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Decision Support

Measuring and rewarding flexibility in collaborative distribution, including two-partner coalitions ☆

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ABSTRACT

Horizontal collaboration among shippers is gaining traction as a way to increase logistic efficiency. The total distribution cost of a logistic coalition is generally between 9% and 30% lower than the sum of costs of each partner distributing separately. However, the coalition gain is highly dependent on the flexibility that each partner allows in its delivery terms. Flexible delivery dates, flexible order sizes, order splitting rules, etc., allow the coalition to exploit more opportunities for optimization and create better and cheaper distribution plans.

An important challenge in a logistic coalition is the division (or sharing) of the coalition gain. Several methods have been proposed for this purpose, often stemming from the field of game theory. This paper states that an adequate gain sharing method should not only be fair, but should also reward flexibility in order to persuade companies to relax their delivery terms. Methods that limit the criteria for cost allocation to the marginal costs and the values of the subcoalitions are found to be able to generate adequate incentives for companies to adopt a flexible position. In a coalition of two partners however, we show that these methods are not able to correctly evaluate an asymmetric effort to be more flexible. For this situation, we suggest an alternative approach to better measure and reward the value of flexibility.

1. Introduction

Horizontal collaboration is defined as collaboration that occurs between companies that operate on the same level of the supply chain (European Commission, 2011). Horizontal logistic collaboration can take on many forms (Verstrepen, Cools, Cruijssen, & Dullaert, 2009). The focus in this paper is on coalitions in which several shippers outsource the delivery of their goods to a single third-party logistics provider (3PL). The 3PL organizes the delivery of the orders of all companies, and all companies allow their orders to be distributed in the same trucks as those of their partners. This strategy differs from a simple bundling of orders by the logistics service provider itself, because the benefits, costs and risks are shared among the partners, and the long-term-nature and commitment of a horizontal logistic coalition allow for continuous improvement (Slone, Dittman, & Mentzer, 2010).

One of the main positive effects of horizontal logistic collaboration is the achievement of economies of scale by transporting more volume in each trip and reducing the number of redundant trips. Several successful pilot cases have been started, that prove that this concept is viable. Examples are collaborative networks of inland waterways (Wiegmans, 2005), but also consumer goods manufacturers that optimize their distribution networks collaboratively (Bahrami, 2002), as well as 3PLs (Cruijssen, Cools, & Dullaert, 2007). Other applications vary from wood bartering in Sweden (Frisk, Göthe-Lundgren, Jörnsten, & Rönnqvist, 2010) to combining long-haul shipments from a plastic manufacturer and a steel-manufacturer from Germany to the Czech Republic (Verstrepen & 't Hooft, 2011), and horizontal collaboration among airline carriers (Oum, Park, Kim, & Yu, 2004). Moreover, there are an increasing number of papers creating the necessary frameworks for horizontal collaboration. They address issues such as the role of third party logistics providers in collaborative networks (Stefansson, 2006), the estimation of risk, benefits and environmental impact, and a multi-criteria method to support decision-making in collaborative urban freight systems (Gonzalez-Feliu & Salanova, 2012), and coordination mechanisms and benefit sharing (Audy, Lehoux, D'Amours, & Rönnqvist, 2010). However, many barriers still impede a widespread adoption of horizontal collaboration. Cruijssen, Dullaert, and Joro (2006) list the following main impediments: "finding and trusting appropriate partners", "determining and dividing the gains", "difficulties during the negotiation process", and "the absence of the right coordination and ICT-mechanisms".

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In this paper, the focus is on the second impediment listed by Cruijssen et al. (2006), i.e. determining and dividing the coalition gains. In general the total distribution cost of a coalition that bundles orders is significantly lower than the sum of the individual companies' costs. This is due to a more effective use of truck capacity, or, when using a logistics service provider, better rates due to higher volumes. A challenge is that the difference between the sum of all stand-alone costs and the coalition cost (i.e., the coalition *gain*) has to be distributed back to the partners. For this purpose, a *cost allocation method* has to be used. In Section 2 we give an overview of cost allocation methods found in the literature.

An important aspect influencing the coalition gain is the flexibility in delivery terms allowed by the partners. Allowing deliveries to be shifted in time rather than specifying a precise delivery date, allowing the pallets or boxes of a single order to be split across multiple trucks rather than forcing them to be delivered in the same truck, and so on, are good examples of such flexible delivery terms. All contribute to the optimization opportunities for the coalition and thus lead to a larger consolidation gain.

Companies that relax their delivery terms contribute more to the total reduction in cost than companies that do not. This paper states that, in order to encourage flexibility, such partners should therefore be awarded a larger portion of the gain (or, should be allocated a smaller cost). We find that methods limiting the criteria for cost allocation to the marginal costs and the values of the subcoalitions are the most adequate cost allocation methods to reward flexibility. This is demonstrated in Section 3.

In Section 4 however, we show that in small coalitions in which the effort delivered to be flexible is asymmetric and flexibility is perceived as having some (perhaps hidden) cost, those methods can easily be perceived as unfair. For this case, we develop a method to more accurately measure the added value for the coalition of a partner relaxing its delivery terms and changing from a rigid position to a flexible one. Section 5 presents some conclusions and remarks.

2. Cost allocation methods and fairness criteria

Although intuitively clear, an operational definition of the concept of *fairness* is difficult to create. Moreover, fairness may be perceived differently by different partners in a strategic coalition. Still, the literature on co-operative game theory has developed a number of characteristics (fairness criteria) that a cost allocation (or gain sharing) method should possess in order to be considered "fair".

Leng and Parlar (2005) give an overview of papers in which co-operative game theory is used in supply chain collaboration problems. After a thorough review of the literature, the authors demonstrate that collaborative supply chains present a perfect application for game theory. Collaborative supply chains consist of companies that make their own decisions, but doing so, influence the total supply chain performance. Co-operative game theory correctly assumes that collaboration will yield gains when compared to each company working individually, and focuses on how to create and divide these gains.

The concepts from game theory can readily be transferred to the setting of collaborative distribution. Given is a set of $|N|$ companies (players i), each having a stand-alone distribution cost $c(i)$, representing the cost that has to be paid by company i to deliver all its orders. The grand coalition N is defined as the coalition of all companies.

For any (sub)coalition (or group) $S \subseteq N$, there exists a distribution cost $c(S)$ that has to be paid in order to deliver all the orders of all the companies in the coalition. In this case, we assume that the distribution cost of a (sub)coalition is equal to the sum of the cost of all trips needed to deliver the pallets q of all partners of that (sub)coalition. A profit $v(S) \geqslant 0$ is defined as the difference between the sum of the stand-alone distribution costs and the global coalition distribution cost, i.e., $v(S) = \sum_{i \in S} c(i) - c(S)$. The profit of a partner working alone is thus $v(i) = 0$. This profit can be achieved by bundling orders, i.e., by allowing orders of different companies to be transported in the same trips. We assume subadditivity ($c(i+j) \leqslant c(i) + c(j), \forall i, j$), which implies that a player can not add more cost to the coalition than its original stand-alone cost.

The aim of a cost allocation method is to divide the total cost of the grand coalition $c(N)$ in such a way that each player i pays an individual cost φ_i and considers this to be fair. The difference between a company's stand-alone cost and its allocated cost $(c(i) - \varphi_i)$ is called its *gain*. Because the sum of all gains is equal to the difference between the sum of all stand-alone costs and the total coalition cost, allocating the total coalition cost is equivalent to allocating the total coalition gain. For this reason, cost allocation methods are sometimes called *gain sharing* methods. In practice, cost allocation or gain sharing is done by a method (which may be a simple rule) that is agreed upon by all partners of the coalition. For an overview of the notations and characteristics of the cost and profit function, see Table 1.

The most fundamental axioms of co-operative game theory, state that a cost allocation should satisfy *Pareto-efficiency* and *individual rationality*. The first axiom enforces that the allocation is such that no player can reduce its costs without adding additional costs to the other players. The latter requires that no player will benefit from working alone and will therefore refuse to collaborate. When these axioms are fulfilled, such an allocation is generally called an *imputation*. As this is not guaranteed for all methods, we use the more general term allocation (Moulin, 1988).

Frisk et al. (2010) sum up the following list of possible cost allocation methods in horizontal logistical coalitions:

- *Activity-Based Costing* (ABC) allocates the coalition cost according to different cost drivers and activities. Investigating which activities cause costs and how to divide those costs is often time-consuming. In this paper, we assume that an activity is a trip executed and the cost driver is the number of trips, as well as the number of pallets in that trip. This means that per trip, we will allocate the costs of that specific trip proportionally to the number of pallets that a company has in that trip.

$$\varphi_i^{\mathrm{ABC}} = \sum_t \frac{q_{i,t}}{\sum_{j \in N} q_{j,t}} \tag{1}$$

- The *Equal Charge Method* allocates the *separable costs* (i.e., the marginal costs of each partner joining the final coalition) in their totality. The *non-separable costs* (the remaining costs) is allocated in an equal way.

Table 1
Important notations and the characteristics of the cost and profit function.

Notation	
N	The grand coalition
$S \subseteq N$	A subcoalition
$c(S)$	Cost of subcoalition S
$v(S)$	Profit in subcoalition S
φ_i	Allocated cost to partner i
$q_{i,t}$	Number of pallets of partner i in trip t
Characteristic function	
$\sum_{i \in S} \sum_{t \in S} q_{i,t} = c(S) \quad \forall S$	
$v(S) = \sum_{i \in S} c(i) - c(S) \quad \forall S$	
$v(S) \geqslant 0 \quad \forall S$	
$c(i+j) \leqslant c(i) + c(j) \quad \forall i, j$	