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Collaborative shipping under different cost-sharing agreements

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ABSTRACT

We study collaborative shipping where two shippers bundle their shipments to share the same transportation vehicle (also known as co-loading). The goal of such a collaboration is to reduce the total number of transports, thereby reducing transportation costs and CO₂ emissions. To synchronize the replenishment of both companies, we adopt a can-order joint replenishment policy for both companies, and we analyze how the costs of each individual company are impacted by the collaboration. We consider different agreements to redistribute the costs (or the gains) of the collaboration, ranging from no cost redistribution at all, sharing the transportation costs (or its gains) only, to sharing the total logistics costs (or its gains) that are impacted by the collaboration, i.e., transportation + inventory costs. We show that the stability (and thus the long-term viability) of the partnership strongly depends on the cost-sharing agreement, in combination with the allocation mechanism used to share the costs (or gains) of the coordination. Although most companies focus on the redistribution of transportation costs, we show that this might not lead to a stable situation where each individual company eventually benefits from collaboration.

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1. Introduction

Collaborations in the supply chain have proven to be a successful means to reduce logistics costs within one and the same supply chain (Goyal & Gupta, 1989). This type of *vertical* supply chain collaborations are typically established between suppliers and buyers. *Horizontal* collaborations, on the other hand, are established between companies that operate at the same level in different supply chains, i.e., between suppliers or between buyers. Sharing transportation capacity when moving freight is an example of this type of horizontal collaboration, an option that benefits the environment and yields substantial network efficiencies (Saenz, 2012). Cruijssen, Cools, and Dullaert, (2007a); Cruijssen, Dullaert, and Fleuren, (2007b) review the literature on horizontal cooperation in transport and logistics and highlight its opportunities and impediments.

These horizontal collaborative shipping agreements are gaining attraction in today's business world. By bundling or co-loading transport shipments, the available space in transportation vehicles can be utilized more efficiently. A 2009 World Economic Forum re-

port indicates that 24% of “goods vehicles kms” in the EU are running empty. When carrying a load, vehicles are typically loaded for only 57% of their maximum gross weight (Doherty & Hoyle, 2009). This problem of low utilization rates is getting worse. The total cost was estimated at 160 € billion in 2012, compared to 120 € billion in 2001 (Saenz, 2012). After optimizing internally, companies now look for opportunities beyond their own walls. That is why companies have started co-loading or bundling their shipments, by setting up partnerships with other shippers, whether or not they are direct competitors, with the objective to further reduce transportation costs and CO₂ emissions. Vanovermeire, Sörensen, Van Breedam, Vannieuwenhuysse, and Verstrepen (2014) report on some recent (successful) horizontal logistics alliances.

A collaboration agreement is usually set up to maximize the gains of the partnership. However, in order to have a stable (i.e., successful and sustainable in the long term) collaboration, each company should be able to reduce its individual costs, otherwise there is no incentive to participate. This means that not only the total logistics cost of the coalition should be reduced, the individual performance of each company is equally important, compared to the stand-alone situation where there is no collaboration. Therefore, an agreement can be made to either redistribute the (joint) collaboration costs to each company according to a partition rule, or to allocate the gains of the collaboration among each participating company. A wide range of possible cost and/or

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gain sharing allocation mechanisms are available for this purpose. Besides the selected allocation mechanism, the companies also need to agree on which set of costs (or gains) will be redistributed. In most horizontal logistics alliances, the primary focus has always been on (gains and allocations of) the transportation costs. However, the synchronization of shipments also impacts each company's inventory holdings. To maximize the gains of collaborative shipping, the collaborating partners are required to be flexible: they have to replenish their inventories either sooner or later than originally planned in order to benefit from joint transport. It may thus occur that a company reduces its transportation costs at the expense of higher inventory levels. Therefore, one should look at the total logistics costs resulting from the collaboration, as both transportation and inventories are impacted by the collaboration.

In this article, we analyze each company's transportation and inventory cost performance when they set up a collaborative shipping agreement that maximizes the coalition gains (i.e., minimizes the total joint logistics costs). We consider four types of cost-sharing agreements:

1. Each company pays for its own transportation and inventory costs, and no costs or gains are redistributed. When company i joins the transport organized by company j , then company i does not pay for it; when company j joins the transport of company i , company j does not pay for it neither.
2. When multiple companies share space on the same vehicle (or any other transportation mode), they can decide to share the costs of the vehicles, which we denote as the *major* transportation costs. When the shipments do not have the exact same origin and/or destination, they may be consolidated using multi-stop truckloads. Under this agreement, each shipper pays for their own handling, or *minor* transportation costs to accommodate for its individual pick-up and/or drop-off. Each company also pays for its own inventory holding costs.
3. Given that the benefits in joint major transportation costs are not possible without the multi-stop pick-ups, companies may agree to share and redistribute the total transportation costs, which is the sum of both major and minor transportation costs. Again, each company pays for its own inventory holding costs.
4. Finally, we consider the case where all logistics costs that are impacted by the coordination are redistributed. This means that both transportation as well as inventory holding costs are accounted for in the partnership, and either the total logistics costs or gains are redistributed among the participating companies.

The objective of this article is to investigate how the stability (and thus the long-term viability) of the collaborative shipping agreement is impacted by the cost-sharing agreement and the allocation mechanism used to share the costs or gains of the collaboration. We study a simplified setting with two companies. We assume that both companies sell a single item and the demand for each item follows an independent Poisson process. A can-order policy is used to synchronize the orders, and to enable joint replenishment of both companies. Assuming zero lead times, a Markov model is used to quantify the individual cost performance of transportation and inventory holdings under the can-order policy.

The article is structured as follows. Section 2 discusses the literature related to our work. Section 3 describes the analysis to quantify the transportation and inventory costs of each company when they adopt the can-order policy to synchronize orders, or when they operate independently. Section 4 discusses the cost-sharing agreements and the allocation mechanisms to distribute the costs or gains of the collaboration. Section 5 presents the results of an extensive computational experiment, and Section 6 concludes.

2. Related literature

In this article, we adopt a joint replenishment policy to synchronize orders of different shippers in a collaborative shipping agreement. The Joint Replenishment Problem (JRP) is a common problem in inventory-management literature, dealing with the synchronization of orders of different items within one and the same company. The goal of the JRP is to identify an order policy that minimizes inventory and ordering costs. The JRP usually assumes that there is a major and a minor order cost: the major cost is incurred each time an order is placed whereas the minor cost is incurred for each item that is added to the order. The JRP literature is rich: it can be divided into deterministic vs. stochastic models and periodic- vs. continuous-review models. We refer to Goyal and Satir (1989) and Khouja and Goyal (2008) for an overview of the JRP literature.

Ignall (1969) has shown that, even in a setting with zero lead times, the optimal JRP policy is not straightforward (e.g., the order quantity of one product can depend on the inventory level of another product). In this article, we focus on one particular class of JRP policies: the can-order policy. The can-order policy was first introduced by Balintfy (1964) and is a natural extension of the (S, s) policy with a third parameter: the can-order level c . In Section 3, we describe the control mechanisms of the can-order policy in greater detail.

Although the control mechanism of the can-order policy is rather simple, the interaction between the products makes determining the optimal parameters difficult. Silver (1974), Silver (1981), Federgruen, Groenevelt, and Tijms (1984); Thompstone and Silver (1975), and others suggest to decompose the N -item problem into N single-item problems by representing the joint orders as "special discount opportunities" that incur a reduced set-up costs for all the other items after item i has been ordered. As such, the discount opportunity for a given item is the superposition of the order processes of all other items. However, since the order decisions at one company depend on the inventory level of the other company, analyzing each company's inventory system separately results in a model that is no longer exact. The algorithm of Silver (1974) with Poisson demand and constant lead times is closest to our setting; however, their approach tends to overestimate the joint cost. The decomposition approach of Silver (1981); Thompstone and Silver (1975) and Federgruen, Groenevelt, and Tijms (1984) approximates the number of joint orders by means of a Poisson process; Schultz and Johansen (1999) show (using simulation) that the Erlang- r distribution provides a better fit for the time between two joint orders – they find that in most cases, their approach outperforms the approach of Federgruen, Groenevelt, and Tijms (1984). However, it is evident that the number of joint orders of each company is not independent, which means that the decomposition approach will always remain an approximation.

In this article, we do not decompose the problem into two single-item inventory systems. We use a Markov chain with two dimensions instead of only one (i.e., for each additional item an extra dimension is required to keep track of its inventory level). This approach allows us to obtain exact cost figures. Our solution approach is closely related to the two-item models presented in Kayaş, Bilgiç, and Karabulut (2008) and Timmer, Chessa, and Boucherie (2013). Kayaş, Bilgiç, and Karabulut (2008) model the two-item problem with positive lead times of equal length and an identical demand and cost structure (but different penalty costs for each company). Timmer, Chessa, and Boucherie (2013) present a two-company coordination model where each company has an independent Poisson demand process and zero lead times. However, they do not include minor order costs, and consequently both companies *always* order jointly if one of the two reaches its respective reorder point (this policy coincides with a can-order policy where

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