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Technical Paper

A negotiation protocol to improve planning coordination in transport-driven supply chains

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ABSTRACT

This paper addresses the coordination problem of activities between manufacturers and transport operators (*third party logistics*) in the context of tactical planning. This critical problem is encountered in many supply chains. Collaborative solutions, such as the *Collaborative Planning, Forecasting and Replenishment* (CPRF) model, are not fully automatized and remain poorly suited for enhancing the relation between manufacturers and transport operators. Furthermore, centralized planning is not suitable in keeping confidential the objectives of each partner of the same supply chain. Therefore, this work aims to develop a decentralized planning approach based on a negotiation protocol.

Our approach tries to reach a "win–win" planning solution and to give some decisional flexibility to transport operators. This protocol is founded on an incentive mechanism that can be used by transport operators to progressively persuade manufacturers to accept a pickup plan. This study is focused on the case of one manufacturer and one transport operator. The key determinants of the coordination protocol and a set of planning models based on linear programming are presented here, followed by the design of the experiments used to identify the factors affecting the overall performance of each partner. The results demonstrate that it is possible to obtain plans that satisfy the manufacturer (i.e., the client of the transport operator) while increasing profit for the transport operator. This is in favor of the application of these principles to the coordination of multiple transport operators.

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1. Introduction

Third party logistics providers (3PL) are firms in charge of executing a more or less significant part of logistics activities. Using their services generally provides means for companies to subcontract storage and transport activities to third parties. Nevertheless, it raises the issue of how the relationship between third parties and distribution activities could be improved when they are performed by independent industrial partners, who usually aim to keep confidential their own data and knowledge. The synchronization of distributed operations primarily occurs through aggregated tactical information sharing, thus giving the master planning function great importance for insuring an effective coordination of supply-chain partners.

The present work focuses on the collaborative relationship between manufacturers and third parties providing transport activities, also called transport operators. This relation has two main singularities in comparison with those that link production facilities in a supply network. First, the transport operator's profit margins are much lower than the revenue of manufacturers (i.e., clients[1] of the transport operator) generated by product sales. Transport operators also have difficulties forecasting activities because their various clients (i.e., transport orders) require multiple and different transport services. In such cases, the transportation activities of 3PLs are planned by manufacturers, based on the use of specific tools such as DRP (distribution requirement planning), when they intend to create a long-term climate of confidence with their clients. If these tools provide useful services for companies in facilitating information and material-flow control, from consumer demand to raw material supply, their implementation requires information sharing. However, these tools are rarely implemented by 3PLs with low transport capacity (i.e., 3PLs that own a small fleet of vehicles: less than 5). Their weak level of computerization

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[1] The following notations are adopted: '*Client*' refers to a customer of transport services, and '*customer*' refers to a final customer.

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and the lack of finance to access to the Electronic Data Interchange (EDI) usually reduce the usefulness of the DRP. Therefore, the difficulty is the coordination of transport operations and the balance between transport resources and needs.

The main objective of this work consists of developing an approach to coordinate transportation planning with production planning models. More precisely, this research aims to study the problem of production and transportation in the 3PL environment under a decentralized coordination mode [20].

This paper is organized as follows. Section 2 proposes a literature review, and Section 3 presents the problem studied. Section 4 proposes the description of mathematical models and the negotiation protocol. Section 5 gives the numerical results for performance evaluation. Section 6 summarizes conclusions and future research directions.

2. Literature review

Collaborative planning in supply chains has drawn strong interest for many years [1,27]. First, we present an overall view of collaborative supply-chain planning approaches. Then, we focus on the relation between distribution and production.

2.1. Supply chain collaborative planning

Although an exhaustive literature survey of this field is beyond the scope of this paper, a classification of the main paradigms for the planning coordination of partners is presented. The collaborative approaches are broadly composed of two main groups, presented below:

- Centralized approaches are based on a full model of partners that supports the decision making for all supply-chain participants [4]. They rely on the hypothesis of complete information sharing. These models are then solved using either exact approaches, based on mathematical programming, such as decomposition approaches [5], or approximated approaches, such as heuristics or metaheuristics. Also included in this group are hierarchical planning methods, which aim to address the centralized problem through its decomposition into a hierarchy of interdependent sub-problems. These centralized approaches are often difficult to use in practice, primarily because companies do not want to share their confidential data.
- Decentralized or distributed approaches consider fully independent partners. A comprehensive classification of decentralized coordination methods in supply-chain planning can be found in Taghipour and Frayret [29]. These approaches can take various forms, such as information exchange, request for actions or more advanced cooperation. For instance, supply contracts that link customers with suppliers currently represent an important influence on the production and delivery of final products. Amrani et al. [3] showed that supply commitments, such as frozen horizon (i.e., ordered quantities are considered fixed during this time interval and cannot be modified between two planning decisions) or flexibility rate (i.e., customers can change the ordered quantities within a certain limit outside of the frozen horizon), as stipulated in this contract, can be a powerful way to manage and plan the product flow in a supply chain.
- Among more advanced cooperation forms, negotiation is a central paradigm whose definition varies with authors. It can be defined as an exchange between two or more partners with a view to obtain an agreement [16]. Automated negotiation approaches can be inexhaustively classified into three main following categories:
  - o *Heuristic approaches*: Partners iteratively adjust their local initial plan according to the capabilities of other partners. One of the first approaches was proposed by Dudek [10], who developed a negotiation-based scheme. It combines mathematical programming for the optimal planning of each party so that the two parties' orders/supply plans can be synchronized for planning in the supply chain. Taghipour and Frayret [30] proposed an extension of this model to address the dynamic changes in the supply-chain environment that affect planning. In the same lineage, Albrecht and Stadtler [2] formulated a theoretical scheme for coordinating decentralized parties that intends to encompass all functionalities of supply chains. Ben Yahia et al. [6] proposed a negotiation mechanism for collaborative planning within a supply chain that is based on fuzzy rules. Their approach is limited to cooperation between manufacturers, considering only production planning without distribution, supplier or retailers. These approaches are a practical and easy way to implement negotiations between partners, though they are not mathematically proven; for instance, their convergence toward an agreement is not guaranteed.
  - o *Game theory-based approaches*: The best decision made by a given partner in a supply chain is found taking into account the possible decisions of others. One of the first studies to apply coordination and negotiation inside a supply chain was proposed by Cachon and Netessine [8], who mentioned that two main types of games-cooperative and non-cooperative (i.e., a competitive game)-can be used. Game theory provides very powerful strategies. However, their implementation to solve a practical problem, such as planning coordination, remains a delicate topic due to their reliance on the hypothesis of perfect rationality.
  - o *Multi-agent system-based approaches*: Developed in artificial intelligence problem solving, this paradigm has been intensively applied to supply-chain collaboration. It is particularly suited to automated negotiation due to the implementation of decision mechanisms such as auctions or biding. Hernández et al. [17] proposed a negotiation-based mechanism that is supported by a multi-agent system and focuses on the collaboration of demand, production and replenishment planning, combined with the use of standard planning methods, such as the material requirement system (MRP) method. Fischer et al. [15] proposed a methodology and a multi-agent tool for the simulation of the transportation domain. Their negotiation-based decentralized planning approach is applied to the scheduling of the transportation orders among an agent society consisting of shipping companies and their trucks. The multi-agent paradigm is a central and powerful paradigm. Its application for collaborative planning is limited only by the methodology used to build the model and the decision mechanisms integrated in the agents.

This previous classification has a practical interest to give a simplified view of the domain. However, it must be noted that many approaches are developed at the cross between each category. For instance, the multi-agent paradigm can also be used to implement some game-theory principles.

2.2. Production and distribution planning

Reviews [12,13,23] have indicated that most studies focus on the formulation of an integrated production- and distribution-planning model. Barbarosoglu and Ozgur [5] developed a mixed-integer linear programming model solved by Lagrangian and heuristic relaxation techniques to transform the problem into a hierarchical two-stage model: one for production planning and another for transportation planning. Dhaenens-Flipo and Finke [9] developed a mixed-integer linear programming-based planning model in a multi-firm, multi-product and multi-period environment in

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