Supply Chain Optimization: Application to a real case

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Abstract

The increase focus of companies in clients' satisfaction, independently of the market they operate in, results from a growing degree of consumers expectations. To fulfill such increase, companies have to arm themselves with the correct internal capabilities, achieving not only efficacy in the satisfaction of each customer, but also efficiency, by operating at the lower possible cost. One of those internal capabilities is the logistics network, which is representing, more and more, a great challenge for companies, given the complexity of the variables that compose it. In this paper, an optimization model is developed that contemplates simultaneously the design and planning of supply chains with reversed flows, through a multi-period and a multi-product network. The proposed model acts as a support tool for the decisions to be made in a real case of a Portuguese telecommunications company, in order to optimize its logistics network.

Keywords: Forward supply chain, closed loop supply chain, logistics providers, supply chain modeling, supply chain integration.

1- Introduction

Whatever the business sector, customer satisfaction has become the central focus of any company that wants to win in an increasingly competitive market. The concept of customer satisfaction no longer refers only to the performance of goods and repairs a company offers, it also considers its interconnection with the internal capabilities that enable the company to respond adequately to the needs of increasingly demanding customers.

Supply chains management, and in particular the associated logistics networks, can be one of the most relevant internal capabilities to meet customers' needs. Companies must deliver products to the right places and quantities, at the appropriate time and at the lowest possible cost. However companies have customers spread across several geographical regions, national or worldwide, with demands for different types of products. This makes the management of the forward flow of products a challenge when efficiency and effectiveness are at stake. Adding to this the different life cycle times products have and a good quality after sales service (product breakdowns, repairs or replacements, i.e., the reverse flow of products), the challenge becomes even greater.

Such problem is addressed along the present paper where the case of a national telecommunications company is studied. In order to deal with this complexity, the company in study outsourced most of its logistics operations namely transportation, warehousing and repair. Different third-party logistic (3PL) providers manage forward and reverse flows. Due to this decision, the company currently faces the challenge (not less complex) of coordinating and managing all the involved 3PLs. If, outsourcing on one hand, allows the company to focus on their core business, leaving such operations for those who are supposed to run it in an effective and efficient manner, on the other hand, the company may lose control over such activities if not properly supervised, which can create a negative image in end customers.

Within this context, the objective of this study is to investigate a possible integration of product flows. Particularly in terms of transportation and sharing of facilities to support the logistics processes in order to minimize total costs, without diminishing the after sales quality service provided to the consumer. To achieve this goal a Mixed Integer Linear Program (MILP) model is developed and different scenarios based on the logistics network main decisions are studied. This paper is organized as follows. In Section 2 an overview of the existing literature related with this work is presented. In Section 3 the case study is characterized including forward and reverse supply chains. The problem’s description is given in Section 4. The characterization of the model formulation follows in Section 5, where some model aspects are explained. In Section 6 are presented the main results obtained for the case study under study. Finally, some conclusions and future research directions are drawn.

2- Literature Review

Each industry has very particular characteristics respecting its supply chains, differing even between companies in the same field. Despite these differences, and independently from the type of industry in which companies operate, supply chains models are quite similar in the approach they follow. Besides that, there is a need to have in mind that no model can capture all the aspects of the processes of a supply chain, reflecting only the essential key aspects to its study, while being capable enough of being mathematically solved (Min and Zhou, 2002).

The key components for the construction of supply chains models as suggested by Min and Zhou (2002) are essentially three: 1) drivers, which consist in the establishment of the aims that arise from the identification of the main drivers of the supply chain; 2) constraints, that represent the real restrictions of the logistics network, like production capacity constraints, etc.; 3) decision variables, that represent the answers that we want to extracted from the construction of the supply chain model, being these answers that, in a last analysis, will contribute to the final decision. Everything mentioned above applies to all supply chain models, whether they are strategic, tactical, operational nature, or even of a mix nature, like strategic and tactical models. The strategic models generally involve temporal horizons of four to five years, depending on the industry in question. According to Goetschalckx and Vidal (1997), the strategic level contemplates long-term decisions, for example, the number, location, capacity and type of facilities to use. Most of the case studies in supply chain management published in the literature are strategic in nature, mostly because of its modeling easiness. A good review on the subject is provided by Melo et al. (2009). At the tactical level, a smaller temporal horizon is considered when compared to the strategic one, generally between a quarter and a year. Tactical decisions are more detailed than the strategic ones. Being associated with the supply chain's planning in itself, they establish performance levels related to inventory, transport and sales policies. According to Swaminathon et al. (2003), these levels allow for an orientation so that daily tasks might be executed. However, few are the purely tactical models found in the literature, being mostly strategic or operational (daily decisions). According to Dogan et al. (2002), to achieve a global and integrated system, the strategic decisions must be considered simultaneously with the tactical aspects, since the integration of decisions with different time units might imply high savings for the company.

It is based on this premise that the present work is developed. Within the context of closed-loop supply chains, a case study is presented together with a model that simultaneously integrated strategic and tactical decisions. The supply chain structure is defined, in terms of logistics centers to install. Furthermore, different tactical decisions on how much capacity is required and on how operate the structure chosen are also evaluated.

3- Case study

3.1 General description

The company in study has, in the recent past, restructured its logistics network by outsourcing most of its logistical operations, with recourse to third-party logistics (3PL) providers. Currently, this company operates with two logistics operators and four different distributors. The two logistics operators are individually responsible for the forward and reverse logistics. Distributors can operate with flows of both supply chains. Overall the company's network consists of one warehouse and two logistics centers, with different characteristics in terms of dimensions, locations and performed functions. The company logistics department is in charge of the management of all logistics processes involved in both forward and reverse flows. This management is done independently for the two flows, i.e., the forward and reverse flows are not integrated. Nonetheless some reverse flow products are reused through the forward network. In order to evaluate the quality of the collected products, the company has a Repair Center where equipments are tested and its housing is exchanged for a new one.

3.2 Forward supply chain description

The forward supply chain has four different levels: suppliers, Logistics Center/warehouse, Distribution Channels/Service Providers (SPs) and clients (see Figure 1). The first level represents all suppliers, which provide the various components and products. Transportation between the suppliers and the next level in the chain is their responsibility. All components and products are transported to the logistics center that, along with a warehouse (which operates in cross-docking) composes the second level of the forward supply chain. The logistics center also operates as a warehouse and is responsible for all the forward logistics operations (includes reception, dispatch, inventory, kitting and serial number reading). The third level of the forward supply chain is composed by the Service Providers (SP), which main function is to supply the final customer (last level of the forward supply chain). The SPs are split in two major groups according to their geographical location: north and south. The southern SP are supplied by the Logistic Center, while the SPs of the northern area are supplied from the warehouse which in turn, is supplied by the Logistics Center (transhipment). As mentioned above, customer supplying is an outsourced operation (performed by the SPs). These distribution channels work on consignment, i.e., products flowing in these channels belong to the company. This forward supply chain can be characterized as a push-pull system. The service providers place their orders and are responsible for the transportation. After SP orders have been placed, the production planning as well as the placement of orders to suppliers is based on a make-to-stock strategy. Production planning, as well as orders to suppliers, is based on monthly and weekly forecasts (respectively), with a security inventory level between 7-8 weeks of expected demand.

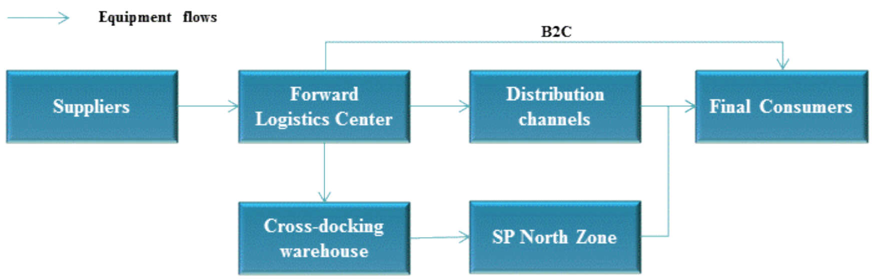

Figure 1- Simplified forward supply chain scheme

3.3 Reverse supply chain description

The complexity of processes and flows of the reverse supply chain is much higher when compared to forward supply chain. This is explained by the multiple origins and destinations of the returning equipment. However, the underlying principle of the two chains is similar. That is, the reverse chain operations are also centralized in a single logistics center (different than the one of the forward flow). To this center returns all sorts of products included in the company's portfolio. Main reasons for this reverse flow are faulty equipment, the service cessation and upgrade equipment. The intrinsic uncertainty of the quantity and quality of equipment returned is difficult, if not impossible, to predict. This uncertainty is mainly reflected in terms of transport planning and operations at the logistics center. In terms of structure, the reverse logistics network can be also decomposed into four levels (see Figure 2): distribution channel, reverse logistics center, support entities and consumers. The first level consists in some distribution channels, which can stem the equipment returned. The second level is composed by the Logistics Center. While forward products are transported directly to the respective distribution channels, in the reverse this is not the case. Depending on the equipment processed at the Logistics Center, they may be referred to the repairers, for the slaughter (which includes resale and scrap dealers), or circuits for maintenance and / or post-sale (third level). The latter feeds the last level which consists of consumers. The Repair Centre integrates the reverse supply chain, being the operations split between two entities: logistics operator performs equipments test operations and an external repairer performs the equipment housing exchange operation.

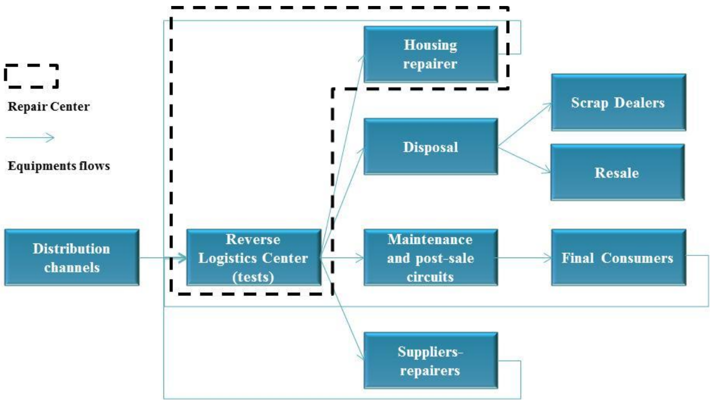

Figure 2 - Simplified reverse supply chain scheme

4 - Problem's Description

The company wants to restructure its logistics network where the location and operation of the logistics center, Repair Center and cross-docking warehouse are to be evaluated. Two alternatives to the Logistics Center are studied: the actual one (see Section 3) and a future one where the Logistics Center common to both flows with outsourcing. The operation of the Repair Centre and the cross-docking warehouse, and consequently the monthly payment to SPs, is studied and results compared to the direct distribution to this channel by the company. So, the objective of this work is to evaluate different logistics network structure and planning schemes having the best structure as a reference base. The studied problem can be defined as:

Given:

- The super-structure composed by the potential entities in the supply chain;
- The demand volumes of the commercial circuit, the maintenance circuit and the distribution channel;
- Bill of materials;
- The relation between distributed products and the returned ones, given by the return fraction;
- The initial stock levels at the facilities;
- The relation between returned products considered as new and the ones considered obsolete, given by an historical fraction;
- The relation between tested products and possible results of those tests, given again by historical fractions;
- Transportation cost between each pair of entities;
- Cost of the products bought from the suppliers;
- Cost structure of the logistics operators;
- Logistics Center’s investment cost;
- Repair Center’s investment cost;
- Operation costs of the Repair Centers;
- Labor costs;
- Maximum warehousing capacity of the logistics operators and the Repair Center;
- Maximum and minimum limits of the flows between facilities;
- Maximum transportation capacity of the transportation companies vehicles;
- Physical characteristics of the products such as weight and volume;
- The time for kitting, rework, testing and housing by product.

To determine:

- The number and type Logistics Centers;
- The type of Repair Center;
- Distribution strategy for the Repair Provider (SP) distribution channel;
- Products stock levels, in each micro time unit;
- Levels of kits production, housing and tests in each micro time unit;
- Number of necessary trips between logistics operators and SP or vice-versa, in each micro time unit;

- Number of people necessary to execute the tasks of testing equipment, kitting, housing and rework without the occurrence of backlog of the Logistics Center and Repair Center;
- The stock amounts, in each micro time unit;
- Amount of products transported between each pair of facilities and in which micro period they happen, including amount of equipment bought from the suppliers.

So as to minimize the total cost of the supply chain.

5 – Model Formulation

The mathematical model used to solve the problem under study was based on the model presented by Salema et al. (2010). In this work, authors propose a MILP model that integrates the strategic decisions with the tactical ones through the integration of two interrelated temporal scales. The network representation is achieved through a graph approach, where nodes represent entities (e.g. suppliers, logistics centers, etc.) and the arcs represent the flow of material moving between entities. For further details the reader is referred to the work of Salema et al. (2010).

The model involves the definition of the network super-structure. Starting from the defined structure, a set linear equations are able to represent the constraints of the problem to be satisfied. Considering the indices *i*, *j*, *k* for the entities, and *m*, *n* for the products the following variables (continuous, binary and integer) were defined:

quantity of product m dislocated from entity i to entity j, during micro period t′ ;

quantity of product m in stock in entity i, during micro period t′.

if entity is open, otherwise About the remaining entities, it is imposed that they are open ( ), since the suppliers, the clients and the junkyard are always included in the model;

if the flow between entity i and entity j occurs during micro period t′, otherwise . This variable is an auxiliary variable that allows the modeling of the flows existing in the model.

number of trips from entity i to entity j, during micro period t′ ;

number of pallets of product m in entity i, during micro period t’;

number of workers in entity i, during micro period t’.

Using the above variables and considering the characteristics of the problem the model was developed. An objective function that minimizes the total logistics costs is considered. This includes investment and operational costs. In terms of restrictions, the model includes a diverse set of constraints, namely: (i) material balance in each entity, thus ensuring that everything that comes out is equal to anything that enter, (ii) the demand of each distribution channel in each time unit is fully satisfied in the same period, (iii) the amount of returned products (which depend on the amount demanded) must be collected in the shortest possible time, (iv) storage capacity in the entities, (v) safety stock levels, (vi) consider the minimum and maximum capacity constraints flows between entities, (vi) ensure that a flow exists if the respective entities also exist, (vii) the number of each type of entities opened, (viii) number of transportation trips between entities, (ix) the number of human resources to carry out operations on entities.

The above model was built in a generic form and allows the solution of the case-study previously described. The obtained results are presented next.

6 – Results

In this section are presented the results obtained from the execution of the previously described model to the study case described in section 3. In this analysis only aspects related to the logistics network and respective costs are considered although planning results are also obtained. The results for the actual logistics network (Current case - section 6.1) and for the optimal network which is being implemented by the company (Future Case - section 6.2) are presented and a brief comparison between both is made.

The MILP model was solved by GAMS/CPLEX (version 23.1.2), an Intel ® Core ™ 2 Duo CPU, 4, 2.66 GHz.

6.1 - Current case (Case 1)

The current logistics network is composed by two logistics centers dedicated to each flow (forward and reverse) with outsourcing, the Repair Center in charge of the reverse chain logistics operator and is of the responsibility of a third entity. In this case, the payment of settlements to the SP distribution channel is used. After applying the model to this case, the costs obtained are shown in Table 1. These are the base of comparison for the analysis developed along this article. The cost of the current logistics structure is of 107.674.641 monetary units (m.u.).

Table 1 – Costs of Current Case

Rubrics	Cost (m.u.)	Rubrics	Cost (m.u.)	Rubrics	Cost (m.u.)
Suppliers	103 315 800	Repair Center	256 787	Rework	1 031 086
Transport	1 208 488	Logistics Operator	1 868 476	Junkyard	(5 723)

Total: 107 674 641m.u.

When analyzing the costs it can be seen that the costs related to new products acquisition represent 97% of the total costs due to the high prices associated. Follows the logistics operators costs related to the operations performed in the logistics centers representing almost 1,9M m.u.. Transports costs 1,2M m.u./year while Rework operation, which represents the operation of kitting used and functional equipments, costs 1M m.u.. Finally, the costs related to equipment tests and housing exchange (Repair Center) are 256 787 m.u. while the sale of damaged products to scrap dealers (Junkyard) contributes to a cost reduction of 5 723 m.u..

6.2 - Future Case (Case 2)

The optimal case is composed by a common Logistics Center that manages all the outsourced forward and reverse chain operations. The logistics operator responsible for the Logistics Center is also responsible for the Repair Center. After running the model the costs associated with such option are shown in Table 2. The total cost of this scenario is 106 845 214 m.u..

Table 2 - Costs associated with the Future Case

Rubrics	Cost (m.u.)	Rubrics	Cost (m.u.)	Rubrics	Cost (m.u.)
Suppliers	103 315 800	Repair Center	179 061	Rework	1 031 086
Transport	1 125 957	Logistics Operator	1 199 982	Junkyard	(5 723)

Total: 106 845 214 m.u.

6.3 - Comparison between the actual and the future case

The comparison of the results of the two previous cases aims at analyzing the differences between the logistics network in operation with the one that is under analysis by the company, allowing the conclusion of what network configuration is better suited from a financial perspective. Comparing both scenarios Figure 3 shows the cost differences between the future case and the current one. The future network presents better results since it allows for larger annual savings than the current network, a total of 826.908 m.u.. These savings appear at the level of transportation, of Logistics Center operations and Repair Center operations (see Figure 3). When analyzing the transportation costs, three factors contribute to the savings of 82.530 m.u./year of the future case. Those factors are the consolidation of orders, the elimination of flows between different logistics centers and the fact that the operations of housing of equipment are now located in the Logistics Center own facilities, opposing to what happens in the actual case in which the Repair Center is split between two entities in different locations. About the Logistics Center operations, the results show that the billing imposed by the logistics operator of Case 2 is more advantageous for the company, since it allows the nonoccurrence of fixed costs related to information systems maintenance (less 245.000 m.u./year) and the reduction of reception and expedition costs of 145.000 m.u. and 176.000 m.u./year respectively. Additionally, the 40.000 m.u. saved in the kitting operation indicates that a method of cost based on work hours is more advantageous than the one based on processed unit.

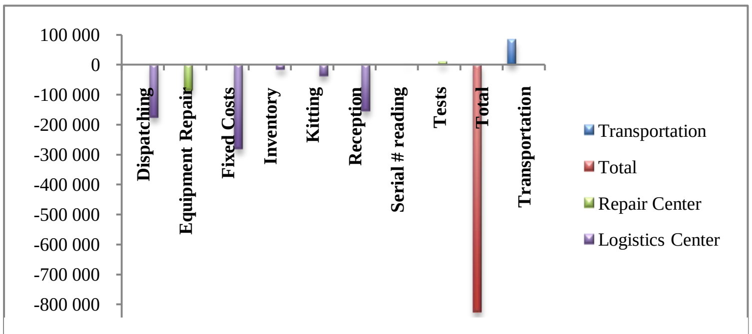

Figure 3 - Cost difference (€) between Case 2 and 1

The new network structure has no impact on acquisition costs (suppliers), which means that no renegotiation has to be performed with the current suppliers.

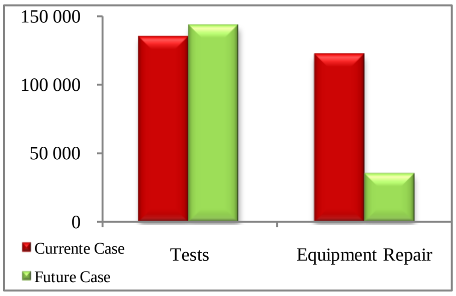

Figure 4: Repair Center operations costs (€)

Finally, Figure 4 shows the operational costs within the Repair Centre for both scenarios. Concerning the testing operation, the cost is higher in the future case which reveals that, for this operation, it is not advantageous a method of cost based on work hours but rather on processed units, as it happens in the actual case. However, for the housing operation the costs are inferior for the future case 86.000 m.u./year, being of advantage the cost based on the hour worked. Comparing to the actual case, the total savings of the future case are of 826.908 m.u./year.

7– Conclusions

This work studies the restructuring of a Portuguese company's logistics network. To that end, an optimization model was developed, based on the work of Salema et al. (2010).

The developed model is applied to design and access the cost structure of two different logistics networks: the current operating network and a new one that the management board intent to put in place. In a yearlong analysis, the structure that presents the least total costs is the new one, where the Logistics Center and the repair centre become part of a single logistics operator. The annual savings with this new network structure are estimated to be more than €1 m.u..

As future work, some limitations of this work are to be overcome. The first one is related the temporal aggregation. The present study was conducted assuming a week basis (mostly due to computational problems). A smaller time unit such as a day would allows a more detailed planning of kit production and equipment testing (for instance), which would be very useful for the company.

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