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Continuous review inventory control in the presence of fuzzy costs

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Abstract

This paper presents new models of continuous review inventory control with or without backorder in the presence of uncertainty. Fuzzy set concepts are used to treat imprecision regarding the costs of continuous review inventory control, while probability theory is used to treat uncertainty regarding customer demand. Fuzzy total annual cost functions, which involve fuzzy arithmetic operations, are defined using the function principle. The optimal order quantity and the optimal reorder point are found in such a way as to minimize the fuzzy costs. Furthermore, a decision support system has been developed, which can be used for efficient evaluation of continuous review inventory systems with both crisp and fuzzy costs, incorporating a simulation analysis tool.

Keywords: Inventory control; Continuous review; Fuzzy sets; Decision support systems; Simulation

1. Introduction

Analysis of an inventory control system is one of the outstanding subjects in operations research and industrial engineering. In most of the inventory models that had been proposed in the early literature, the associated costs are represented as real numbers, although the real world inventory costs usually exist with imprecise components. When uncertainty becomes a matter of debate, conventional approaches to treating uncertainty in inventory control focus on probability theory. In this case, customer demand as one of the key parameters and source of uncertainty have been most often treated by a probability distribution. However, the probability-based approaches may not be sufficient enough to reflect all uncertainties that may arise in a real world inventory system. Modelers may face some difficulties while trying to build a valid model of an inventory system, in which the related costs cannot be determined precisely. For example, costs may be dependent on some foreign monetary unit. In such a case, due to a change in the exchange rates, the costs are often not known precisely. Another source of uncertainty may arise because of the difficulty of determining

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exact cost components. In some cases trying to determine the precise values of such cost components may be very difficult and costly, if not impossible. For example, inventory-carrying cost is often dependent on some parameters like current interest rate and stock keeping unit's market price, which may not be known precisely. In addition, shortage cost is often difficult to determine precisely, particularly in the case when it reflects not just "lost sale" but also "a loss of customers will".

Since some uncertainty within inventory systems cannot be considered appropriately using concepts of probability theory, fuzzy set theory has been used in modeling of inventory systems since 1980s. Fuzzy set theory, originally introduced by Zadeh (1965), provides a framework for considering parameters that are vaguely or unclearly defined or whose values are imprecise or determined based on subjective beliefs of individuals.

Park (1987) applied fuzzy set concepts to EOQ formula by representing the inventory-carrying cost with a fuzzy number and solved the economic order quantity model using fuzzy number operations based on the extension principle. On the other hand, Chen et al. (1996) used fuzzy set concepts in the EOQ model that replaced inventory costs with fuzzy numbers and solved the fuzzy order quantity problem using fuzzy number operations based on the function principle. Petrovic et al. (1996) presented a model for the newsboy problem in a fuzzy environment where uncertain demand was represented by a discrete fuzzy set and the inventory cost was given as a triangular fuzzy number. They used the method of arithmetic defuzzification to obtain the optimal order quantity. Roy and Maiti (1997, 1998) solved the classical EOQ problem with a fuzzy goal and fuzzy inventory costs using a fuzzy non-linear programming method where different types of membership functions for inventory parameters were specified. They examined the fuzzy EOQ problem with a demand-dependent unit price and an imprecise storage area using both fuzzy geometric and non-linear programming methods. They also formulated a multi-objective inventory model of deteriorating items with stock-dependent demand in a fuzzy environment. Gen et al. (1997) proposed a new method for the continuous review inventory model where triangular fuzzy numbers represented input data. They used a transformation for reducing a fuzzy number into a closed interval mean value concept proposed by Dubois and Prade (1987). Yao and Lee (1999), Yao and Su (2000) and Yao and Chiang (2003) discussed various inventory problems in fuzzy environments, including inventory control without backorder, with backorder and production inventory control. They modeled an order quantity using triangular and trapezoidal fuzzy numbers. The membership function of the fuzzy total cost and the order quantity were determined based on the extension principle. The optimal solution was obtained using different defuzzification methods and then compared each other. Li et al. (2002) developed two fuzzy models for a single-period inventory problem and achieved the optimal solution through fuzzy ordering of fuzzy numbers with respect to their total integral values. Kao and Hsu (2002) proposed an approach to finding the optimal quantity, which led to the minimum cost using a method for fuzzy numbers ranking. Recently Xie et al. (2006) presented a new hierarchical, two-level approach to inventory management and control in supply chains under fuzzy customer demand.

In this paper, fuzzy set concepts are used to treat the uncertainty regarding costs in some inventory control systems. New models of continuous review inventory control with or without backorder, with fuzzy costs and probabilistic demand are developed extending the classical continuous review inventory models with stochastic demand and crisp costs given in Johnson and Montgomery (1974). A decision support system, which can be used for efficient evaluation of these new and previous continuous review inventory models is implemented and developed which incorporates a simulation analysis tool.

The rest of the paper is organized as follows. In Sections 2 and 3, two crisp models and corresponding two fuzzy continuous review inventory models with and without backorder are introduced, respectively. In Section 4, a decision support system with a user-friendly interface for obtaining efficient solutions of crisp and fuzzy inventory problems and investigation of effectiveness of the proposed fuzzy models is presented. The model base of the decision support system includes the crisp and fuzzy models that are given in Sections 2 and 3, respectively.

2. Fuzzy continuous review inventory model without backorder

In a continuous review inventory system, the inventory level is monitored after every transaction and when it drops to a constant reorder point, an order is placed. It is supposed that demand in any