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A collaborative strategy for deteriorating inventory system with imperfect items and supplier credits

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ABSTRACT

In this study, we develop a deteriorating inventory system consisting of one supplier and one buyer. The system considers supplier–buyer collaboration and trade credit. The objective is to maximize the total profit of the whole system when shortage is completely backordered. In order to entice buyer and compensate his shortage loss, the supplier allows the buyer's permissible delay in payment. Four proposed mathematical scenarios demonstrate how a collaborative approach to decision making can achieve a global optimality. A negotiation mechanism is incorporated to share fairly the profit between the players. The sensitivity analysis of the demand rate, replenishment rate, deterioration factor and other related parameters show that the collaboration strategy and the deterioration factor have significantly affected the total profit.

1. Introduction

Recently, due to rising costs, globalization, decreasing resources, shortening product life cycles and quicker response time, increasing attention has been placed on supply chain collaboration. Supply chain collaboration is when members in a supply chain have a common objective to construct a collaborative network and share information, such as sales and stock levels. Through collaboration, different facilities develop their partnership to achieve long-term benefits and global optimality of the system (Chikán, 2007).

This study discusses a high-priced item for a monopolistic market channel. Imperfect items are produced due to faulty production process, damaged items and breakages during handling or transport; therefore the lot sizes produced/received may contain certain percentage of defective items. The imperfect items may cause shortages and lead to massive losses for the buyer. Due to our monopolistic market assumption, there is only one supply source. Therefore, the supplier has a close vender–buyer relationship with the buyer. Thus, complete backorder for the defective items and trade credit financing as compensation are assumed to maintain the win–win relationship. In order to compare the effects regarding collaboration and compensation, we classify the decision-making policies into four types according to the relationship of the supplier and the retailer (buyer). The scenario matrix is shown in Fig. 1. Scenario 1 is an individual model and the decisions of the supplier and retailer are independently made. Scenario 2 is also an individual model except the retailer is more dominant than the supplier, supplier offers a permissible delay in payment as compensation and entice buyer to buy more. Scenario 3 is a collaborative model without permissible delay in payment because the supplier is more dominant than the retailer. Scenario 4 considers both compensation and collaboration.

Scenario 1 and Scenario 4 often are used in a two leader supply chain (SC) where both supplier and retailer are dominant. The choice of policy is dependent on their cooperative relationship. In Scenario 4, supplier and buyer have a close relationship, and form a strategic alliance. The decision in Scenario 2 is from the retailer's perspectives. The retailer is a leader in the SC. WAL-MART is a typical example for this scenario. Scenario 3 is from the supplier's perspectives. The supplier is a leader in the SC. INTEL is a typical example for this scenario. Comparing the effects of the four scenarios, this study develops a win–win collaborative strategy model for deteriorating items with permissible delay in payment, finite replenishment rate and price sensitive demand. To ensure mutually beneficial strategy, a negotiation factor is incorporated to enable profit sharing between both players.

2. Literature review

An effective supply chain network requires a cooperative relationship between the supplier and the buyer. Based on mutual trust, cooperation includes the sharing of information, resources and profit. The result of close cooperation is a mutually beneficial

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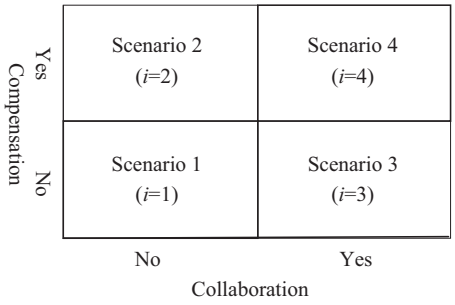

Fig. 1. Four decision-making scenarios are characterized by the relationship of the supplier and the retailer.

environment, which increases the joint profit as well as enables quicker response to customer demand. One of the most common strategies of a collaborative system is to develop an optimal replenishment and mutually beneficial policy acceptable to both the supplier and the buyer.

Clark and Scarf (1960) were the first to present the concept of serial multi-echelon structures to determine the optimal policy. Chikán (1985) proposed a heuristic method to model a multi-echelon production-inventory system. Then, Banerjee (1986) derived a joint economic lot size model for a single vendor, single buyer system where the vendor has a finite production rate. Kelle et al. (2009) presented an optimization yield model for supplier–buyer partnership design. They focus on the inventory-related costs that can be influenced by adjusting the ordering, setup and delivery policy to the random yield. Lyu et al. (2010) studied the store-level retailer's replenishment problems and proposed three collaborative replenishment mechanism models in the collaborative supplier and store-level retailer environment. Yan et al. (2011) developed an integrated production–distribution model for a deteriorating item in a two-echelon supply chain and outlined a procedure for determining the optimal supply chain decisions with the objective of minimizing the total system cost. Ding et al. (2011) studied the analysis of the value created from information sharing by decreasing inventory level and investigation of the collaborative mechanism of providing incentive to retailer by upstream partner via sharing profit gained information sharing in the context of three-echelon supply chain system.

In real life, decay and deterioration occur in products, such as medicine, fruit and vegetables. On-going deterioration inventory model have been widely studied by several authors in recent years. Ghare and Schrader (1963) were the first authors to consider ongoing deterioration of inventory. In this study, deterioration is assumed to depend on the condition of the on-hand inventory within the whole supplier chain. In order to reduce cost and loss due to products deterioration, the supply chain players collaboratively implement a joint decision to determine the optimal number of deliveries.

As a result of the imperfect production and transportation, arriving stocks often contain some defective items. The arrival of defective items may lead to massive losses for the buyer. Therefore, the suppliers have to offer compensation for the losses. Defective items resulting from imperfect quality production processes were initially studied by Rosenblatt and Lee (1986). Other factors, such as damages and breakages during the handling process may also result in defective items. These considerations were discussed by Salameh and Jaber (2000) who are among the first few authors to consider imperfect quality. Chang and Ho (2010) revisited their study and applied the well-known renewal–reward theorem to obtain a new expected net profit per unit time and derived the exact closed-form solutions without using differential calculus.

In the real world, suppliers usually provide delay payment to encourage larger orders from the buyers who benefit from the delay payment. Many researchers have given attention to the effect of permissible delays in payment. Haley and Higgins (1973) were the first to consider trade credit financing in inventory research. Aggarwal and Jaggi (1995) developed ordering policies for deteriorating items under permissible delay in payments. Yang and Wee (2006) proposed a collaborative inventory system consisting of a single vendor and a single buyer and incorporated a negotiation factor to balance each other's profit sharing. Huang and Hsu (2008) investigated the retailer's inventory policy under two levels of trade credit. The retailer has the powerful decision-making right. She/he obtains the full trade credit offered by the supplier and offers the partial trade credit to his/her customer simultaneously. Liao (2008) presented the optimal retailer's replenishment policies in the EPQ model for deteriorating items with two-level trade credit. Yu (2010) modified Yang and Wee's (2006) model into a collaborative deteriorating inventory system with imperfect quality and shortage backordering. In this paper, we extend Yu's model and propose four decision-making strategies against the different relationship between the supplier and the buyer.

3. Mathematical modeling and analysis

The mathematical models in this paper are developed on the basis of the following assumptions:

(a) Single item with a constant rate of deterioration is considered.
(b) Single supplier and single buyer are considered.
(c) The annual demand rate is a linearly increasing function of retail price.
(d) Supplier allows the buyer's permissible delay in payment to entice the buyer and compensate his shortage loss.
(e) The defective items are instantaneously detected at the beginning of the buyer's replenishing cycle.
(f) The players share complete information to each other.
(g) Supplier's replenishment rate is deterministic.
(h) The replenishment of the buyer is instantaneous; the related transporting time can be neglected.
(i) Shortage is completely backordered.

To develop the proposed model, we adopt the following notations:

Parameters:

C_o Buyer's ordering cost per order.
ρ_b Unit purchasing price at the buyer.
ν Percentage holding cost per year and per dollar at the buyer.
q_{bi} The inventory level at the beginning of each buyer's cycle for scenario i.
δ The defective percentage in q_{bi}.
S The maximum backordering quantity at the buyer.
C_b Buyer's backordering cost.
p Annual replenishment rate at the supplier.
α The initial inventory level at the supplier.
β The first replenishment time at the buyer.
C_s Setup cost per setup at the supplier.
ρ_s Unit cost at the supplier.
μ Percentage holding cost per year and per dollar at the supplier.
θ Deterioration rate of on-hand-stock.
ζ Negotiation factor of extra profit sharing between the supplier and the buyer.