper, the warehousing strategy of a tomato derivatives is analyzed in order to find improvement opportunities that contest the identified problems.

An optimization model which uses penalties to prevent the decentralization of products within the warehouses with the main goal of determining the optimal allocation of products to locations within the warehouses was proposed. To present the results in an easy and understandable way, a dashboard was designed for results analysis.

The model was applied to different scenarios, and by partially using the Warehouse 1 for storing finished product and removing the constraint separating products destined to different markets in different warehouses, a total cost reduction of 67% was achieved.

The development of the present work made it possible to identify some future work developments, such as: integrating the optimization model with Sugal's existing labelling process, installing a pallet tracking system, applying the turnover analysis into optimizing production planning and to apply the model in different time scales.

To the best of our knowledge the study performed by Carvalho (2018) is the only available in the literature which presents an allocation model concerning multiple internal warehouses and rented storage space. Since the optimization model is adaptable to any layout and to any combination of internal and external warehouses, it can be used in different industries and combined with different warehousing strategies.

As a final note, we expect that the present paper provides Sugal's management team and the academic community with a decision support tool to aid in a more efficient decision-making process.

7. References


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