Total Logistic Costs Efficiency with an Alternative for Consolidate Goods

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ABSTRACT
This paper considers an application of the capacitated transshipment problem on a real case of supply chain network design, considering a problem of large-scale dimension as the main principle in the modeling of important natural and social phenomena. The problem first is formulated as a mixed-integer linear programming model. Then, a Benders decomposition algorithm is appropriately developed as the solution methodology. In the presented algorithm, the problem is decomposed into two models, called master and subproblem. The master problem is improved by means of a preprocessing and solving the primal of the subproblem, exploiting its network structure. Moreover, the Benders Cuts, optimality and feasibility, are developed for the algorithm. The general relative performance of the algorithm is proposed for its experimentation and evaluation.

Keywords: Benders Decomposition, transshipment problem, supply chain, logistic costs

1. INTRODUCTION

The impact in emergent economies globalization, and product life cycles shorter and more complex, in part due to new supply chain era consumers, are not just tendencies anymore. Day by day we see how these factors push us to achieve an operative logistics environment that can be in due time and form according to the necessities of every economy participant.
The world around us is full of important questions without answer, nevertheless, exist the security of every intent of find their solution, requires of the use of mathematics, in most of the cases, through the creation, application and refinement of math models. Math modeling is a great support to large organizations in the decision making to solve complex problems.
Is common for the organizations to have a generalized policy of filling containers under the rationale that this practice will result in lower unit total costs however the excess product brought will end up into inventory thus increasing the inventory cost, depending on the cost relationship between transportation and carrying cost, this situation does not always hold. It's complex to accomplish a balance between freight and inventory costs without using sophisticated techniques and solid strategic planning.
According to a study made by (Gutierrez and Jaramillo 2009), the automatization of warehouses, to optimize the operation and management, and the tools for the processes and analysis that optimize time and space available, are growingly utilized by organizations of different sectors in the country. According to this study, 57% of enterprises use quantitative tools to generate and improvement in the supply chain management, of this 57%, 30% focus on the use of the type of tools to reduce costs.
The total logistic cost goes from the aggregation of the following four type of costs: transport, inventory, storage, administrative and supply. Being transport and inventory costs, the first associate ones to logistic costs (Montanez *et al*. 2015).
In figure 1, it can be observed the correlation that exists between the total logistic costs, if one of them decreases or increases, the total logistic cost is affected, in other words, if the approach is to reduce inventory costs, it would implicate an increase in transport costs given the reason that it will be required more lower volume shipments.

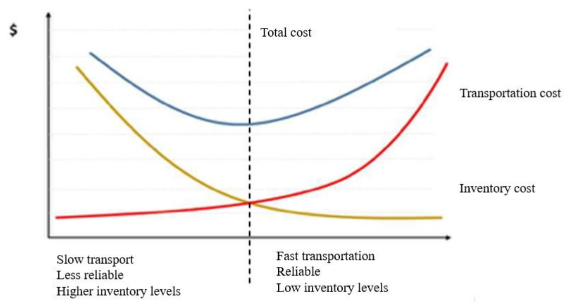

Figure 1: Correlation between logistic costs.

2. THE TRANSSHIPMENT PROBLEM

In real life, transshipment problems are composed of a considerable number of products and suppliers, when trying to be translated into mathematical modeling they take a very high solution time, there are many techniques that have been studied to combat this problem. The problem that will be raised in this paper, is expressed as a problem of mixed integer linear programming, as it has both discrete and continuous variables, therefore, there

are decision variables that must be seen as a whole, such as the quantity of pallets of products that must be sent from the supplier facilities to a consolidation center, or directly to the customer, as well as shipments through containers; Other variables can be relaxed, such as the amount of product to keep in inventory, which causes the response time to solve the problem is long.
A total of 4 different scenarios are tested for the purpose of this research, all based on a real supply chain problem in an automotive components' manufacturer company, that imports components ready to assemble from China, we consider 3 components to test for every scenario, 4 periods, 2 types of containers, 20ft and 40ft capacity, for every scenario. Details of said scenarios are shown below:

Table 1: conditions in the 4 scenarios tested

Scenarios evaluated				
Scenario	1	2	3	4
Periods	4	4	4	4
Distribution Center	1	2	3	4
Containers size	20ft and 40ft	20ft and 40ft	20ft and 40ft	20ft and 40ft
Components	3	3	3	3
Suppliers	3	4	6	9

3. METHODOLOGY

3.1. Literature review

To solve complicated problems with a considerable number of variables that are unknown, it is necessary to use special techniques, as are the decomposition methods. These decomposition techniques allow certain types of problems to be solved in a decentralized way and, alternatively, lead to a drastic simplification of the problem-solving procedure being studied in a considered less time than other linear programming techniques (Conejo *et al*. 2006).
In literature is observed that deal with problems of greater complexity require support in more than one solution technique in order to arrive at a better solution that would be initially available. (Chen and Garcia-Diaz 2011), use the combination of lagrangian relaxation with heuristics for the creation of lagrangian heuristics. (Marjani *et al*. 2012) use a heuristic to generate the initial solution that will be the beginning of the algorithm of three different heuristics. While (Naderi 2019) used a two-stage stochastic programming model, achieving an optimality gap of 0.1%.
There are other solution tools that consider the structure of the problem presented in this paper, as is the case of the branching and dimensioning method, which is used to solve mixed medium-sized integer programming problems, using decomposition methods for large scale problems, where the branch and bound method can no longer provide an effective solution (Moradi-Nasab 2018).
In this investigation, a solution is proposed through the decomposition of Benders, since it is a technique that allows us to offer a solution to the problem presented, however, its application can be extended to problems of greater dimensions.

3.2. Definition of the problem

Its importance lies in establishing the objectives to be achieved, the limitations to reach these objectives and the information that is available, which may be valuable for the solution of the problem, this information is called assumptions. The assumptions of the present problem are:
• The demand for each product is known.
• Products can be sent directly from the supplier, or sent from the supplier to a consolidation center, and then to their final destination.
• The number of suppliers, consolidation centers, ports, transportation costs, inventory costs, and container capacity that make up the supply network is known.
• We have the option of keeping the inventory for future periods at the final destination.
• In the consolidation centers no inventory is maintained for future periods.
• Transportation costs are seen as total costs, that is, they include costs for containerization, paperwork, transportation from the point of origin to the destination, human capital, collection costs from the supplier to the consolidation center, etc.
• Inventory costs are total, that is, they cover costs for damage, obsolescence, inventory management, human capital, etc.

Sets

e: Set of container capacity.

p: set of suppliers.

s: Set of products.

b: Set of distribution centers.

t: Set of time periods.

k: Set of a future time period $t + 1$.

Parameters

CD_{ep}: Cost of direct shipment from the supplier $p \in P$ of a container of capacity $e \in E$ (en tarimas) to Mexico.
CC_{spb}: Cost for shipment a pallet of component $s \in S$ from the supplier $p \in P$ to the consolidation center $b \in B$.
CM_{eb}: Cost of shipment of one container of capacity $e \in E$ from the distribution center $b \in B$ to Mexico.
CI_s: Cost of inventory a component $s \in S$.
d_{st}: Demand in pallets of the product $s \in S$ in the period $t \in T$.
Q_e: Capacity of the containers, expressed in pallets.

Variables

XM_{ept}: Quantity of containers from capacity $e \in E$ sent from the supplier $p \in P$ in the period $t \in T$ directly to Mexico.

XC_{spbt}: Quantity of pallets of component $s \in S$ sent from the supplier $p \in P$, to the distribution center $b \in B$ in the period $t \in T$.

XT_{spt}: Quantity of pallets of product $s \in S$ sent from the supplier $p \in P$ in the period$t \in T$ directly to Mexico.

XL_{ebt}: Quantity of containers of capacity $e \in E$ that are sent from the distribution center $b \in B$ to Mexico in the period $t \in T$.

$I_{stk:}$ Quantity of pallets of product $s \in S$ to store in the period $t \in T$ and the inventory in the period $k \in K$.

Once the parameters are well defined and the variables are clearly understood, the problem is obtained as it shows:

3.3. Benders decomposition applied to a transshipment problem

It is proponed a solution for the problem presented, utilizing the Benders decomposition, for testing, GAMS math modeling tool will be used due to maintaining an interface with great quantity of other math modeling software, specifically CPLEX.

The generic modeling of the problem is shown below:

$$\boldsymbol{Min\,Z = \sum_e^E \sum_p^P \sum_t^T CD_{ep} XM_{ept} + \sum_s^S \sum_p^P \sum_b^B \sum_t^T CC_{spb} XC_{spbt} + \sum_e^E \sum_b^B \sum_t^T CM_{eb} XL_{ebt} + \sum_s^S \sum_t^T \sum_{k=t+1}^T (k-t)_e (CI_s) I_{stk}} \quad \textbf{(1)}$$

$$\boldsymbol{\sum_s^S XT_{spt} - \sum_e^E Q_e XM_{ept} \leq 0 \begin{cases} p = 1, 2, \ \dots, P \\ t = 1, 2, \ \dots, T \end{cases}} \quad \textbf{(2)}$$

$$\boldsymbol{\sum_s^S \sum_p^P XC_{spbt} - \sum_e^E Q_e XL_{ebt} \leq 0 \begin{cases} b = 1, 2, \ \dots, B \\ t = 1, 2, \ \dots, T \end{cases}} \quad \textbf{(3)}$$

$$\boldsymbol{\sum_s^S XT_{spt} + \sum_p^P \sum_b^B XC_{spbt} + \sum_{k=1}^T I_{skt\,[k \neq t]} - \sum_{k=1}^T I_{stk\,[k \neq t]} = d_{st} \begin{cases} s = 1, 2, \ \dots, S \\ t = 1, 2, \ \dots, T \end{cases}} \quad \textbf{(4)}$$

$$\boldsymbol{XM_{ept}, XT_{spt}, XC_{spbt}, I_{stk}, XL_{ebt}} \in \mathbb{Z}_{\mathbf{0}}^{+} \quad \textbf{(5)}$$

Where (1) represents the minimization of the total costs integrated by total direct shipment cost, consolidated cost, and inventory cost.

We have two sets of constraints that can be resolved separately, being the first set (2) that refers to the capacity condition of the direct shipment from the foreign supplier to Mexico, meanwhile the second constraint (3) achieves the capacity of the consolidate goods. Furthermore, a set of constraints of demand achievement it is presented (4), where it takes account of keeping the product in inventory.

Due to the special structure of the problem, it is proposed to get a solution by the Benders decomposition method, parting the problem in two, in this case, a master problem (6), and a subproblem(7), considering the constraints mentioned above, the master problem and subproblem objective function are expressed in the following:

$$\boldsymbol{Min \sum_e^E \sum_p^P \sum_t^T CD_{ep} XM_{ept} + \sum_e^E \sum_b^B \sum_t^T CM_{eb} XL_{ebt} + \alpha} \quad \textbf{(6)}$$

$$\boldsymbol{Min \sum_t^{T-1} \sum_{k=t+1}^T (K-1)\,(CI_s) I_{stk} + \sum_s^S \sum_p^P \sum_b^B \sum_t^T CC_{spb} XC_{spbt}} \quad \textbf{(7)}$$

$$XM_{ept,}\ XT_{spt,} XC_{spbt,} I_{stk,}\ XL_{ebt} \ \in \mathbb{Z}_{\mathbf{0}}^{+} \quad \textbf{(8)}$$

4. RESULTS AND DISCUSSION

Results obtained for every scenario are shown below:

Scenario	Total logistic cost	Absolute gap	Computing time
1	36798	0.00%	1.703 s
2	16732.156	0.0%	1.109 s
3	16887.156	0.0%	1.87 s
4	13205.43	0.21%	3.7 s

Figure 2: logistic costs evaluation

According to the performance of the algorithm, in every scenario is considered to reach an optimum result, where the best solution possible is the scenario 2, in distribution center exploitation means, where 2 distribution centers are used at a minimum transportation and inventory cost. This option is viable when a company has no choice but use the distribution centers. Whereas scenario 4 shows a lower logistic cost result, for the nature of the test, evaluating 9 suppliers with only 3 components, most of the components are picked by the same supplier and sent directly from their location to the destination, implying that no usage of distribution centers result in a lower logistic cost, for this case.

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