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The Application of Functions of Several Variables Analysis in an Optimal Replenishment Policy for Deteriorating Items

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Abstract

Very often must be taken into account the gradual deterioration of goods in inventory management. This fact is not taken into account in multiple management systems. Traditional inventory models at the same time assume that a retailer pays for the goods the moment they are received. Nowadays, however, it is becoming a common practice that a supplier offers a retailer the option to pay for the goods with a certain delay. If the retailer is not able to meet his obligations within the deadline, he is charges an interest. In this study we introduce a newly constructed suitable model which enables a retailer to set an optimal price of deteriorating goods under permissible delay in payments, and to determine the maximum repayment term. We considered a deterministic inventory model with time-dependent demand, holding costs variable in time where deterioration is directly proportional to the time. The model is based on the assumption of time-dependent demand and has been developed for deteriorating goods. The paper further analyses a situation in which the retailer sell all the goods in time, and a situation in which the deadline was not met. Further assumption is that the inventory is depleted only by demand. The scientific aim is to verify if such an optimizing problem can be solved. Theoretical results are illustrated with numerical example for the model. Results show that the developer model is capable of solving the theoretical problem illustrated by an example. It helps to the retailer to set the selling price and the replenishment interval in order to maximize profit. The authors of the paper used methods of analysis and synthesis, and the method of mathematical analysis (differential calculus of multivariable functions, solution of ordinary differential equations, Taylor series). The model suggested in the paper can be expanded in the future. One option is generalization of the model, allowing for the lack of goods, bulk discounts, time value of money, inflation etc.

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Keywords: inventory management, EOQ model, deteriorating goods, multivariable functions;

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1. Introduction

In today's world, more and more emphasis is put on increasing the productivity of work, effectiveness of management processes and all the other activities taking place within an enterprise. In spite of their generally positive role in a modern enterprise, inventories are usually thought of as a reserve in the managers´ work, and ways of reducing inventory level are looked for. Due to the fact that the level of inventories is easily measurable and that modern computer technologies enable us to monitor the inventory level in entire supply chains, inventory management is in the centre of attention of people specializing in the application of mathematical methods to enterprise management.

Traditional inventory models assume that the trader pays for the goods he has purchased at the moment when it is moved into stock. However, it is currently a common practice that the supplier offers the trader the possibility of paying for the goods with a certain delay. Until the end of this period, the trader is able to sell the goods and withhold the money on his account and thus gain interest on it. If he is unable to pay for the goods within the contractual period, he is charged an interest. In other words, the supplier grants the trader an interest-free loan for the contractual period.

This article is aimed at constructing a mathematical model allowing the trader to determine (based on the knowledge of certain parameters) the optimal selling price per item and the maximum time interval for which the goods can be sold with profit. The model is based on the assumption of a time-dependent demand and developed for deteriorating items with a specified deterioration rate. Also, it is assumed that inventory is drawn on the basis of demand only. From the scientific point of view, our goal is to verify whether such an optimization problem is solvable. To achieve this goal we have used the methods of mathematical analysis (differential calculus of several variables, solution of ordinary differential equations).

The new model created in this article is illustrated by a concrete problem and the solution is presented in graphical form.

2. Literature research

The basic EOQ model is based on the implicit assumption that retailer must pay for the items as soon as he receives them from a supplier. However, a common practice in industries is to provide a specific delay period for the payments after the items are delivered. In this regard, a number of research papers appeared which deal with the EOQ problem under fixed credit period. Whitin (1955) was the first researcher to extend the basic EOQ model by considering the selling price in addition to the order quantity as the decision variables.

Deterioration is a fact of life in inventory items, such as volatile liquids, agricultural products, radioactive substances, films, drugs, blood, fashion goods, electronic components and high-tech products. These items are subject to depletion by phenomena other than demand, i.e. through spoilage, shrinkage, decay and obsolescence. Ghare and Schrader (1963) extended the classical EOQ model by considering the exponentially decaying inventory when the demand is constant. Covert and Philip (1973) developed an economic lot-size model for situation in which the deterioration follows a Weibull distribution, under the assumptions of a constant demand rate with no shortages allowed. Hariga (1996), Teng, Yang, and Ouyang (2003) and Wu (2002) also extended EOQ-based deteriorating inventory models by considering a time-varying demand function, with or without shortages and some with partial backlogging. Manna and Chaudhuri (2001) discussed an EOQ model with deteriorating items in which the production rate is proportional to the time dependent demand rate.

Goyal (1985) developed an EOQ model under conditions of permissible delay in payments. He ignored the difference between the selling price and the purchase cost, and concluded that the economic replenishment interval and order quantity generally increases marginally under the permissible delay in payments.

Although Dave (1985) corrected Goyal's model by assuming the fact that the selling price is necessarily higher than its purchase price, his viewpoint did not draw much attention to the recent researchers. Aggarwal and Jaggi (1995) then extended Goyal's model for deteriorating items. Jamal et al. (1997) further generalized the model to allow for shortages and deterioration. Hwang and Shinn (1997) developed the optimal pricing and lot sizing for the retailer under the condition of permissible delay in payments. Liao et al. (2000) developed an inventory model for stock-depend demand rate when a delay in payment is permissible. Recently, Chang and Dye (2001) extended