Mathematical and Computer Modelling 54 (2011) 1273–1285

Contents lists available at ScienceDirect

Mathematical and Computer Modelling

journal homepage: www.elsevier.com/locate/mcm

Meta-heuristic algorithms for solving a fuzzy single-period problem

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ARTICLE INFO

Article history:
Received 17 August 2010
Received in revised form 26 March 2011
Accepted 28 March 2011

Keywords:
Inventory control
Single-period problem
Multi-product multi-constraint
Meta-heuristic

ABSTRACT

Single-period problem (SPP) is a classical stochastic inventory model that has become very popular recently. In this research, we developed a SPP with fuzzy environment. The demand of each product is considered as LR-fuzzy variables (ranking fuzzy numbers based on the left and right deviation degrees), and multiple constraints (including service level, batch order, budget, space and upper limit for each order). The aim of this paper is to maximize the total expected profit under incremental discount strategy. Five hybrid intelligent algorithms based on fuzzy simulation (FS) and meta-heuristic methods are presented; they are bees colony optimization (BCO), harmony search (HS), particle swarm optimization (PSO), genetic algorithm (GA) and simulated annealing (SA). Three numerical examples are presented to illustrate the performance of the algorithms. Our study shows that the BCO-FS hybrid method performs better than the HS-FS, GA-FS, PSO-FS, and SA-FS hybrid methods.

1. Introduction

In a single-period model, the useful life of a product is one planning cycle and demand is assumed to be stochastic. This is the case for products such as fresh food, styled goods, newspapers, magazines, and holiday decoration like Christmas trees. It is also referred to as the traveling saleman problem, the newsboy problem or the Christmas tree problem. The model is also suitable for solving hotel rooms and ticketing problems. The aim of the single-period problem is to determine the optimal order quantity for each item at the beginning of the period.

Hsu et al. [1], Chung and Wee [2] developed replenishment policies for products with short life-cycle. Ishii and Konno [3] introduced fuzziness of shortage cost explicitly into the classical single-period problem. They investigated the fuzzy single-period problem in which its shortage cost is vague. Ishii and Konno [3] considered SPP in the presence of uncertainties. They considered the presence of either the fuzzy cost or the fuzzy demand. Kao and Hsu [4] extended the SPP model for the case where rank fuzzy numbers is adopted. Gue and Chen [5] investigated the uncertainty of new products demand. Duttaal [6] presented SPP in an imprecise and uncertain mixed environment. Shao and Ji [7] considered multi-product SPP problem with fuzzy demands under budget constraint. Ji and Shao [8] considered the model for SPP with fuzzy demands and quantity discounts in hierarchical decision system. Taleizadeh et al. [9] considered multi-product multi-constraint SPP with random fuzzy demands and discount. Hu and Yan [10] considered bi-level SPP which included a single leader and multiple followers, with consistent and inconsistent negative exponential quantity discounts. Dutta and Chakraborty [11] developed an approach for solving SPP in a fuzzy environment. Wee et al. [12] developed a multi-objective joint replenishment inventory model of deteriorated items in a fuzzy environment. Huangal [13] studied a multi-product competitive newsboy problem in which shortage and partial product substitution are permitted. Yao et al. [14] proposed a newsboy model with

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doi:10.1016/j.mcm.2011.03.038

products return policy. Chen and Chen [15] studied a newsboy problem with reservation policy. Zhang and Du [16] developed a newsboy problem with limited capacity and two different outsourcing policies. Lee and Hsu [17] studied the effects of advertising on newsboy problem. Zhang and Hua [18] used a portfolio approach to optimize constraint newsboy problem.

The real-world application of this problem is most appropriate for perishable items such as cheese, milk, ice cream and yogurt. Similar use of SPP model can be found in fashion-products businesses [9]. In real life situation, it may not be possible to know the exact distribution function of product demand. This results in the need to consider fuzzy demand or rough variables.

Unlike what have been done, our proposed model considers shortage, incremental discount, L–R fuzzy variables and multi-product multi-constraint.

The rest of the paper is organized as follows: In Section 2, some definitions of fuzzy and rough environment are described. The problem along with its assumptions is defined and modeled in Section 3. In Section 4, the five hybrid solution algorithms are described. Section 5 shows a numerical example to demonstrate the applicability of the proposed model. Finally a summary is given in Section 6.

2. Definitions in Fuzzy theory [20]

Definition 1. A Fuzzy number is of L–R Type, if there is a reference functions L (for the left), R (for the right), and scalars $l > 0, r > 0$:

$$\mu(\tilde{\theta}) = \begin{cases} L\left(\dfrac{m-\tilde{\theta}}{l}\right) & \tilde{\theta} \le a \\ 1 & \tilde{\theta} \in [a, b] \\ R\left(\dfrac{\tilde{\theta}-n}{r}\right) & \tilde{\theta} \ge b. \end{cases} \tag{1}$$

And L–R fuzzy variable is denoted by $\tilde{\theta} = (a, b, l, r)_{L\text{–}R}$. The triangular and trapezoidal fuzzy variables are specific kind of L–R Type.

Definition 2. Let $\tilde{\theta}$ be a fuzzy number with the membership function $\mu(\tilde{\theta})$. Then the possibility, necessity, and credibility measure of the fuzzy event $\tilde{\theta} \ge \alpha$ can be represented, respectively, by:

$$\text{Possibility}\{\tilde{\theta} > \alpha\} = \sup_{\tilde{\theta} \ge \alpha} \mu(\tilde{\theta}) \tag{2}$$

$$\text{Necessity}\{\tilde{\theta} \ge \alpha\} = 1 - \sup_{\tilde{\theta} < \alpha} \mu(\tilde{\theta}) \tag{3}$$

$$\text{Credibility}\{\tilde{\theta} \ge \alpha\} = \frac{1}{2}[\text{Possibility}\{\tilde{\theta} \ge \alpha\} + \text{Necessity}\{\tilde{\theta} \ge \alpha\}]. \tag{4}$$

Definition 3. The expected value of a fuzzy variable $\tilde{\theta}$ is defined by Liu [20] as:

$$E[\tilde{\theta}] = \int_0^{\infty} \text{Cr}\{\tilde{\theta} \ge \alpha\} \mathrm{d}\alpha - \int_{-\infty}^{0} \text{Cr}\{\tilde{\theta} \le \alpha\} \mathrm{d}\alpha. \tag{5}$$

Definition 4. Let $\tilde{\theta}$ be a fuzzy variable. Then the optimistic function of β is defined by Liu [20] as:

$$\tilde{\xi}_{\sup}(\beta) = \sup[\alpha | \text{Cr}\{\tilde{\theta} \ge \alpha\} \ge \beta], \quad \beta \in (0, 1]. \tag{6}$$

3. Problem definition and formulation

In this section, we propose a multi-product and multi-constraint fuzzy SPP problem. For p products, demands are assumed to be L–R fuzzy and the buyer orders the products at the beginning of each period in multiple batch sizes. The total capacity of warehouse and budget are restricted. To satisfy customer demand, the buyer considers a minimum service level. The vendor presents incremental discount strategy to the buyer. The shortage and holding costs are considered at the end of the period.

3.1. The parameters and variables

The parameters and variables that are used to formulate the problem are as below (p: Number of products j : 1, 2, . . . , p):