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Revisiting a fuzzy rough economic order quantity model for deteriorating items considering quantity discount and prepayment

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ABSTRACT

This study revisits a fuzzy rough economic order quantity (EOQ) model for deteriorating items considering quantity discount and prepayment. Since the proposed model is a mixed integer nonlinear programming type, it is solved using Meta heuristic algorithms. Based on three different case examples, we have shown that our results using the Bees Colony Optimization (BCO) algorithm performs better than the other techniques which are used.
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1. Introduction and literature review

In the existing literature, few researchers have investigated the inventory models under fuzzy rough environments. Our study investigates these phenomena for the EOQ model considering quantity discount and prepayment. The consideration of fuzziness and roughness with uncertainty is an important area of research [1].

Several researchers have applied fuzzy or rough sets theory to solve production–inventory problems. Park [2] and VujoSevilc et al. [3] extended the classical EOQ model by introducing a fuzzy ordering and holding cost. Chen and Wang [4] fuzzified demand rate, fixed ordered and inventory costs. Also they considered backorder cost as trapezoidal fuzzy variables in an Economic quantity model in which backordered shortage is permitted. Roy and Maiti [5] presented a fuzzy EOQ model with demand-dependent unit cost under limited storage capacity. Chang et al. [6] developed a triangular fuzzy model for inventory with backorder. Lee and Yao [7] discussed the production–inventory problems for fuzzy demand quantity. Yao et al. [8] proposed the fuzzy EOQ model where both the order quantity and the total demand were triangular fuzzy numbers. Ouyang and Yao [9] presented a mixed inventory model with variable lead-time for a triangular and statistic fuzzy number. Kao and Hsu [10] considered a single period inventory model with fuzzy demand. Kao and Hsu [11] extended the lot size-reorder point inventory problem with fuzzy demands and backorder. Dutta et al. [12] maximized the profit of a single-period inventory model in an imprecise environment. Taleizadeh et al. [13] extended an uncertain EOQ model for joint replenishment strategy with incremental discount policy and fuzzy rough demand. Panda et al. [14] considered a multi-item EOQ model in which the cost parameters were fuzzy. Liu [15] developed a solution method to derive the fuzzy profit

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of an inventory model when the demand quantity and unit cost were fuzzy numbers. Bjork [16] extended the EOQ model with backorders in an uncertain situation with fuzzy demand and lead times. Xu and Zhao [1] proposed a multi objective inventory model where the costs were fuzzy rough variables. Taleizadeh et al. [17] extended an EOQ model under fuzzy demand and rough cost factors in which shortage is not permitted. Some related studies can be found in Sahebjamnia and Torabi [18], Hadi-Vencheh and Mohamadghasemi [19], Taghizadeh et al. [20], Pirayesh and Yazdi [21], Kazemi et al. [22], Sadeghimoghadam et al. [23], Rezaei and Davoodi [24,25].

In this paper, we develop a joint replenishment policy for expensive imported raw materials with a certain percentage (x%) of prepayment. The remaining cost is paid sometime later Demands are considered fuzzy rough variables and the quantity ordered must be an integer number. The lead time is assumed to be less than the replenishment cycle, and the purchasing policy follows a quantity discount strategy with backorders. In real life situation, applying fuzzy and rough theory to estimate product demands is necessary due to the uncertainty in demand distribution.

2. Fuzzy and rough environments

2.1. Some definitions of fuzzy environment

In this section, we will define the meaning of credibility and the expected value of a fuzzy variable. According to Liu [26], we prepare following definitions.

Definition 1. Considering $\alpha > 0,\ \beta > 0$, for a fuzzy LR-Type variable, ψ, membership function is being defined as a below,

$$\mu(\psi) = \begin{cases} L\left(\dfrac{L-\psi}{\alpha}\right) & \psi \le L \\ 1 \quad \psi \in [L, R] \\ R\left(\dfrac{\psi - n}{\beta}\right) & \psi \ge R \end{cases} \tag{1}$$

where ψ is defined by $\psi = (L, R, \alpha, \beta)_{L-R}$. It should be noted that both trapezoidal and triangular fuzzy numbers are specific kinds of LR-Type [8].

Definition 2. For any fuzzy number ψ for which its membership function is being defined by $\mu(\psi)$, possibility of $\psi \ge r$ is defined by Liu [26] as,

$$\text{Possibility}\,\{\psi > \lambda\} = \sup_{\tilde{\xi} \ge r} \mu(\psi). \tag{2}$$

While its necessity and credibility is being measured by,

$$\text{Necessity}\,\{\psi > \lambda\} = 1 - \sup_{\psi < \lambda} \mu(\psi) \tag{3}$$

$$\text{Credibility}\,\{\psi > \lambda\} = \frac{1}{2}\left[\text{Possibility}\,\{\psi > \lambda\} + \text{Necessity}\,\{\psi > \lambda\}\right]. \tag{4}$$

Definition 3. Liu and Liu [27] defined the expected value of a fuzzy variable ψ as,

$$E\left[\tilde{\xi}\right] = \int_0^{\infty} \text{Cr}\,\{\psi \ge \lambda\}\, dr - \int_{-\infty}^{0} \text{Cr}\,\{\psi \le \lambda\}\, dr. \tag{5}$$

While a triangular fuzzy variable's expected value is $\psi = (\psi_1, \psi_2, \psi_3)$,

$$E[\psi] = \frac{1}{4}(\psi_1 + 2\psi_2 + \psi_3). \tag{6}$$

2.2. Some definitions in rough theory

Rough set theory, initialized by Pawlak [28], is an excellent mathematical tool to describe vague objects. Any object from the universe is perceived through available information; if information is insufficient to describe the object exactly, rough variable should be used. Referring to the studies by Liu [26] and Xu and Zhao [1] some concepts in rough theory are explained as follow.

Definition 4. Let Λ be a nonempty set, a $\sigma - Algebra$ of subsets of Λ, and Δ an element in A, and π a trust measure, then $(\Lambda, \Delta, A, \pi)$ is called a rough space [26,8].

Due to a lack of information, it may be hard to evaluate the value of π in a real life problem. We assume all elements in Λ are equally likely to occur (Laplace criterion). For this case, the value of π may be taken as the cardinally of set Λ.

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