



An EPQ-based inventory model for exponentially deteriorating items under retailer partial trade credit policy in supply chain

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ABSTRACT

The main purpose of this paper is to investigate the optimal retailer's replenishment decisions for deteriorating items under two levels of trade credit policy to reflect supply chain management situation within the economic production quantity (EPQ) framework. In this paper, it is assumed that the retailer maintains a powerful decision-making right and can obtain the full trade credit offered by the supplier yet retailer just offers the partial trade credit to his/her customers. Under these conditions, the retailer can obtain the most benefits. Then, we model the retailer's inventory system as a cost minimization problem to determine the retailer's optimal replenishment decisions under the supply chain management. Some easy-to-use theorems are developed to efficiently determine the optimal replenishment decisions for the retailer. We deduce some previously published results of other researchers as special cases. Finally, numerical examples are given to illustrate the theorems obtained in this paper. Then, as well as, we obtain a lot of managerial phenomena from numerical examples.

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1. Introduction

The EOQ model is widely used by practitioners as a decision-making tool for the control of inventory. The basic EOQ model is based on the implicit assumption that the retailer must pay for the items as soon as he receives them from a supplier. However, this may not be true. In today's business transactions, it is more and more common to see that the supplier will allow a certain fixed time period (say, 30 days) for settling the amount that the supplier owes to retailer for the items supplied. We term this period as trade credit period. Usually, interest is not charged for the outstanding amount if it is paid within the permissible delay period. This credit term in financial management is denoted as 'net 30'. Therefore, the retailer can sell the goods and earn the interest on the accumulated revenue received, and delay the payment up to the last moment of the permissible period allowed by the supplier. However, if the payment is not paid within the permissible delay period, then interest is charged on the outstanding amount under the previously agreed terms and conditions. This brings some economic advantage to the retailers as they may earn some interest from the revenue realized during the period of permissible delay.

The trade credit financing produces two benefits to the supplier: (1) It should attract new customers who consider it to be a type of

price reduction, and (2) it should cause a reduction in the sales outstanding, since some established customers will pay more promptly in order to take advantage of permissible delay more frequently. In a real world, the supplier often makes use of this policy to promote his commodities. In India, gas stations adopted a price policy that charged less money per gallon to the customer who paid by cash, instead of by a credit card. Likewise, a store owner in many China towns around the world usually charges a customer 5% more if the customer pays by a credit card, instead of by cash. As a result, the customer must decide which alternative to take when the supplier provides not only a cash discount but also a permissible delay. In this regard, a number of research papers appeared which deal with the EOQ problem under the condition of permissible delay in payments. Goyal (1985) is the first person to consider the economic order quantity (EOQ) inventory model under the condition of trade credit. Chand and Ward (1987) analyzed Goyal's model under assumptions of the classical economic order quantity model, obtaining different results. Shinn, Hwang, and Sung (1996) extended Goyal (1985) model and considered quantity discount for freight cost. Hwang and Shinn (1997) developed the optimal pricing and lot sizing for the retailer under condition of permissible delay in payments. Chung (1998) presented the DCF (discounted cash flow) approach for the analysis of the optimal inventory policy in the presence of trade credit. Liao, Tsai, and Su (2000) developed an EOQ model for stock-depend demand rate when a delay in payment is permissible. Teng (2002) assumed that the selling price is not equal to the purchasing price to modify Goyal's model (1985). Shinn and Hwang (2003) determined the retailer's optimal price and

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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. Chung and Huang (2003) extended this problem within the economic production quantity (EPQ) framework and developed an efficient procedure to determine the retailer's optimal ordering policy. Huang and Chung (2003) extended Goyal's model (1985) to cash discount policy for early payment. Salameh, Abboud, El-Kassar, and Ghattas (2003) extended this issue to the continuous review inventory model. However, the perishability of goods is a realistic phenomenon. In real-life situations there are certain products like volatile liquids, medicines, food stuff, blood bank, materials, etc., in which the rate of deterioration due to vaporization, damage, spoilage, dryness etc. is very large. Therefore, the loss due to deterioration should not be ignored. Aggarwal and Jaggi (1995) developed inventory model with an exponential deterioration rate under the condition of permissible delay in payments. Chu, Chung, and Lan (1998) extended Goyal's (1985) model to allow for deteriorating items. Chung, Chang, and Yang (2001) extended this issue to the varying rate of deterioration. Jamal, Sarker, and Wang (1997) and Chang and Dye (2001) extended this issue with allowable shortage. Liao et al. (2000) and Sarker et al. (2000) developed a model to determine an optimal ordering policy for deteriorating items under inflation, permissible delay in payments and allowable shortage. Chang, Hung, and Dye (2001) proposed an EOQ model with varying rate of deterioration and linear trend demand under permissible delay in payments. Chang, Ouyang, and Teng (2003) and Chung and Liao (2004) dealt with the problem of determining the EOQ for exponentially deteriorating items under permissible delay in payments depending on the ordering quantity. Chang (2004) extended this issue to inflation and finite time horizon. Huang (2004) investigated that the unit selling price and the unit purchasing price are not necessarily equal within the EPQ framework under a supplier's trade credit policy. Shawky and Abou-el-ata (2001) investigated the production lot-size model with both restrictions on the average inventory level and trade credit policy using geometric programming and Lagrange approaches. Mahata and Goswami (2006) presented a fuzzy EPQ model for deteriorating items when delay in payment is permissible. Teng, Chang, and Goyal (2005) developed the optimal pricing and lot sizing under permissible delay in payments by considering the difference between the selling price and the purchase cost and demand is a function of price. Shah and Shah (1998) developed a probabilistic inventory model when delay in payment is permissible. They developed an EOQ model for deteriorating items in which time and deterioration of units are treated as continuous variables and demand is a random variable. There are several interesting and relevant papers related to trade credit such as Jamal, Sarker, and Wang (2000), Arcelus, Shah, and Srinivasan (2003), Abad and Jaggi (2003), Chang (2004), Chung, Goyal, and Huang (2005), Chung and Liao (2006), Mahata and Goswami (2007), Chung and Haung (2007) and Huang (2007a) and their references.

All the above inventory models implicitly assumed one-level trade credit financing, i.e. it is assumed that the supplier would offer the retailer a delay period and the retailer could sell the goods and accumulate revenue and earn interest within the trade credit period. They implicitly assumed that the customer would pay for the items as soon as the items are received from the retailer. That is, they assumed that the supplier would offer the retailer a delay period but the retailer would not offer any delay period to his/her customer. In most business transactions, this assumption is unrealistic. Usually the supplier offers a credit period to the retailer and the retailer, in turn, passes on this credit period to his/her customers. For example, in India, the TATA company can delay the payment of purchasing cost until the end of the delay period offered by his supplier. The TATA Company also offers permissible delay

payment period to his dealership. Recently Huang (2003) presented an inventory model assuming that the retailer also permits a credit period to its customer which is shorter than the credit period offered by the supplier, in order to stimulate the demand. Huang (2006) extended Huang's (2003) model to investigate the retailers inventory policy under two levels of trade credit and limited storage space. Mahata and Goswami (2007) developed an inventory model to determine an optimal ordering policy for deteriorating items under two-level trade credit policy in the fuzzy sense. Huang (2007b) incorporated Huang's (2003) model to investigate the two-level trade credit policy in the EPQ framework. Kreng and Tan (2010) modify Huang's (2003) model by developing optimal wholeseller's replenishment decisions in the EOQ model under two levels of trade credit policy depending on the order quantity. Min, Zhou, and Zhao (2010) developed an inventory model for deteriorating items under stock-dependent demand and two-level trade credit. Ho, Ouyang, and Su (2008) developed an integrated supplier-buyer inventory model with the assumption that demand is sensitive to retail price and the supplier adopts a two-part trade credit policy. Huang and Hsu (2008) have developed an inventory model under two-level trade credit policy by incorporating partial trade credit option at the customers of the retailer. Liao (2008) developed an EOQ model with non-instantaneous receipt and exponentially deteriorating items under two-level trade credit financing. Tsao (2009) developed an EOQ model under advance sales discount and two-echelon trade credits. Teng and Chang (2009) extended the Huang's (2007b) model by relaxing the assumption $N < M$.

The main purpose of this paper is to amend the paper Huang (2007b, 2003) and Chung and Huang (2003) with a view of making their model more relevant and so applicable to practice. Here, we are taking into account the following factors: (1) the supplier is willing to provide the retailer a full trade credit period for payments and the retailer offers the partial trade credit period to his/her customers; (2) the retailer's trade credit period (M) offered by the supplier is not necessarily longer than the customer's trade credit period (N) offered by the retailer; (3) the replenishment rate is finite; (4) the selling items are perishable such as fruits, fresh fishes, gasoline, photographic films, etc. Under these conditions, we model the retailer's inventory system as a cost minimization problem. Some theorems are developed to determine retailer's optimal ordering policies and numerical examples are given to illustrate these theorems. In addition, some managerial insights from the numerical examples are also concluded.

2. Notations and assumptions

The following notations and assumptions are used throughout.

2.1. Notations

D	demand rate per year
P	production rate per year
ρ	$= 1 - \frac{D}{P} \geq 0$
h	stock-holding cost per unit per year excluding interest charges
A	ordering cost per order
c	unit purchasing cost per item
s	unit selling price per item of good quality
α	customer's fraction of the total amount owed payable at the time of placing an order offered by the retailer, $0 \leq \alpha \leq 1$
M	retailer's trade credit period offered by the supplier in years
N	customer's trade credit period offered by the retailer in years

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