Layout Optimization in a Perishable Products’ Warehouse

The Jerónimo Martins Case Study

Miguel Horta

Department of Engineering and Management, Instituto Superior Técnico

Abstract

The increasing competitiveness and instability in the global market pressures companies to implement strategies aimed to increase its efficiency, either by an increase in the service level provided to the customer or by a cost reduction. Jerónimo Martins, the largest food distribution group in Portugal, aims to maximize its operational efficiency. Thus, Jerónimo Martins wants to know what would be the most suitable layout for a warehouse that operates in a just-in-time environment. The problem studied in this paper is related to a perishable products’ warehouse (fruits and vegetables), located in the Azambuja’s distribution center. Based on the conducted literature review, an integer programming model is proposed to solve the problem. The model aims to minimize the distance travelled in the warehouse and to take into account the orders’ shipping priorities. Different scenarios are analyzed and compared, namely the scenario related to the warehouse current layout and the best-case scenario. The results showed that the implementation of the layout proposed by the model may lead to a reduction of the distance travelled in the warehouse by 23%, which enables a resource and cost reduction.

Keywords: warehouse management, layout, just-in-time, logistics operations, optimization

1. Introduction

The current pressure to increase the service level and reduce costs along with the increasing complexity of supply chains create considerable logistics challenges to retailers (Fernie & Sparks, 2004). Warehouses are an essential component of any supply chain. Their major roles are: (1) buffering the material flow along the supply chain; (2) consolidation of products from multiple suppliers; (3) performing value added activities such as kitting, labeling, and product customization (Gu et al., 2007). With the increasing focus on the supply chain performance optimization by managers, warehouses are recognized as an area where significant performance improvements can be achieved (Won & Olafsson, 2005). Richards (2011) stated that the choice of a suitable warehouse layout should increase the throughput, reduce costs, improve the service provided to the customers and provide better working conditions. There are different studies in the literature that addressed the warehouse layout problem. However, these studies generally focus on conventional warehouses, e.g. having the storage function. The literature that addresses methods for managing warehouses operating in just-in-time (JIT) is scarce. Given the lack of studies in the literature and the similarity in the warehouses operations, some methodologies used to design layouts for a cross docking center will be described in this paper.
Vis and Roodbergen (2011) proposed three different concepts and procedures that can be used to design a layout in a cross-docking environment: fixed layout, category-based layout and flexible layout. The first methodology aims to design a warehouse layout that is fixed for considerable time period. A fixed layout is characterized by a fixed number of aisles or by a fixed aisle length, with the non-fixed variable derived from the warehouse capacity requirements for the considered time period. The category-based layout seeks to incorporate more flexibility than the previous procedure. In this methodology, daily activity can be categorized based on the information available at the start of the day. For each category a fixed layout can be determined using the previous methodology. Finally, a flexible layout is defined as a layout that changes every day according to the expected daily activity. The three methods and concepts described above focus on the layout design, in particular on the knowledge of the number of aisles and its length. However, it was considered that the layout of the warehouse studied in this paper could also be modified by changing the location of the unit loads (orders) in the warehouse, since this allocation is long-term decision in that particular warehouse. Additionally, it turns out that a new allocation of the orders to the warehouse locations leads to a change on the aisles size and on the layout structure, as there is no physical layout structure in the warehouse. Vis and Roodbergen (2008) approached this problem for a cross-docking center with the objective to minimize the distance travelled in the warehouse. The problem is modeled as a minimum cost flow problem and it is assumed the reception and the shipping docks locations are known, for a particular order, beforehand. Sandal (2005) also addresses the same problem but focusing exclusively in the space next to the shipping docks. In this study, the author demonstrates the importance of the shipping priority by allocating orders to areas next to shipping docks according with that criterion. More generalist methods, such as the method presented by Frazelle (2002), approached the problem of locating high adjacency requirements’ departments/ functions at nearby locations in the warehouse.

The main goal of this paper is to propose a new warehouse layout for a food retail company that meets the operational efficiency improvement strategy outlined by the company. The methodology used to propose a new layout for a Jerónimo Martins (JM) warehouse will focus on changing the current location of the unit loads (orders) in the warehouse. In order to solve this problem an integer programming model was developed. This model incorporates two criteria that were identified in the literature review: the distance travelled in the warehouse (Vis & Roodbergen, 2008) and the orders shipping priorities (Sandal, 2005).

2. Case Study

2.1 Brief description of the warehouse operation

As mentioned previously, this paper addresses the warehouse layout of a perishable products’ (fruits and vegetables) warehouse. This warehouse operates in a JIT environment. Unlike conventional warehouses, in warehouses that operate in JIT the products remain, in general, a short time in the warehouse. Therefore, in this type of warehouses the products are not stored. Besides that, the main operational difference of a warehouse that operates in JIT when compared to a typical warehouse involves the picking operation.

The picking operation in a conventional warehouse consists in collecting different products in the warehouse, according to one (or more) order(s), and place them on a pallet that will be shipped to the customer. In a warehouse that operates in JIT, the warehouse employee starts the picking operation with a full pallet of a certain product and travels through the warehouse in order to distribute the pallet content by the warehouse locations of the clients (in this case stores/supermarkets) that ordered that product. So, it can be concluded that this difference in the picking operation will influence the warehouse layout, since its area has to be divided into dedicated spaces for each one of the stores that are supplied by the warehouse.

2.2 Warehouse layout

The current layout of the perishable products’ warehouse studied in this paper is exhibited in figure 1. On the upper and lower side of the figure are represented the docks used to receive and to ship the products (quadrangular numbered spaces with green color).

While the receiving operation is carried out only at the docks on the lower side of the figure, the shipping operation can be performed on both sides with docks of the warehouse.
The colored spaces represented in figure 1 correspond to warehouse locations dedicated to each one of the stores that JM has across Portugal. On the other hand, the different colors assigned to each store are related with the different shipping time windows.

In figure 1 is also indicated the daily space capacity of each warehouse location. It can be noted that the locations placed at the center of the warehouse have a space capacity of 18 pallets, while the locations positioned near the docks have a smaller space capacity (11 and 12 pallets). The space capacities are defined in a daily basis, as the maximum duration of the products in the warehouse is equal to 24h.

3. Mathematical Model

The mathematical model that was developed aims to determine the allocation of the stores to the available warehouse locations in order to minimize the distance travelled in the warehouse and to take into account the orders shipping priorities.

The total distance travelled in the warehouse is divided into two parts: the distance travelled in the picking operation and the distance travelled during the shipping operation. The picking operation is also divided into picking of carton boxes and picking of plastic boxes, since it is considered that each warehouse location is divided into two spaces, one space for products in carton boxes and another space for products in plastic boxes. This division of the warehouse locations by box type aims to improve the efficiency on the construction of the pallets by the employees, as the plastic boxes have a standard size and are easily stackable.

The model considers the space capacity of each warehouse location and space requirements of each store. The model also ensures that the shipping priorities of the stores are respected as the highest priority stores can only be allocated to the warehouse locations situated near the shipping docks.

The problem can be summarized as follows:

Given:
- A set of available locations in the warehouse and a set of stores to allocate to those same locations;
- The distance from the reception point to each warehouse location;
- The distance from each warehouse location to two shipping points;
- The space capacity, expressed in logistic units (pallets for example), of each warehouse location for a given time period;
- The space requirements, expressed in logistics units, for each store for a given time period;
- Number of pickings of each store for a given time period;
- Number of pallets shipped for each store in a given time period;
- The average number of pickings per pallet for a given time period;

Figure 1: Warehouse current layout.
Determine:

- The assignment of the stores within the warehouse, defining the allocation of the stores to the available warehouse locations;

So as to minimize the total distance travelled in the warehouse, taking into account the stores shipping priorities.

### 3.1 Assumptions

The model considers the following assumptions:

- It is assumed that the warehouse is rectangular and has reception and shipping docks on both sides of the warehouse. It is also assumed that the reception operation is carried out only on one side of the warehouse, while the shipping operation can be performed at the docks located on both sides of the warehouse;

- It is defined a reception point from where the picking operations starts and two shipping points, located on opposite sides of the warehouse, where the orders are shipped. The definition of reception and shipping midpoints aims to reduce the model complexity that would result from the computation of the distance from each warehouse dock to each warehouse location. In addition, the computation of these distances would require knowing the assignment of the trucks to the shipping docks. For cross docking centers, this problem is addressed in the literature by various authors (Bartholdi & Gue, 2000; Miao et al., 2009; Tsui & Chang, 1992);

- It is assumed that each warehouse location is divided into two areas, one area for products in carton boxes and another area for products in plastic boxes;

- It is assumed that the warehouse locations positioned next to the shipping docks have less space capacity than the remaining warehouse locations;

- As mentioned before, in the picking operation an employee can visit several warehouse locations within the same picking route. However, the route travelled by each employee is subject to a large variability as it depends on the products that are ordered by the stores. Knowing that was unreasonable to predict the different routes that could be travelled by the employees during the picking operation, it was decided to group the warehouse locations into clusters. Therefore, it was assumed that an employee, in a single picking route, visits a group of stores that are situated in contiguous warehouse locations. The warehouse locations were clustered based on the average number of pickings per pallet.

### 3.2 Model Formulation

The model formulation uses the following indexes, sets, parameters and variables.

#### Indexes and Sets

- $a$ - index that represents an available area in the warehouse, $a \in A$
- $l$ - index that represents a store to allocate to one or more warehouse areas, $l \in L$
- $P_{l,a}$ - set of ordered pairs of areas and stores for which the allocation is possible, $(l, a) \in P_{l,a}$
- $cl$ - index that represents a cluster of warehouse areas, $cl \in CL$

#### Parameters

- $cap_a$ - space capacity (in number of pallets) of the warehouse area $a$ for given time period
- $dispatuat_{l,a}$ - indicates the current disposition of the stores in the warehouse, i.e., the allocation of the store $l$ to the warehouse area(s) $a$
- $dispcluster_{cl,a}$ - indicates the warehouse areas $a$ that comprise each cluster $cl$
- $dist2a$ - distance from the warehouse area $a$ to the shipping point
- $distclcc_{cl}$ - distance related to the picking operation in the cluster of areas $cl$ (for picking of carton boxes)
- $distclcp_{cl}$ - distance related to the picking operation in the cluster of areas $cl$ (for picking of plastic boxes)
- $exp_l$ - number of pallets shipped to the store $l$ within a given time period
- $necess_{l}$ - average space requirements (in number of pallets) of the store $l$ for a given time period
- $necessarea_l$ - average space requirement (in number of warehouse areas) of the store $l$ for a given time period

Equation (1) illustrates the computation of this parameter.
\(\text{necessarea}_i = \left[ \frac{\text{necess}_i}{\text{cap}_a} \right], \quad \forall (l,a) \in P_{l,a}\)  

\(\text{perccp}\) - percentage of plastic boxes picked compared to the total number of boxes picked for a given time period 

\(\text{possiballoc}_{l,a}\) - indicates the possible warehouse areas where a store \(l\) can be allocated according to its shipping priority. This parameter equals 1 if the store \(l\) can be allocated to the area \(a\) (otherwise equals 0) 

\(\text{stops}_l\) - number of pickings of the store \(l\) for a given time period 

**Variables**

\(x_{l,a}\) - binary variable that equals 1 if the store \(l\) is allocated to the warehouse area \(a\) (otherwise equals 0) 

\(\text{stopsmax}_a\) - non-negative integer variable that indicates the number of visits to the cluster \(cl\)

**Mathematical Formulation**

Given the indexes, sets, parameters and the variables presented, the generic model developed to be applied to the case study is formulated as follows:

\[
\begin{align*}
\text{Min} & \quad \sum_{c\in C} \left[ \text{dist}_{clc} \times \text{stopmax}_c \times (1 - \text{perccp}) \\
& + \text{dist}_{clp} \times \text{stopmax}_c \times \text{perccp} \\
& + \sum_{a \in A} \sum_{l \in L} \text{dist}_{a} \times x_{l,a} \times \text{exp}_{l} \right] \\
\sum_{l \in L} x_{l,a} & \leq 1, \quad \forall a \in A \\
\sum_{a \in A} x_{l,a} & \leq \text{necessarea}_l, \quad \forall l \in L \\
x_{l,a} & \leq \text{possiballoc}_{l,a}, \quad \forall l \in L, \forall a \in A \\
\sum_{a \in A} x_{l,a} \times \text{cap}_a & \geq \text{necess}_l, \quad \forall l \in L \\
x_{l,a} & \leq x_{l,a+1} + x_{l,a-1}, \quad \forall l: \text{necessarea}_l \geq 2, \forall a \in A \\
\text{stopsmax}_c & \geq \text{stop}_{l,a} \times x_{l,a}, \quad \forall c,l,a: \text{dispcluster}_{c,l,a} = 1, \forall l \in L \\
x_{l,a} & \in (0,1) \\
\text{stopmax}_c & \in \mathbb{Z}^+ 
\end{align*}
\]

The objective function of the model aims to minimize the total distance travelled in the warehouse (2). The first term is relative to the distance travelled during the picking of products in carton boxes, while the second term correspond to distance travelled during the picking of products in plastic boxes. The third and last term is relative to the distance travelled in the warehouse during the shipping operation.

Constraint (3) guarantees that each warehouse area cannot be allocated to more than one store. Constraint (4) limits the number of possible warehouse areas that can be assigned to one store. Thus, this constraint ensures that the number of warehouse areas assigned to one store will be less or equal than the average space requirements (in number of warehouse areas) of that store.

Constraint (5) limits the possible warehouse areas that can be assigned to one store according to its shipping priority. This constraint ensures that stores shipping priorities are satisfied by restricting the location of high shipping priority stores to the warehouse areas located next to the shipping docks.

Constraint (6) guarantees that each store is located in one or more warehouse area(s), which have a total space capacity greater or equal than the store space requirements.

Constraint (7) ensures that if a store needs to be allocated at least to two warehouse areas that store will be assigned to contiguous warehouse locations. By assigning one store to contiguous warehouse areas it will avoid errors in the shipping operation (such as the loading of a wrong pallet in one truck), since all the pallets of one store will be located side-by-side. Moreover, the pallet construction is also facilitated, as it is possible to transfer boxes from one pallet to another pallet of the same store in order to properly construct the pallets and to optimize the truckload capacity. It should be noted that it is assumed that the set of warehouse areas is organized according to contiguity warehouse criteria.

Constraint (8) ensures that the number of visits to a cluster will be greater or equal than the
largest number of pickings of the stores that were assigned to that cluster. In order to guarantee that the number of visits to a cluster \((\text{stopsmax}_c)\) equals the number of pickings of the most visited store of the cluster, this variable is minimized in the objective function, establishing a Min Max formulation (Shimizu et al., 1997). Finally, the constraints (9) and (10) define the variables domain.

4. Results

This section covers the application of the model to the case study described in section 2. The model was implemented with GAMS (General Algebraic Modeling System) language, 24.1.3 version, and was run by the algorithm CPLEX, 12.5 version, in a Intel Core Duo 2,4GHz machine with 4 GB RAM. In section 6.1 three different scenarios are presented and analysed. The scenarios are compared based on the monthly distance travelled in the warehouse and on the warehouse occupancy rate, defined as the ratio between the number of occupied warehouse locations and the total number of locations available in the warehouse. In section 6.2 a sensitivity analysis is performed in order to evaluate the impact of changing the parameters of the model that may be subject to higher uncertainty.

4.1 Scenarios

Three different scenarios are studied in this paper: a current scenario, a best-case scenario and a future scenario (in 3 years). It was decided to analyse a future scenario since JM plan to maintain the fruits and vegetables products in the same warehouse for a minimum time period of 3 years.

Current Scenario

The first scenario aims to evaluate the layout that is currently implemented in the warehouse. In this scenario the stores locations were fixed according to their actual allocation in the warehouse. The total distance travelled in the warehouse was equal to 9428 kilometers per month (figure 2). In this scenario, the distance travelled during the picking operation accounts to 79,6% of the total distance travelled in the warehouse. The warehouse occupancy rate was equal to 83,7%.

Best-case Scenario

This scenario corresponds to the application of the model to the case study with the assumptions made for each parameter and no additional restrictions. The application of the model in this scenario led to a total distance of 7266 kilometers per month (see figure 3). In this case, the picking operations represents 77,9% of the total distance travelled in the warehouse. The warehouse occupancy rate remained equal to 83,7%.

By comparing the current scenario with the best-case scenario it can be concluded that the layout proposed in the best-case scenario can lead to a reduction of the total distance travelled in the warehouse by 23% (see figure 4).
In table 1 the potential savings of the best-case scenario compared to the current scenario are presented.

Table 1: Savings of the best-case scenario in relation to the current scenario.

<table>
<thead>
<tr>
<th>Savings</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance reduction (km/month)</td>
<td>2162</td>
</tr>
<tr>
<td>Distance reduction (km/day)</td>
<td>83</td>
</tr>
<tr>
<td>Reduction in daily hours of operation</td>
<td>20,8</td>
</tr>
<tr>
<td>Potential reduction of employees</td>
<td>2</td>
</tr>
</tbody>
</table>

In table 1 it is possible to see that the allocation of the stores in this best-case scenario enables a reduction of the monthly distance travelled in the warehouse by 2162 kilometers. Considering that the warehouse operates 26 day per month, a reduction of 83 kilometers per day can be achieved. In turn, knowing that the forklifts used in the warehouse move at a maximum speed of 4 kilometers per hour, it can be concluded that it is possible to reduce 20,8 hours of operation per day. This reduction leads to the conclusion that it is possible maintain the same warehouse activity level with less 2 employees (assuming that each employee works in average 7,5 hours per day). However, JM can also be more efficient by maintaining the same number of employees for an increase in the warehouse activity level.

**Future scenario**

This scenario corresponds to a future scenario (in 3 years) where is considered a growth in the number of picked boxes. Based on historical data, it was agreed with JM that annual growth rate studied in this scenario was equal to 6%. This growth rate was considered to be equal to all stores and results from three factors. The first factor that contributes to this growth is the growth trend in the market share of JM supermarkets. The second factor is related to the reduction of the average price of the goods that are sold in the Portuguese supermarkets. This price reduction has the objective to stimulate the consumption and is also a result from the growing competition in the market. The last factor is related with the repackaging strategy adopted by JM suppliers. Nowadays consumers visit supermarkets more frequently and buy less at each visit. Therefore the suppliers choose to reduce the product quantity and, consequently, the package in order to stimulate the consumption. All these factors contribute towards an increase in the number of pickings and in the number of pallets shipped by the warehouse.

The total distance travelled in the warehouse in this scenario was equal 8057 kilometers per month (see figure 5). Nearly 75% of the total distance is travelled in the picking operation.

In this scenario it was verified an overall change in the stores’ assignment in the warehouse in comparison to the best-case scenario. This change is justified by the need of one additional warehouse location by 8 stores. In turn, the need for one additional space by 8 stores results from the growth in the number of pallets shipped by the warehouse. As mentioned previously, the model ensures that if a store needs more than one warehouse location that store will be assigned to contiguous warehouse locations. This factor contributed to change the stores disposition in the warehouse, since the locations to be assigned to these 8 stores were already occupied in the best-case scenario.

In this scenario the warehouse occupancy rate was equal to 86,9%, which represents an increase compared with the value obtained for this indicator in the previous two scenarios (83,7%).

By comparing the best-case scenario with this scenario it can be concluded that the monthly distance travelled in the warehouse increased by 10,9% (figure 6).
Scenarios Comparison

In figure 7 it is possible to see the comparison of the monthly distance travelled in the warehouse for the layouts obtained in each scenario. In order to make a fair comparison the layout obtained in the future scenario was run with current data. From the analysis of the figure it can be conclude that the layout obtained in the best-case scenario allows to achieve a greater gain of immediate efficiency (reduction of the total distance in 23%). However, this layout is not projected for the future, as it is not considered an increase in the number of pickings. On the other hand, currently the layout obtained in the future scenario does not lead to such a significant gain in efficiency (reduction of the total distance in 16,5%) but it is designed considering a future growth.

It should be noted that the implementation of the layout obtained in the best-case scenario might imply future costs, arising from possible changes in the location of the stores in the warehouse in order to adapt the layout to an expected increase in the warehouse activity level. These changes involve modifications in the warehouse management system used by the company and a new adaptation of the employees to a different work environment.

In table 2 are represented the potential savings of the layouts obtained in the best-case scenario and in the future scenario compared to the current scenario. As was mentioned above, the reduction of the monthly distance travelled in the warehouse is greater for the layout of best-case scenario. For each one of the layouts a reduction in daily hours of operation was obtained (following the same reasoning that was already presented in this paper). This hourly reduction shows that implementation of both layouts allows that the current warehouse activity can be maintained with less 2 employees.

4.2 Sensitivity Analysis

In order to assess the robustness of the results a sensitivity analysis was performed. To perform this analysis the best-case scenario was used as a basis of comparison.

The parameter analysed was the number of pickings per pallet given the high standard deviation obtained for this parameter and the impact that this parameter has on the model. As mentioned previously, this parameter determines the size of the clusters and, therefore, the locations that constitute each cluster and distance travelled during the picking operation. In this section the impact on the model resulting from a positive and a negative variation in the number of pickings per pallet by an amount equal to the standard deviation obtained for this parameter, is analysed.

The results of this analysis are shown in figure 8. It can be conclude that a positive and a negative variation in the number of pickings per pallet by approximately 31% results in a reduction of the distance travelled in the warehouse by 22% and
in an increase by 20.6%, respectively. An increase in the average number of pickings per pallet leads that, with the same pallet of a given product, more stores can be visited in the same picking route and that an employee needs to go fewer times to the receiving docks to collect new pallets. Therefore, it is easily concluded that an increase in the number of pickings per pallet results in a decrease in the distance travelled in the warehouse (and vice-versa).

![Figure 8: Number of picking per pallet analysis.](image)

The variation in the number of pickings per pallet caused a change in the allocation of the stores in the warehouse that was obtained in the best-case scenario. Although there has been a change in the disposition of the stores, it turns out that the layout that was proposed in the best-case scenario continues to lead to a reduction in the distance travelled in the warehouse with a variation of the number of pickings per pallet (see table 3). For any case analysed (number of pickings per pallet equal to 9 and 17) the solution obtained in the best-case scenario leads to an efficiency gain in terms of distance travelled in the warehouse. This efficiency gain is equal to 18.1% if the number of pickings per pallet is equal to 9 and equals 19.4% if the parameter analysed equals 17.

<table>
<thead>
<tr>
<th>Number of pickings per pallet</th>
<th>9</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total distance - current layout (km/month)</td>
<td>11602</td>
<td>8054</td>
</tr>
<tr>
<td>Total distance - layout proposed in the best-case scenario (km/month)</td>
<td>9499</td>
<td>6491</td>
</tr>
</tbody>
</table>

5. Conclusions

The problem studied in this paper is related to the layout of a perishable products’ warehouse that operates in a JIT environment. The layout of the warehouse studied in this paper consists in an open area that is divided in several locations allocated to the clients (stores in this case), where the products are placed according to the daily orders. Based on the conducted literature review, an integer programming model was proposed to solve the problem. The model aims to determine the allocation of the stores to the available warehouse locations in order to minimize the distance travelled in the warehouse (Vis & Roodbergen, 2008) and to take into account the orders shipping priorities (Sandal, 2005).

The results show that, according to the information used, the distance travelled in the warehouse can be reduced. It was concluded that with the layout obtained in the best-case scenario the monthly distance travelled in the warehouse can be reduced by 23%. This reduction allows that the same warehouse activity level can be maintained with less two employees. A future scenario (in 3 years) was also studied in this paper. In this scenario it was assumed an annual growth rate of the number of boxes picked in the warehouse in 6%. This growth rate led to an increase in the warehouse occupancy rate and to a change in the disposition of the stores in the warehouse, which resulted from an additional need of one warehouse location by some stores. Despite the increase in the distance travelled in the warehouse in relation to the best-case scenario, the distance obtained in this future scenario was still 14.6% less than the currently distance travelled in the warehouse.

In the sensitivity analysis the parameter that has more impact in the model and that is more uncertain was analysed: the number of pickings per pallet. The variation in the number of pickings per pallet caused a change in the distance travelled in the warehouse and in the disposition of the stores in relation to the best-case scenario. However, it is important to state that the disposition of stores in the warehouse obtained in the best-case scenario continues to lead to reductions in the distance travelled in the warehouse (between 18% and 19%) with a variation of the number of pickings per pallet.

Some future studies can also be performed regarding the problem addressed in this paper. First it would be important to analyse weather a layout change may cause delays in the shipping
operation and a consequent reduction of the service level provided to the stores. It would be also interesting to perform a simulation, before the implementation of the new layout, of the aisles congestion per time period. Additionally, there is potential to incorporate in the model a routing problem in order to consider the different routes of the employees during the picking operation. In this paper the warehouse locations were grouped into clusters according to the average number of pickings per pallet. However, since the distance between contiguous warehouse areas is small and since most of products are ordered by most of the stores, the considered assumption may have a small impact in the monthly distance travelled in the warehouse. Finally, as an additional note, it is important to perform an effective allocation of the trucks to the warehouse docks, taking into account the layout that will be implemented. Thus, it is expected that the allocation of the trucks to the docks be performed in order to minimize the distance travelled in the warehouse to transport the pallets from its warehouse locations to the truck that will transport the goods to the stores.

6. References


