The Transshipment Fund Mechanism: Coordinating the Decentralized Multi-Location Transshipment Problem

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Abstract
The multi-location replenishment and transshipment problem is concerned with several retailers facing random demand for the same item at distinct markets, that may use transshipments to eliminate excess inventory/shortages after demand realization. When the system is decentralized so that each retailer operates to maximize their own profit, there are incentive problems that prevent coordination. These problems arise even with two retailers who may pay each other for transshipped units. We propose a new mechanism based on a transshipment fund which is the first to coordinate the system, in a fully non-cooperative setting, for all instances of two retailers as well as all instances of any number of retailers. The computation and information requirements of this mechanism are realistic and relatively modest. We also present necessary and sufficient conditions for coordination and prove they are always satisfied with our mechanism.

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Transshipments, the movement of stock in the same echelon level, are often used among retailers in practice as a means to increase their profits. Typically, when demands are realized, a retailer facing excess supply transships one or more units to another retailer who is facing excess demand, provided that the cost of doing so is not higher than that of incurring the holding and shortage costs, respectively. A transshipment policy refers to the set of rules used to determine how many units should be transshipped from one retailer to another in different scenarios, if at all. An associated replenishment policy refers to the set of decisions used to determine how many units should be ordered by each retailer from the supplier, while considering the possible use of future transshipments. We refer to the combined decision of determining the replenishment and transshipment policies as the transshipment problem.

Early studies of transshipment problems in the literature considered centralized systems in which a single decision maker acts so as to maximize the total profit of the entire system, see, for example, Herer at el. (2006). In decentralized systems each decision maker operates so as to maximize their own profit, a setting which often results in inefficiencies. It is then desirable to achieve coordination, i.e. motivate the decision makers to act as in the centralized system while still maximizing their own profit. One way to coordinate the system is to allow transfer payments among the decision makers based on their actions. The question which is therefore addressed is what set of transfer payments, referred to as a mechanism or a contract, will achieve this goal.

The work of Rudi et al. (2001) focuses on direct transfer payments between two retailers in the form of unit transshipment prices. Hu et al. (2007) show with a counter example, that such coordinating prices do not always exist and demonstrate this limitation for a wide range of instances. In this paper we extend the domain of problems that Rudi et al.'s mechanism can coordinate.

The contributions of this paper are the following. First, we develop a new mechanism based on a contract between the retailers and a transshipment fund. The transshipment fund in this mechanism is owned by a third party, who manages an account according to
the contract. The account is ‘opened’ by the retailers and subsequently used for financing or rewarding the transshipment activity through payments between the fund and the retailers. The coefficients in these payments can be interpreted as buying and selling prices that depend on the pair of retailers involved in the transaction. This is the first coordinating mechanism for all instances of two retailers and also for all instances of any number of retailers. Second, we present necessary and sufficient conditions for coordination and prove that they are always satisfied with our mechanism. Third, this is the first model formalizing transshipments in a fully non-cooperative setting while achieving coordination under realistic computation and information requirements, where the latter are less demanding than existing mechanisms. Our fully non-cooperative mechanism does not suffer from the disadvantage of many cooperative allocation rules that in general have to rely on a high degree of group rationality, in particular the complete information sharing between decision makers regarding order quantities and demand realizations. Finally, numerical illustration is provided for several instances of the problem with two retailers, showing the payments made between the transshipment fund and the retailers for each unit transshipped.

The use of a transshipment fund can be viewed as a third party financing arrangement. In our mechanism, the third party is a financial entity executing the transshipment related monetary transactions specified in the contract. The third party could be either a sub-contractor serving the system by operating the transshipments and profiting from the transshipment fees, or the supplier, in which case there are natural incentives for participation in order to motivate transactions among and with the retailers. Alternatively, the third party could be paid a (small) portion of system profits to motivate participation. We believe that the idea behind our innovative mechanism may be an important step towards achieving coordination in other decentralized systems in practice as well.

References