

A SURVEY ON INVENTORY MODELS UNDER TRADE CREDIT

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Abstract: This paper presents a review of the advances of inventory literature under permissible delay in payments since 1990s. The models available in the relevant literature have been suitably classified by the objective function that focuses only on the supplier's or buyer's performance or an integrated vendor-buyer inventory system. The motivations, extensions and generalizations of various models have been discussed. Finally, we conclude with suggestions for future research.

1 INTRODUCTION

The traditional economic order quantity (EOQ) model assumes that the retailer's capital are unrestricting and must be paid for the items as soon as the items were received. This is not always true in the actual business world. In practice, the supplier will offer the retailer a delay period, that is the trade credit period, in paying for the amount of purchasing cost. The supplier often makes use of this policy to promote his sale and attract new purchasers who consider it to be a type of price reduction. Before the end of trade credit period, the retailer can sell the goods and accumulate revenue and earn interest. A higher interest is charged if the payment is not settled by the end of the trade credit period.

Inventory problems for permissible delay in payments have been studied extensively by many researchers from time to time. Inventory problems for permissible delay in payments can be broadly classified into two categories: (1) The models focus only on the supplier's or buyer's performance under trade credit. (2) The models focus on the integrated vendor-buyer inventory system under trade credit.

2 THE STUDIES FOCUSED ONLY ON THE SUPPLIER'S OR BUYER'S PERFORMANCE UNDER TRADE CREDIT

The inventory models available in the relevant literature can be classified into the following two

categories according to the replenishment rate that is infinite or not.

(1) Optimal retailer's replenishment decisions in the EOQ model under trade credit.

(2) Optimal retailer's replenishment decisions in the EPQ model under trade credit.

2.1 The EOQ Model under Trade Credit

Goyal (1985) was the first to establish an EOQ model with a constant demand rate under the condition of permissible delay in payments. Then a number of researchers variously extended the model. Chu et al. (1998) extended Goyal (1985) to the case of deterioration. Aggarwal et al. (1995) considered the inventory model with an exponential deterioration rate under the condition of permissible delay in payments. Jamal et al. (1997) and Chang et al. (2001) extended this issue with allowable shortage. Sarker et al. (2000) addressed the optimal payment time under permissible delay in payment with deterioration. Hwang et al. (1997) developed the optimal pricing and lot sizing for the retailer under the permissible delay in payments for an order of a product whose demand rate is represented by a constant price elasticity function. Jamal et al. (2000) developed a retailer's model for optimal cycle and payment times under permitted delay in payment by the wholesaler. Teng et al. (2005) then amended Goyal (1985) by considering the difference between unit price and unit cost, and found that it makes economic sense for a well-established retailer to order less quantity and take the benefits of payment

delay more frequently.

Then many scholars extended the EOQ models under permissible delay in payments which can be classified broadly into the following three categories.

2.1.1 Inventory Models under Trade Credit and Cash-discount Policy

The supplier offers a specified period without interest charge to the buyer that is to be paid off within a permissible delay period. As a result, with an incentive for making early payments, and earning interest through the accumulated revenue received during the credit period, the buyer postpones payment up to the last moment of the permissible period allowed by the supplier. Therefore, from the supplier's perspective, offering trade credit leads to delayed cash in flow and increase the risk of cash flow shortage and bad debt. To accelerate cash inflow and reduce the risk of a cash crisis and bad debt, the supplier may provide a cash discount to encourage the buyer to pay for goods quickly.

Many studies develop the inventory models under the supplier's trade credit policy and cash-discount policy. Huang et al. (2005) investigated the buyer's optimal cycle time and optimal payment time under the supplier's trade credit policy and cash-discount policy. Ouyang et al. (2005) developed an inventory model with non-instantaneous receipt under trade credit, in which the supplier provided not only a permissible delay payment but also a cash discount to the retailer. Recently, Chang (2002), Ouyang (2002) and Huang (2005) developed inventory models in which the supplier provides a permissible delay payment and a cash discount for early payment.

2.1.2 Inventory Models under Trade Credit Linked to Order Quantity

All previous models implicitly assumed that credit terms are independent of the order quantity. In order to stimulate the buyer's demand, the suppliers offer the retailer the trade credit period depending on the ordering quantity.

Shinn et al. (2003) determined the retailer's optimal price and order size simultaneously under the condition of order-size-dependent delay in payments. They assumed that the length of the credit period is a function of the retailer's order size, and also the demand rate is a function of the selling price. Chang et al. (2003) then established an EOQ model for deteriorating items under supplier trade

credits linked to order quantity. Chung et al. (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 and developed an efficient solution-finding procedure to determine the retailer's optimal ordering policy. Chang (2004) extended Chung et al. (2004) by taking into account inflation and finite time horizon. Ouyang et al. (2008) presented an integrated inventory model with variable production rate and price-sensitive demand rate.

However, all above published papers dealing with economic order quantity in the presence of permissible delay in payments assumed that the supplier only offers the retailer fully permissible delay in payment if the retailer ordered a sufficient quantity. Otherwise, permissible delay in payments would not be permitted. We know that this policy of the supplier to stimulate the demands from the retailer is very practical. But this is just an extreme case. That is, the retailer would obtain 100% permissible delay in payment if the retailer ordered a large enough quantity. Otherwise, 0% permissible delay in payments would be happy.

In reality, the supplier can relax this extreme case to offer the retailer partially permissible delay in payments rather than 0% permissible delay in payments when the order quantity is smaller than a predetermined quantity. That is, the retailer must make a partial payment to the supplier when the order is received to enjoy some portion of the trade credit. Then, the retailer must pay off the remaining balances at the end of the permissible delay period.

Huang (2007) established an EOQ model in which the supplier offers a partially permissible delay in payments when the order quantity is smaller than the predetermined quantity. Ouyang et al. (2009) extended Huang (2007) by taking into account the deteriorating items.

In all the above models, however, the effects of the optimal replenishment decisions under two levels of trade credit policy linked to ordering quantity are not taken into consideration. Kreng et al. (2010) established an inventory model to determine the optimal replenishment decisions under two levels of trade credit policy if the purchaser's order quantity is greater than or equal to a predetermined quantity. The major assumptions used in the above research articles are summarized in Table 1.

Table 1: Major characteristics of inventory models on selected researches.

References	Allowing for deterioration	Payment linked to order quantity	Allowing for partial payments	Constant demand rate	Two levels of trade credits	Taking into account inflation
Shinn et al. (2003)	No	Yes	No	No	No	No
Chang et al. (2003)	Yes	Yes	No	No	No	No
Chung et al. (2004)	Yes	Yes	No	Yes	No	No
Chang (2004)	Yes	Yes	No	Yes	No	Yes
Ouyang et al. (2008)	No	Yes	No	No	No	No
Huang (2007)	No	Yes	Yes	Yes	No	No
Ouyang et al. (2009)	Yes	Yes	Yes	Yes	No	No
Kreng et al. (2010)	No	Yes	No	Yes	Yes	No

2.1.3 Inventory Models under Two-level Trade Credit

Almost all of the above-models under trade credit assumed that the supplier would offer the retailer trade credit but the retailer would not offer the trade credit to his/her customer. That is one level of trade credit. Huang (2003) modified the assumption to assume that the retailer will adopt the trade credit policy to stimulate his/her customer demand to develop the retailer's replenishment model. That is two levels of trade credit. This new viewpoint is more matched real-life situations in the supply chain model. Several researchers have studied in this area. Huang (2006) incorporated Huang (2003) and Teng (2002) by two levels of trade credit. Chung et al. (2007) modified Huang (2003) by developing a two-warehouse inventory model for deteriorating items under permissible delay in payments.

Liao (2008) developed an EOQ model with non-instantaneous receipt and exponentially deteriorating items under two-level trade credit. Chang et al. (2010) developed Liao (2008) by relaxing some dispensable assumptions that the retailer received the supplier trade credit and provided the customer trade credit. Huang et al. (2008) extended EOQ model to study the situation under which the retailer has the powerful decision-making right. That is, the retailer can obtain the full trade credit offered by the supplier and the retailer just offers the partial trade credit to his/her customer. There are several interesting and relevant papers related to two-level trade credit such as Teng (2007), Huang (2007), Teng (2009), Thangam (2009) and Min (2010).

2.2 The EPQ Model under Trade Credit

Almost all of the above-mentioned models assume that replenishment is done instantaneously. In real

life cases, however, the ideal case is not quite applicable. Inventories are often replenished periodically at certain production rate which is seldom infinite.

Chung et al. (2003) extended Goyal (1985) to the case that all items are replenished at a finite rate under permissible delay in payment. When the replenishment rate approaches to infinite, Goyal (1985) will be a special case of Chung et al. (2003). But the model in Chung et al. (2003) assumed that the unit selling price and the unit purchasing price are equal. Huang (2004) assumed that the selling price was not equal to the purchasing price to modify Chung et al. (2003). Liao (2008) extended Huang (2004) to the case of deterioration. Hu et al. (2009) extended Chung (2009) to allow for shortages. Huang (2007) investigated the optimal retailer's replenishment decisions under two levels of trade credit policy within the economic production quantity (EPQ) framework. In Teng et al. (2009) the authors studied the inventory model in which the permissible delay period offered by the retailer is independent of the permissible delay period offered by the supplier to the retailer. Hence, it extended the EPQ model to complement the shortcoming of Huang (2007). There are several interesting and relevant papers related to two-level trade credit such as Huang et al. (2008) and Ma et al. (2009).

3 COLLABORATIVE INVENTORY SYSTEM WITH PERMISSIBLE DELAY IN PAYMENTS

Almost all of the above-mentioned models studied the optimal policy for the buyer or the vendor only. However, these one-sided optimal inventory models

neglected the complicated interaction and cooperation opportunity between the buyer and the vendor. In practice, many companies learn that actions taken by one member of the chain can influence the success of all others in the same value chain. Recognizing this principle, the vendor and buyer may consider how to relieve the conflict relationship and attempt to become partners to create a win-win strategy.

Goyal (1976) first developed a single vendor-single buyer integrated inventory model. Subsequently, Banerjee (1986) extended Goyal (1976) and assumed that the vendor followed a lot-for-lot shipment policy with respect to a buyer. Goyal (1988) relaxed the lot-for-lot policy and illustrated that the inventory cost can be reduced significantly if the vendor's economic production quantity is an integer multiple of the buyer's purchase quantity.

Lately, some researchers discussed the impact of delay payment strategy on the integrated inventory models. Abad and Jaggi (2003) provided a seller-buyer integrated inventory model under trade credit and followed a lot-for-lot shipment policy. Jaber et al. (2006) proposed a supplier-retailer supply chain model in which the permissible delay in payments is considered as a decision variable. Yang et al. (2006) developed a vendor-buyer integrated inventory model for deteriorating items with permissible delay in payment. Ho et al. (2008) investigated the production and ordering policy under a two-part trade credit in an integrated supplier-buyer inventory model. Chang et al. (2010) presented a stylized model to determine the optimal strategy for an integrated vendor-buyer inventory system under the condition of trade credit linked to the order quantity, where the demand rate is considered to be a decreasing function of the retail price. Ouyang et al. (2008) gave a best policy that aimed maximizing the joint total profit while the trade credit and freight rate are simultaneously linked to the order quantity. There are several interesting and relevant papers related to two-level trade credit such as Chen et al. (2007), Luo et al. (2007), Yang et al. (2006), Sheen et al. (2007), Sarmaha et al. (2008), Huang (2010) and Chen et al. (2010) and so on.

4 CONCLUSIONS

In this paper we have provided an up-to-date review inventory literature under permissible delay in payments. A future study will incorporate more realistic assumptions in the proposed models. The

proposed models can be extended in several ways. First, demand can be extended to a more generalized demand pattern that fluctuates with time, price or stock-dependent demand rate. Second, models can be extended to incorporate some more realistic features, such as quantity discount, the inventory holding cost and others are also fluctuating with time. Third, integrated models can be extended to more general supply chain networks, for example, multi-echelon or assembly supply chains.

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