ALIGNING INCENTIVES IN A VENDOR MANAGED INVENTORY SYSTEM

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ABSTRACT

This paper studies the benefits of a vendor managed inventory (VMI) system in a supply chain where the vendor supplies multiple retailers. In a typical VMI setting, the vendor takes on the responsibility of replenishing inventory at its downstream partners. The main contribution of this paper is that it develops a replenishment model to investigate the dynamics of operating characteristics within a VMI system where the nested ordering policy is implemented. The paper proposes and assesses an incentive aligned mechanism to reallocate the fixed transportation cost savings appropriately among supply chain partners.

Keywords: vendor managed inventory, nested ordering, supply chain coordination, incentives.

INTRODUCTION

Over the past few decades, businesses have gradually transitioned to accept the new paradigm in the global supply network, which demands systems coordination and holistic approaches to decision making. This transition is a clear departure from local optimization and decentralized approaches which prevailed with business norms of the past. One of the main drivers behind this trend towards coordinated systems is the explosive advancement in information technology since mid-90s, which has contributed to higher degree of information symmetry with business partners. Collaborative initiative in the supply chain is now more than just a preferred way of doing business: companies are coming to the realization that the coordination across the supply network is a mandate to be competitive in the new global business setting.

Among business initiatives implemented with success is the vendor-managed inventory (VMI) system, a replenishment contract between the vendor and its buyers, which incorporates the concept of a centralized replenishment decision based on information visibility with the strategic goal of strengthening relationships and improving supply chain performance. In a VMI contract, the vendor typically makes replenishment and inventory decisions for its downstream buyers (e.g., retailers) as the vendor at the upstream of the supply chain is deemed to be in a better position to make integrated decisions for the entire supply chain. Benefits of VMI on improvement of supply chain performance measures are evident from business practices and existing research. Some of the successful implementations of VMI are exemplified by Wal-Mart and Procter & Gamble partnership, Campbell Soup, and Johnson & Johnson, to name a few [7] [9]. In general, benefits of VMI include reduced inventory holding across the system, improved product availability (e.g., cycle service levels and fill rates), and enhanced relationships with business partners via transparent communications and information symmetry in the supply chain [1]. It is noted, however, that some of the consequences of unsuccessful implementation of VMI cannot be overlooked. One of the main reasons for underperformance of supply chain coordination is that globally optimizing decisions do not necessarily transition into mutual benefits at local levels in a decentralized supply chain [3]. That is, a replenishment decision made in the best interest of the whole system may not imply that benefits would be distributed equitably to all stakeholders. Benefits to retailers may be based on potential transfer of on-inventory and overheads to suppliers located upstream, whereas the benefits to the vendor may take a longer period of adjustment before they are realized [4]. Results from a study on IKEA's19 different VMI partnerships reveal that while VMI leads to an improved service level and supplier's productivity, there is a risk of an increased inventory level across supply chain [5], which may have mixed impacts on different parties in the supply chain. Developing an incentive aligned mechanism to enable the most appropriate allocation of benefit sharing, thus, is crucial for the long term success of a VMI contract.

OBJECTIVE AND RESEARCH QUESTIONS

The objective of this paper is to assess the benefits of a VMI partnership between *a vendor and multiple retailers*, which is both relevant and realistic. The primary focus of this research is to study a supply chain problem that provides insights regarding incentive aligned mechanism among stakeholders in a decentralized supply chain, where each party would be aiming for its own goal and interest. Thus, developing the most appropriate mechanism that is capable of bringing agreement among partners is critical. In identifying the right VMI contract, this paper develops an inventory replenishment model to investigate a VMI system where a nested ordering policy is applied to assess the benefits of a cross-docking practice and examines dynamics of operating characteristics of such a system at the global as well as at local levels. In particular, the intent of the research is to address the following questions:

- How do the design parameters (e.g., number of retailers) in the system affect supply chain performance when a vendor managed inventory (VMI) system is implemented?
- What are the policy settings under which a VMI is beneficial for each stakeholder and the system?
- How is an incentive-aligned mechanism derived to achieve a coordinated VMI contract?

Using numerical methods, this paper considers a range of contingencies not captured in previous research on VMI [2] [8].

VENDOR MANAGED INVENTORY (VMI) IN A DECENTRALZIED SUPPLY CHAIN

Locally managed inventory (LMI)

This research studies a decentralized supply chain consisting of a single vendor supplying multiple buyers (retailers) with a single stock keeping unit (SKU). Each retailer faces steady and deterministic demand, and the vendor, in turn, replenishes the item from an external supplier. A traditional LMI replenishment can be viewed as a practice where the vendor responds to individual buyers' orders by filling and shipping the requested order quantity without having access to the final market demand information. Thus, order quantities, order frequency, and inventory status are controlled and accessible only at local levels and inventory decisions at each retail site are made independently of each other in a decentralized manner without coordination efforts between retailers and the vendor. Therefore, the vendor and each retailer's replenishment practices can be defined according to the well-known results of the deterministic setting. Of special interest in replenishment contracts between the vendor and retailers is the treatment of the fixed portion of the transportation cost to be assigned to buyers (retailers) and the vendor, which is often contingent on negotiations between business partners and their relative power [9]. In a LMI system, each retailer is faced with the task of finding its optimal order quantity or its optimal reorder cycle, whereas, the vendor's decision is mainly focused on determining the length of its ordering cycle (T) with its external supplier, which minimizes the vendor's total inventory related cost.

Vendor managed inventory (VMI)

This paper proposes a VMI contract to coordinate replenishments in the supply chain based on an incentive aligned mechanism among stakeholders. In a VMI contract between the vendor and buyers (or retailers), the vendor takes the responsibility for replenishing orders for the system in such a way that the ordering policy at each retailer is aligned and optimized based on the overall system's ordering practice. It is assumed that retailers are replenished immediately upon receipt of shipment at the vendor from its external supplier, which constitutes the nested ordering policy where buyers and the supplier align their ordering timings so as to minimize unnecessary inventory stocking for inbound and outbound shipments. A practical application of this logistics approach is observed at cross-docking stations used by Wal-Mart, Costco, Home Depot, and others, where inbound shipments are consolidated and shipped out without being stocked at cross docks. Within the vendor's ordering cycle length, *T*, the vendor determines the integer number of replenishments, *y*, to be made to retailers. By utilizing the concept of the well-known nested ordering policy [6] in the multi-echelon supply chain, the vendor can potentially maximize the benefits of cross-docking effects. Note that the fixed portion of the ordering and shipping cost naturally becomes significantly smaller in a VMI contract, indicating substantial savings are possible in this cost component as inventory replenishment tasks are solely managed by the vendor.

Further, in contrast to the traditional LMI system where information is accessible only at local levels, a VMI system presumes information symmetry in the supply chain. That is, demand and inventory information at the retail level is accessible enabling the replenishment decision by the vendor. The vendor's primary concern would be to determine the length of its order cycle (*T*) with the external supplier and the shipment frequency (*y*) to retailers within *T*. The resulting performance of the VMI contract (when compared against the LMI) should provide the vendor a range of possible incentive options under which each retailer would be better off by deviating from its natural ordering practice (LMI) and agree with the coordinated VMI contract. It should be noted that the VMI contract studied here is different from the traditional coordinated replenishment model in that the major replenishment parameters (both *T* and *y*) are determined by the vendor (and *not the retailers*) to obtain the ideal policy for the entire system.

Using the nested ordering features, we write the total inventory cost at retailer *i* (TC_i^{VMI}) and the total cost at the vendor in a VMI system (TC_V^{VMI}) as in (1) and (2) respectively.

$$TC_i^{VMI} = \frac{Q_i^{VMI}}{2}kw + \frac{D_i}{Q_i^{VMI}}S_i^{VMI} = \frac{D_iT}{2y}kw + \frac{y}{T}S_i^{VMI} \quad (1)$$

$$TC_V^{VMI} = \sqrt{2Dkc_V(S + yS_V^{VMI}) \cdot (\frac{y-1}{y})} \quad (2)$$

where

D_i: Demand at retailer *i* over time, where *i* = 1, 2, …, *n*

D: The total demand at all retailers combined, where $D = \sum_{i=1}^{n} D_i$.

Q_i^{VMI}: Replenishment quantity at each shipment made from the vendor to retailer *i*.

k: holding cost rate/year

w: Unit purchase cost or the unit wholesale price.

S_i^{VMI}: Fixed shipping cost (plus administrative cost) charged to retailer *i* under VMI. Also,$S_R^{VMI} = \sum S_i^{VMI}$.

T: Order interval at the vendor from its supplier, where $T = Q_V/D$ and Q_V is the vendor's order quantity.

y: Number of replenishments (an integer) made to retailers by the vendor *T*, under a VMI contract.

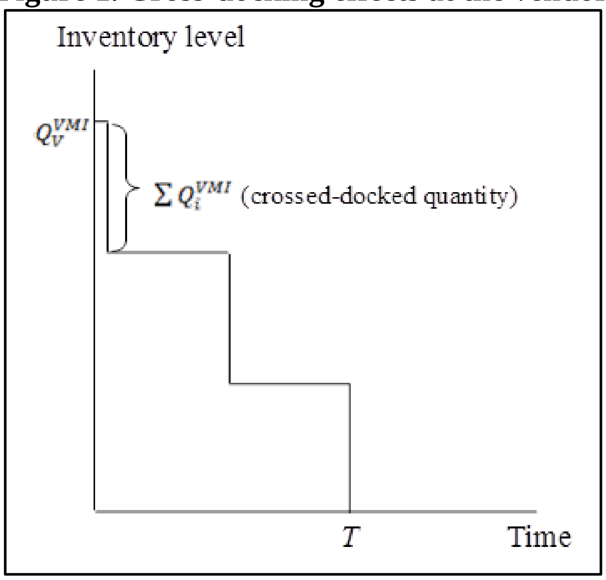
c_V: Unit purchase cost (or production cost) at the vendor.

S: Fixed ordering cost incurred at the vendor when orders are placed with its external supplier.

s_V^{VMI}: Fixed shipping cost from the vendor to retailers per shipment to be determined under a VMI

It is inferred from (2) that the fewer the number of shipments (*y*) made from the vendor to retailers over *T*, the better off it would be for the vendor's cost efficiency criteria in a VMI contract. The vendor's total cost function shows a monotonically increasing pattern in *y* with a minimum cost attained at *y* = 1. That is, under a VMI system, where the vendor is responsible for determining its order cycle and shipment frequency to retailers (i.e., *T* and *y*), the vendor strives to align the timing of its order receipt and the outbound shipments to retailers so that the first shipment to retailers within *T* can be cross-docked, thus saving the vendor a substantial inventory holding, as depicted in Figure 1. However, this may not be in the best interest of retailers as indicated in the relationship between the total inventory cost at each retailer shown in (1) and the number of shipments, *y*, made within *T*, as a single shipment VMI (i.e., *y* = 1) most likely will increase retailers' inventory levels and may not constitute their ideal replenishment policy.

Figure 1. Cross-docking effects at the vendor



Incentive aligned contract: Fixed shipping cost savings allocation under a VMI

This misalignment of policy results clearly calls for a systems approach to find a collaborative policy agreeable to both the vendor and retailers. The vendor's optimal cycle *from the system's perspective*, T_S^*, is determined as (3) below, and the total system cost using (1)~(3) is simplified and depicted in (4)

$$T_S^* = \sqrt{\frac{2y(S+yS_V^{VMI}+yS_R^{VMI})}{Dk[(y-1)c_V+w)}} \tag{3}$$

$$TC_S^{VMI} = \sqrt{\frac{2Dk[(y-1)c_V+w]\cdot(S+yS_V^{VMI}+yS_R^{VMI})}{y}} \tag{4}$$

It is well documented that a VMI leads to significant savings in the fixed shipping costs with the information visibility and the centralized replenishment decision made solely by the vendor. The key issue with the VMI contract discussed here is how these benefits (i.e., fixed cost savings) are to be reallocated between the vendor and retailers. From each retailer's perspective, the resulting VMI contract should be as attractive as its natural LMI replenishment (cost-wise) in order to justify its deviation from the LMI to join the VMI contract. Thus, for each retailer to be interested in the coordinated VMI contract, the adjusted shipping cost for each retailer (post-allocation of the cost savings) should satisfy $TC_i^{VMI}(S_i^{VMI}) \leq TC_i^{LMI}$ which results in the threshold upper bound, $S_i^{VMI}(adjusted)$ for each retailer. The remaining portion of cost savings will be applied to the vendor's fixed shipping cost.

NUMERICAL RESULTS AND MANAGERIAL INSIGHTS

Settings for numerical experiments

This research investigates the impact of supply chain design parameters (e.g., the number of retailers). Also, the effect of policy setting on the fixed cost savings reallocation and cost performance of each party will be examined by varying the frequency of shipments within *T*. Parameters used for the numerical experiments are summarized in Table 1, and reflect the deterministic nature of the market demand and dynamics of replenishment systems in the supply chain. One of the settings worth noting here is the nested ordering policy. As mentioned earlier, with the nested policy in place, (i.e., the vendor makes an integer number of shipments to retailers over *T*), the vendor directly reroutes inbound shipments to retailers without holding inventory at its own site. For the vendor, this alignment of logistics timing leads to lean operations and opportunities for further savings in shipments to retailers via order consolidation.

Table 1. Parameters for numerical experiments

Cost parameters	Design & policy parameters
Holding cost rate (k) = 20% per year Whole price (w) = \$20/unit Retailer's shipping cost in LMI (S_i) = \$200 Retailer's ordering cost in VMI (S_i^{VMI}) = \$50 Manufacturing cost (c_V) = \$5/unit Vendor's ordering cost (S) = \$500/order	Total demand (D) = 10,000 units/year # of retailers (n) = 1, 2, 4, 6, 8, & 10 # of shipments(y) within T = 1, 2, & 3

Managerial implications

Results obtained on the impact of the number of retailers and the shipment frequency on supply chain performance indicate that outcomes for different stakeholders in the supply chain (the vendor and retailers) are mixed based on policy parameters (e.g., replenishment setting) and design parameters (e.g., the number of retailers). It is crucial that businesses have a clear understanding of the impact of design and policy parameters on supply chain performance as well as the managerial implications of results at both the strategic level (supply chain design) and the operational level (replenishment policy). For any given shipment frequency and retailer heterogeneity (e.g., medium), the total system cost (the sum of the vendor inventory cost and retailers' combined total cost) displays an increasing pattern in the number of retailers under a VMI system. Basically, the total system cost reveals a pattern consistent with retailers' combined total cost in how both costs vary in the *design parameter*, the number of retailers, as shown in Table 2.

On the other hand, with regards to how the total system cost varies with *policy parameters* such as the shipment frequency from the vendor to retailers, the cross-docking effect due to the nested ordering policy is evident. In particular, the impact of the shipment frequency on the total system cost in a VMI system reveals that by keeping the frequency as low as possible (i.e., just once over *T*) with many retailers to supply in the system, both the vendor and the system benefit with respect to the total costs. When there are only a few retailers to supply in the system (either one or two retailers), however, both the vendor and the system are better off with shipping frequency of 2 or 3 instances over *T* as summarized in Table 2. It is interesting to note the vendor and the system costs show a common pattern with respect to the shipment frequency (i.e., policy parameter) while retailers' combined total cost and the system cost exhibit similar trend with respect to the number of retailers (i.e., design parameter).

Table 2. Cost comparisons: Impact of design and policy parameters

	Number of retailers in the system					
Medium heterogeneity - VMI	**1**	**2**	**4**	**6**	**8**	**10**
Retailers Combined TC(y=1)	$4,009	$4,999	$6,889	$8,539	$9,934	$11,142
Vendor TC (y=1)	$3,474	$3,008	$2,456	$2,104	$1,878	$1,716
System TC (y=1)	$7,483	$8,007	$9,345	$10,643	$11,812	$12,858
Retailers Combined TC(y=2)	$4,000	$5,446	$7,475	$8,897	$10,055	$11,060
Vendor TC (y=2)	$2,708	$2,501	$2,390	$2,397	$2,424	$2,459
System TC (y=2)	$6,708	$7,947	$9,865	$11,294	$12,479	$13,519
Retailers Combined TC(y=3)	$4,000	$5,488	$7,325	$8,670	$9,780	$10,748
Vendor TC (y=3)	$2,633	$2,677	$2,881	$3,042	$3,179	$3,307
System TC (y=3)	$6,633	$8,165	$10,206	$11,712	$12,959	$14,055

CONCLUDING REMARKS AND FUTURE RESEARCH

This paper adds value to the stream of research on supply chain collaboration by developing an analytical model for a VMI contract and providing insights on dynamics of coordinated replenishment system, where the nested ordering policy can maximize the cross docking benefits in a multistage supply chain. Reallocation of the fixed shipping cost savings obtained as the result of the VMI implementation is considered equitable as well as incentive compatible among the business partners. The overall framework of developing incentive mechanism in a decentralized system setting proposed here is deemed applicable to other collaborative initiatives in supply chain research. A comparison of benefits of a VMI system to other forms of vendor initiated applications, such as consignment sales with different inventory ownership setting can provide another interesting research avenue.

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