Supply Chain Optimization

The Case of Civiparts Spain

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Abstract

Due to increased competitiveness, companies need to make a difference. Managing efficiently the supply chain is one of the factors that can make a difference in a company's costs. Civiparts, a company that sells parts for heavy vehicles and buses, is no exception. The company is trying to improve their supply chain in Spain. There are two distribution centres for the Spanish supply chain, one in Lisbon and one in Madrid. Nowadays, both of them supply the stores in Madrid, Mérida, Barcelona and Valencia. The company wants to improve their supply chain performance by reducing transportation costs and inventory holding costs, without decreasing the service level. Therefore, this dissertation intent to answer to two main questions: 1. What is the optimal delivery frequency to each store, taking into account the trade-off between holding costs and transportation cost for each store? 2. From which DC (Lisbon, Madrid or both) each store should be served, taking into account the trade-off between holding costs at each distribution centre and the transportation costs from each distribution centre to each store? To answer to the previous questions, the company's supply chain, suppliers', customers' and the delivery policies needed to be understood and analysed. A literature review was also made with the major concepts. Similar models to the one that was developed were also studied and analysed to create a new model suited for the company. A mixed integer nonlinear programming model was developed and implemented in GAMS software. The results showed that the best solution was to centralize the distribution operation in Madrid and serve all stores from Madrid. The recommended delivery frequency between the Lisbon and Madrid distribution centre was three times a week. For the stores, daily deliveries were recommend departing from Madrid. In the end, some suggestions are made to Civiparts and some future research topics are raised.

Keywords: Supply chain optimization; transportation costs, inventory holding costs, network design, mixed integer nonlinear programming

1 Introduction

1.1 Problem Background and Motivation

Civiparts is a company that sells parts for heavy vehicles and buses and it is present in five countries and two continents. As the company is constantly trying to improve the efficiency of its operations and is increasing their sales and winning market share in Spain, this master's thesis arises. Currently, Civiparts operate two distribution centres, one in Lisbon and one in Madrid and both of them are supplying the Spanish stores. The company thinks that it is better to improve the supply chain now, when they are entering the Spanish market than later, when they are stabilized with the company already running well. With a more efficient supply chain, they can make greater margins with the same price, or sell it by less and make the same margins. Therefore, the challenge proposed by the company is to analyse if the current distribution strategy is the best option or if there is a better solution for supplying the Spanish market, which can bring the most benefits to the company taking into account a trade-off between transportation costs, inventory holding costs and service level.

To provide a better solution, it is important to study the transportation system and the logistics activities in order to achieve better logistics efficiency, to reduce operation costs, and to promote service quality (Tseng et al, 2005). Furthermore, transportation impacts other areas of the company, since usually transportation costs are diminished by increasing the quantity being shipped, so the company needs to build up inventory, which also represents costs (Rodrigues, 2016).

1.2 Thesis Objectives

The focus of this study is on the supply chain of Civiparts Spain. The goal is to answer to two main questions about logistics optimization: **1.** What is the optimal delivery frequency to each store (Madrid, Merida, Valencia and Barcelona), taking into account the trade-off between holding costs and transportation cost for each store? **2.** From which distribution centre (Lisbon, Madrid or both) each store should be served, taking into account the trade-off between holding costs at each distribution centre and the transportation costs from each distribution centre to each store?

2 Problem Description

2.1 The Civiparts

Civiparts is a company established in 1982. Their main business is the distribution of parts for trucks, buses and "car shop" equipment. The company is part of the business area of integrated aftermarket solution from Nors Group.

In Spain, Civiparts has four stores (that also works as warehouses): Barcelona, Madrid, Valencia and Merida.

Most of the Civiparts clients are workshops (car shops), bus companies - passenger transport - and truck companies - freight transport

2.2 The Civiparts Spain' Supply Chain

The supply chain consists of four main components: suppliers, distributors centres, retailers and customers. Civiparts only controls the distribution centres and the retailers in their supply chain. They don't have production or factories.

Civiparts Spain has different flows depending on the supplier. There are four different ways to get the products to Civiparts Spain customers:

- Direct delivery. Clients buy the products in stores, Civiparts informs the supplier and then the supplier delivers the items in the customer's address without passing by Civiparts warehouses or stores.

- Direct delivery to stores (from the local suppliers) without passing in any distribution centre.

-Traditional warehousing in Madrid. The supplier delivers the items at only one place and then the items are delivered to the stores.

- Traditional warehousing in Lisbon.

Civiparts has a central warehouse where they perform activities that have effect in all their retailers over the world. This central warehouse is the distribution centre of Lisbon. Located on the outskirts of the Portuguese capital, this distribution centre is not only the distribution centre of the Portuguese supply chain but also the distribution centre for all the Civiparts stores in Spain.

The distribution centre of Madrid only supplies the stores in Spain. The warehouse is relatively smaller than the Lisbon warehouse. This warehouse, like all the retailer's warehouse in Spain, also has a store where clients can buy and pick up their items. The retailers of Barcelona, Merida and Valencia have smaller warehouses than the one in Madrid.

There are orders leaving Lisbon to Mérida, Valencia, Madrid and Barcelona once a week. There are also orders leaving Madrid: daily to Valencia and Barcelona and weekly to Merida.

2.2.4 Civiparts' Delivery Policy and System

2.3 The Civiparts' Problem

The transportation and the level of stock are two important factors that are in continuous improving. Civiparts aims to find the best relationship between the cost of transportation, the cost of holding stock and service level. This work is motivated by the desire of reduce costs and improve the supply chain in Spain.

The company wants to conclude whether the company benefits more in having more stock and less deliveries or if the company should have less stock with more frequent deliveries. Civiparts doesn't want to reduce the service level but wants to optimize its supply chain routes of distribution since there are doubts arising regarding the two distribution centres sending orders to the same stores instead of doing transhipment between them and assign one of them to replenish each retailer.

As said, one hypothesis is to centralize the distribution in Madrid. In case of centralization, the orders from the stores would be requested to Madrid instead of Lisbon, therefore, the stock in Madrid would have to increase (or not if the delivery frequency from Lisbon increase). In order to reduce all orders from Lisbon as much as possible, Madrid would need to keep stock that were previously stored in Lisbon. It is necessary to study whether this is an advantage or not and, if so, to define the stock level in Madrid. Summing up, there are two questions to be answered:

1. What is the optimal delivery frequency to each store, taking into account the trade-off

between holding costs and transportation cost for each store?

2.From which distribution centre (Lisbon, Madrid or both) each store should be served, taking into account the trade-off between holding costs at each distribution centre and the transportation costs from each distribution centre to each store? (figure 1)

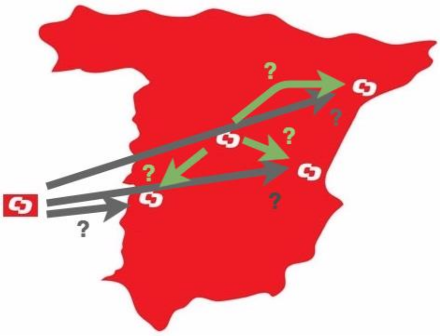


Figure 1 - Distribution possibilities

3 State of the Art

3.1 Supply Chain Management

According to Chopra & Meindl, (2007), a Supply Chain consists in all parties involved in fulfilling a customer request, as well as all the functions necessary in this task. The supply chain includes not only the manufacturer and the suppliers, but also distributors, warehouses, retailers, and customers. Supply Chain Management is the set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, distributors, retailers, so that goods are produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements (Simchi-Levi et al., 2008).

3.2 Transportation

Coyle et al. (2011) stated that Transportation is the glue that holds the supply chain together and is a critical ingredient for overall supply chain performance. Transportation refers to the movement of product from one location to another as it makes its way from the beginning of a supply chain to the customer.

3.2.1 Transportation Problem

The definition of the **transport network**, establishing the set of nodes and routes along which the flow of goods is processed, has a major impact on the performance of the Supply Chain. An optimal network allows for a high level of service at the lowest cost but requires a complex approach that integrates several dimensions, such as transportation costs and inventory holding costs (Carvalho, 2010). The transportation with intermediate warehouses problem is related with the centralization or decentralization of the supply chain (Figure 2). Centralized inventory control is a common cooperative strategy, where the stock control activities of the whole system become concentrated at a particular member (or a group of members), which takes full control of the inventory replenishment of the supply chain, and uses available demand and cost information in planning the operations. Centralizing inventory management provides cost reductions and improved service levels by decreasing uncertainty and providing better utilization of resources for production and transportation (Çelebi, 2015).

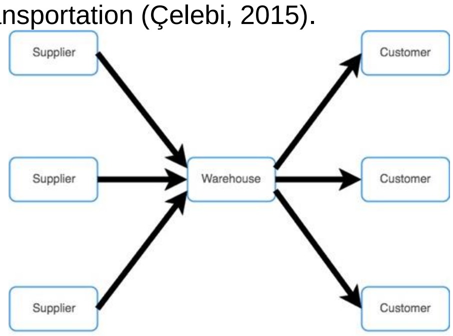


Figure 2 - Centralization Scheme

3.2.2 Transportation Risks

There are three general types of transportation risks: risk that the shipment is delayed, risk that the shipment does not reach its destination because intermediate nodes or links are disrupted by external forces and the risk of hazardous material (Chopra & Meindl, 2007).

3.2.3 Transportation Costs

A transportation service incurs in various costs, such as labour, fuel, maintenance, terminals, roads, administration and others. The costs can be divided into those that vary with services or volume (variable costs) and those that do not (fixed costs). Of course, all costs are variable if one considers a sufficiently long time and a sufficiently large volume. However, for transportation pricing purposes, it is useful to consider the costs that are constant during the carrier's "normal" volume of operation as fixed. All other costs are treated as variables (Ballou, 2008).

3.2.4 Transportation trade-offs

The efficient management of a supply chain requires a systemic and integrated approach. In another words, the various activities should be seen as elements of a system and should not be studied, analysed and optimized individually, but in the context in which they are inserted in and, taking into account the interactions with the other elements that form the system. In transportation management, the dependency relationships in the various processes that are associated with it are particularly relevant on the impact that some decisions have, for example, on inventory holding costs, operations effort and coordination in customer responsiveness, among others.

3.2.4.1 Time vs Space

The frequency of a transport system is also a factor with great impact on the costs of a transport system. For example, a high frequency of supply reveals a large capacity of response by the supplier (for example, deliveries in 24 hours after the request), that leads to higher cost of transportation (lower vehicle occupations and therefore higher cost / unit). If, on the other hand, the frequency decreases, the loads can be consolidated over time until they become fully charged, maximizing the occupancy of the vehicle space, and lowering the transport costs. Thus, a lower response capacity would allow significant reductions in transport costs as a result of the economies of scale obtained in transport (Carvalho, 2010).

3.2.4.2 Transportation vs Inventory

In general, the trade-offs between inventory and transportation costs come from the facts that: transportation influences the time that inventories remain in transit and on the premises; and the fact that configuration of the logistics network (which maintains inventories) influences transportation. Fast transportation allows inventory to remain for a short time in the vehicles and offers certainty conditions that allow the reduction of safety stocks in the warehouses. In this way, they provide the compensation between high transportation costs and low inventory holding costs. Slow transportation shows the opposite situation and, although they present lower costs, they induce the need of maintenance of inventories for long time in transit and demand a greater quantity of safety stocks (Amaral & Guerreiro, 2014).

Table 1 summarizes the main trade-offs between inventory and transportation costs achieved by Amaral & Guerreiro (2014). The authors also stated that: “The impact on the operating income is composed by the difference in cost between transportations, by the cost difference between inventories held and by the difference in profit tax arising from these cost distinctions. In addition to operating income, the situation impacts the cost of capital, as it interferes with the amount of investments in inventories.”

3.3 Inventory

Pure storage does not add value to the product, the value of a product to the customer when entering and leaving the warehouse is exactly the same, or on the contrary, may even decrease (risk of obsolescence, breakage, deterioration, among other reasons). However, the whole process of making the product available to the customer is based, among other things, on a set of storage and transport activities that allow the fulfilment of the demand (Carvalho, 2010).

According to Chopra & Meindl (2007), inventory exists in the supply chain because of a mismatch between supply and demand. The mismatch is also intentional at a retail store where inventory is held in anticipation of future demand. An important role that inventory plays in the supply chain is to increase the amount of demand that can be satisfied by having the product ready and available when the customer wants it. Another significant role that inventory plays is to reduce cost by exploiting economies of scale that may exist during production and distribution.

3.3.1 Inventory Risks

Too much supply leads to inefficient capital investment, expensive markdowns and needless handling costs, while too much demand generates the opportunity cost of lost margins. Each situation is the consequence of one of two types of inventory risk: the former is the risk of excessive inventory (inventory risk) while the latter is the risk of insufficient supply (supply risk). Because most supply chains are incapable of perfectly matching supply and demand, all of the firms in a supply chain

Table 1 - *main trade-offs between inventory and transportation costs (Amaral & Guerreiro (2014)*

↑ Inventory Holding Costs		↓ Inventory Holding Costs	
↓ Transportation Costs	- Delayed transportation - Contracting informal companies and individual carriers - Batch consolidation - Decentralized stocks - Policy of not prioritizing stock items - Push strategy	↑ Transportation Costs	- Appropriate transportation - Hiring formal and modern companies - Non-consolidation of lots - Centralized stocks - Policy of prioritizing stock items - Pull strategy

bear at least some supply risk. But some firms may be able to avoid inventory risk completely (Cachon, 2004).

3.3.2 Inventory Holding Costs

According to Chopra & Meindl (2007), Inventory Holding Cost is estimated as a percentage of the cost of a product and is the sum of the following major components:

• Obsolescence cost: The obsolescence cost estimates the rate at which the value of the stored product drops because its market value or quality falls.

• Handling cost: should include only incremental receiving and storage costs that vary with the quantity of product received. If the quantity handled requires more people, an incremental handling cost is added to the holding cost.

• Occupancy cost: The occupancy cost reflects the incremental change in space cost due to changing cycle inventory.

• Miscellaneous costs: This component of the holding cost deals with a number of other relatively small costs. These costs include theft, security, damage, tax, and additional insurance charges that are incurred.

• Opportunity Cost: Amaral & Guerreiro (2014) and Zahran & Jaber (2017) stated that we should also consider the cost of capital or opportunity cost. The value kept in inventory can be considered as a logistic investment. The value used in inventory prevent its application in a more attractive and profitable application.

3.4 Supply Chain Optimization

According to Dhakry & Bangar (2013), there are two important issues in the supply chain area that contribute to the total cost of the supply chain network, namely, transportation and inventory holding costs. That being said, retail companies can achieve significant savings by considering these two costs at the same time rather than trying to minimize each separately. The authors developed a nonlinear integer programming problem solved by a heuristic to find an initial solution and an upper bound followed by a branch-and-bound algorithm based on the Lagrangian relaxation of the non-linear program. Three scenarios were analysed in their work: flow-through, single distribution centre and regional distribution centre. These scenarios were made to correspond with the ways that the suppliers ship their products. The suppliers ship products according to tree different paths. In the first path, product is shipped through a cross dock facility to a store, meaning that no inventory is held at the facility but only at the store. In the second path, product is shipped by the suppliers directly to the stores. In the third path, inventory is held at a distribution centre and then shipped to the stores. The goal is to identify distribution locations as well as quantities shipped between various points that minimize the total costs. The results obtained shows that the single and regional distribution centres are more cost-efficient when compared to the flow-through approach.

4 Model Development

4.1 Model Characterisation and Data Collection

A mathematical model was developed to optimize the supply chain of Civiparts Spain and to answer to the questions presented.

The problem at hand can be described as a generic problem of transportation from the suppliers to the stores passing through distribution centres. Given:

- Transportation cost function;
- Retailers/stores demand for each day;
- Distribution centres capacities;
- Distribution centres expenses;
- Inventory opportunity cost;

Determine:

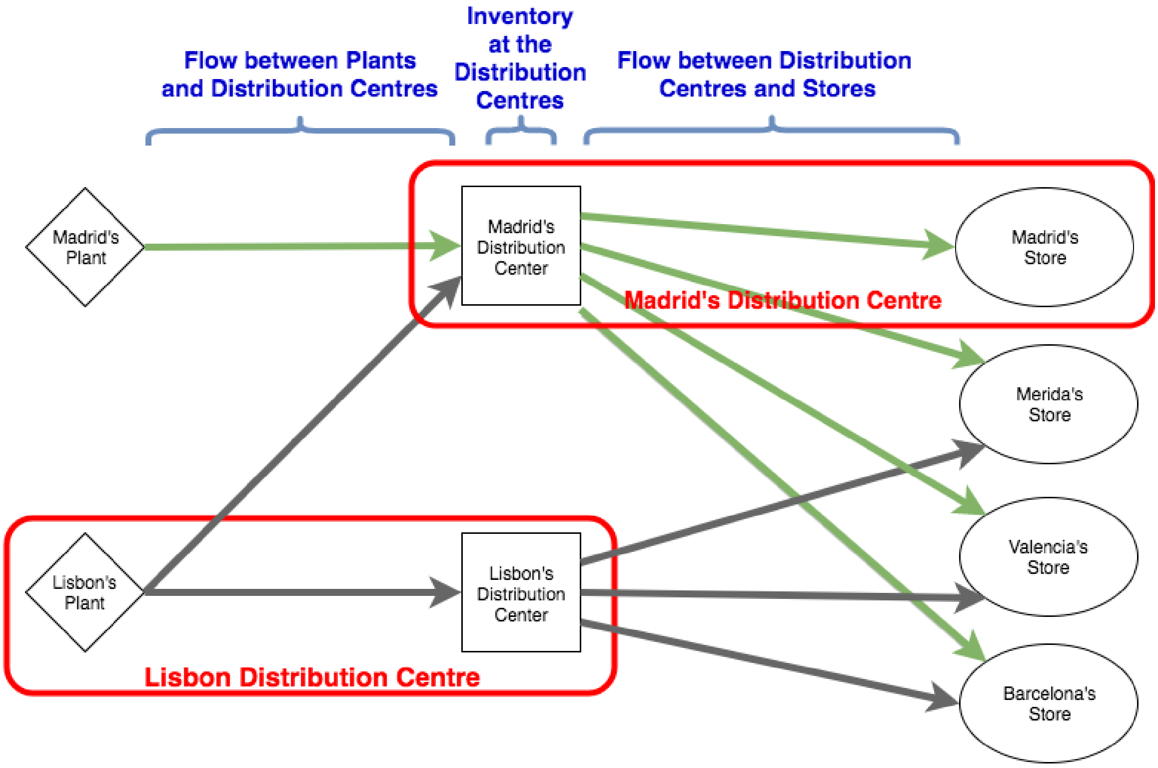
- Optimum delivery frequencies
- Which distribution centre (or both) should serve each store

The optimization model aims to minimize the logistics total cost, which includes transportation cost and inventory holding costs, improving the distribution strategy used by Civiparts. However, reducing the transportation cost can lead to an increase in inventory holding cost, so a trade/off must be taken into account.

As the focus are in the operations that only depend on Civiparts, a plant has been set up for each distribution centre to simulate the existence of a supplier. The flow in the model will go from the plant to the distribution centres and later to the stores. A route between the distribution centres was added to give the possibility of transhipment and subsequent centralization of distribution in Madrid. The route from the distribution centre of Lisbon to the store of Madrid is done through the distribution centre of Madrid. This way, the flow to Madrid will pay inventory in all the scenarios that will be tested. The transportation costs between plants and distribution centres was not considered.

Figure 3 summarizes the network design to be implemented in the model. The flow that goes from the distribution centre to store of Madrid and “can go for free”, since the cost of transport between the distribution centre and the Madrid’s store is 0€/kg. In case of

Figure 3 - Network design to implement in the mathematical model



centralization, only the inventory holding cost of Madrid is charged to the centralized flow.

The demand has been set in kilograms. This simplification was made, since the use of flows by product would imply the collection of information on the weight of each product or average weight of each family of products. The complexity that this analysis would bring to the computational model would be greater than the advantage in terms of precision of the results since the focus of the work is the global transportation costs. Moreover, the transportation cost charged by company T (outsourced company that makes the transportation) is a function of the weight transported. Therefore, the demand can be set in kilograms.

By analysing historical data on the route Madrid-Merida, it was found that the majority of the weeks have daily deliveries, so the weakly-delivery to Merida was transformed in a daily-delivery.

Two types of demand were defined: the one that must be supplied by the Madrid's distribution centre ($demand\_madrid_{s,t}$) and total demand ($demand_s$). $Demand\_madrid_{s,t}$ is a daily demand for each store and is defined for one week from Monday to Friday (t1 to t5). The total $demand_s$, is a weekly demand for each store and includes the previous demand plus a demand from Lisbon. The demand from Lisbon can go directly to each store or can go through a centralization in the Distribution centre of Madrid.

The demand values were calculated trough a study period of 20 weeks and obtained in visits, meetings or with access to the SGIX software (Inventory management software). To calculate the demand of each store, an average weight was considered based on the information of both companies (Civiparts and company T) regarding the kilograms transported. The values contain a coefficient to guarantee the confidentiality of the results without changing the outcome of the results.

Regarding the distribution centre capacities, the average inventory was considered to represent 90% of the storage capacity. Leaving the remaining 10% to be used by the model. When the model informs that there are 0 kg in stock, it means that the warehouse has its average inventory in stock.

The time period considered for the model was two weeks. Each store is supplied on a weekly and on a daily basis, depending on the origin. The demand of products that leave Portugal is weekly for each store. The demand for the products from Madrid is daily. Although the demand repeats itself every week, the two weeks' time interval was considered in order to study if the behaviour is the same for the two weeks or if it would keep inventory from one week to the other and thus have less frequent deliveries.

Transportation rates are tabulated according to the weight carried and the route - origin and destination, according to the distance between origin and destination. The rates are tabulated in kilogram intervals for each route in piece wise functions. A power regression was made to each route to reach the transportation costs function per kilogram. The upper limit of each interval was used to calculate the cost per kilogram and to do the regression.

Initially, it was considered that a mixed-integer linear program would be performed (using the linear function, on the left), but, in the course of the development of the model, it quickly came to conclusion that it would have to be a non-linear function (using the nonlinear function, on the right). The reason for this change is due to the tabulated values in transportation costs. In a linear function we have $y = a\,x + b$, it could be seen as a fixed cost "a" per which kilogram "x" plus a fixed cost of opening the route "b". The advantage in transporting more items at the same time is only "b", that is divided by more kilograms "x". In a power function $y = x * (a * x^b)$, the expression between parentheses is the cost per kilogram when transporting "x" kilograms, paying less per kilogram when transporting more. This value is then multiplied by the number of kilograms "x" transported. It is important to notice that "b" will be a negative number and the power function (x^b) is not defined when "x" is zero and "b" is negative.

The inventory holding costs were calculated according table 2. The values from lines [1], [2], [3], [4], [6], [8] and [9] were given by the company trough SAP Software.

Table 2 – *Inventory Holding Costs*

Inventory Holding Costs		
[1]	Obsolescence	
[2]	Handling Cost	
[3]	Occupancy Cost	
[4]	Miscellaneous Costs	
[5]	Total Cost	[1] + [2] + [3] + [4]
[6]	Average inventory value	
[7]	Rate warehouse cost per average inventory (%)	[5] / [6]
[8]	Opportunity cost (%)	
[9]	Average Cost of item	
[10]	Average inventory holding cost/year	[9] * ([7] + [8])
[11]	Average inventory holding cost/day	[10] / 261 (business days)
[12]	Average inventory holding cost/day.Kg	[11] / Average Weight

The inventory holding costs from the one from the stores was not considered, only the one from the distribution centres.

4.2 Mathematical Formulation

4.2.1 Sets

Distribution centres: $DC = \{dc_1, \dots, dc_n\}$

Stores: $S = \{s_1, \dots, s_n\}$

Plants: $P = \{p_1, \dots, p_n\}$

Days: $T = \{t_1, \dots, t_5\}$

Weeks: $= \{w_1, \dots, w_n\}$

4.2.2 Parameters

cap_dc_{dc} – Inventory capacity for distribution centre (dc) in kilograms.

ic_{dc} – Inventory holding cost for each distribution centre (dc) in euros.

$demand_s$ – Weekly demand for each store (s), that can be answered from both distribution centres (dc), in one week (w) in kilograms. This demand includes the $demand\_madrid_{s,t}$ plus a demand from Lisbon.

$demand\_madrid_{s,t}$ – Demand for each store (s), that must be answered by the distribution centre of Madrid (dc_{Madrid}) in kilograms.

$aa\_t\_p\_dc_{p,dc}$ – Values of A for each route from plant (p) to distribution centre (dc) in the equation ($y == A\,x^{\,B}$).

$bb\_t\_p\_dc_{p,dc}$ – Values of B for each route from plant (p) to distribution centre (dc) in the equation ($y == A\,x^{\,B}$).

$aa\_t\_dc\_s_{dc,s}$ – Values of A for each route from distribution centre (dc) to store (s) in the equation ($y == A\,x^{\,B}$).

$bb\_t\_dc\_s_{dc,s}$ – Values of B for each route from distribution centre (dc) to store (s) in the equation ($y == A\,x^{\,B}$).

4.2.3 Variables

All variables presented in this section are nonnegative variables.

$f\_dc\_s_{dc,s,w,t}$ – Flow between distribution centre (dc) and store (s) on week (w) and day (t), in kilograms.

$f\_p\_dc_{p,dc,w,t}$ –Flow that arrives at the distribution centre (dc) from plant (p) on week (w) and day (t), in kilograms.

$inv\_dc_{dc,w,t}$ – Inventory at the distribution centre (dc) in day (t) and week (w), in kilograms.

z – auxiliary variable to use in the objective function, in euros.

4.2.4 Objective Function

The objective function (1) minimizes the transportation costs and the inventory holding costs of Civiparts supply chain.

$$MIn\ Z = \sum_{p}\sum_{dc}\sum_{w}\sum_{t} Transportation\_Costs\_p\_dc_{\ p,dc,w,t} + \sum_{dc}\sum_{s}\sum_{w}\sum_{t} Transportation\_Costs\_dc\_s_{\ dc,s,w,t} + \sum_{dc}\sum_{w}\sum_{t} Inventory\_Costs_{\ dc,w,t} \quad (1)$$

$$Transportation\_Costs\_p\_dc_{\ p,dc,w,t} = f\_p\_dc_{p,dc,w,t} * aa\_t\_p\_dc_{p,dc} * (f\_p\_dc_{p,dc,w,t})^{\ bb\_t\_p\_dc_{p,dc}} \quad (2)$$

$$Transportation\_Costs\_dc\_s_{\ dc,s,w,t} = f\_dc\_s_{\ dc,s,w,t} * aa\_t\_dc\_s_{dc,s} * (f\_dc\_s_{dc,s,w,t})^{\ bb\_t\_dc\_s_{dc,s}} \quad (3)$$

Subject to:

$$Inventory\_Costs_{\ dc,w,t} = inv\_dc_{dc,w,t} * ic_{dc} \quad (4)$$

$$demand_{s} <= \sum_{dc}\sum_{t} f\_dc\_s_{\ dc,s,w,t}\ , \ \forall s \in S,\ \forall w \in W \quad (5)$$

$$demand\_madrid_{s,t} <= \sum_{dc}\sum_{t} f\_dc\_s_{\ dc\_Madrid,s,w,t}\ , \ \forall s \in S,\ \forall w \in W,\ \forall t \in T \quad (6)$$

$$inv\_dc_{dc,w,t} <= cap\_dc_{dc}\ , \quad \forall dc \in DC,\ \forall w \in W,\ \forall t \in T \quad (7)$$

$$if\ t = 1;\ inv\_dc_{\ dc,w,t} = inv\_dc_{\ dc,w-1,t+4} + \sum_{p} f\_p\_dc_{p,dc,w,t} - \sum_{s} f\_dc\_s_{dc,s,w-1,t+4}\ , \ \forall dc \in DC,\ \forall w \in W,\ \forall t \in T \quad (8)$$

$$if\ t > 1;\ inv\_dc_{\ dc,w,t} = inv\_dc_{\ dc,w,t-1} + \sum_{p} f\_p\_dc_{\ p,dc,w,t} - \sum_{s} f\_dc\_s_{\ dc,s,w-1,t+4}\ , \ \forall dc \in DC,\ \forall w \in W,\ \forall t \in T \quad (9)$$

$$f\_dc\_s_{\ dc,s,w,t} <= inv\_dc_{dc,w,t}\ , \forall dc \in DC,\ \forall w \in W,\ \forall t \in T \quad (10)$$

$$f\_dc\_s_{\ \text{dc\_madrid,s\_madrid},w,t} = 0.00001\ , \ \forall w \in W,\ \forall t \in T \quad (11)$$

$$f\_p\_dc_{\ \text{p\_madrid, dc\_madrid},w,t} = \sum_{s} demand\_madrid_{s,t},\ \forall w \in W,\ \forall t \in T \quad (12)$$

$$\sum_{t} f\_p\_dc_{p\_lisboa,dc\_madrid,w,t} \leq demand_{s\_madrid} - \sum_{t} demand\_madrid_{s\_madrid,t}, \quad \forall w \in W \quad (13)$$

$$f\_dc\_s_{dc\_lisboa,s,w,t} \leq 0.00001, \quad , \ \forall s \in S,\ \forall w \in W,\ \forall t \in T \quad (14)$$

4.4 Model Application

In the application of the mathematical model in the GAMS software, tree scenarios will be studied. The first will be the baseline (Scenario 1) where the current solution is studied. The second scenario will be the optimal solution without any restrictions (Scenario 2). The third scenario will be the total centralization scenario (Scenario 3).

Constrains 13 and 14 are only used in the first and third scenario, respectively. Constrain 13 states that only the demand from the store of Madrid will go through the distribution centre of Madrid. Constrain 14 states that the flow from the distribution centre of Lisbon to the stores is 0. However, this constrain allows the flow to go to the distribution centre of Madrid.

5 Results and Discussion

5.1 Results

Regarding the results, Table 3 shows that the cheapest scenario in terms of inventory holding costs is the baseline scenario. If we only consider the transportation costs, the cheapest scenario is the centralization one. However, if we consider the total cost, the cheapest is the second one.

The optimal scenario (second one) centralizes only the distribution to the stores of Barcelona and Valencia. The store of Merida received orders from both distribution centres.

The total centralization solution is only more expensive in 21 € per month than the optimal solution (second scenario),

Taking into account the company's inventory management system, the total centralization of distribution allows for better management of inventory because it leads to a concentration of safety stocks and an optimized purchase management (with the possibility for more frequent shipments) leading to a reduction of average stock in all Spanish locations, and also with a faster delivery, since Madrid can get to any location in 24 hours and, from Lisbon to Barcelona and Valencia the shipment takes 48 hours.

Table 3 – *Total costs comparison*

Total Costs			
	Scenario 1 - Baseline	Scenario 2 - Optimal	Scenario 3 – Total Centralization
Inventory holding costs	1007.48 €	1087.72 € **+80.24 €** **+7.96%**	1125.48 € **+118 €** **+11.71%**
Transportation Costs (Total)	4487.55	4110.93 € **-376.62 €** **-8.39%**	4082.68 € **-404.87 €** **-9.02%**
Transportation cost from Lisbon to Madrid	493.02 €	978.61 € **+485.59 €** **+98.49%**	1094.94 € **+601.92 €** **+122.09%**
Transportation costs from both DCs to stores	3994.53 €	3132.32 € **-862.21 €** **-21.58%**	2987.74 € **-1006.79 €** **-25.20%**
Total Costs (z)	5495.03 €	5198.65 € **-296.38 €** **-5.39%**	5208.16 € **-286.87 €** **-5.22%**

The big point against centralization will always be the cost of inventory where handling costs are included. Whether the inventory level is maintained or lowered at the distribution centre of Madrid, handling costs will always be higher, either by receiving a larger volume that needs to be consolidated or by sending more volume to each store at a time. With regard to the handling cost in stores, it is expected that this cost will decrease since the stores will have less stock and also because the stores will receive only from Madrid in case of centralization.

Centralization can also be considered as a strategy for the future. If there is a gain in centralizing the distribution for the current number of stores, then, this trend will be even more evident if the company wants to open more stores in other places in Spain. If one day the agent of Vigo happens to be turn into a store, the most probable scenario is that the centralization of the distribution is the most suitable and the most affordable.

6 Conclusions and Future Work

An analysis of the organization's global system, together with the scientific research were undertaken to identify potential opportunities for improvement derived from the overall flow across the supply chain instead of considering the gain from one particular warehouse. From this process, a study was carried out using a mathematical model that embeds the trade-off between inventory holding costs and transportation costs, and it concludes that total centralization in Madrid was the best option for the distribution of products in Spain. On one hand, this decision saves on transportation costs, allows for an improvement in the service level by being able to put the products in stores faster and allows for a reduction of stock due to centralization. On the other hand, additional inventory holding cost emerge (only in Madrid). After analysing all these factors, it was possible to conclude that the option of centralizing the distribution to Spain in Madrid is valid and beneficial to the organization.

Also, in terms of environmental impact, it is believed that the results are better in the centralized distribution. Although the company that does the transportation is an outsourced company (so it may do the same routes), Civiparts will no longer require the travels from Lisbon to Barcelona, Valencia and Merida and will only increase the route from Lisbon to Madrid two times.

With regard to the final solution of the optimization model, the results are substantially better when compared to the current scenario (baseline), with savings representing around 5% of total costs (8% if consider the transportation costs only), which is a very attractive situation that the company needs to study to later implement. With centralization it is possible to make bigger margins at the same price, or sell the items for less money and make the same margins, gaining competitive advantage either because it has lower operation costs or because it sells at a more affordable price, gaining the clients preference.

6.1 From which distribution centre each store should be served?

Regarding the distribution centre that should serve each store, although it is not the cheapest option, all stores in Spain should be supplied by the Madrid distribution centre.

The analysis of all the determining factors reinforce the fact that the centralization of the distribution contributes to the optimization of the supply chain, allowing to reduce distribution costs by around 650 € per month (22 business days). On the other hand, it turns out that centralizing the distribution to Merida is not the optimal solution but centralizing it has an extra cost of around 21 € per month. The company won't have full control over the distribution since it is an outsourced service, but they can always avoid the delayed transportation, synchronizing the orders, which means that what arrives has to arrive in the morning, and what goes out has to leave at the end of the day, so that it gives time to do crossdocking in Madrid if necessary, otherwise it will take more than 48 hours to go from Lisbon to Barcelona and Valencia.

6.2 Delivery Frequency

Regarding the frequency of deliveries, the mathematical model tells us that the Lisbon-Madrid route should be done 2 or 3 times a week (result from the first and second week). More than one or two times than what is currently being done.

On the other hand, the mathematical model tells us not to do the Lisbon-Valencia and the Lisbon-Barcelona routes. Lisbon-Merida is a route that also disappears despite the opposite indication from the mathematical model, as said, 21 € per month more expensive with the centralization. The saving in kilometres is therefore considerable, it increases two times the distance between Lisbon and Madrid and withdraws once each of the routes from Lisbon to the stores of Merida, Valencia and Barcelona. This reduction in kilometres also points to a reduction of the emission of pollutant gases, being therefore a decision that also helps the environment.

6.3 Future Work

For the future work, it is highlighted the implementation of the centralization of the distribution to Spain, thus reducing the existing stock in stores. In this sense, a detailed analytical study of the number of each item that should be kept in the stores and in the Madrid distribution centre should be done to create an automatic tool (probably to implement in the SGIX software – software used by Civiparts to manage inventory) able to manage this process.

The centralization of distribution will lead to a new supply chain dynamic, so it is crucial to study which internal limits should be adopted to optimize the process. Given the relationships among the various entities of the supply chain, it is essential that this analysis will be done with the focus of being implemented in a computer software. It is also essential to define all the necessary requirements to ensure all the proposed improvements and the maximum integrity and quality of information. The work to be developed could be integrated into the optimization of the inventory management strategy and the analysis of the transportation profitability, completing detailed study of the supply chain from an end-to-end perspective.

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