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Optimization of production inventory with pricing and promotion effort for a single-vendor multi-buyer system of perishable products

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A R T I C L E I N F O

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A B S T R A C T

In this study, we consider a new decision issue for perishable products in production inventory with pricing and promotion for a single-vendor multi-buyer system comprising one manufacturer and multiple retailers. First, a centralized decision model with a vendor managed inventory (VMI) control system under a just-in-time shipment policy is developed. In order to understand the advantages and disadvantages of VMI, a benchmarking decision model is then developed called the decentralized model with completely independent replenishment (CIRP). Numerical examples and sensitivity analysis are conducted to demonstrate the applicability of the proposed models and their managerial implications. In the decision models, we employ a new concept for constructing the demand function, where we propose a brand competition ratio and two promotion cost strategies: the promotion cost shared by the manufacturer with retailers and that borne solely by the retailers. The results show that although VMI has a systematic advantage compared with CIRP in terms of profitability, the effects are dissimilar for the vendor and the buyer. Promotion cost sharing and increasing the wholesale price have different effects on decisions. Thus, promotion cost sharing can lead to an increase in the profits for retailers and the vendor–buyer system but a reduction in the manufacturer's profit, whereas increasing the wholesale price can increase the manufacturer's profit but reduce the profits for retailers and the vendor–buyer system. Only the strategies that reduce the transportation cost and increase the competitive abilities of retailers are win–win strategies for both the vendor and the buyer.

1. Introduction

It has been reported that the U.S. grocery industry generates more than $600 billion in yearly sales, with approximately 55% of sales derived from perishables (Progressive Grocer, 2015). Perishable products such as dairy products, fishes, fruits, vegetables, and chemicals are readily damaged, decayed, and spoiled as time passes, where these phenomena are known as deterioration. Deterioration usually leads to shrinkage of the effective value of the goods, and ultimately the usable volume decreases. As a result, the deterioration of perishable goods affects the production decision, which then influences the inventory decision in the sales channel. In addition, perishable products are short-life cycle products; therefore, in order to speed up the sales rate and inventory turnover, as well as reduce the loss due to deterioration, many companies apply marketing strategies such as pricing and promotion to stimulate the desire to purchase among consumers. Therefore, optimizing the production-inventory decisions by incorporating a marketing strategy is particularly important for perishable products in practice.

The inventory problem for perishable products has been studied since the 1960s (e.g., Ghare and Schrader, 1963; Haijema, 2014; Chua et al., 2017). In addition, integrated models of pricing and inventory decisions for perishable goods have been investigated for many years. Goyal and Gunasekaran (1995) developed an integrated production-inventory-marketing model for deteriorating items under different market policies, such as pricing and advertisement. Abad (1996) formulated a generalized model of dynamic pricing and lot-sizing by a reseller who sells a perishable product where partial backlogging was allowed. Li et al. (2009) studied pricing and inventory control for a perishable product in an infinite period, where they analyzed the optimal solution structure for a two-period lifetime problem and developed a base-stock/list-price heuristic policy. Saha and Basu (2010) modeled a pricing and inventory decision for seasonal deteriorating products, where demand was time and price dependent in their model. Maihami and Abadi (2012) studied joint control for inventory and pricing for non-instantaneously deteriorating items under permissible delay in payments and partial backlogging. Chintapalli (2015) studied the simultaneous pricing and inventory replenishment for perishable products, where a myopic policy for perishable products with a two-period lifetime and an arbitrary lifetime were examined.

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Some studies also considered the issue of joint pricing and replenishment for the multi-echelon production-inventory single-vendor multi-buyer (SVMB) system, but this problem has been investigated less widely compared with the single-echelon inventory issue because the problem is more complex and it is difficult to solve mathematically. Nachiappan and Jawahar (2007) studied the single vendor multi-buyer supply chain under a vendor managed inventory (VMI) mode of operations, where the optimal sales price and sales quantity were obtained using a genetic algorithm. However, their models did not consider the production decision of the vendor. Chen and Chang (2010) studied the optimal ordering and pricing policies for deteriorating items in a one-vendor multi-retailer supply chain, where they numerically compared the difference between the integrated and non-integrated model. Yu et al. (2011) also studied an integrated pricing and inventory decision model for a vendor-managed-inventory system of deteriorating items, where a genetic algorithm was used to solve the model. Similarly, Taleizadeh et al. (2015) studied the pricing and replenishment problems for an SVMB system.

Clearly, according to this review of previous studies, the inventory models or integrated inventory and pricing optimization models for perishable products have been studied frequently but there have been no reports of an integrated model of pricing, promotion, and production inventory for an SVMB system under the VMI inventory control mode with a just-in-time (JIT) shipment policy for perishable products. Thus, the present study considers the operating mechanism for an SVMB supply chain with the JIT + VMI hybrid business mode for perishable products. In particular, we investigate the optimization decision problem for production inventory with pricing and promotion for perishable products in an SVMB system comprising a manufacturer and multiple retailers under VMI inventory control and a JIT small batch Milk-Run shipment policy, which we compare with a non-VMI system to investigate its advantages and disadvantages. Our findings provide firms with helpful guidelines for implementing JIT production and VMI inventory control for perishable products.

The main novel contributions of this study are as follows. *First*, by constructing a demand function, we introduce a new concept that reflects the competition behavior of the market, i.e., a brand competition ratio. Furthermore, dynamic price elasticity is employed as an adjustment parameter for the demand. *Second*, most previous models applied a lot-for-lot large batch shipment policy in VMI, where the vendor produces and delivers each ordered lot for the buyer at one time, i.e., the production and delivery lot sizes are equal to the ordered lot size, whereas we use a JIT small batch and Milk-Run shipment policy, i.e., the vendor splits the production lot (lot ordered by the buyer) into some small lots for delivery and multiple retailers share one transportation truck to deliver cyclically. *Third*, in order to reflect practical operations, shortage and backlogging are allowed in this study, and the customer service level of retailers is also incorporated into the model as a constraint. *Fourth*, promotion is taken as a decision variable and two promotion strategies, where retailers bear their own promotion costs and the manufacturer shares the promotion cost, are examined to compare the difference between the VMI and non-VMI inventory control systems.

2. Problem description, assumptions, and notations

2.1. Business process in the SVMB-VMI system and problem definition

The background of the problem addressed in this study is shown in Fig. 1. The manufacturer purchases perishable raw materials from a supplier and produces a single perishable product, which is delivered to different retailers through a third party logistics (TPL) company. The product deteriorates during the production, transportation, and warehousing processes. We assume that the manufacturer and retailers are also located in limited regions, and the distances from the manufacturer to the retailers are not very great (e.g., less than 50 km) because excessively long distances are not suitable for a small batch Milk-Run shipment policy. Examples of this type of product are dairy products because they are fresh and perishable, so they cannot be transported long distances and must be sold within a short time due to deterioration. In addition, information sharing between the manufacturer and each retailer is possible via information infrastructure, such as the Internet, which satisfies the conditions required for implementing VMI systems, i.e., information sharing and inventory control power transfer (Dong et al., 2014).

In this context, the present study addresses the following critical questions with respect to an SVMB system.

(a) What are the optimal sales price, promotion effort, and inventory replenishment policy for retailers, and the production and raw material lot sizes for the manufacturer?
(b) Compared with the decentralized inventory control completely independent replenishment (CIRP) system, what are the advantages and disadvantages of the centralized inventory control VMI system?

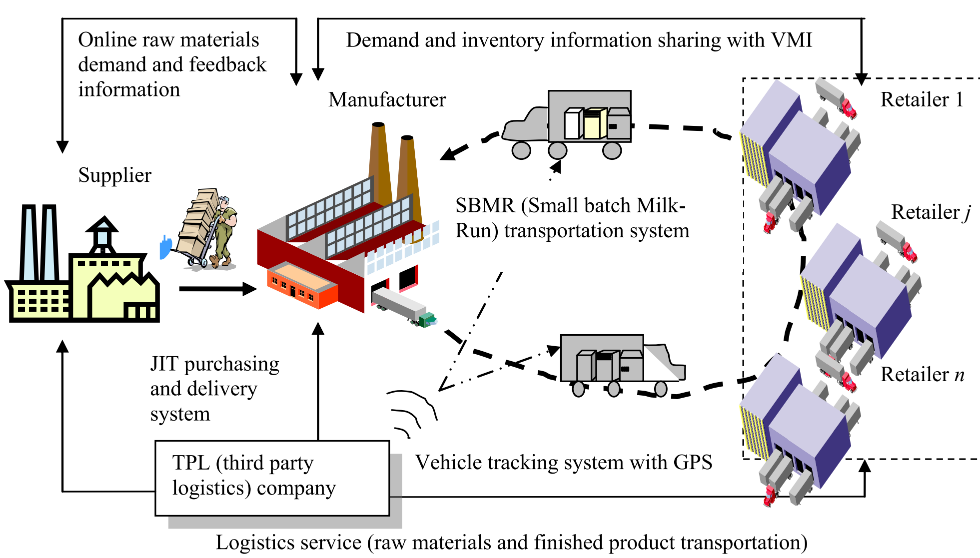

Fig. 1. Business processes involved in the problem considered in this study.