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An integrated retail space allocation and lot sizing models under vendor managed inventory and consignment stock arrangements

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ABSTRACT

In this paper, we develop integrated retail shelf space allocation and inventory models for a single item with a stock dependent demand. The integrated models are developed for a supply chain operating under vendor-managed inventory (VMI) and consignment stock (CS) agreement. More precisely, the supplier is responsible for initiating orders on behalf of the retailer and decides about the size of each order, the quantity to be displayed on the shelves, and the reorder point. In addition, the supplier owns the stock at the retailer's premises until it is sold. We develop mathematical models to assess the benefits accrued by both parties as a result of the adoption of VMI–CS partnership. Results from the numerical experimental study show that such partnership is more attractive to all supply chain members when the retailer provides a flexible display capacity. Moreover, the supplier can use his/her selling price and the maximum allocated shelf space as negotiation means to benefit from the partnership.

1. Introduction

Several programs of collaboration and coordination between supply chain (SC) partners have been successfully implemented in practice. Such programs help the different parties involved in the SC to collaborate, through the sharing of demand and inventory data, and to coordinate their decision making process in order to manage their inventory systems more efficiently and to improve their services. Vendor managed inventory (VMI) and consignment stock (CS) are collaborative initiatives which have been theoretically and empirically shown to improve SC efficiency and responsiveness.

Under VMI partnership, the supplier is responsible for managing inventory levels at the retail store by determining the right timing and size of the orders. In return, the supplier gets a better visibility about the final customer demand. Historically, VMI originated in the retail industry to overcome some of the problems regarding the amount of required retail shelf space, the amount of inventory to be kept on hand, inventory obsolescence, and the logistics of returned products (Blatherwick, 1998; Cachon & Fisher, 1997). Blatherwick (1998) stated that VMI practices can be very helpful because the suppliers with greater familiarity of a smaller number of products should be able to forecast and manage the flow of those products through the end of customers. The benefits of VMI are well recognized by successful retail businesses such as Wal-Mart, JC Penney, and Dillard Department Stores (Dong & Xu, 2002). Successful VMI implementations in retailing are more observed in the apparel industry (Kaipia & Tanskanen, 2003). For example, VF Corporation was able to increase the sales of its men's jeans by 20% through the adoption of a replenishment system based on point-of-sales data and VMI principles.

According to APICS Dictionary (Blackstone & Cox, 2004), consignment stock is defined as "The process of supplier placing goods at a customer location without receiving payment until after the goods are used or sold." In other words, under CS partnership, the stock of items belongs to the supplier until it is used by the retailer. Therefore, the retailer is not charged for the cost of capital (financing cost) resulting from tying up capital in inventory. However, it is the retailer who decides about the timing and size of the orders. Although, it seems that only the retailer gains from CS partnership, Battini, Grassi, Persona, and Sgarbossa (2010) reported several benefits for the vendor as well. Indeed, through the adoption of CS partnership, the vendor reduces transportation and inventory holding costs, saves storage space as items are stored at the retailer's location, and has access to real-time demand information. Moreover, CS initiatives are attractive for consumer items, such as metallic and plastic fasteners, small parts, tools, packaging parts, and personal protection equipment (Battini et al., 2010).

The implementation of both VMI and CS initiatives leads to a change in the costs structure for both parties involved in the

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Table 1
Comparison of VMI, CS and VMI&CS Supply chain initiatives.

	Decision responsibility		Cost responsibility		
	Order quantity	Timing	Ordering	Holding	
				Capital	Storage
VMI	Supplier	Supplier	Shared	Retailer	Retailer
CS	Retailer	Retailer	Retailer	Supplier	Retailer
VMI&CS	Supplier	Supplier	Shared	Supplier	Retailer

partnership. VMI and CS require a transfer of certain inventory cost components from one party to another as a result of the changes in decision making responsibility and inventory ownership. Table 1 compares these two SC partnerships against the combined VMI and CS initiative in terms of inventory decisions and costs responsibilities (Gümüş, Jewkes, & Bookbinder, 2008).

Under VMI and VMI&CS programs, the supplier assumes the responsibility for setting the quantity and timing of the orders. Consequently, the cost of initiating an order shifts from the retailer to the vendor. However, under CS it is the retailer who decides about the ordering policy and is charged for any resulting costs. The holding cost is incurred by the retailer under VMI but it is shared under both CS and VMI&CS.

Given the well-recognized benefits achieved by the implementation of VMI and CS programs, we consider a distributor/supplier who is investigating the economic feasibility of offering a combined VMI and CS partnership to a single retailer. We assume that the distributor is authorized to manage the stocks of a single item at the retail location. More precisely, the supplier decides about the ordering quantity, the quantity of the product to be displayed on the shelves, and the reorder point. In this framework, we develop an integrated model for the shelf space allocation and replenishment problems for a single item with a shelf space dependent demand. In order to assess the cost benefits of the VMI–CS partnership for both parties, we also determine optimal ordering policies for the supplier and retailer when they act independently (their decisions are not coordinated). To the best of our knowledge, this paper is the first to study the combined benefits of VMI and CS partnerships within the retailing context.

The remainder of this paper is organized as follows. The following section presents relevant literature related to the problem addressed in this paper. Section 3 states the problem and outlines the modeling assumptions and notation. Section 4 presents the developed inventory model for the case of no partnership, while Section 5 provides the integrated space allocation and inventory model under VMI–CS partnership from the supplier's perspective. Section 6 discusses the numerical analysis of the benefits realized by both parties when operating under VMI and CS partnership. Finally, the last section concludes the paper and suggests further research avenues.

2. Literature review

Sales in retail stores have been shown empirically to be proportional to the quantity displayed on the shelves (Silver, Pyke, & Peterson, 1998). Consequently, several authors extended some of the classical inventory models by assuming that the demand is a function of the inventory level. Baker and Urban (1988) were the first to extend the economic order quantity (*EOQ*) by considering a demand rate that is a function of the instantaneous inventory level of an item. They developed an extended *EOQ* model for a power-form inventory level dependent demand. Baker and Urban's model was further extended to cover other inventory situations such as deteriorating items, different classes of customers, presence of defective items, effects of inflation and time value of money, and stochastic demand. Among these extensions, Datta and Paul (2001) considered a demand rate that is function of the instantaneous inventory level until a threshold inventory level has been reached, after which the demand rate stabilizes. This is quite the reverse situation that is usually observed in retail stores. In fact, the number of units of a displayed item is usually maintained constant for a certain period until the quantity in the backroom facility is completely transferred to the display area. During this period of time the demand is constant since the same quantity is displayed on the shelf. Starting from the moment when the backroom inventory is depleted, the demand will depend on the inventory displayed level.

It was implicitly assumed in the above cited papers that the entire ordering quantity is available for sale. However, in practice the ordering lot size is initially stored in the backroom facility upon its receipt and then transferred in smaller batches to the display area to replace the sold quantity. The customer is, therefore, affected only by the quantity displayed on the shelves, which should be considered as a decision variable in order to maximize the item's sales. Several authors attempted to integrate shelf space allocation and inventory lot-sizing problems. Hayya (1991) stated that the integration of the inventory decision making process with retailing problems, such as the allocation of shelf space in supermarkets, is a challenging area of research. Corstjens and Doyle (1981) formulated a nonlinear programming model for the shelf space allocation model in which the demand rate is a function of shelf space allocated to the product. Their model maximizes the profit subject to constraints on the available supply for each product and lower and upper bounds on the space assigned to each item. Zufryden (1986) developed a dynamic programming model for the shelf space allocation problem which allows for the consideration of general objective function and provides integer solutions. Urban (1998) proposed a model that integrates assortment (item selection), space allocation, and replenishment decisions. More recently, Hariga, Al-Ahmari, and Mohamed (2007) extended Urban's model to include also the display locations as decision variables.

In another stream of research studies, some authors analyzed the integrated shelf space allocation and inventory control problem for two-stage supply chains. Zhou, Min, and Goyal (2008) discussed the coordination issues of a two-echelon supply chain composed of a distributor with an infinite production rate and a retailer facing a stock dependent demand. They assumed that the distributor follows a lot-for-lot delivery policy and offers a quantity discount scheme to entice the retailer to order in large quantities. They proposed a simple profit-sharing mechanism to achieve perfect channel coordination. Goyal and Chang (2009) developed an inventory model to determine the retailer ordering quantity and the frequency and size of the transfer quantity from the warehouse to a display area with limited space. Their objective was to maximize only the retailer's average profit per unit of time. In a recent paper, Sajadieh, Thorstenson, and Akbari Jokar (2010) proposed an integrated manufacturer–retailer model to maximize the total profit of a centrally-coordinated supply chain. They assumed that the manufacturer has finite production rate and makes deliveries in equal sizes to the retailer. Part of the delivered quantity is displayed on the shelves while the rest of the quantity is stored at the retailer's warehouse. The results of their numerical analysis showed that coordination is more attractive in situations when demand is more stock dependent. In this paper, we also assess the benefits of supply chain coordination but in a different context. We assume that the supply chain members operate under VMI and CS partnerships.

Several papers in the SC literature have been devoted to the study of the economic benefits resulting from the implementation of VMI and CS partnerships. Dong and Xu (2002) evaluated the impacts of VMI on the profits of the different supply channel's