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A multi-objective wholesaler–retailers inventory-distribution model with controllable lead-time based on probabilistic fuzzy set and triangular fuzzy number

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Abstract

This paper develops a single wholesaler and multi retailers mixture inventory distribution model for a single item involving controllable lead-time with backorder and lost sales. The retailers purchase their items from the wholesaler in lots at some intervals throughout the year to meet the customers' demand. Not to loose the demands, the retailers offer a price discount to the customers on the stock-out items. Here, it is assumed that the lead-time demands of retailers are uncertain in both stochastic and fuzzy sense, i.e., these are simultaneously random and imprecise. To implement this behavior of the lead-time demands, at first, these demands are assumed to be random, say following a normal distribution. With these random demands, the expected total cost for each retailer is obtained. Now, the mean lead-time demands (which are crisp ones) of the retailers are fuzzified. This fuzzy nature of the lead-time demands implies that the annual average demands of the retailers must be fuzzy numbers, suppose these are triangular fuzzy numbers. Using signed distance technique for defuzzification, the estimate of total costs for each retailer is derived. Therefore, the problem is reduced to optimize the crisp annual costs of wholesaler and retailers separately. The multi-objective model is solved using Global Criteria method. Numerical illustrations have been made with the help of an example taking two retailers into consideration. Mathematical analyses have been made for global pareto-optimal solutions of the multi-objective optimization problem. Sensitivity analyses have been made on backorder ratio and pareto-optimal solutions for wholesaler and different retailers are compared graphically.

Keywords: Fuzzy inventory; Controllable lead-time; Signed distance; Fuzzy total cost; Multi-objective; Global criteria

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1. Introduction

Now-a-days, due to the globalization of market with introduction of multi-nationals in the business, status of inventory problems are faced by the business houses has been changed a lot. It is observed that multinationals store their products in a place of a country where maximum financial benefits in terms of rent, taxes, excise duty, etc., are available. Then products are distributed to customers at different corners of the country/ neighboring countries using franchisees. So, the interests of both multinationals (viz, wholesalers) and their franchisees (viz, retailers) have been coupled together and so objectives of both the parties are to be considered simultaneously. Hence, these considerations normally lead to the formulation of multi-objective decision making (MODM) inventory control problems.

Over the past two decades, no extensive research work has been done to deal with more than one objective in inventory management problem. Bookbinder and Chen [1] developed a non-linear mixed integer programming model with two objectives for the warehouse–retailer system under deterministic demand. The objectives in this model are minimization of annual inventory and transportation costs. They (1992) also considered two probabilistic models with customers service as another objective. Earlier, Padmanabhan and Vrat [2] formulated an inventory problem of deteriorating items with two objectives—minimization of total average cost and wastage cost in crisp environment and solved by non-linear goal programming method. Roy and Maiti [3] formulated an inventory problem of deteriorating items with two constraints, namely, storage space constraint and total average cost constraint and two objectives, namely, maximizing total average profit and minimizing total wastage cost in fuzzy environment.

Lead time and unit cost are important factors for inventory and business houses. According to Tersine [4] lead time usually consists of the following components: order preparation, order transit, supplier lead time, delivery time and setup time. Most of the authors deal with inventory lead time as a control variable. Liao and Shyu [5] considered lead time as a variable and controlled it by paying extra crashing cost. This model has been extended by Ben-Daya and Raouf [6], Ouyang et al. [7], Ouyang and Wu [8]. Although, all of them considered the lead time reduction cost as a function of the number of order only but it is not so because Pan and Hsiao [9] proposed that the transportation cost, the overtime wages and extra inventory holding cost for expedition of delivery are all proportional to the item order quantities rushed. Therefore the crashing cost consists two parts (i) one part is constant part and (ii) other is proportional to the ordered quantity. Again, till now, almost all investigations with lead time is related to the inventory models with infinite replenishment rate. But, in a production system with finite replenishment, it also plays a significant role. In this system, preparation for the next production is very important. Next production is dependent on the time when decision for it is taken by decision maker (DM). Here, it has been named preparation time instead of 'lead time'. Taking this into consideration, Mahapatra and Maiti [10,11] formulated and solved two production–inventory models for deteriorating item with imprecise preparation time for production (Figs. 1–3).

In this paper, a single wholesaler and N-retailers inventory distribution model for a single item is described involving controllable lead-time with backorder (for which the price discounts given by the retailers to the customers) and lost sales. The retailers purchase their items from the wholesaler in lots at some interval throughout the year to meet the customers' demand. Here, demands during the lead time is of random fuzzy nature.

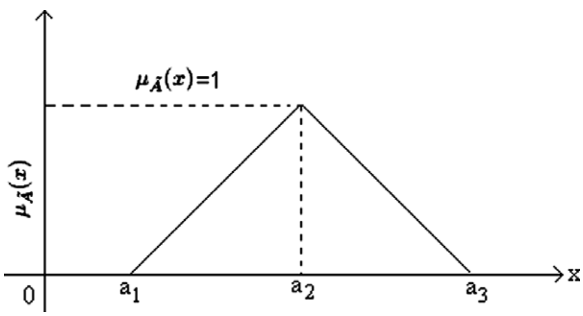

Fig. 1. Triangular fuzzy number (TFN).