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Inventory policy of a deteriorating item with variable demand under trade credit period ☆

Partha Guchhait [a,*], Manas Kumar Maiti [b], Manoranjan Maiti [a]

[a] Department of Mathematics, Vidyasagar University, Midnapore, Paschim-Medinipur 721102, West Bengal, India
[b] Department of Mathematics, Mahishadal Raj College, Mahishadal, Purba-Medinipur 721628, West Bengal, India

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ABSTRACT

In this paper, an inventory model of a deteriorating item with stock and selling price dependent demand under two-level credit period has been developed. Here, the retailer enjoys a price discount if he pays normal purchase cost on or before the first level of credit period, or an interest is charged for the delay of payments. In return, retailer also offers a fixed credit period to his customers to boost the demand. In this regard, the authors develop an EOQ model incorporating the effect of inflation and time value of money over all the costs. Keeping the business of seasonal products in mind, it is assumed that planning horizon of business is random and follows a normal distribution with a known mean and standard deviation. The model is formulated as retailer's profit maximization problem for both crisp and fuzzy inventory costs and solved using a modified Genetic Algorithm (MGA). This algorithm is developed following fuzzy age based selection process for crossover and gradually reducing mutation parameter. For different values of MGA parameters, optimum results are obtained. Numerical experiments are performed to illustrate the model.

1. Introduction

Influence of inflation and time value of money on inventory costs, etc has been extensively studied by several researchers in last few decades (Buzacott, 1975; Bierman & Thomas, 1977; Bose, Goswami, & Choudhuri, 1995). In recent years, Wee and Law (2004) addressed an inventory problem with finite replacement rate of deteriorating items taking time value of money into account. Chang (2004) proposed an inventory model for deteriorating items with trade credit under inflation. On the other hand, there are lot of research papers for deteriorating item in the literature of inventory control problems (Wee & Yu, 1997; Jaggi, Aggarwal, & Goel, 2006; Lo, Wee, & Huang, 2007; Chung & Wee, 2008). Most of these studies considered the influence of inflation and time value of money on selling price and ignored the effect of selling price on demand which was well established by many authors such as Bhuina and Maiti (1997), Maiti and Maiti (2006), Pal, Maiti, and Maiti (2009) and others. Though few works have been reported considering inflation induced demand (Jaggi et al., 2006), none has studied the effects of inflation and time value of money with price dependent demand.

In the last two decades, inventory/production-inventory models with trade credit have been widely studied by several researchers (Dye, 2002; Chang, Hung, & Dye, 2004; Goyal, Teng, & Chang, 2007; Wee, Wang, & Chung, 2009a). Most of these models considered only one-level trade credit i.e., only supplier offers a fixed credit period to the retailers to generate his demand. Law and Wee (2006) addressed an integrated production-inventory model for ameliorating and deteriorating items taking account of time discounting. In real practice, retailer too might offer a credit period to its customers to stimulate his own demand. Huang (2007) first developed an inventory model with two-level credit period. Later Jaggi, Goyal, and Goel (2008) extended the Huang (2007) model incorporating a two-level trade credit policy where demand of the item depends on retailers trade credit. But, in some situations, the supplier also offers a cash discount to encourage the retailer to pay for his purchase quickly (Ouyang, Teng, Chuang, & Chuang, 2005).

Again inventory models are normally developed with infinite lifetime for products. In reality, lifetime of the products, specially the seasonal products for which the planning horizon fluctuates every year depending upon the environmental effects, is finite and imprecise (fuzzy or random) in nature. Few research papers have already been published incorporating this assumption

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* Corresponding author.
E-mail addresses: parthaguchhait@gmail.com (P. Guchhait), manasmaiti@yahoo.co.in (M.K. Maiti), mmaiti2005@yahoo.co.in (M. Maiti).

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(Maiti, Maiti, & Maiti, 2006; Moon & Yun, 1993; Pal et al., 2009; Roy, Pal, & Maiti, 2009). But none has studied the inventory model under random planning horizon allowing two-level credit, effect of inflation and time value of money on costs and variable demand.

Uncertainty of inventory parameters is a well established phenomenon in recent years. Estimation of parameters in the cost functions using traditional econometric methods is not always possible due to insufficient historical data specially, for newly launched products. Generally, nature of uncertainties can be classified into two major groups - random (stochastic) and fuzzy (imprecise). Extensive research works have been made on stochastic inventory models. After introduction of fuzzy set (Zadeh, 1965), it has been well developed and applied widely in different areas of science and technology (Liu, 2002) including inventory control problems (Lee & Yao, 1998; Maiti & Maiti, 2006; Wee, Lo, & Hsu, 2009b; Chung & Wee, 2008; Maiti, 2011; Guchhait, Maiti, & Maiti, 2010, 2013).

For deteriorating items, as huge number of quantity invite more deterioration, retailers normally avoid large number of order. To increase sale and avoid more deterioration (both supplier and retailer), two level partial trade credit in business is normally practiced. In this paper, an inventory model of a deteriorating item is considered where supplier provides not only permissible delay in payment but also cash discount to the retailers to pay for their purchases quickly. If retailer pays at M_1, he gets a cash discount. Retailer can also get a delay period of $M_2(> M_1)$ without any cash discount. Against these concessions, retailer too offers a delay period 'α' to its customers to pay for their purchases. Here demand of the item depends on selling price, stock level and retailer's credit period α. Effect of inflation and time value of money on inventory costs as well as demand is studied. Lifetime of the product is assumed to be random and normally distributed with known mean and standard deviation. Models are formulated with both crisp and fuzzy inventory costs as profit maximization problems with respect to the retailer.

Different heuristic algorithms are extensively studied and applied by several authors for inventory control problems during the last decade. Due to complexity of the model considered in this paper, a modified genetic algorithm named MGA is developed and used to optimize the profit function and appropriate decisions are derived for Decision Maker (DM). Different well established benchmark test functions are used to test the effectiveness of the algorithm. Performance of the proposed MGA against these test functions are also compared with a simple GA with Roulette wheel selection, arithmetic crossover and random mutation. Models are also solved using both MGA and GA and results are presented. It is observed that the proposed MGA is efficient to derive the optimal decisions for DM with respect to the present model. The models are illustrated with numerical examples.

The rest of the paper is organized as follows. In Section 2, assumptions and notations of the proposed inventory model are listed. In Section 3, mathematical formulation of the model is presented. In Section 4, modified GA is described. Numerical examples to illustrate the model are provided in Section 5. Managerial implications and insights are presented in Section 6 Finally, a brief conclusion is drawn in Section 7.

2. Assumptions and notations for the proposed inventory model

The following notations and assumptions are used in developing the models.

(i) Inventory system involves only one deteriorating item.
(ii) It is assumed that demand of the item in the market is finite and stochastic in nature.
(iii) The planning horizon $\widehat{H}$ is assumed to be random and follows normal distribution with known mean m_H and standard deviation σ_H.
(iv) For simplicity a constant deterioration rate θ is assumed during the whole planning horizon.
(v) Shortages are allowed in each cycle except in the last cycle.
(vi) T is the length of each cycle except the last cycle and T_L is the length of last cycle. T and T_L are decision variables.
(vii) Shortages are allowed for a duration λT $(0 \leqslant \lambda < 1)$ at the end of each cycle, except in the last cycle, where λ is a decision variable.
(viii) $q(t)$ is the inventory level at any time t.
(ix) α is customer's credit period offered by the retailer, which is a decision variable.
(x) I is inflation rate, d is discount rate and R = d − I.
(xi) c_h is holding cost per unit quantity per unit time in \$ at the beginning of the planning horizon.
(xii) c_s is the shortage cost per unit quantity per unit time in \$.
(xiii) c_p is normal purchase cost per unit in \$ at the beginning of the planning horizon.
(xiv) Let N full cycles are made during the planning horizon. So there is one stochastic constraint $NT + T_L \leqslant \widehat{H}$ and let p_r be the probability of realizing the constraint.
(xv) m_1 is time period up to which the retailer enjoys a cash discount from the wholesaler along with the delay in payment.
(xvi) m_2 is time period for the delay in payment for the retailer without cash discount.
(xvii) I_c is interest charged per unit time.
(xviii) I_e is interest earned per unit time.
(xix) Z is the total expected profit from the planning horizon.
(xx) $\widetilde{G} = (G_1, G2)$ (a LFN) is the goal of Z when some inventory costs are fuzzy.
For i-th $(1 \leqslant i \leqslant N+1)$ cycle, following assumptions and notations are used:
(xxi) Demand of the item $D_i(t)$ depends on stock level, $q(t)$, selling price, s_{pi} and credit period, α, offered by the retailer and is of the form:

$$D_i(t) = \begin{cases} \frac{a+bQ_0-cr^{\alpha}}{(mc_{pi})^{\gamma}} & \text{for } Q_0 \leqslant q \leqslant Q_{hi} \\ \frac{a+bq-cr^{\alpha}}{(mc_{pi})^{\gamma}} & \text{for } 0 \leqslant q \leqslant Q_0 \\ \frac{\beta(a-cr^{\alpha})}{\{mc_{p(i+1)}\}^{\gamma}} & \text{for } -Q_{ri} \leqslant q \leqslant 0, \end{cases}$$

where $a, b, c, \beta(0 < \beta < 1)$ and $r(0 < r < 1)$ are the parameters so chosen to best fit the demand function. Here γ is called price elasticity and β is called partially backlog factor of the demand function.
(xxii) c_d is cash discount rate offered by the whole-seller to the retailer if the account is settled at $M_1 = (i-1)T + m_1$.
(xxiii) $M_2 = (i-1)T + m_2$ is last time limit of permissible delay in settling the accounts, with $M_2 > M_1$.
(xxiv) Q_{hi} is maximum inventory level.
(xxv) Q_{ri} is the shortage level, i.e., $Q_i = Q_{hi} + Q_{r(i-1)}$ is order quantity, where $Q_{r0} = 0$.
(xxvi) C_{oi} is ordering cost in \$. It is partly constant and partly quantity dependent and is of the form: $C_{oi} = c_0 + c_1 Q_i$.
(xxvii) $c_{pi} = c_p e^{-R(i-1)T}$ is present value of normal purchase cost per unit in \$.
(xxviii) Selling price s_{pi} is a mark-up m of purchase cost c_{pi}, i.e., $s_{pi} = mc_{pi}$, where m is a decision variable.
(xxix) Deteriorated units are sold at a reduced selling price s_{pri} i.e., $s_{pri} = m_r c_{pi}, c_{pi}$ is the purchase cost, m_r is the mark-up.
(xxx) t_{0i} is the time when stock level reaches Q_0, if $(Q_{hi} > Q_0)$.
(xxxi) $t_{1i} = (i-1)T + (1-\lambda)T$ is the time when stock level reaches zero.