

A Capacity Game in Transportation Management

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Emerging concerns about competitiveness induce a growing number of firms to outsource their outbound transportation operations to third-party logistics providers. The resulting increase in the number of actors often leads to sub-optimal supply chain actions due to the antagonistic nature of the economic objectives of the partners. With the aim of determining possible deviations from the optimal system performance in such supply chains, this study analyzes the contractual relation between a retailer and a third-party logistics provider (carrier) using game theoretical approaches.

We consider a two-level supply chain with a carrier and a retailer. The retailer, R , owns a warehouse, where an infinite quantity of a single item is stored, and a store which faces a stochastic demand for this item. The carrier, C , is in possession of an infinite number of trucks. The problem is to determine the number of trucks that will be reserved for the deliveries between the warehouse and the store before the uncertainty is resolved. Backorders are allowed but the retailer must satisfy a minimum proportion of the final demand, u , which is determined exogeneously. Moreover, each truck used has a maximum load, $maxcap$.

Different costs are incurred during the process. First, the carrier pays a fixed price c_1 per truck reserved before uncertainty is resolved. Once demand is realized, if the number of trucks is insufficient, the carrier has the opportunity to requisition additional trucks at a higher price $c_2 > c_1$. Finally, each item shipped incurs a transportation cost r and is sold at the price of s .

In order to ensure a minimum service level, the retailer submits a contract to the carrier. This contract is composed of two terms (a, p) where a is the amount paid by the carrier per truck effectively used by the carrier and p is the price paid per item transported.

In this Stackelberg game, the following sequence of events occurs : before the demand is realised, (1) the retailer proposes the contract to the carrier ; (2) if the carrier accepts this contract, he decides how many trucks he reserves ; once the demand is known, (3) the carrier decides to requisition additional trucks or not and to satisfy the whole or a fraction of the demand following the contract specifications.

Finally, the problem faced by each member of the supply chain is the following. The carrier has a two-stage problem. In the first stage, when demand is still uncertain, he has to decide the capacity that he reserves, Y . In the second stage, when demand x is known, he decides the additional capacity, Z , obtained by requisitioning trucks and the quantity that he transports, Q . He also has some constraints. Each truck cannot carry more than $maxcap$ items. The carrier must at least satisfy a minimum proportion of the demand, $u.x$, but he cannot transport more than the demanded amount. On the other side, the retailer's profit depends on the quantity shipped, Q , on the number of backorders, V and on the number of trucks used, $Y + Z$. Beside the nonnegativity constraints, the retailer only has to ensure that the carrier accepts the contract. In order to simplify the computations, we suppose that all the decision variables Y , Z , Q and V are continuous.

We first determine the optimal contract for the retailer and how the whole system behaves under this contract. To obtain the optimal values of the two parameters a and p , we study the carrier's reaction to any proposed contract by the retailer. After, knowing the carrier's response function, we are able to compute the optimal values of a and p for the retailer. Finally, we compare this situation with a centralized model where a single decision maker manages everything.

Numerical analysis are conducted to study the effects of capacity, variability of demand, reservation and requisition costs. The results show that the contract may coordinate the supply chain under some conditions on the parameters. In most cases, the gap between the optimal benefits of the centralized model and the decentralized model is small. As the Stackelberg leader, the retailer captures the greatest part of the profits.

Références

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