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The value of VMI beyond information sharing in a single supplier multiple retailers supply chain under a non-stationary (R^n, S^n) policy ☆

Devendra Choudhary *, Ravi Shankar

Department of Management Studies, Indian Institute of Technology Delhi, New Delhi, India

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ABSTRACT

This study aims to determine the value of vendor-managed inventory (VMI) over independent decision making with information sharing (IS) under non-stationary stochastic demand with service-level constraints. For this purpose, we utilize mixed-integer linear programming formulations to quantify the benefits that can be accrued by a supplier, multiple retailers and the system as a whole by switching from IS to VMI. More specifically, we investigate the incremental value that VMI provides beyond IS in terms of expected cost savings, inventory reductions, and decrease in shipment sizes from the supplier to the retailers by conducting a large number of computational experiments. Results reveal that the decision transfer component of VMI improves these performance measures significantly when the supplier's setup cost is low and order issuing efficiency is high. The benefits offered by VMI are negligible under the problem settings where the supplier's order issuing efficiency is low and the production setup serves solely a single replenishment under IS.

1. Introduction

A VMI initiative encompasses two distinct components – information sharing and a shift in decision making responsibility from a downstream retailer to the upstream supplier [5]. In other words, under VMI, inventory is managed at both echelons by the supplier. The academic literature and industry reports have shown mixed results from the implementation of VMI and related programs. For example, Spartan Stores had to shut down its VMI initiative due to higher inventory levels and planning inefficiencies [23]. The study of Blackhurst et al. [1] also suggests that the implementation of the VMI initiative at a large electronics manufacturer actually resulted in increased inventory levels at the downstream partners. Recently, companies like Toyota and Honda have moved away from VMI, and are focusing on information sharing as well as locating suppliers as close as possible to their facilities [10]. Nowadays, in spite of these unsuccessful VMI adoption occurrences, there has been growing interest in implementing VMI in many supply chains after successful execution by several world-class businesses such as Wal-Mart, Sara Lee, Nabisco, etc. ([17]). Several studies also provide analytical validation for economic benefits offered by VMI by comparing it to a traditional system with no information sharing (e.g., [34,2,11]). However, these industry reports and studies do not conclude whether benefits could have been achieved mostly through the information sharing or the decision transfer component of VMI.

In practice, adoption of VMI over retailer-managed inventory with information sharing (IS) leads to greater implementation difficulties and may increase operational costs. Thereby, switching from IS to VMI can be justified if the decision transfer component generates significantly higher value above information sharing. Distinguishing the incremental value that could be achieved from VMI over IS is a difficult task, and there have been a few attempts to do so under stationary stochastic demand (e.g., [6,22,20]) and non-stationary deterministic demand (e.g., [4]). Furthermore, the complexity is substantially greater when demand is non-stationary and stochastic, which is nowadays quite common because of short product life cycles, seasonality, customer buying patterns, etc. [14]. For example, while the product life cycle of a Hewlett-Packard (HP) personal computer could be as low as only three months, HP digital cameras have an average life cycle of less than 12 months. Even through the launch, ramp, peak, and end-of-life phases of the product life cycle, not only is demand non-stationary, but also the uncertainty changes (Fig. 1). The demand for many products has a seasonal component or experiences monthly/quarterly "hockey stick" patterns because of sales-force incentives and customer buying behavior. For example, Microsoft experiences about 66% of the annual demand for its Xbox video game consoles during the last 13 weeks before Christmas. Similarly, a peak in demand is observed for Dell's enterprise products in the last week of every month.

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* Corresponding author.
E-mail address: dceca@rediffmail.com (D. Choudhary).

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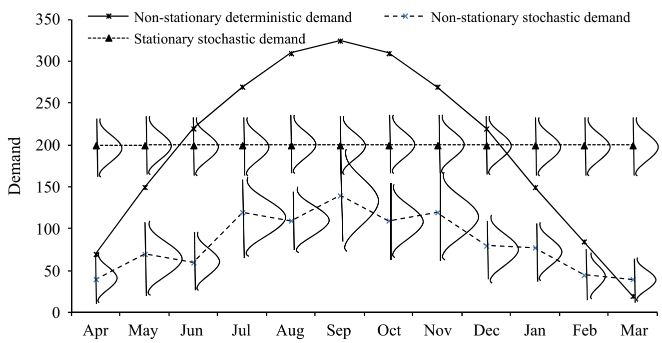

Fig. 1. Demand processes.

The extent and intensity of competitive advantage gained from VMI above and beyond IS varies from company to company depending on the demand process and business environment in which a supply chain operates. Realizing these facts, this study aims to determine the incremental value offered by VMI beyond that of IS alone under non-stationary stochastic demand with service-level constraints. For this purpose, we first model a serial supply chain consisting of a single upstream supplier and multiple downstream retailers under both the IS and VMI initiatives. Then, a comprehensive numerical study is carried out considering a large number of business settings to figure out the conditions where the value of VMI over IS is significant. In the IS initiative, we consider that the supplier and retailers manage their inventory independently. The retailers determine their own replenishment schedules and place orders with the supplier. Moreover, the retailers provide full information to the supplier via information technology tools such as electronic data interchange (EDI) or through internet [6]. In other words, the supplier gets an access to the retailers' replenishment-up-to levels, expected inventory levels, and timings of planned orders as well as demand distribution data. Based on this information, the supplier decides its production schedule to meet orders of the retailers. On the other hand, under the VMI initiative, the supplier also manages inventory at the retailers along with full information sharing. Earlier studies compare VMI with IS mainly in terms of the economic benefits. It is less clear whether the benefits have been achieved through a decrease in inventory levels or consolidation of shipments at the expense of increased inventory levels. Also, there is a lack of clarity on whether shipment sizes from the supplier to retailers increase or decrease using VMI [32,33,12]. In this paper, we assess the incremental benefits offered by VMI above and beyond IS on various supply chain performance measures such as expected cost savings, reduction in inventory levels and increase in replenishment deliveries at the retailers. A comparison of VMI with IS based on these performance measures helps in clarifying situations where the economic benefits can be realized either through increased frequency of shipments and decrease in inventory levels, or through consolidation of shipments.

2. Problem statement and background

We consider a two-echelon serial supply chain in which a product is delivered from a common supplier to a set $r=\{1,\ldots,R\}$ of retailers over a time horizon T. Each discrete time period $t=\{1,\ldots,T\}$ is of the same duration. We assume that the retailers serve geographically dispersed (thus independent) retail markets. The end-user demand at each retailer in each period is normally distributed with a known probability density function. In addition, for each retailer, different periods have mutually independent demands, which vary over time. In case of not fulfilling end-user demand, stock-out occurs at the retailers' side and demand is backordered. Moreover, the quantity of backorders at the retailers end is restricted by a cycle service-level requirement, which is very common in practice where a stock-out situation is costly and independent of its duration [30]. As is the case in practice, it is assumed that the supplier has several sources of the product such as overtime production and/or subcontracting to meet the order of retailers, which makes the supplier's production capacity sufficiently high. The quantity is produced or made available at most once in each period. We ignore the lead time of ordering and production and hence the required replenishment quantities are made available in the same period. This assumption is in line with previous studies [6,22,4]. The space available to store inventory at the end of each period for both echelons is unconstrained. While the existing literature has considered stochastic single-item dynamic lot-sizing problem at a single-echelon level, the same has not been studied so far at two-echelon level, even though it is a well known fact that an integrated approach may provide more effective means to reduce system-wide inventory.

Bookbinder and Tan [3] propose three policies – static, dynamic, and static-dynamic – to deal with non-stationary stochastic demand. Under the static uncertainty policy, the replenishment schedule and quantities are obtained in advance for the entire planning horizon. However, under the dynamic uncertainty policy, one may revise the replenishment levels in subsequent periods by updating the inventory status as demand evolves. While the former policy is the most expensive because of larger safety stock requirements, the latter policy suffers from quantity- and order-oriented nervousness because each period's lot-size is chosen only at the start of that period. The deviation in planned orders and timings is known as quantity- and order-oriented nervousness, respectively. To combine the positive features of both the policies, Bookbinder and Tan [3] propose a static-dynamic uncertainty policy which is also known as non-stationary (R, S) type of inventory control policy. This policy is characterized by two control parameters R^n and S^n for each replenishment cycle n, where R^n denotes the length of n'th replenishment cycle and S^n stands for the replenishment-up-to level of the n'th replenishment [26,15]. In this policy, at the beginning of planning horizon, non-stationary review intervals R^n as well as replenishment-up-to levels S^n are determined in advance. But the actual order quantity in each replenishment period is decided only after the demands in the preceding periods have been observed. Although this policy is liberated from order-oriented nervousness, but it suffers from quantity-oriented nervousness.

The sequential procedure of determining the timings and replenishment-up-to levels ignores the interaction between these two problem aspects. As a result, the heuristic approach of Bookbinder and Tan [3] may not provide optimal solutions. Taking this aspect into account, Tarim and Kingsman [25] formulate a mixed-integer programming model to determine both review intervals and replenishment-up-to levels in a single step. This formulation operates under the assumption that excess stock is carried forward and not returned to the supply source if it exceeds the replenishment-up-to level for a review cycle. As a result, the model only computes suboptimal policy parameters and an approximate expected total cost [18]. Tempelmeier [27] extends the work of Tarim and Kingsman [25] by replacing cycle service-level requirement with cycle fill rate. A heuristic solution procedure is proposed by Tempelmeier [28] to determine the replenishment schedules under a capacity constrained resource for multiple products.

The non-stationary (R, S) type of inventory control policy is a more accurate representation of industrial practice as pointed out by Sox [24] due to the fact that it is liberated from order-oriented nervousness, which is considered to be most critical in practice [31]. Even more, the (R, S) policy also dominates over the (s, S) policy in