

Replenishment and pricing policy for deteriorating items taking into account the time-value of money

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Abstract

A deteriorating inventory model taking into account the time-value of money is developed for a deterministic inventory system with price-dependent demand. This study applies the discounted cash flows (DCF) approach for problem analysis. A heuristic approach is presented to derive the near optimal replenishment and pricing policy that tries to maximize the total net present-value profit. A numerical example is implemented to illustrate the theory. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Varying rate of deterioration; Price-dependent demand; Time-value of money

1. Introduction

The problem of deteriorating inventory has received considerable attention in recent years. This is a realistic trend since most products such as medicine, dairy products and chemicals start to deteriorate once they are produced. Ghare and Schrader [1] were among the first authors who studied inventory problems considering deterioration of items. Since then, a number of studies on deteriorating items have been done (see for instance [2,3]). Covert and Philip [4] assumed a two-parameter Weibull distribution deterioration to consider varying deterioration rate of deterioration. Dave and Patel [5] incorporated the effect of deterioration and time-varying demand to derive an economic order quantity (EOQ) with equal

replenishment cycles. Hollier and Mak [6] and Bahari-Kashani [7] extended the model by Dave and Patel to consider variable replenishment periods. Sachan [8] and Wee [9,10] extended the model by Dave and Patel to allow for shortages. Wee [11] later developed a replenishment policy for items with a price-dependent demand and a varying rate of deterioration.

Most researches in inventory do not consider the time-value of money. This is unrealistic since the resource of an enterprise depends very much on when it is used and this is highly correlated to the return of investment. Therefore, taking into account the time-value of money should be critical especially when investment and forecasting are considered. Buzacott [12] was the first author to include the concept of inflation in inventory modeling. He developed a minimum cost model for a single item inventory with inflation. Misra [13] simultaneously considered both the inflation and the time-value of money for internal as well as external inflation rate, and analyzed the influence

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of interest rate and inflation rate on replenishment strategy. Chandra and Bahner [14] extended the result in Misra to allow for shortages. Grubbstrom [15] formulated models in which the physical production processes and their associated cash flow are analyzed. Sarker and Pan [16] assumed a finite replenishment model and analyzed the effects of inflation and time-value of money on order quantity when shortages are allowed. Hariga [17] extended the study to analyze the effects of inflation and time-value of money on an inventory model with time-dependent demand rate and shortages. Bose et al. [18] then developed an EOQ model for deteriorating items with linear time-dependent demand rate and shortages under inflation and time discounting. Van Delft and Vial [19] proposed a simple economic order quantity for inventory with a short and stochastic lifetime. Their approach was performed in the framework of the total discounted cost criterion.

For most products, the demand rate and the unit price of items are closely correlated. Krishnan et al. [20] analyzed the diffusion models that focus on deriving optimal price. They observed, using the sales pattern of new model color TVs as an illustration, that optimal price is largely driven by rise and fall pattern of the product sales curve. We observed that at certain time of the product cycle, the monotonically decreasing price pattern results in sales increase. This pattern conforms to our price-dependent demand model. In general, our model is limited to certain product (such as electronic goods or luxury items) at specific time of the product cycle when the demand will fluctuate with the price of product; this means that when the price increases, the demand will be reduced and vice versa.

Most works on inventory models do not take into account of deterioration, the time-value of money and the price-dependent demand factor. This is not true in real life since the above factors are significant. For this reason, a deteriorating inventory model taking into account the time-value of money is developed in this study.

2. Mathematical modeling and analysis

The mathematical model in this paper is developed with the following assumptions:

1. The distribution of time until deterioration of the item follows a two-parameter Weibull distribution.
2. Deterioration occurs as soon as the items are received into inventory.
3. There is no replacement or repair of deteriorating items during the period under consideration.
4. The demand rate is a decreasing linear function of the selling price.
5. The replenishment rate is instantaneous; the order quantity and the replenishment cycle is the same for each period.
6. The system operates for a prescribed period of a planning horizon.
7. Shortages are completely backordered.
8. The order quantity, inventory level, replenishment epoch and demand are treated as continuous variables while the number of replenishments is restricted to an integer variable.
9. Continuous cost compounding is implemented throughout the analysis.
10. Product transactions are followed by instantaneous cash flow.

The following notation is used:

s	per unit selling price of the item (\$/unit); where $c < s < g/h$
$d(s)$	demand rate, $d(s) = g - hs$, is a decreasing linear function of selling price where $g - hs > 0$ for positive demand
g, h	constant values where $g > 0$ and $h > 0$,
c	per unit cost of the item (\$/unit)
$I_1(t_1)$	inventory level at any time t_1 ; $0 \leq t_1 \leq T_1$ (positive inventory)
$I_2(t_2)$	inventory level at any time t_2 ; $0 \leq t_2 \leq T - T_1$ (negative inventory)
H	planning horizon
T	replenishment cycle
N	number of replenishment during the planning horizon; $N = H/T$
T_1	time with positive inventory
$T - T_1$	time when shortage occurs
r	interest rate
Q	the 2nd, 3rd, ..., N th replenishment lot size (units)
I_m	maximum inventory level

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