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Analysis of a fuzzy economic order quantity model for deteriorating items under retailer partial trade credit financing in a supply chain

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ABSTRACT

This paper investigates the economic order quantity (EOQ) — based inventory model for a retailer under two levels of trade credit to reflect the supply chain management situation in the fuzzy sense. It is assumed that the retailer maintains a powerful position and can obtain the full trade credit offered by the supplier yet the retailer just offers a partial trade credit to customers. The demand rate, holding cost, ordering cost, purchasing cost and selling price are taken as fuzzy numbers. Under these conditions, the retailer can obtain the most benefits. Study also investigates the retailer's inventory policy for deteriorating items in a supply chain management situation as a cost minimization problem in the fuzzy sense. The annual total variable cost for the retailer in fuzzy sense is defuzzified using Graded Mean Integration Representation method. Then the present study shows that the defuzzified annual total variable cost for the retailer is convex, that is, a unique solution exists. Mathematical theorems and algorithms are developed to efficiently determine the optimal inventory policy for the retailer. Numerical examples are given to illustrate the theorems and the algorithms. Finally, the results in this paper generalize some already published results in the crisp sense.

1. Introduction

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, in practice, the supplier will allow a certain fixed period (credit period) for settling the amount that the supplier owes to retailer for the items supplied. Before the end of the 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. In a real world, the supplier often makes use of this policy to promote his commodities. In this regard, a number of research papers appeared which deal with the EOQ problem under fixed credit period. Goyal [1] first studied an EOQ model under the conditions of permissible delay in payments. Chand and Ward [2] analyzed Goyal's [1] problem under assumptions of the classical EOQ model, obtaining different results. Chung [3] presented the DCF (discounted cash flow) approach for the analysis of the optimal inventory policy in the presence of trade credit. Later, Shinn et al. [4] extended Goyal's [1] model and considered quantity discount for freight cost. Recently, to accommodate more practical features of the real inventory systems, Aggarwal and Jaggi [5], Shah [6], Hwang and Shinn [7] extended Gayal's [1] model to consider the deterministic inventory model with a constant deterioration rate. Shah and Shah [8] developed a probabilistic inventory model when delay in payment is permissible. They developed an EOQ model for deteriorating items in which

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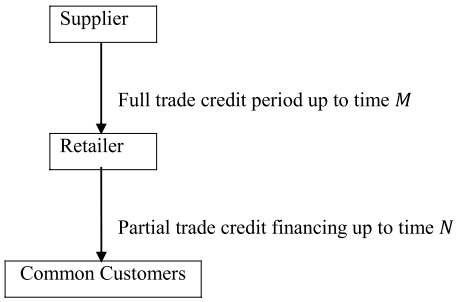

Fig. 1. Two-level trade credit policy with partial trade credit financing to common customers.

time and deterioration of units are treated as continuous variables and demand is a random variable. Later on, Jamal et al. [9] extended Aggarwal and Jaggi's [5] model to allow for shortages and make it more applicable in the real world. Shawky and Abou-El-Ata [10] 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 [11] presented a fuzzy EPQ model for deteriorating items when delay in payment is permissible. Huang [12] assumed that retailer would adopt a similar trade credit policy to stimulate demand from customer to develop the retailer's replenishment method. There are several interesting and relevant papers related to trade credit such as Chung et al. [13], Chung and Liao [14], Mahata and Mahata [15] and Huang [16] and their references.

All the above articles 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. That is one level of trade credit. 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. Recently, Huang [12] modified this assumption to assume that the retailer will adopt the trade credit policy to stimulate his/her customers' demand to develop the retailer's replenishment model. That is two levels of trade credit. Haung [17] incorporated Haung's [12] model to investigate the two-level trade credit policy in the EPQ framework. This new viewpoint is more matched to real-life situations in the supply chain model. Therefore, we want to extend Huang's model [12] to investigate the situation under which the retailer has the powerful decision-making right. That is, we want to assume that the retailer can obtain the full trade credit offered by the supplier and the retailer just offers a partial trade credit to his/her customer. The path of the trade credit policy is illustrated in Fig. 1. In practice, this circumstance is very realistic.

For example, in India, the TATA Company can require his supplier to offer the full trade credit period to him and just offer a partial trade credit to his dealership. That is, the TATA Company can delay the full amount of the purchase cost until the end of the delay period offered by his supplier. But the TATA Company only offers a partial delay payment to his dealership on the permissible credit period and the rest of the total amount is payable at the time the dealership places a replenishment order.

It is a formidable task for the retailers to estimate different inventory parameters as crisp or stochastic as due to rapid changes of product specification and the introduction of new products; in the market sufficient past data is not available for such an estimation. In the above inventory models, it was assumed that the demand rate and the inventory costs are constant in nature. Due to various uncertainties, the annual demand rate may have a little fluctuation, especially in a perfect competitive market. For developing inventory models, a major difficulty faced by a decision maker (retailer) is to forecast the demand. In the present day scenario, it is tough to decide the exact annual demand rate, namely, how many items customers will purchase during the whole year. Also the cost parameters such as the purchase cost, the holding cost and the ordering cost are constants. These kinds of assumptions are not always true. It may not be possible to specify the values of these cost parameters precisely but they may contain some uncertain values such as "unit holding cost is about h", or "unit purchase cost is approximately c or more", etc. In another sense, these parameters may contain some uncertain values. In these circumstances it is better to model these parameters as fuzzy because the estimation (fuzzy) is done by experts' opinions and salesmens'/representatives' experience. Again in the present competitive market along with the profit/cost function, customer service also becomes a crucial factor. Due to high bank interest, and limitation of resources, profit with respect to investment is also important. So the goal of present day inventory problems are multiple rather than single. As a result, retailers of all corners in the World very frequently face non-linear optimization problems whose objective involves fuzzy parameters. The significance of this study is to develop an inventory model incorporating the above-mentioned real life situations that will help the retailers to survive in the market.

On this view, several researchers developed fuzzy inventory models in situations where these parameters are described imprecisely. Several authors namely Chang et al. [18], Lee and Yao [19], Lin and Yao [20], Yao et al. [21], Mahata et al. [22], Mahata and Goswami [11] developed inventory models in the fuzzy sense by considering different parameters as fuzzy parameters.