Supply Chain Network with Contracts

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Abstract:
In this paper, we introduce the Supply Chain Network with contracts (SCNC) based on Service Level agreement (SLA). The model includes classic decisions such as the number of facilities and their locations, capacities, the quantity of product flows carried between facilities. Further the service level agreement which coordinates the players of the considered supply chain and the transportation resource management, the model considers also the transportation modes between each couple of facilities. The aim is to select a transportation mode between two connected facilities with the minimal total cost (fixed and variable costs) regarding the minimal allowed load of the mode. The problem is modeled as a single-objective mixed integer program. In this modele, two derived variants are considered: (i) a first version of the modele considers to minimize the maximum cost and (ii) the second version aims at minimizing the total transportation cost. Then, we will compare both the obtained solutions by the commercial solver \textit{Cplex} v12.8.

keywords: Supply chain, service level agreement, contract, penalty, coordination, optimization.

1 Introduction

Since the last two decades, supply chain management (SCM) has been the subject of many research work and findings. We can distinguish two kinds of papers: (i) models and methods papers and (ii) survey papers. While there is a vast amount of literature available on supply chain without contract \cite{1,5}, supply chain models with contracts \cite{2} has only been covered by a few works in the literature which makes it a research subject that it is under investigation.

This paper proposes to build an optimization model taking into account the objectives of all actors to build more realistic solutions, and to compute the added cost of the decisions taken locally (shared decisions). The final goal is to design collaborative policy proposals which maintain an acceptable level of fairness. However, the nature of commercial relationships between the actors may not allow this for all SCs. The proposed model should consider the main parameters than influence these actors decisions. As a first step, we focus on the transportation contracts and their influence on the decisions of the transportation firms involved in the SC. Our main assumption is that SLA contracts may induce a somewhat “virtuous behavior” of the actors as defined in the reference \cite{3}.

Hence this paper proposes a mathematical model for a SC including the SLA \cite{6} with multiple actors and levels (producers: plants, warehouses, retailers, transporters). We also consider multi-commodity (several products) with finite transportation capacities (vehicles fleet, train containers...). To be more realistic, the transportation resources are explicitly managed and may belong to different modes.
2 Problem description

In this work, we consider a multi-layer, multi-products, supply chain with additional features: different transportation modes, SLA type contracts, and sustainable development objectives. The considered supply chain includes two stages: (i) plants that manufacture products to supply the warehouses and (ii) warehouses (or distribution centers) that provide products to several retailers (see Figure 1). Besides, we have transportation companies (carriers) that transport products between plants, warehouses, and retailers. Each transport company has a finite set of transportation mode such as road, rail or inland water way to ship products between the nodes of the network. We assume that the demands of warehouses/retailers are deterministic and known in advance. In order to obtain a more realistic model, each firm, i.e., plant and warehouse establish a Service Level Agreement (SLA) with one or several transportation companies to transport these demands. In our model, a contract is defined as follows:

1. Origin and destination nodes
2. Transportation company
3. Product
4. Services
   (a) $S_1$: Quantity of product
   (b) $S_2$: Delivery time
   (c) Others: Carbon Dioxid emission, ...
5. Penalties in the case where some service requirements are not met
6. Rewards

The resulting optimization problem consists in determining the quantities of each product to deliver to warehouses and retailers at each time period to meet at best with the contracts requirements. The primary objective of each transporter is to minimize its transportation costs, the penalties costs (missed quantity to deliver penalty, arrival delay penalty and eventually
other penalties). The CO\textsubscript{2} emission might be considered as a secondary objective for a given carrier or as one service for one or several contracts (but in our presented model, it is not taken into account). Some other considerations such as the transportation resources, back to depots, empty journeys... From network design, the considered problem is generalizing the one discussed in [4], however, it is also considering further the service level agreements which play a role of the coordination between the supply chain players and the transportation resource management. However, we do not take into account the strategic decision in our problem.

To the most of our knowledge, there is no work dealing with service level agreement (SLA) for supply chain optimization in the literature. Our purpose is to adapt the concept of SLA to the supply chain.

3 Mathematical formulation

We propose two variants to the studied problem in the form of a MLIP which consider to minimize their objective function. We solved both the versions : as follows :

1. the first one considers to minimize the maximum cost;
2. the second one aims at minimizing the total transportation cost.

In (1), the model minimizes the global cost and does not take into account the local preferences while in (2), the model, equivalently, minimizes the average cost of the transporters. It is the classical performance criterion.

4 Conclusions

We proposed a model to design a generic supply chain network which is able to handle multi-layer, multi-products, through supply chain from plants to retailers. We also integrated transporters with transportation modes selection and the SLA type contracts.

The obtained first results allowed us to validate the model in its two derived versions. The next crucial step will be to include the sustainable consideration in this model for the SLA in the transportation contracts and to consider a multi-period model by adding the inventory management constraint. The transportation contracts will then depend on the stock level in the warehouses or at the retailers stage. Another challenging step will be to adapt some heuristics to solve the problem approximately regarding its high complexity and hardness to solve to optimality medium and big size instances.

Références


