Designing and planning José de Mello Saúde’s supply chain in Lisbon area

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Abstract - For several years, analyzing logistics of the companies was not considered relevant. However, due to an increasing competitiveness and to the globalization phenomenon, this paradigm is changing. This paper is focused on the logistics of the main group of private health care - José Mello Saúde –, who is the owner of CUF hospital and clinics. Nowadays, each hospital has a central warehouse, where all the products are stocked. The major goal of this paper is thus to study the financial viability of a centralized stock of all CUF units, from Lisbon district, in one central warehouse. With this project, José de Mello Saúde can benefit from economies of scale and optimize financial resources. This paper presents a generic mixed integer mathematical programming model that can be applied to other realities or companies. This methodology informs decisions on where to locate a central warehouse, on which area is required to maintain stocked products and to structure of costs associated with the central warehouse, and this while minimizing the total costs. The general characteristics of the model allows its application under different scenarios to explore the impact of changes in José de Mello Saúde’s logistics structure. Particularly, the proposed model is used to evaluate different centralization’ cost structures, namely: 1 or 2 distribution car; changes in warehouse income; construction of new hospitals; and accounting for project’ benefits. Also, the developed model is also used to test the impact of uncertainty across parameters using as a basis sensitivity analysis. Based on this analysis, it was concluded that results do not change significantly. Based on obtained results, it is possible to conclude that centralization of inventory has financial viability and represents a saving of resources for José de Mello Saúde.

Keywords - logistics operations; central warehouse; optimization; localization; logistical costs; mathematical programming.

I. INTRODUCTION

Portugal has been witnessing an investment reduction in the public health sector. On the other hand, the private health sector has experienced a remarkable growth. In 2014, the president of the association private hospitals said that the private health sector grew by 15/20%. This sector represented 1.5 billion euros in 2014, and, since then, there is a growing trend.

The present master paper was developed in a group of the private health sector, José de Mello Saúde, JMS. It is the principal market player and is mainly implemented in Lisbon region, with four hospital and six clinics. In line with market growth, JMS plans to invest 200 millions of euros, by 2018, in Lisbon region.

Actually, each hospital has one central warehouse, where the consumed products are stocked. The existed warehouses are small when compared with hospital activity and necessities. As such, there are several inefficiencies, for example, in warehouse’ layout. The inefficiencies compromise several activities related to logistics, for example, products picking. Considering that the group’ expansion, JMS intends to evaluate the financial viability of centralising stocked products in one central warehouse for Lisbon region.

This goal translates into several objectives:

- Identification and description of JMS’ logistical problems;
- Identification and description of possible central warehouse’ location;
- Choose the best warehouse location that minimises logistic cost;
- Reduction demand costs;
- Release space in hospital units;
• Optimisation of financial resources.

Accordingly, it was necessary to evaluate what has been done in this area. To do this, a review of the literature was performed based on several online search engines, for example, Science Direct.

II. STATE OF THE ART

For several years, companies’ logistics was not considered relevant for their results (Barbosa-Póvoa, 2014). On the other hand, with companies’ globalisation and competitive environment change their paradigm.

A supply chain, SC, is defined as a set of an interconnected process, such as production, assembly, storage and product distribution. In this activity, the major goal is to satisfy clients’ needs, with minimum cost as possible. SCs have different types of flows (Salema, et al., 2010):

• Tradition: between raw materials and final client;
• Inverse cycle: between final consumer and client;
• Closed loop: considered the above mention streams.

This paper focuses on the products distribution between the central warehouse and JMS’ units. Therefore, it is a traditional flow.

SC management is defined by the processes of the plan, implement, supply chain control, as efficiently and effectively way. This activity is divided in (Melo, et al. 2009):

• Strategic level: long-term focus with implication for several years;
• Tactical level: medium-term focus. It is included decision with less space of time, and capital invested, when compared with strategic-level;
• Operational level: management of quotidian logistics.

Therefore, one can conclude that paper is about strategic level.

Several authors defend that mathematical programming is based on information technologies and they are the future of plan SCs (Min and Zhou, 2002) and Barbosa-Póvoa (2014)). They defend that, it is possible to module different events and approximate reality to mathematical simulation (Wang, 2005).

For several years, health sector was not sensible to resource optimisation. However, in the last years, several studies arose in this area. Aronsson and Abrahamsson, 2011, estimates that hospital’ logistics represent 30 – 40 %, of the total of hospital expenses. The previous values may be reduced by 50%, using logistics optimisation.

There is some literature on the application of mathematical programming for the health sector. These models have been applied essentially to long-term plan problems. In the health sector, there are some studies where is used mathematical programming to promote all components of health equity. Mestre, Oliveira and Barbosa-Póvoa, 2012, developed a mathematical model to organise hospital services in order to maximise geographical equity of health care access. It responds to several questions, such as: where to build the hospital; best hospital network; what is the cost that maximises the objectives; which area should be covered by the hospital. It was applied to Portuguese National Health Service, in the south region. As in the previous authors, Cardoso, et al., (2015) and Cardoso, et al., (2016), developed other mathematical programs to promote health equity. Lavieri and Puterman, 2009, developed a mathematical model to predict how many nurses will be necessary to hire or form, considering market needs, during 20 years

This study fills the gap of the literature devoted to the development of mathematical programming to support health’ logistics planning. Particularly, the application of this methodologies is on health’ logistics optimisation.

III. METHODOLOGY

a. Description

The constructed model is characterised by:

• Multiple units: all the JMS’ hospital in Lisbon region were considered;
• Multiple products: clinical material, administrative, hospital’ clothes, hospitality material were considered.
• Suppliers: it is considered that suppliers just delivery the products in central warehouse and JMS will be responsible for their distribution;
• Different human resources: faithful warehouses, buyers, carriers.

The developed methodology considered that demand products per JMS’s units will grow according to their expansion. The hospital’ demand was considered for 30 days of activity, as such the central warehouse has been designed to demand for the same period. This stock level is similar with JMS’ average stock, because it is approximately 24 days of demand.

The figure 1 resume the model’s objectives.
Human resources

\( fa \) - Number of faithful warehouse, per square meter;
\( t_{ij} \) - Number of carriers, for year \( t' \), between central warehouse and JMS units;
\( c_{ij} \) - Number of product buyers, for year \( t' \);
\( rem_{ij} \) - Annual income, in euros, per year \( t' \), of faithful warehouse
\( rem_{it} \) - Annual income, in euros, per year \( t' \), of buyers;

Dismissal

\( cdesp_{it} \) - Number of buyers’ fire;
\( rmdeesp_{it} \) - Monthly income, in euros, of buyers;
\( rmdeesp_{it} \) - Monthly income, in euros, of faithful warehouse;
\( nae \) - Average years, that each employee works to company;
\( lv \) - Labor law;
\( nf'd \) - Number of faithful warehouse, before centralization;

Inventory/product demand

\( Iaux_{ij} \) - Average inventory, in euros, per hospital’ warehouse, \( j \);
\( p_{m,j,t,t} \) - Demand of product, \( m \), hospital/clinic, \( j \), month, \( t \), per year \( t' \);
\( nc_{it} \) - Number of days that hospital’ warehouse, supports the hospital supply without suppliers, per year \( t' \);
\( ss_{it} \) - Safety stock, in number of days, per year \( t' \);
\( ap_{j,t,t} \) - Tax of demand increase, %, for each hospital/clinic, \( j \) and year, \( t' \);
\( pau_{m,j,t} \) - Demand of product, \( m \), hospital/clinic, \( j \), month, \( t \), during the first year;
\( IUMCaux_{m,j,t,t} \) - Safety stock, in moved units, of product, \( m \), warehouse, \( i \), month, \( t \), during the first year;
\( ai_{it} \) - Grow, in percentage, of safety stock, for year, \( t' \);

Savages/taxes

\( rp_{it} \) - Reduction, in percentage per year, \( t' \), of products’ price, considering just one deliver point.
\( cte_{it} \) - Total cost, in euros, per year \( t' \), of purchase of products under study;
\( WACC_{it} \) - Weight average cost of capital, in percentage, and per year \( t' \);
rah_{j,t}, \text{ Value, in euros, that each hospital manager, } j, \text{ will pay for central warehouse space;}
\textit{t}_{i,t}, \text{ Inflation rate, } \% \text{, per year } t';
BigM, \text{ Constant define by user, for restrict model variables.}

**Continuous variables**

\textit{area}_{aux,i,t,t'} - Area, in square meters, necessary for central warehouse, in location, i, month, t, and year, t';
\textit{area}_{i} - Warehouse’ area, in meters per square, in location, i;
\textit{trans}_{i} - Cost, in euros, of products transport, between central warehouse and hospital/clinics, in year t';
\textit{Desp}_{i} - Cost of fire human resources, in year, t';
\textit{ctrh}_{i} - Cost per year, t', in euros, with human resources;
\textit{ctcar}_{i} - cost, in euros, during year, the the t', with car(s);
\textit{ID}_{i,j,t} - Average stock, in euros, with decentralization, in unit, j and year, t';
\textit{IDseg}_{i,j,t} - Average safety stock, in euros, per hospital unit, j, and year, t';
\textit{ICseg}_{i,j,t} - Average safety stock, in euros, with centralization, warehouse, i, year, t';
\textit{x}_{m,i,j,t,t'} - flow of products, m, between central warehouse, i and hospital unit, j, in month, t, year, t';
\textit{l}_{m,i,t,t'} - Safety stock, in moved units, of product, m, warehouse, i, month, t and year, t';
\textit{F}_{m,i,t,t'} - Demand of products, m, in warehouse, i, month, t and year, t'.

**Binary variables**

\textit{a}_{i} - Defines open/no open of warehouse in location, i. It is equal to 1 when warehouse open and 0 otherwise.

**c. Equations**

The developed methodology considers benefits and costs related with centralization.

\textit{Max} \ z = b - c \ [1]

The major goal has maximised the difference between benefits [1a] and costs [1b].

**Benefits:**

\[
b = \sum_{t'} rpf_{t'} \times ctc_{t'} \times \frac{1}{\Pi_{(l+\epsilon_{t'},r)}} + \sum_{i} WACC_{i,t} \times (\sum_{j} IDseg_{i,j,t'} - ICseg_{i,j,t'}) \times \frac{1}{\Pi_{(l+\epsilon_{t'})}} + \sum_{t'} \sum_{j} rah_{i,j,t} \times 12 \times \frac{1}{\Pi_{r(t+\epsilon_{t'})}} \ [1a]
\]

**Equation [1a] consider different benefits, for example, the decrease of cost related to demand products, rent that each hospital manager will pay for warehouse’ space and benefits related with safety stock decrease.**

- **Inventory**

\[
ID_{j,t} = l_{aux,j} \times ap_{j,t}, \forall j, t' \in T' \ [1a_1]
\]

**future decentralised stock calculation, in euros, for each hospital unit, j, based on actual stock and expected demand increase.**

\[
IDseg_{j,t} = \frac{ID_{j,t}}{nc_{j,t}} \times ss_{t'} , \forall j, t' \in T' \ [1a_2]
\]

**Decentralised safety stock calculation, per each hospital unit, j and year, t'.**

\[
ICseg_{j,t} = \sum_{i} IDseg_{i,j,t} \times \sqrt{\frac{\Pi}{\nu_{a}}}, \forall t' \in T' \ [1a_3]
\]

Centralised safety stock calculation, based on square law (Figueired e Nettol, 2011).

**Costs:**

\[
c = \sum_{i} c_{i} a_{i} \times \frac{1}{(l_{aux} + \epsilon_{t'})} + \sum_{i} trans_{i} \times \frac{1}{\Pi_{(l+\epsilon_{t'})}} + \sum_{i} \sum_{area} a_{i} \times \frac{1}{\Pi_{(l+\epsilon_{t'})}} + \sum_{i} \sum_{area} a_{i} \times FSE \times \frac{1}{\Pi_{(l+\epsilon_{t'})}} + \sum_{i} (ctrh_{i} + ccar_{i} + desp_{i}) \times \frac{1}{\Pi_{(l+\epsilon_{t'})}} \ [1b]
\]

Equation [1b] allows estimating total costs related with centralization. It is composed of several items:

- **Transportation costs**

\[
trans_{i} = \sum_{j} dist_{j,i} \times a_{i} \times c_{i,t} \forall t' \in T' \ [1b_1]
\]

**Products’ transportation costs between warehouse, i, and JMS’ units.**

- **Human resources costs**

\[
nfac = \sum_{i} (f_{a} \times area_{i}) \ [1b_2]
\]

The number of needed faithful warehouse.

\[
ctrh_{i} = c_{i} \times rem_{e} \times c_{i} \times rem_{f} \times nfac + t_{i} \times rem_{f}, \forall t' \in T' \ [1b_3]
\]

**Total costs related to remuneration of all human resources, per year, t'.**

- **Cost of fire**

\[
desp_{i} = l_{uv} \times n_{a} \times (c_{desp} \times rmdesp_{i} + (ntf_{d} - ntf_{ac}) \times rmdesp_{f} \times i), \forall t' \in T' \ [1b_4]
\]

**Cost, per year, t', to fire human resources.**

- **Car costs:**

\[
ctcar_{i} = (ncar_{i} \times (ccar_{i} + s_{i})), \forall t' \in T' \ [1b_5]
\]
Fixed costs (insurance and leasing) related with the car.

- Warehouse opening cost:
  \[ ca_i = cf \times area_i \forall i \in I \ [1b_n] \]

Warehouse opening cost, in function of the area.

### d. Restrictions

- Area

\[
area_{aux,i,t,t'} = \sum_{i} \sum_{m} aum_{m} \ast x_{m,i,t,t'} \forall i \in I, t \in T, t' \in T' \ [1c_1]
\]

\[
area_i \geq area_{aux,i,t,t'} \forall i \in I, t \in T, t' \in T' \ [1c_2]
\]

Equation [1c₁] calculate the area to maintain stocked products per each month and year. [1c₂] allows to obtain the warehouse area to maintain stocked products, by choosing the biggest area obtained in [1c₁].

\[
area_i \leq BigM \times a_i \forall i \in I \ [1c]\]

Define that’s warehouse’ area only takes a positive value.

- Flow of materials

\[
p_{m,j,t,t'} = paux_{m,j,t} \times ap_{j,t} \forall m \in M, j \in J, t \in T, t' \in T' \ [1c_3]
\]

Future demand calculation of products, per each unit, month and year.

\[
l_{m,i,t,t'} = IUMCaux_{m,i,t} \times a_{i,t'} \forall m \in M, i \in I, t \in T, t' \in T' \ [1c_3]
\]

Stock calculation of future centralised security for each product, warehouse, month and year.

\[
F_{m,i,t,t'} + l_{m,i,t,t'-1} = l_{m,i,t,t'} + \sum_{j} x_{m,j,t,t'}, \forall m \in M, i \in I, j \in J, t \in T, t' \in T' \ [1c_3]
\]

Material balance: supplies plus inventory may be equal to demand plus inventory.

\[
\sum_{m} \sum_{j} x_{m,j,t,t'} \leq BigM \times a_i \forall i \in I, t \in T, t' \in T' \ [1c_3]
\]

Restriction of the material flow material if warehouse in location, \(i\), do not exist.

\[
\sum_{i} x_{m,i,j,t,t'} = \sum_{j} p_{m,j,t,t'} \forall m \in M, t \in T, t' \in T' \ [1c_{10}]
\]

Ensure that demands are satisfied by supplies.

- Transport

\[
t_{t,t'} = n \times car_{t'} \forall t' \in T' \ [1c_{11}]
\]

Each car has associated a human resource.

- Number of central warehouses:

\[
\sum_{i} a_i \leq n, n \geq 1 \ [1c_{12}]
\]

Restriction of the number of central warehouses to open.

### IV. RESULTS AND DISCUSSION

#### Dataset and assumptions used

The incomes were calculated based on the Portuguese law. It refers that for each employee, the company may pay salary, holiday and Christmas subsidy. For these values, it must pay 23% for social security and 4% work insurance and other taxes.

Centralization leads to process optimisation, as such, it is necessary less human resources when compared with actual logistics. In Portugal when someone is fired, the company needs to indemnify the workers, for each year of work. In this study, it was considered that each fired worker had 15 years of labour in JMS, and indemnification was calculate based on it (provided by JMS).

JMS consider that central warehouse will be rent, but it will be necessary building works to adapt it. It was assumed that construction will cost 150 €/m² (provided by JMS)

JMS do not have data about cost transportation, as such, it was necessary some assumptions and calculations. To calculate the transportation cost it was necessary to assume different routes and their cost. It was possible to obtain 0.24 €/km.

The developed model was applied to Lisbon district. It was considered four possible locations to central warehouse: Poço do Bispo, Sacavém, Telheiras and Alcântara. It was chosen to consider the location of hospitals with biggest and access ways. The remaining data are related with transportation, human resources and warehouse costs.

Also, it was considered some taxes to do some calculations, for example, inflation rate and weight average cost of capital, WACC.

The paper studies a strategic problem, as such time horizon is 5 years, just like Salema, et al. (2010).

#### Results

In figure 2 it is possible to resume all the evaluated scenarios.
All the results were obtained by applying the developed methodology, except scenario C1. C2 and C3 do not consider centralization benefits, as such, in these cases equation [1b] was not used. Just in the C4 scenario benefits were considered.

To evaluate the impact of different assumptions and JMS’ logistics modifications, it was elaborated different scenarios, with JMS’ units (5 hospitals and 6 clinics):

C1: a scenario that evaluates the costs related with decentralisation of stocks. In this scenario was not considered the developed methodology, because all the costs associated with scenario are fixed.

As it has said JMS will have a big expansion, and logistics costs will be larger than today. As such, was evaluated the costs related to actual and future logistics.

Each JMS’ hospital have a central warehouse, where are stocked products that will be consumed in hospitals. Each central warehouse has many costs associated. Human resources represent a cost of 263 304.02 € per year. Costs related to the FSE and warehouse income depends on the year. In the first year of the project is expected that FSE represents 91 374.0 € and warehouse income, 63 994 €. Costs for the rest period of the project are different when compared with the first year. FSEs costs will be 129 549.4 € and warehouse income 94 377.9 €. Considering each hospital warehouse area, it is possible to conclude that JMS will have 880 m², affects to stocked products. Seeing the planning time, it obtained a cost of 2 269 440.0 €.

C2A: This scenario reflects the costs related with centralization stock, using developed methodology. In distribution costs was considered that JMS only need one transportation car.

It was possible to obtain different costs related with central warehouse, for 5 years: warehouse area 938.18 m²; warehouse income 189 019.2 €; FSEs costs 639 227.0 €; transportation costs 57 642 €; warehouse open cost 139 195.8 €; car cost 70 210.9 €; human resources cost 771 881.9 €; dismissing cost 173 167.2 €. It is the cost structure of central warehouse, and the total is 2 040 345.2 €. Warehouse’ location that minimize the logistics’ cost is Sacavém.

C2B: This scenario is the same as above, except that the number of transportation cars. It was considered 2 cars with respective human resources. The scenario costs are equal of above scenario except for car cost and human resources cost, they are 140 421.9 € and 835 850.0 €, respectively. Total cost obtained is 2 174 524.4 € and the optimal location is Sacavém.

C2C: It is equal to C2A except for income warehouse. Each possible warehouse location has associated an income. Poço do Bispo income is 4.0 €/m² and Sacavém 3.5 €/m². It was considered both values equal to 4.0 €/m², with the objective to study the impact of it in location result. Obtained that Poço do Bispo is the location that minimize the logistics cost. The total cost, 2 066 675.7 €, suffered a slight increase when compared with C2A.

C3A: It is equal to C2A but considers the possibility to open new hospitals. It was assumed that each hospital will have CUF Torres Vedras dimension, and logistics costs similar with it. The opening of new hospitals will have implication in costs structure. The central warehouse will be larger than other scenarios, to include new hospital stocked products. The majority the costs depend on the warehouse area, as such, the related costs will increase. In this scenario was considered the possibility to open a new hospital in Leiria. It represents a total cost of 2 123 953.3 €.

C3B: It is like the above scenario, but the new hospital will be constructed in Almada. The total cost is 2 095 669.6 €.

C3C: It conjugates C3A and C3B, in other words, the possibility to construct two new hospitals: Leiria and Almada. The total cost is 2 216 507.1 €.

C4: All the described scenarios just consider costs related with centralization, and disregard the benefits. This scenario was contradictory with that and consider centralization benefits. However, these benefits were not quantified the most appropriate way. JMS do not want to sustain financial viability of centralization based on their indirect benefits, but it was considered that centralization is more than dismissal. The benefits were quantified in the conservative way and based on centralization and decentralisation costs. It was considered safety stock reduction, a decrease of demand cost and warehouse income that each hospital manager is willing to pay for the space of hospital warehouse. These benefits represent 575 429.2 €, during project time plan.
Considering all the benefits related with stock centralization, it was obtained 1\,464\,916.0 € of central warehouse logistics costs.

**Discussion**

All the scenario results are resumed in table 1. Comparing all scenarios with C1 it is possible to conclude that centralization has financial viability.

**Table 1 – Resume scenarios’ results.**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Area (m²)</th>
<th>Total cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>880</td>
<td>2,269,440.0</td>
</tr>
<tr>
<td>C2A</td>
<td>938.1</td>
<td>2,040,345.2</td>
</tr>
<tr>
<td>C2B</td>
<td>938.1</td>
<td>2,174,524.4</td>
</tr>
<tr>
<td>C2C</td>
<td>938.1</td>
<td>2,066,675.4</td>
</tr>
<tr>
<td>C3A</td>
<td>990.0</td>
<td>2,123,953.3</td>
</tr>
<tr>
<td>C3B</td>
<td>999.0</td>
<td>2,095,669.6</td>
</tr>
<tr>
<td>C3C</td>
<td>1041.9</td>
<td>2,216,507.2</td>
</tr>
<tr>
<td>C4A</td>
<td>938.1</td>
<td>1,464,916.0</td>
</tr>
</tbody>
</table>

When comparing C2 and C3, it is possible to observe that C3 warehouse area is bigger than C2 and centralization cost has the same logic. Construction of new hospitals affects the central warehouse area, as logistic cost, because it is major depended on the area and increases with that. The difference of total cost between C3A and C3B are due to the distance between Leiria/ Almada and central warehouse’ location.

As stated above JMS do not want to consider centralization’ benefits. As such, it was considered C2A as based scenario of centralization.

When comparing C2A with C1 it is possible to conclude that centralization represents a saving of 229\,094.8 €, when comparing with decentralisation.

With figure 2 and 3 is possible to observe the cost structure and their percentages.

Comparing figure 3 and 4 it is possible to conclude that centralization viability is sustained by a decrease of human resources expenses. In C1A it represents 56 % of total cost, while in C2A it represents only 38 %. However, in C2A dismissal represents 9 % of total cost, but it can be eliminated with human resources requalification or fire people with less experience in JMS. The warehouse income is another important factor, in C2A it represents 9 % and in C1A 18 %. This difference is justified, because hospital’ warehouse has an income per meter equal to all hospital, and it is in locations that exist a great demand. On the other hand, the expect location for the central warehouse is slightly out of Lisbon city, and the price, in euros, per meter, is very low when compared with hospital warehouse. The referred justify the difference of warehouse income of both scenarios. When compared both figures FSEs is the only cost with a percentage in C2A larger than C1. With centralization, FSEs costs will increase because C2A area will be larger than C1 area. As FSE cost was calculated in euros per square meter, based on JMS warehouses. This value was used to estimate central warehouse FSE cost, as such C2A has a larger cost than C1A. C2A have others costs that do not exist in C1. They are cost related with product transportation, car costs, dismissal cost and costs related to warehouse opening. These costs are minor when compared with total, as such does not have a huge influence in total.

In table 2 it is possible to analyse increased logistics cost related to the new hospital, in the case of centralization and decentralisation.
Table 2 – Variation cost, in euros, centralization versus decentralisation, in the case of new hospitals. (centr – centralization; decentr – decentralization) (5 years)

<table>
<thead>
<tr>
<th></th>
<th>Δ cost, €, centr.</th>
<th>Δ cost, €, decentr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3A</td>
<td>83 608.1</td>
<td>243 158.0</td>
</tr>
<tr>
<td>C3B</td>
<td>55 324.4</td>
<td>243 158.0</td>
</tr>
<tr>
<td>C3C</td>
<td>176 161.9</td>
<td>486 316.0</td>
</tr>
</tbody>
</table>

Considering table 2 it is possible to conclude that centralization is possible saving a lot of money, when compared with decentralisation, in a scenario where is possible the construction of new hospitals.

In C2C was tested the impact in warehouse location of increase Sacavém income. It was considered that Poço do Bispo income equal to Sacavém, and the optimal location change for Poço do Bispo. It was possible to conclude that 0.5 €/m², separates Poço do Bispo and Sacavém location. This is a very small difference and it compromises the warehouse location.

In C4A was considered other benefits plus reduction of human resources. When compared this scenario with C1, centralization will have a savage of 804 504 €. It represents a huge potential related with centralization.

This paper study a strategic problem, with a time horizon of five years, in this long period many things can change and exists uncertainties. In addition to that, JMS has not a lot of usable data. As such it was necessary to do many assumptions and calculation. It was done a sensibility analysis, to evaluate the impact of parameters variations. This evaluation focused on critical parameters, as warehouse income, inflation tax, increased rate of demand, transportation cost, the number of human resources.

The parameters variations were done in C2A and compared with it. In table 3 is possible to evaluate the impact of -10 % in parameters values, have in the result.

Table 3 – Parameters variation -10 %, using C2A, and compared with it. (I.C – income cost; I.T – inflation tax; I.D – increased rate of demand; T.C – transportation cost; N.H.R – number of human resources)

<table>
<thead>
<tr>
<th></th>
<th>I.C</th>
<th>I.T</th>
<th>I.D</th>
<th>T.C</th>
<th>N.H.R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation (%)</td>
<td>-0.9</td>
<td>-0.36</td>
<td>-3.5</td>
<td>-0.28</td>
<td>-1.8</td>
</tr>
</tbody>
</table>

Based on table 3, it is possible to conclude that variations in expected increase rate of demand, is the factor that affects significantly more the final result. The growth rate influence the number of moved units, which modify the warehouse area. The major costs are related with that, as such all the factor that influence warehouse area, will influence the result. The number of human resources also influence the results, but less than the growth rate. As observe in figure 2, human resources have a huge importance in the final result, as such this factor significantly affects it. Transportation cost is the factor with major uncertainty because it is dependent on variations in fuel cost and freeway tools. However, as can observe in table 3 factor variations does not affect the results.

V. FINAL REMARKS

Analysing the results obtained through the application of the model to the scenario, it was possible to concluded that centralization of inventory has a huge potential, with financial viability being strictly based on costs. If benefits are considered, the potential of centralization increases. Nevertheless, there are also others benefits that are not consider in this study (e.g process standardization).

The financial viability is sustained by reduction of human resources and decreased of warehouse income. Sustainability can be enhanced if one considers that dismissed employees are allocated to other functions. As mention, C1 will have a huge difference between costs related to the first year of activity and the second year. This difference is explained by JMS’ expansion and consequently the increase of logistics costs. If the centralization begins in 2018, the second year of the project, is possible to increase the viability. The difference costs between first and second year is about 68 558.9 €, this difference can increase centralization’ financial viability, if centralization begins in the second year, 2018.

During this master paper, the author found several points for future work, as follow:

• The pharmaceutical products were not considered in this study considering their complexity and according to JMS, the regulators are not prepared to this situation. On the other hand, would be interesting study the impact of this product centralization;
• Integrate inverse logistics to be possible to include sterilisation of material, it would be the collection of hospital materials and their distribution again to hospitals;
• Considering the human resources impact in results will be interesting a depth study about human resources needs;
• Consider a small-time unit, the order of days, instead of moths. With that it is possible to put developed model closer to reality;
• Include in model three pillars of sustainability;
• Develop a stochastic model, to include different types of uncertainty;
- Undertake further data collection about tactical/operational costs;
- Rigorous survey about all the benefits related with centralization and their quantification;
- Study tactical/operational level about future warehouse layout.

Some suggestions will increase the model complexity but will close it for reality. It was concluded that exists a long way to obtain all the data of operational/tactical level.

This study reinforces the importance to associate engineering solutions to the business world, to helping managers to decide about different themes.

VI. REFERENCES


