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An optimal integrated vendor–buyer inventory policy under conditions of order-processing time reduction and permissible delay in payments

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ABSTRACT

This study deals with the order-processing cost reduction and permissible delay in payments problem in the single-vendor single-buyer integrated inventory model. We consider that the order-processing cost can be reduced at an extra crashing cost, which varies with the reduction in the order-processing time length . In addition, the buyer is allowed a fixed time period before they settle the account with the vendor. The objective of this study is to minimize the annual integrated total cost by optimizing simultaneously the delivery interval, the number of deliveries per order and the investment cost in order-processing time. An integrated total cost function is derived, and an algorithm procedure is proposed for determining the optimal decision variables. Finally, numerical examples are provided to illustrate the algorithm procedure.

1. Introduction

In order to streamline the supply chain, some vendors are expected to synchronize their production cycles with their buyers' ordering cycles so that the total inventory cost for the entire chain can be reduced. The cooperation between vendor and buyer for improving the integrated performance of inventory control has thus received a great deal of attention from researchers. The joint optimization concept for vendor and buyer was initially proposed by Goyal (1976). Subsequently, numerous researchers developed integrated inventory models under various assumptions. For example, Banerjee (1986) considered a joint economic lot size model that a vendor produces to order for a buyer on a lot-for-lot basis. Goyal (1988) relaxed the lot-for-lot policy and suggested that vendor economic production quantity should be an integer multiple of buyer purchase quantity. Hill (1997) introduced a general policy for the integrated production–inventory model in a supply chain system. Ha and Kim (1997) analyzed the integrated vendor–buyer inventory level using a graphical method and derived an optimal solution. Yang and Wee (2000) proposed an economic ordering policy of deteriorated item for the vendor–buyer integrated model. Huang (2002) considered an integrated vendor–buyer cooperative inventory model for items with imperfect quality under equal-shipment policy. Chung and Wee (2007) developed an integrated deteriorating inventory policy for a single-buyer single-supplier model with multiple just-in-time (JIT) deliveries considering the transportation cost, inspection cost and the cost of less flexibility. Ben-Daya et al. (2008) have recently presented a comprehensive and up-to-date review of the joint economic lot-sizing problem and also provided some extensions of this important problem. Many related articles can be found in Chen and Kang (2010); Ha (2010); Omar (2009); Zavanella and Zanoni (2009), and in their references.

In modern inventory management, ordering cost reduction is an important means to business success and has also attracted considerable research attention. Ordering cost reduction can be attained through procedural changes, worker training and specialized equipment acquisition (e.g., electronic data interchange (EDI) system). Porteus (1985) first introduced the concept and developed a framework for investing in reducing ordering cost in the economic order quantity (EOQ) model. Banerjee and Banerjee (1992) considered an EDI-based vendor-managed inventory system in which the vendor makes all replenishment decisions for his/her buyers to improve the joint inventory cost. Woo et al. (2001) extended the model of Banerjee and Banerjee (1992) to incorporate ordering cost reduction and raw material procurement into the integrated inventory decision. Chang et al. (2006) studied an integrated vendor–buyer inventory model with controllable lead time and ordering cost reduction. Zhang et al. (2007) presented an integrated vendor-managed inventory model for a two-echelon system with order cost reduction. The integrated model was an extension of Woo et al. (2001), but it relaxed their assumption of a common cycle time for all buyers and the vendor. The capital investment in reducing buyer's

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ordering cost is assumed a logarithmic function of the ordering cost. This function is consistent with the Japanese experience as reported in Hall (1983) and has been utilized in many researches (e.g., Porteus, 1985; Nasri et al., 1990; Paknejad et al., 1995; Chang et al., 2006; Hou, 2007). In case studies of industrial situation, Trevino et al. (1993) indicated that there are only a finite number of investment possibilities to reduce setup cost. For example, let us assume that new fixtures to facilitate lower setup will cost X dollars. Investing $0.9X$ dollars may accomplish nothing in setup cost reduction and spending $1.1X$ dollars will not help reduce setup costs anymore than spending X dollars. In addition, Sarker and Coates (1997) developed a method to determine the optimal amount of capital investment to reduce setup costs when there is a discontinuous investment–setup cost relationship. Therefore, the capital investment–setup cost level function may be discrete in reality. This paper will investigate the discrete case.

The above-mentioned integrated inventory models almost assumed that the buyer must be paid for the goods as soon as the goods are received. However, in some practical situations, the vendor may offer the buyer a fixed delay period, which is the trade credit period, in settling the accounts. This gives a very big advantage to the buyers because they do not have to pay the vendor immediately after receiving the goods, but instead, can delay their payment until the end of the allowed period. Therefore, the effects of supplier credit policies on optimal order quantity have received the attention of many researchers. There are two methods used in the research of the permissible delay in payments. Chand and Ward (1987) assumed that the delay of t periods in making the payment to the supplier is equivalent to a price discount and the buyer has to pay the vendor at the delay period. Other related articles can be found in Gupta (1988) and Huang et al. (2010). In general, once items are sold and before the replenishment account is settled, the generated sales revenue is deposited in an interest-bearing account for the buyer. At the end of this period, where the account is settled and the situation is reversed, the items still in stock have to be financed effectively at an interest rate. Based on this phenomenon, Goyal (1985) developed a model that differs from that of Chand and Ward (1987). Subsequently, Jamal et al. (1997) and Chang and Dye (2001) extended this issue with allowable shortage. Sarker et al. (2000) proposed a model to determine an optimal ordering policy for deteriorating items under inflation, permissible delay of payment and allowable shortage. Huang and Chung (2003) extended the Goyal's (1985) model to cash discount policy for early payment. Chang et al. (2003) and Chung and Liao (2004) dealt with the problem of determining the economic order quantity for exponentially deteriorating items under permissible delay in payments depending on the ordering quantity. Huang (2006) investigated the retailer's inventory policy under two levels of trade credit and limited storage space to reflect the real-life situations. Teng (2009) established an inventory lot-sizing model for a retailer who receives a full trade credit from its supplier and offers either a partial trade credit to its bad credit customers or a full trade credit to its good credit customers. It should be noted that most of the existing papers discussing the problem of permissible delay in payments are extensions of the Goyal's (1985) model.

From the above literature review, we found that though there is no shortage of those studying integrated vendor–buyer inventory models, ordering cost reduction and permissible delay in payments, but little work has been done on considering them simultaneously. Consequently, Huang et al. (2010) incorporate the Chand and Ward's view of trade credit and ordering cost reduction in the integrated inventory models. However, most papers discuss the problem of permissible delay in payments by the Goyal's (1985) model. In comparison with the Huang et al.'s (2010) model, we choose the different cost structure, which allowed the buyers settle the replenishment account before the end of the allowed period or after the period. The proposed model makes the scope of the application broader. The objective is to minimize the integrated total cost by optimizing simultaneously the delivery interval, the investment cost in order-processing time and the number of shipments. A solution procedure is developed to determine the optimal policy, and three numerical examples are employed to illustrate the results and the benefits of integration.

2. Notation and assumptions

To develop the integrated inventory model, the following notation and assumptions are adopted:

2.1. Notation

(1) Parameters:

D	Annual demand
R	Production rate, $R>D$
S_v	Setup cost per production run for the vendor
h_v	Unit stock-holding cost per item per year for the vendor
h_b	Unit stock-holding cost per item per year excluding interest charges for the buyer
p	Unit purchase price
F	Fixed transportation cost per shipment
U	Order-processing cost per unit time for the buyer
L_0	Original order-processing time per shipment
t	Permissible delay in settling accounts
I_c	Interest charges per dollar investment in stocks per year
I_d	Interest which can be earned per dollar per year, $I_c \geq I_d$

(2) Decision variables:

n	Total number of shipments in a batch from the vendor to the buyer, a positive integer
T	Time interval between successive deliveries
K	Expenditure per year to operate the planned ordering system between the vendor and the buyer, which is a decision variable and $K \geq 0$, $K=K_i$, $i=0,\ldots,m$, $K_0=0$

(3) Functions:

$L(K)$	Planning order-processing time per shipment, which is a strictly decreasing function of K, with $L(K)=L_0e^{-rK}$, where $K=K_i$, $i=0,\ldots,m$
$JTC(n,T,K)$	Annual integrated total cost function

2.2. Assumptions

(1) There is only a single-vendor and a single-buyer for a single product.
(2) The demand for the item is constant over time.
(3) Shortages are not allowed.
(4) The capital investment in reducing buyer's ordering cost is assumed a logarithmic function of the ordering cost. There are only a finite number of investment possibilities to reduce ordering cost. The capital investment-ordering cost level function is discrete.
(5) The account is not settled during the credit period, and the generated sales revenue is deposited in an interest-bearing