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A comparison of different dispatching policies in two-warehouse inventory systems for deteriorating items over a finite time horizon

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ABSTRACT

This paper considers a two-warehouse inventory problem for deteriorating items with a constant demand rate over a finite time horizon. A modified first-in-first-out dispatching policy is first proposed, and a new two-warehouse inventory model based on this dispatching policy is developed. The results of this model are then compared with those of other models based on classical dispatching policies, such as the last-in-first-out, modified last-in-first-out and first-in-first-out dispatching policies. We also prove the existence and uniqueness of the optimal solutions for the models considered. Finally, a numerical example is presented to illustrate the results, and several key conditions are derived for comparing the general cases of these four models.

1. Introduction

The two-warehouse inventory problem is one of the most important problems in inventory management. In the formulation of models related to this problem, it is usually assumed that a manager owns a warehouse of limited capacity, denoted by OW. Quantities exceeding the OW capacity must be stored in a rented warehouse, denoted by RW. Because of their realistic features, such problems have received considerable attention since Hartely [1] proposed the basic two-warehouse inventory model. Since that study, many researchers have conducted significant studies on two-warehouse inventory models. Related literature can be found in the works of Zhou and Yang [2], Huang [3], Teng et al. [4], Das et al. [5], Chung et al. [6], Panda et al. [7], and Maity [8], among others. Sarma [9] was the first to develop a two-warehouse inventory model for deteriorating items with a constant demand rate and shortages. Deterioration refers to negative changes such as damage, spoilage, dryness, and vaporization of products. In reality, many products, such as vegetables, milk and fruits, deteriorate during storage. Over the past several decades, many researchers have investigated inventory problems based on the model for deteriorating items proposed by Ghare and Schrader [10]. Four comprehensive literature reviews addressing related work are those of Nahmias [11], Raafat [12], Goyal and Giri [13], and Bakker [14]. More recent publications include Jaber et al. [15], Tat et al. [16], Taleizadeh et al. [17], and Chen and Teng [18], among others.

Several authors have studied two-warehouse inventory systems for deteriorating items based on various considerations. For example, Dye et al. [19] proposed a two-warehouse inventory model for deteriorating items with constant demand and

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time-proportional backlogging rates. They discussed several useful properties for determining the optimal replenishment policy. Liao and Huang [20] developed a deterministic inventory model for deteriorating items with trade credit financing and capacity constraints. Assuming a constant demand rate, they presented two theorems for determining the optimal replenishment cycle time. Jaggi et al. [21] considered a two-warehouse inventory problem for deteriorating items under inflationary conditions. They developed a procedure for solving the optimal replenishment policy under the assumption that the demand rate is a linearly increasing function of time. Yang [22] incorporated the effects of time on the deterioration rate into a two-warehouse inventory model with partial backlogging. In her model, the deterioration rate is assumed to follow a three-parameter Weibull distribution. She proved the existence and uniqueness of the optimal replenishment policy that minimizes the current net value of the total cost per unit time. Ghiami et al. [23] considered a two-echelon supply model for deteriorating items consisting of a wholesaler and a retailer with limited warehouse capacity. Those authors used a genetic algorithm to determine the optimal inventory policy when the demand rate of the retailer is dependent on the stock level. Bhunia et al. [24] developed a two-warehouse model for deteriorating items with a permissible delay in payment. In their model, the demand rate is constant and shortages are allowed with partial backlogging. Those authors proved several optimal properties of the solutions and designed a new algorithm for determining the optimal inventory policy. Under the assumption that the demand rate is a linear function of time, Bhunia et al. [25] proposed a two-warehouse inventory model for deteriorating items under inflation. For the two cases in which inventory follows shortage and shortage follows inventory, the authors formulated two nonlinear constrained optimization models and designed an effective algorithm to solve them. Other studies in this area include Yang [26], Hsieh et al. [27], Yang and Chang [28], Soni [29], Agrawal et al. [30], and Liao et al. [31], among others.

In developing the models discussed above, the researchers generally assumed that the cost of holding inventory in the RW is higher than that in the OW. Consequently, these models naturally use the LIFO (last-in-first-out) dispatching policy, in which items in the OW are stored earlier and used later, whereas items in the RW are stored later but used earlier. However, Lee [32] noted that such a policy should be further investigated, as many companies follow the FIFO (first-in-first-out) rule to ensure better freshness of the stored items. Under a FIFO policy, items that are stored first in the OW will be consumed before those in the RW. In the context of two-warehouse inventory problems for deteriorating items with the LIFO policy proposed by Pakkala and Achary [33], Lee [32] further suggested a modified last-in-first-out (MLIFO) dispatching policy and developed two additional models with fully backlogged shortages based on the MLIFO and FIFO policies. In addition, the author compared the performance of all three models under the assumptions that the items stored in the two warehouses have the same deterioration rate and that the total cost function in a single predetermined cycle time is convex. Niu and Xie [34] made additional observations when analyzing these problems. Assuming that the demand rate is dependent on the selling price, Jaggi et al. [35] proposed a two-warehouse inventory model for deteriorating items with a permissible delay in payment. For the case in which shortages are allowed and fully backlogged, the authors formulated mathematical models based on the LIFO and FIFO dispatch policies and designed an algorithm to determine the optimal inventory and pricing policies to maximize the total average profits.

Several other researchers have investigated two-warehouse models for deteriorating items over a finite planning horizon. For example, Kar et al. [36] proposed a model with linear and time-dependent demand. For the case in which shortages are allowed and fully backlogged, the authors solved the model using a gradient method. Under the assumptions that all ordering intervals are equal and that shortages are not allowed, Lee and Ma [37] designed a heuristic algorithm to solve the two-warehouse inventory model with general time-dependent demand. Lee and Hsu [38] extended the model of Lee and Ma [37] to a situation with a finite replenishment rate based on an LIFO dispatching policy. To determine the number of production cycles and the replenishment time, the authors proposed a new method that permits variation in the production cycle times to solve the developed model; their proposed method is based on the convexity of the total cost function. Recently, Das et al. [39] extended the model proposed by Lee and Hsu [38] to a model with fully backlogged shortages. They used a genetic algorithm to determine the optimal number of production cycles and cycle times over a finite planning horizon.

The main assumptions and results of the above studies on two-warehouse inventory models for deteriorating items are summarized in Table 1. This summary shows that the convexity/concavity of the total cost/profit function has not yet been proven and that several effective dispatching policies for a two-warehouse deteriorating inventory model over a finite planning horizon still require further study. In the real world, however, dispatching policies play an important role in satisfying market demand and minimizing the total cost for the manufacturer. For example, in China, many small food manufacturers must produce their products in RWs because of the limited capacity of their OWs. Generally, the OW is located in the marketing center, whereas the RW is located far from the marketing center. Products are delivered directly to the OW to satisfy market demand after their production is complete. During production, the products that have deteriorated in the OW are often replaced with fresh products from the RW to attract more customers. Thus, the products in the OW are sold first, followed by the products in the RW. For the decision-maker, the following questions are important: (i) Does the dispatching policy have a minimum total cost? (ii) Are there other dispatching policies that are superior to the current policy? (iii) How does the dispatching policy compare with other dispatching policies?

Motivated by such practical challenges, in this paper, we study a two-warehouse inventory model for deteriorating items over a finite planning horizon and propose a modified FIFO (MFIFO) dispatching policy. We first formulate a new inventory model with a constant demand rate based on this MFIFO dispatching policy. For the case in which shortages are not allowed,