



A supply chain with variable demand under three level trade credit policy



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ABSTRACT

In this paper, an integrated supply chain model has been developed under three level trade credit policy with price, credit period and credit amount dependent demand, where a supplier offers a credit period to his/her wholesaler to boost the demand of the item. Due to this facility, wholesaler also offers a credit period to his/her retailer and the same practice is followed by the retailer to increase the base demand of the item. Here it is assumed that, both wholesaler and retailer enjoy the same full credit facility but retailer just offers the partial trade credit to his/her customers. The main purpose of this paper is to maximize the joint profit of the wholesaler and the retailer. Model is formulated in crisp, fuzzy and rough environments. Here, a Particle Swarm Optimization (PSO) algorithm is used to find marketing decision for the proposed models. For fuzzy model, credibility measure of fuzzy event and for rough model, trust measure of rough event are used to compare the corresponding objectives for PSO. Models are illustrated with numerical examples and some parametric studies are performed.

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1. Introduction

A supply chain (SC) involves several stages which directly or indirectly satisfy the customers requirements. In a supply chain, there are manufacturers, transporters, suppliers, wholesalers, retailers, final customers etc., those are bonded by a decision in such a manner that all the players in the chain are mostly profitable. It is also well known that all players of a co-ordinated supply chain get better shares of benefit which cannot be obtained when one optimizes its own decision individually.

With the advent of multi-nationals in the market of developing countries, competition among the business enterprises is very stiff, and they adopt various promotional tools to sale the products efficiently, which increases the base demand. Trade credit policy is one the most effective tools to push the products. There are two types of trade credit policies, one of them is full trade credit policy, which refers to the manner that a player gives the full credit to his/her customers on the total purchased amount, and on the other hand if the player gives the credit on a fraction of the total purchased amount, it is known as partial trade credit. Again if the credit period is depend on some conditions, then it is known as conditional delay in payment or conditional trade credit. If the

credit period is offered to the retailer only by the wholesaler, it is called one level trade credit policy. On the other hand if both the wholesaler and the retailer offer credit period to the retailer and the customer respectively, then it is known as two level trade credit policy. Goyal (1985) first developed an EOQ model under the conditions of permissible delay in payment. Aggarwal and Jaggi (1995) extended Goyal's model for a deteriorating item. Chung and Liao (2004) studied a lot-sizing problem under supplier's trade credit depending on the retailer's order quantity. Huang (2007) established an EOQ model in which the supplier offers a partially permissible delay in payment when the order quantity is smaller than a predetermined quantity. Ouyang, Teng, Goyal, and Yang (2009) developed an EOQ model for deteriorating items with partially permissible delay in payments linked to order quantity. In these studies, it is usually assumed that the supplier would offer a credit-period to the retailer but in turn, the retailer would not offer any credit-period to its customers, which is unrealistic, because in real practice retailer might offer a credit-period to its customers in order to stimulate his own demand. Huang (2003) first explores an EOQ model under two level trade credit policy considering that the customer purchases one item from the retailer at the time t belonging to $[0, N]$, then the customer has a trade credit period $(N-t)$ and must make the payment at time N . A major drawback of the model is that here credit period of the customer is not same for all customers, who purchase earlier will

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get more credit period than those who purchase later. The inventory/supply chain models under two level trade credit policy using the viewpoint of Huang (2003) can be found in several papers such as Huang and Hsu (2008), Chung (2008), Chung (2011), Chung (2013), Huang (2006), Huang (2007), Teng, Cheng, Chern, and Chan (2007) and others. Teng (2009) established an EOQ model under two level trade credit considering that credit period given to the all customers are same. From the view point of Teng (2009) there are several research papers for deteriorating items such as Teng and Chang (2009), Teng, Yang, and Chern (2013), Chen and Kang (2010), Ho (2011), Chung, Cardenas-Barron, and Ting (2014) and many others. Mahata (2012) developed an EPQ model to investigate the optimal retailer's replenishment decisions for a deteriorating item, where retailer avails full credit period from the wholesaler but, offers a partial credit to his/her customers. According to the authors' best knowledge, all the inventory models/supply chain models under trade credit policy are developed from the retailer's point of view only. But in today's competitive business, decision has to be made from the supply chain point of view where retailer's as well as supplier's and wholesaler's costs/profits should be considered. Also, trade credit policy in business is observed in different levels- Manufacturer, Distributor, Supplier, Wholesaler, Retailer, Customer etc. But till now, all the models are developed under single level or two level trade credit policies only.

Min, Zhou, and Zhao (2010) developed an inventory model for deteriorating item under two level trade credit with stock dependent demand, but their analysis is imposed a terminal condition of zero ending-inventory. However with a stock dependent demand, it may be desirable to order large quantities. Recently, Soni (2013) extended their model to optimize replenishment policies for deteriorating items with stock sensitive demand under two level trade credit with limited capacity, considering the non-zero ending inventory and used an upper limitation on the stock items, as too much stock leaves a negative expression to the buyer. Huang (2007) developed an EPQ Model under two level trade credit, but in this model, retailers credit period has no effect on the demand of the item. To remove these shortcomings Jaggi, Goyal, and Goel (2008) developed an inventory model under two-level trade credit policy, where demand of the item depends on retailer's credit-period. Maiti (2011) developed an inventory model under two level trade credit where credit period offered to customers for few cycles to boost the demand. When demand of the item reaches a certain level, the credit period is withdrawn by the retailer. Guchhait, Maiti, and Maiti (2014) developed an inventory model for a deteriorating item with selling price and customer's credit period linked demand. From the above discussion it is shown that researchers considered the demand either constant in nature or stock dependent or selling price linked or customer's credit period linked. But, none considered the demand as a function of the customer's credit amount. As in the real practice the customer's credit amount is proportional to the base demand, i.e., if the customer's credit amount increases/decreases, then the base demand of the item also will be increase/decrease, so customer's credit amount is an effective argument for the demand function.

In the recent years, due to the uncertainty of inventory parameters in the cost functions, the cost function becomes imprecise in nature i.e., in fuzzy sense. Now-a-days, this phenomenon is well established by some researchers. After the introduction of fuzzy set (Zadeh, 1965), it has been well developed and applied widely in different areas of science and technology including inventory control problems. Maiti and Maiti (2007) developed a multi-item inventory model with stock dependent demand and two storage facilities in fuzzy environment where processing time of each unit is fuzzy. Lee and Yao (1998), Maiti (2011), Guchhait, Maiti, and

Maiti (2010), Guchhait et al. (2014) and many others developed their models in fuzzy environment.

Due to vague description of the parameters in a cost function, it became a crucial issue. After fuzzy set theory, rough set theory is another attempt to this problem. After the introduction of rough set theory (Pawlak, 1982), it attracted the attention of many researchers and practitioners all over world. It is well developed and applied widely in computer science and in the field of artificial intelligence. Now-a-days, many researchers used rough set theory in developing their models in the field of inventory control system. Recently, Guchhait et al. (2014) developed an inventory model allowing two-level trade credit assuming the parameters in rough nature.

From the above discussions, some shortcomings in the formation of the inventory models may be summarized as below:

- No inventory model/supply chain model considered the customer's credit amount linked demand.
- None of the investigators considered supply chain models with the trade credit in more than two levels (Wholesaler → Retailer → Customer).
- Very few supply chain models are formulated considering the cost/profit from both wholesaler's and retailer's point of view.

Incorporating the above mentioned phenomenon, here a supply chain model with selling price, customer's credit period and customer's credit amount dependent demand has been developed under three level trade credit policy. The supplier offers a fixed grace period to the wholesaler and consequently wholesaler also offers a credit period to the retailer. Due to this facility, retailer also offers a partial trade credit period to the customers on a fraction of amount purchased to boost the base demand. Obviously the demand depends on the duration of the credit period offered. Demand also depends on the amount of item for which credit period is offered. The supplier and wholesaler both charges the same interest to the wholesaler and to the retailer respectively, if the grace period is over, but there is no penalty is to be considered for the case of customers. Here it is assumed that the wholesaler and the retailer both pay the total amount to the supplier and to the wholesaler respectively just after the end of the credit period by taking a loan from a bank, with the same interest. And then wholesaler and the retailer both repay the loan amount to the bank immediately as the items are sold. The proposed model is formulated in crisp, fuzzy and rough environment. Here, some parameters like ordering cost, interest rate etc. are considered as fuzzy/rough in nature. Models (Crisp, Fuzzy, Rough) are formulated following profit maximization principle and depending upon different parameters, different models are obtained. The Non-linear optimization problems for different models are solved by a PSO algorithm developed for this purpose. In the fuzzy/rough model, credibility (Section 2.4)/trust (Section 2.6) measure is used to compare the fuzzy/rough objectives of the problem directly without transferring the objectives into the equivalent crisp objectives and using this PSO is followed to optimize the objectives. Numerical experiments are performed to illustrate the models and some parametric studies are made.

2. Mathematical prerequisite

2.1. Triangular Fuzzy Number (TFN)

A TFN $\tilde{a} = (a_1, a_2, a_3)$ has three parameters a_1, a_2, a_3 , where $a_1 < a_2 < a_3$ and is characterized by the membership function $\mu_{\tilde{a}}$, given by

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