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Coordination mechanism for a deteriorating item in a two-level supply chain system

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ABSTRACT

The subject of the coordination between the suppliers and the buyers in multi-echelon inventory-distribution systems has been studied by many researchers. This paper considers a supply chain including a manufacturer and several buyers and assumes that the inventory items deteriorate over time and its inventory level decreases. In order to determine the order policies, coordination over the supply chain is achieved by scheduling the buyers' delivery days and their coordination with the manufacturer's production cycle. A mathematical model is developed and analyzed. To test the efficiency of the proposed model, two other models with the supposition of lot-sizing policies with common order cycle and independent deciding are also developed. In comparison to the other two models, the numerical results show that the synchronizing model of production and delivery cycles works better and has less total cost. In addition, in order to encourage the buyers in cooperation, a model on profit sharing is proposed that equitably shares the total savings with all the parties.

1. Introduction

The "multi-stage" inventory system is formed when an item moves through more than one stage before reaching the final consumer. The supplier or a retailer at each stage traditionally makes decisions locally to restock their inventory. However, such policies result in local improvement, and do not improve the global functioning of the system. If buyers coordinate their orders, it would reduce the inventory cost to the manufacturer and hence the total system cost. Accordingly, factual and up-to-date data enable suppliers to coordinate supply with demand effectively. Recent studies have resulted in considerable cost savings through information sharing [1].

As the environment becomes more competitive, multi-stage inventory-distribution systems have increasingly come to the attention of the researchers. Jaber and Zolfaghari [2] reviewed the literature on integrated supply chain and coordinated inventory management over the last two decades. Moreover, Glock [3] provided an up-to-date review of integrated inventory models for multi-level supply chain.

Many authors have developed coordination models for optimizing supply chain integrated systems. Some of the recent work in this field includes Abdul-Jalbar et al. [4], Chen and Chen [5], Sarmah et al. [6], Li and Liu [7], Chen and Chen [8]. Furthermore, Viswanathan and Piplani [9] developed a model to analyze the coordination between a vendor and several buyers in a supply chain using common replenishment periods. The vendor requires all buyers to order only at those periods, and offers a price discount to encourage them to accept the strategy. Mishra [10] generalized the model of Viswanathan and

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Piplani [9] to minimize the supplier's cost by coordinating with a few buyers, or segmenting the buyers and offering multiple common replenishment epochs. Chan and Kingsman [11] have conducted research on the coordination in a supply chain including a single-vendor and multi-buyers through synchronizing the actual delivery time of the buyers and the vendor's production cycle. They showed that coordination had a significant role in production and inventory systems and that considering the chain as a whole would be much more profitable than deciding independently. Transchel and Minner [12] studied the dynamic pricing and replenishment issues in the warehouse scheduling problem to find the optimal lot-size and selling price for multiple products. They assumed a common-cycle strategy which implies that each product is replenished exactly once in each order cycle. Their study showed that coordinated decision-making yields a higher selling price than a decentralized decision-making framework.

Most of the existing inventory models are based on the assumption that items can be stored durably. However, some frequently used products such as fruits, vegetables, meat, drinks, photographic films, electronic components, etc. deteriorate during their life time. Therefore, when the rate of deterioration is significant, it should be considered in modeling inventory systems [13]. Goyal and Giri [13] classified inventory items into three categories: goods with obsolescence, goods with deterioration, and goods with no obsolescence or deterioration.

When a new product is introduced by competitors or technology is changed, obsolescent goods lose their value through time. These goods have not been studied widely. However, we can refer to the research of Cobbart and Oudheusden [14] who developed inventory models for fast moving items subject to sudden death obsolescence.

Deterioration results when items cannot be used any more or their quality becomes reduced. Deteriorating items can be damaged, spoiled, dried, evaporated, and so on. Goyal and Giri [13] classified the inventory models of deteriorating items into the following categories: models of inventory with a fixed life time, models of inventory with a random life time, and models for inventory in which the items deteriorate according to proportional inventory. This paper assumes that items decay with exponential distribution according to the proportional inventory.

An exponential model for deteriorating inventory was first developed by Ghare and Schrader (1963) [as cited in 13]. Other scholars such as Bhunia and Maiti [15], Chung and Tsai [16], Wang [17], Balkhi and Benkherouf [18], and Hou [19] continued to improve deterioration models. Most of these inventory models consider the members in the supply chain independently.

In recent years, many researchers have worked on coordination models for deteriorating items. Yang and Wee [20] developed a model for a supply chain with a single producer and multi-buyers. In their model, the rate of deterioration was constant and shortage was not allowed. The purpose of their study was to determine the length of the production cycle, the number of deliveries to the buyers, and the number of orders of raw material. They showed that integration would contribute significantly to cost reduction. Rau et al. [21] considered the model with a single supplier, a single producer and a single buyer for a deteriorating item. They performed two sensitivity analyses: one with a range of the ratio of production rate to demand rate, and the other with a range of deterioration rates.

Huang and Yao [22] revised Yang and Wee's model [20] using the Fourier series to estimate precisely the inventory holding costs of the vendor. They showed that the proposed algorithm is more suitable than the existing solution approach in the literature, especially when the number of buyers is increased in the supply chain system. Their model determined the number of deliveries of finished products from the vendor to the buyers in the duration of the vendor's production cycle. Yang and Wee [23] developed a collaborative inventory system of a single vendor and single buyer to maximize the total profit. They considered a deteriorating inventory with finite replenishment rate and price sensitive demand.

Lin and Lin [24] considered a supply chain that included a single supplier and single buyer in which the items of inventory deteriorated with the constant rate θ. Their model was not limited with the condition of equal periods and shortage was allowed for the buyer except for the last period. It also determined the length of delivery and shortage periods. Lo et al. [25] developed an integrated production and inventory model; they assumed a varying rate of deterioration, partial backordering, inflation, imperfect production processes and multiple deliveries. They showed that an effective decision strategy would benefit both the manufacturer and the retailer in the long run.

Thangam and Uthayakumar [26] formulated an EPQ based inventory model for perishable items under a two-echelon trade credit policy. The purpose of their model was to maximize profit by determining the optimal selling price, credit period and replenishment time. Lin et al. [27] conducted a study on cooperation in a two-echelon inventory model for deteriorating items. They studied four scenarios considering cooperative behavior for inventory policies between suppliers and retailers. The results showed that the cooperation scenario with information sharing is the best way to reach a win–win position.

Wang et al. [28] considered a three-echelon supply chain system consisting of a producer, a distributor, and a retailer. They assumed that product deterioration is time-sensitive and no replacement of deteriorated items is allowed. Yan et al. [29] developed an inventory model in a supply chain with one supplier and one buyer for a deteriorating item. Their model determined the number of deliveries per production cycle. Their results showed that by increasing the deterioration rate, both the optimal production lot size and the cycle time decrease. Yu [30] considered a supply chain that includes one supplier and one buyer. In their model, the supplier allows the buyer's permissible delay in payment to compensate his shortage loss. The results show that the collaboration strategy and the deterioration factor have significantly affected the total profit.

It is worth mentioning that a new stream in inventory and logistics management is emerging. Jaber et al. [31] hypothesize that the performance of production systems is similar to physical systems. They suggested applying the laws of thermodynamics can improve production systems by reducing system disorder. Moreover, Jaber et al. [32] extended the mathematical model of Jaber et al. [31] for deteriorating items.