Available online at www.sciencedirect.com
ScienceDirect
European Journal of Operational Research 187 (2008) 785–805
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH
www.elsevier.com/locate/ejor

Quantifying the value of buyer–vendor coordination: Analytical and numerical results under different replenishment cost structures ☆

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Received 12 September 2005; accepted 30 May 2006
Available online 13 November 2006

Abstract

Despite a growing interest in channel coordination, no detailed analytical or numerical results measuring its impact on system performance have been reported in the literature. Hence, this paper aims to develop *analytical* and *numerical* results documenting the system-wide cost improvement rates that are due to coordination. To this end, we revisit the classical buyer–vendor coordination problem introduced by Goyal [S.K. Goyal, An integrated inventory model for a single-supplier single-customer problem. International Journal of Production Research 15 (1976) 107–111] and extended by Toptal et al. [A. Toptal, S. Çetinkaya, C.-Y. Lee, The buyer–vendor coordination problem: modeling inbound and outbound cargo capacity and costs, IIE Transactions on Logistics and Scheduling 35 (2003) 987–1002] to consider generalized replenishment costs under centralized decision making. We analyze (i) how the counterpart centralized and decentralized solutions differ from each other, (ii) under what circumstances their implications are similar, and (iii) the effect of generalized replenishment costs on the system-wide cost improvement rates that are due to coordination. First, considering Goyal's basic setting, we show that the improvement rate depends on cost parameters. We characterize this dependency *analytically*, develop analytical bounds on the improvement rate, and identify the problem instances in which considerable savings can be achieved through coordination. Next, we analyze Toptal et al.'s [A. Toptal, S. Çetinkaya, C.-Y. Lee, The buyer–vendor coordination problem: modeling inbound and outbound cargo capacity and costs, IIE Transactions on Logistics and Scheduling 35 (2003) 987–1002] extended setting that considers generalized replenishment costs representing inbound and outbound transportation considerations, and we present detailed numerical results quantifying the value of coordination. We report significant improvement rates *with* and *without* explicit transportation considerations, and we present numerical evidence which suggests that larger rates are more likely in the former case.

Keywords: Channel coordination; Coordination mechanisms; Joint lot-sizing; Cargo/truck costs; Cargo capacity; Vendor-managed inventory

☆ This research was supported in part by NSF Grant CAREER/DMII-0093654.
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0377-2217/$ - see front matter
doi:10.1016/j.ejor.2006.05.047

1. Introduction and related literature

The buyer–vendor coordination problem is one of the classical research areas in the multi-echelon inventory literature. A fundamental stream of research in this area, known as *centralized modeling*, recommends integrating and solving the decision problems of the buyer and the vendor together, e.g., [2,4–6,8]. Although this approach provides the best result in terms of total system-wide profit/cost, it may not be feasible or desirable in many practical cases due to incentive conflicts. The alternative approach, known as *decentralized modeling*, suggests that the buyer and the vendor solve their decision problems independently of each other. However, the total system profits resulting from the centralized approach are superior to those resulting from the corresponding decentralized approach.

In other words, decentralized models often result in lost profits for the system when compared to centralized models. As a remedy, another line of research in the literature proposes an alternative approach that relies on using the profit/cost gap between the centralized and decentralized approaches as an inducement to improve decentralized solutions, e.g., [9,10,12]. This alternative approach, known as *channel coordination*, requires the decentralized solution to be improved in a way that (i) it results in the same values for the decision variables as the centralized solution, and (ii) it suggests a mutually agreeable way of sharing the resulting profits. The sharing can be done by means of quantity discounts, rebates, refunds, and fixed payments between the parties, or some combination of these. All of these methods represent different forms of incentive schemes, or so-called *coordination mechanisms*, whose terms can be made explicit under a contract. Consequently, the output of channel coordination, i.e., the *coordinated solution*, combines the benefits of both centralized and decentralized solutions.

Despite a growing interest in channel coordination over the past few decades [1,4,9,10,15,12,14], no detailed analytical or numerical results measuring its impact on system performance have been reported in the literature. For this reason, we revisit the classical buyer–vendor coordination problem introduced by Goyal [4] (called Goyal's Problem from now on) and extended by Toptal et al. [13]. Goyal's basic setting assumes that both the buyer and the vendor operate under the assumptions of the deterministic constant demand EOQ model with the traditional inventory holding and fixed replenishment costs. Toptal et al. [13] take a broader view of this setting to consider generalized replenishment cost structures representing inbound and outbound transportation considerations. More specifically, Toptal et al. [13] first consider the case where the *vendor's replenishment cost* includes a stepwise inbound transportation cost component, representing the cargo cost (called Problem I from now on). They then extend the problem setting to consider the case where *both the vendor and the buyer* are subject to stepwise transportation costs (called Problem II from now on). Clearly, Goyal's Problem is a special case of Problems I and II, and the current paper is aimed at providing *analytical* and *numerical* results documenting the system-wide cost improvement rates that are due to coordination in all of these three problem settings . Since Toptal et al. [13] focus on centralized models *only* and Goyal [4] does not investigate channel coordination mechanisms, here we investigate the counterpart decentralized models, develop effective channel coordination mechanisms, and quantify the value of channel coordination through a comparison of the counterpart centralized and decentralized solutions of Problems I and II as well as Goyal's Problem.

Making an analytical comparison of the centralized and decentralized solutions for Goyal's Problem for certain parameter ranges, we are able to develop analytical results[1] representing the improvement rates resulting from channel coordination. These analytical results are useful in characterizing the relationship between the improvement rates and the underlying model parameters that have a direct impact on the magnitude of these improvements. Our analytical results reveal two important insights. First, the value of coordination depends on two important ratios that can be expressed in terms of the critical cost parameters. Secondly, the value of coordination does not depend on the demand rate, i.e., the demand rate is not a critical model parameter for our purposes. Furthermore, by developing bounds on the improvement rates, we identify the problem instances for which considerable savings can be achieved through coordination. However, unlike Goyal's Problem, insightful analytical results, representing the improvement rates due to channel coordination, cannot be obtained for Problems I and II, i.e., under generalized replenishment costs. Hence, in these cases, we rely on a detailed numerical study for quantifying the value of coordination.

[1] See Corollary 1 and Proposition 5.