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Two parameter-tuned meta-heuristics for a discounted inventory control problem in a fuzzy environment

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ABSTRACT

In this paper, a nearly real-world multi-product, multi-period inventory control problem under budget constraint is investigated, where shortages in combination with backorders and lost sales are considered for each product. The ordered quantities of products are delivered in batch sizes with a known number of boxes, each containing a pre-specified number of products. Some products are purchased under an all unit discount policy, and others are purchased under an incremental quantity discount with fuzzy discount rates. The goal is to find the optimal ordered quantities of products such that not only the total inventory cost but also the required storage space (considered as a fuzzy number) to store the products is minimized. The weighted linear sum of objectives is applied to generate a single-objective model for the bi-objective problem at hand and a harmony search algorithm is developed to solve the complex inventory problem. As no benchmarks are available to validate the obtained results, a particle-swarm optimization algorithm is employed to solve the problem in addition to validate the results given by the harmony search method. The parameters of both algorithms are tuned using both Taguchi and response surface methodology (RSM). Finally, to assess the performance of the proposed algorithms some numerical examples are generated, and the results are compared statistically.

1. Introduction and literature review

Most real-world problems, in industries and commerce, are studied using a single-objective optimization model. The assumption that organizations always seek to minimize cost or maximize profit rather than make trade-offs among multiple objectives has been used extensively in the literature. In this regards, classical inventory models have been developed under the basic assumption that a single product is purchased or produced. However, in many real-life situations, this assumption does not hold. Instead of a single item, many firms, enterprises or vendors are motivated to store a number of products to enhance their business profitability. They are also motivated to attract customers to purchase several items simultaneously.

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Ben-Daya and Raouf [1] considered a multi-product, single-period inventory control problem with stochastic demand, for which the multi-periodic inventory control problem was investigated in depth for multiple seasonal products. Recently, Wang and Xu [37] studied a multi-period, multi-product inventory control problem having several inventory classes that can be substituted for one another to satisfy the demand for a given reservation class. Chiang [4] investigated a periodic review model in which the period is partly long. The important aspect of his study was to introduce emergency orders to prevent shortage. A dynamic programming approach was employed to model the problem. Das et al. [6] developed a multi-item inventory model with constant demand and infinite replenishment under restrictions on storage area, average shortage, and inventory investment cost. Mohebbi and Posner [17] studied an inventory system based on periodic review, multiple replenishment, and multilevel delivery. They assumed that the demand follows a Poisson distribution, that shortages were allowed and that the lost sale policy could be employed. Lee and Kang [13] developed a model to manage the inventory of a single product in multiple periods, whereas Padmanabhan and Vrat [24] developed a multi-item/objective inventory model having deteriorating items with stock dependent demand using a goal programming method. Moreover, Taleizadeh et al. [35] proposed a multi-product inventory control problem with a stochastic replenishment period in which the demands were fuzzy numbers, and shortages were allowed to occur with a combination of backorders and lost sales.

Quantity discount has attracted further attention because of its practical importance in purchasing and control of a product. It derives better marginal cost of purchase/production availing the chances of cost savings through bulk purchase/production. In supply chains, quantity discounts can be considered as an inventory coordination mechanism between a buyer and a supplier (Shin and Benton [31]). Benton [2] considered an inventory system having quantity discount for multiple price breaks and alternative lot-sizing policy. Maiti and Maiti [15] developed a model for multi-item inventory control system based on breakable items, taking into account all units (AUD) and incremental quantity discount (IQD) policies. In this paper, a combination of AUD and IQD is used, which is rather similar to the work by Sana and Chaudhuri [29]; however the deterministic discount rates were used in the latter study of the research in this paper. Sana and Chaudhuri [29] extended an economic order quantity (EOQ) model based on discounts through the relaxation of the pre-assumptions associated with payments. Furthermore, Taleizadeh et al. [34] considered a mixed integer, nonlinear programming for solving multi-product multi-constraint inventory control systems having stochastic replenishment intervals and incremental discounts for which a genetic algorithm was employed to find the near-optimum order quantities of the products. Recently, Mousavi et al. [20] improved the solution of a discounted multi-item multi-period inventory control problem for seasonal items, in which shortages are allowed, and the costs are calculated under inflation and time value of money.

In general, many of the variables, resources, and constraints used in a decision-making problem are considered to be either deterministic or stochastic. However, real-life scenarios demand them to be imprecise, i.e., uncertainty is to be imposed in a non-stochastic sense. According to Maity [14], a business may start with some warehouse space in an inventory control problem. However, due to unexpected demands, some additional storage spaces may need to be added. These added spaces are normally imprecise and fuzzy in nature. Moreover, one of the weaknesses of some current inventory models is the unrealistic assumption that all items are purchased under a crisp discount policy. Nevertheless, in many inventory control systems, fuzzy discount rates are natural phenomena. Maity and Maiti [16] formulated an optimal production strategy for an inventory control system of deteriorating multi-items under a single owner based on resource constraints under inflation and discounting in a fuzzy environment. Recently, Chen and Ho [3] investigated a newsboy inventory problem in a fuzzy environment by analyzing the optimal inventory policy for the single-order newsboy problem considering fuzzy demand and quantity discounts. Moreover, Guchhait et al. [10] modeled an inventory control problem under discount based on fuzzy production rate and demand.

In this research, a multi-periodic inventory control problem is modeled for seasonal and fusion products in which the replenishment process begins at a pre-specified time (or season) and ends at another one. Binary variables are used in this research to model the purchasing cost based on discounted prices (similar to the work by Lee and Kang [13] that models price break points). However, an AUD policy for some products with crisp discount rates and an IQD policy for other items based on fuzzy discount rates are also considered in this research. Das et al. [6] that considered the shortage to be fully backordered; however, in this paper, shortages include a combination of backorders and lost sales. The constraints of the proposed model are budget, truck space, and the order quantities of the products in a given period. The problem will be investigated in two single-objective and bi-objective optimization approaches. In the first approach, the goal is to find the ordered quantities of the products in different periods such that the total inventory cost of ordering, holding, shortage, and purchasing is minimized. In the second approach, the objective is to minimize both the total inventory cost and the required fuzzy storage space. The problems will be formulated into mixed binary nonlinear programming based on three binary variables to demonstrate the ordering, shortage, and purchasing costs. The weighted linear sum (WLS) method is used to transform the bi-objective inventory problem into a single-objective one. A harmony search (HS) algorithm is developed to solve the complex inventory problem. As no benchmarks are available to validate the obtained results, a particle-swarm optimization (PSO) algorithm is employed to solve the problem as well as the validation of the performance of HS algorithm. The parameters of both algorithms are tuned using both Taguchi and RSM methods.

In recent decades, scientists have been mimicking natural phenomena to propose methods and algorithms for solving complex optimization problems. Based on the complexity of real-life optimization problems, one may not be able to use exact algorithms. Therefore, typically, meta-heuristic methods are frequently used to find a near optimum solution in an acceptable period of time. Genetic algorithms (Mousavi et al. [19]), simulating annealing (Taleizadeh et al. [32]), particle