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An integrated vendor-managed inventory model for a two-echelon system with order cost reduction

Tinglong Zhang[a,b,*], Liang Liang[a], Yugang Yu[a], Yan Yu[a]

[a]Management School, University of Science and Technology of China, HeFei, AnHui 230026, PR China
[b]Institute of Economics and Management, Anhui Normal University, WuHu, AnHui 241000, PR China

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Abstract

Simultaneously reducing inventory levels of raw materials, work-in-process, and finished items has become a major focus for supply chain management. In order to achieve a higher degree of coordination and automation among the supply chain parties, the supply chain sometimes invests in reducing the ordering cost to streamline and speed up transactions via the application of information technology. In this paper, an integrated vendor-managed inventory (VMI) model is presented for a single vendor and multiple buyers, where the vendor purchases, and processes raw materials and then delivers finished items to multiple buyers. A joint relevant cost model is developed with constant production and demand rates under the assumption that the buyers' ordering cycles may be different and that each buyer can replenish more than once in one production cycle, in which the investment decision is also considered. A solution procedure of the optimal investment amount and replenishment decision for all the buyers and the vendor is proposed. Three numerical examples with an exponential ordering cost function are presented to provide insight.

Keywords: Inventory; Vendor-Managed Inventory (VMI); Integrated model; Multiple buyers

1. Introduction

In a competitive market, a buyer has the privilege of deciding the ordering cycle. But the optimal ordering cycle favored by the buyer may not be the most economical for the vendor. In order to streamline the supply chain, the vendor is expected to synchronize his production cycle, as well as his raw material procurement cycle, with the buyers' ordering cycles, so that the total inventory cost for the entire chain can be reduced. The problem considered in this paper concerns a single vendor supplying multiple buyers with a product. Each buyer has to meet a fixed external demand, with backlogging allowed. The vendor purchases raw materials in batches and each batch is used as a production lot size. The buyers' ordering cycles may be different, and each buyer can replenish more than once in a single production cycle. We also consider a situation in which vendor and buyers decide upon an investment in ordering cost reduction and coordinate their inventory policies to

*Corresponding author. Institute of Economics and Management, Anhui Normal University, WuHu, AnHui 241000, PR China. Tel.: +86 05533875220.
E-mail address: ztlustc@gmail.com (T. Zhang).

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minimize their joint average annual cost. Ours is an extension of Woo et al. (2001), but we relax their assumption that the cycle times for all buyers and the vendor are the same, i.e., a common cycle.

The cooperation between vendor and buyers for improving the performance of inventory control has received a great deal of attention, and the integration approach has been studied for years. For example, Banerjee (1986) developed a joint economic lot size model for a single-buyer, single-vendor system with a lot-for-lot policy. Goyal (1988) generalized Banerjee's model (1986) by relaxing the assumption of the lot-for-lot policy. Lu (1995) improved the policies proposed by Banerjee and Goyal, by assuming that the delivery quantity to the buyer is identical at each replenishment. Goyal (1995) proposed a policy in which the delivery quantity to the buyer is not identical at each replenishment. Viswanahtan (1998) compared the above two policies and proved that there is no strategy that obtains the best solution for all possible problem parameters. Ha and Kim (1997) analyzed the integration between buyer and supplier by setting up a mathematical model in which the inventory cost of the vendor is derived through a discontinuous sawtooth function. Yang and Wee (2000) developed an integrated economic ordering policy for deteriorating items for vendor and buyer. Wu and Wee (2001) considered multiple lot size deliveries in the model proposed in Yang and Wee (2000). Ouyang et al. (2004) presented a single-vendor single-buyer integrated production inventory model under the assumption that lead time demand is stochastic and the lead time can be reduced at an added cost. But whereas these studies focused on joint lot sizing and vendor–buyer coordination, the case of multiple buyers was overlooked, except in Lu (1995).

In recent years, several authors have studied integrated inventory models for a single vendor and multiple buyers. Yang and Wee (2002) generalized Wu and Wee (2001) by considering a single vendor and multiple buyers. Yang and Wee (2003) extended the model proposed in Yang and Wee (2002) by taking into account raw material inventory. Yu et al. (2004) considered raw materials procurement decisions and proposed an integrated inventory model for the supply chain in which a single vendor supplies a single deteriorating item to multiple buyers with a common replenishment cycle. Jalbar et al. (2005) studied a multistage distribution/inventory system with a central warehouse and multiple retailers. They developed a heuristic for computing near-optimal integer-ratio policies to minimize the overall cost in the system.

Most previous work on integrated vendor–buyer inventory systems does not consider ordering cost reduction. It has been a trend for firms to invest in logistics technology and methodology development in order to gain competitive advantage from lowered logistics costs and customer loyalty. For example, it is possible to reduce ordering cost and time by using third-party logistics and vendor-managed inventory. Applying electronic data interchange (EDI) not only links, but also automates the ordering, shipping, inquiring, and payment activities between vendor and buyers. Porteus (1985) considered investment in reduced setups in the EOQ model. Billington (1987), Kim et al. (1992) and Coates (1996) developed EPQ models with setup cost reduction. However, these researchers investigated the benefit from order or setup cost reduction from a single party's viewpoint. As shown by Gottardi and Bolisani (1996), the implementation of logistics technology and methodology needs both trading partners to interchange transaction documents, to standardize transaction procedures, and to integrate related applications. Therefore, considering the dyadic vendor–buyer relationship is necessary for implementing an advantageous logistics system. Chang et al. (2006) studied one vendor–single buyer integrated inventory models with controllable lead time and ordering cost reduction. They considered two different situations. In the first, the ordering cost reduction has no relation to lead time crash; in the second, the lead time and ordering cost reduction interact. Two models were developed and an iterative algorithm was devised to determine the optimal solutions for both vendor and buyer. Banerjee and Banerjee (1992) considered an EDI-based system in which vendors make all replenishment decisions for their buyers to reduce joint inventory cost. Their work focused solely on the inventory policy by assuming that an EDI system has already been operating between vendor and buyers, and, hence, no ordering cost would be incurred by either party.

Woo et al. (2001) extended Banerjee and Banerjee (1992) to incorporate ordering cost reduction and raw material procurement into the integrated inventory decision. They investigated an integrated inventory system in which a single vendor purchases and processes raw materials to produce finished items and then delivers those finished items to multiple buyers with a common cycle time for all buyers and the vendor. In their paper, an analytical model was developed to derive the optimal investment amount and replenishment decisions for