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Economic order quantity models for ameliorating/deteriorating items under inflation and time discounting

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Abstract

The items that incur a gradual loss in quality or quantity over time while in inventory are usually called deteriorating items. In reality, there are some items whose value or utility or quantity increase with time and those items can be termed as ameliorating items. In this paper, an effort has been made to incorporate these two opposite physical characteristics of stored items into inventory model. We develop models for ameliorating/deteriorating items with time-varying demand pattern over a finite planning horizon, taking into account the effects of inflation and time value of money. Optimal solutions of the proposed models are derived and the effects of amelioration/deterioration on the inventory replenishment policies are studied with the help of numerical examples.

Keywords: Inventory; Time-varying demand; Deterioration; Amelioration; Inflation; Time discounting

1. Introduction

In the past decades, the replenishment scheduling problems were typically attacked by developing proper mathematical models that consider practical factors in real world situations, such as non-stationary demand, physical characteristics of inventoried goods, effects of inflation and time value of money, partial backlogging of unsatisfied demand, etc. It is usually observed in the marketplace that the demand for inventory items increases with time in the *growth phase*, and decreases in the *decline phase*. So researchers commonly use a time-varying demand pattern to reflect sales in different phases of product life cycle. In the early 1970s, Silver and Meal [27] derived an approximate solution procedure for the general case of a deterministic, time-varying demand pattern. Donaldson [12] then considered an inventory model with a

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linear trend in demand. After Donaldson [12], numerous research works have been carried out incorporating time-varying demand into inventory models under a variety of circumstances.

The assumption that the goods in inventory always preserve their physical characteristics is not true in general because there are some items which are subject to risks of breakage, evaporation, obsolescence etc. Decay, change or spoilage that prevent the items from being used for its original purpose are usually termed as deterioration. Food items, pharmaceuticals, photographic film, chemicals and radioactive substances, to name only a few items in which appreciable deterioration can take place during the normal storage of the units. The first attempt to obtain optimal replenishment policies for deteriorating items was made by Ghare and Schrader [13], who derived a revised form of the economic order quantity (EOQ) model assuming exponential decay. Thereafter, a great deal of research efforts have been devoted to inventory models of deteriorating items, the details can be found in the review articles by Raafat [25] and Goyal and Giri [14].

One of the assumptions in most derivations of the inventory model has been a negligible level of inflation. But in recent times many countries have been confronted with fluctuating inflation rates that often have been far from negligible [22]. Silver et al. [28] investigated the impact of inflation on the choice of replenishment quantities in the basic EOQ model. The pioneer in this field was Buzacott [5], who developed the first EOQ model taking inflation into account. Several researchers have extended their approach to various interesting situations by considering the time value of money, different inflation rates for the internal and external costs, finite replenishment rate, shortages, etc. The models of Mishra [21], Bierman and Thomas [2], Aggarwal [1], Chandra and Bahner [6], Hariga and Ben-Daya [17], Ray and Chaudhuri [26], Mangiameli et al. [20], Brahmbhatt [4], Dohi et al. [11], Moon and Yun [24], and Moon and Lee [23] are worth mentioning in this direction.

Bose et al. [3] first explored a deteriorating inventory model under inflation and time value of money. Unfortunately, their model contains some mathematical errors in the formulation of the holding cost and the purchase cost which lead to incorrect total cost function [22]. Chen [8] proposed a generalized dynamic programming model over a finite planning horizon for items with Weibull distribution deterioration where the demand rate is assumed to be time-proportional, shortages are allowed and are completely backordered and the effects of inflation and time value of money are taken into consideration. This model permits variation in both the replenishment intervals and the service levels between the order cycles. Chung et al. [10] discussed the inventory replenishment policy over a finite planning horizon for a deteriorating item taking account of time value and presented a line search technique to decide the optimal interval which has positive inventories. Recently, Chung and Lin [9] extended the inventory replenishment model of Chung et al. [10] to the situation where shortages are allowed in each replenishment cycle (the model starts with inventory, and ends with shortages). They considered the demand rate to be known and constant and applied the DCF approach to determine the optimal number of replenishments and the corresponding cycle length, consisting of positive and negative inventories.

Although degradation (or loss) of value or utility or quantity of some physical goods is a common experience in reality, there are some items whose value or utility increase over time by ameliorating activation, e.g. wine. It is a practical experience in wine manufacturing industry that utility or value of some kind of wine increases by age. Other examples can be high breed fishes in breeding yard (fish culture facility) or fast growing animals like broiler, pig, etc. in farming yard. In this paper, the term "amelioration" means to make better or increase goods in quantity or amount in an inventory. Hwang [18,19] for the first time developed EOQ models for items which are ameliorating in nature. In the present article, our attempt is to incorporate both the opposite physical characteristics viz. amelioration and deterioration of stored items into inventory model. We develop models with zero-ending inventory for fixed order intervals over a finite planning horizon allowing (A) shortages in all but not in the last cycle and (B) shortages in all cycles [15], taking into account the effects of inflation and time value of money. Optimal solutions of the proposed models are derived and the effects of amelioration/deterioration on the inventory replenishment policies are studied with the help of numerical examples.