An Optimal Policy for Deteriorating Items With Generalized Deterioration, Trapezoidal-Type Demand, and Shortages

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ABSTRACT

This paper focuses an optimal policy of an inventory model for deteriorating items with trapezoidal type demand rate and the three-parameter Weibull distribution deterioration rate. The model allows shortages which are completely backlogged in order to achieve better preserving amenity. The authors present some optimal solutions which leads to determine the total inventory cost in which the collective behavior of customers hinges on the waiting time. An easy-to-use optimization technique is included to find the shortage time point and order quantity to minimize the total system cost. Taking into account the above-mentioned assumptions, different kinds of numerical examples are considered to illustrate the theoretical behavior of the framed optimization model. The sensitivity analysis is made for this problem with variation of parameters. The study shows that the optimal solution not only exists but also is unique and is less expensive to operate if the factors of three-phase variation, representing the growth, the steady, and the decline phases of demand with respect to time are considered.

KEYWORDS

Deteriorating Items, Economic Order Quantity, Inventory, Shortages, Three-Parameter Weibull Distribution Deterioration Rate, Trapezoidal Type Demand Rate

INTRODUCTION

In the recent years, the observation and control of the effect of deterioration on physical items on the inventory has been very important for the researchers. By and large the literature assumes that a constant proportion of items will deteriorate per time-unit while they are in storage. From the beginning of the twentieth century to till date various inventory models are investigated for controlling the deteriorating or perishable items. The first and basic inventory model, which is known as economic order quantity (EOQ) model, was developed by Harris (1913) in order to minimize the total relevant cost. In this classical inventory model, it is assumed that the value of inventory items is unaffected by the duration of time. The classical Harris's inventory model was based on the depletion of inventory due to constant demand rate. However, the loss of inventory is not only due to the demand but also for the deletion of items in due course of time. In real life situations, items like volatile liquids, chemicals, blood stored in blood banks, medicines, fashion goods and electronic items cannot be held in store indefinitely for future requirement, they deteriorate significantly during

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the normal storage period. Therefore, the market demand and the consequence of deterioration are two major factors for the development of inventory models for deteriorating items. The first research on optimum policy deteriorating items was established by Ghare and Schrader (1963). They derived the mathematical inventory model for deteriorating items by using both constant demand pattern and constant deterioration rate in their model. According to them, direct spoilage, physical depletion and deterioration are the three important categories of the decaying inventory. Deterioration is defined as decay or damage, spoilage, evaporation, or drying out of products. Items like fruits, vegetables, films, pharmaceuticals, electronics devices and radioactive substances are some such products in which the deterioration may take place during the standard storage period of the units and as a result the loss must be judged while evaluating the model. Therefore, the effect of deterioration is very ideal in most of the inventory systems, for making the future decision of enterprises and solving the problem of how to control and maintain inventories of items which is a major issue for decision makers in modern organizations. In the model of Ghare and Schrader, the deterioration rate was considered as constant. Furthermore, several researchers have focused on time varying demand pattern that plays a major role in the determination of optimal order quantity. In this regard, Dave and Patel (1981) first considered the inventory model for deteriorating items with time proportional demand pattern. They considered a linear increasing demand rate over a finite horizon and a constant deterioration rate.The order cancellation effect in the inventory model for perishable items' waiting time dependent on the customer orders was represented by Thangam and Uthayakumar (2009). They adopted optimal pricing strategies for determining optimal order quantity and maximizing the total profit. Tripathi and Misra (2012) established an inventory model for a retailer to determine its optimal order quantity under the constraints of constant deterioration rate and constant pattern of demand. They used calculus technique of maxima and minima for the determination of optimal order quantity. Pentico et al. (2014) presented the two heuristics for the economic order quantity and economic production quantity (EPQ) with shortages as partial backordering. They determined EOQ and EPQ by using the time between orders and the proportion of demand and stated that the performance of both heuristics was very well when the critical value of the backlogging rate is at least 0.50. Singh et al. (2017) studied the inventory problem with stock dependent demand under permissible trade credit period.

Practically, the deterioration rate is not always constant in developing the inventory models. Sometimes it is neglected for the items like glassware, hardware, steel and toys as their deterioration rate is very slow. However, with the passage of time or the longer the items remain unused, the outflow failure of dry batteries and life period of decent drugs can be expressed in terms of Weibull distribution. This experimental inspection has given confidence to researchers to symbolize the time of deterioration of an item by a probability distribution like Weibull. Taking such consideration into account, Covert and Philip (1973) modified Ghare and Schrader's inventory model for deteriorating items by replacing deterioration rate from constant to the two-parameter Weibull distribution deterioration to represent the deterioration rate. In practice, some items do not start deteriorating as soon as they are kept in the stock, but after some time, they start deteriorating. For such cases the three-parameter Weibull distribution deterioration rate can be used for the representation of time of deterioration while developing the mathematical model. Mathematically, the three-parameter Weibull distribution deterioration is the generalisation of the two-parameter Weibull distribution and the exponential form when the location parameter is zero and the shape parameter is 1, respectively. Since the beginning of introduction of the three-parameter Weibull distribution in inventory model in inventory control research, with the help of the three-parameter Weibull distribution deterioration rate, the inventory model of Covert and Philip is extended by Philip (1974). The economic order quantity model with ramp-type demand, shortages and a three-parameter Weibull distribution deterioration is developed by Giri et al. (2003). But shortages are not appropriate in business competition, which is rarely seen. Nam et al. (2010) used the stochastic optimal theory for determining optimal solution for price and order quantity based on different levels of coordination under the uncertainty in demand and supplier's wholesale price. Jaggi et al. (2013) described an optimal policy on the two-warehouse

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