

## **VENDOR-MANAGED INVENTORY IN THE RETAIL SUPPLY CHAIN**

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Vendor-managed inventory (VMI) is one of the most widely discussed partnering initiatives for improving multi-firm supply chain efficiency. Also known as continuous replenishment or supplier-managed inventory, it was popularized in the late 1980's by Wal-Mart and Procter & Gamble. VMI became one of the key programs in the grocery industry's "quick response." Successful VMI initiatives have been trumpeted by other companies in the United States, including Campbell Soup and Johnson & Johnson and by European firms such as Barilla, the pasta manufacturer.

In a VMI partnership, the supplier, usually the manufacturer but sometimes a reseller or distributor, makes the main inventory replenishment decisions for the consuming organization. This means that the vendor monitors the buyer's inventory levels (physically or via electronic messaging) and makes periodic resupply decisions regarding order quantities, shipping, and timing. Transactions customarily initiated by the buyer (such as purchase orders) are initiated by the supplier. Indeed, the purchase order acknowledgement from the vendor may be the first indication that a transaction is taking place: an advance shipping notice informs the buyer of materials in transit.

In this relationship, buyers relinquish control of key resupply decisions and sometimes even transfer financial responsibility for the inventory to the supplier (whether by letter or spirit of their agreement). The arrangement transfers the burden of asset management from the consuming organization to the vendor, who may be obliged to meet a specific customer service goal ( usually some kind of stock target).

Various published accounts have described VMI benefits that range from cheaper new product introductions to reduced returns at product end-of-life, but the literature often fails to explain just why these benefits have resulted from VMI. As with many new

management theories, it is sometimes difficult to distinguish the achievable results from the hype, just as it is difficult to determine how these results might be replicated elsewhere.

We provide fresh insights into the approach, along with plausible answers to these questions. We start by explaining why savings so often accrue from VMI. We then describe some underlying technologies required to make the arrangement work. Next, we introduce a simulation model that examines VMI quantitatively in order to understand the effects of key variables. Finally we address several less than ideal conditions often found in consumer electronics industry in order to assess the robustness of the approach.

## **WHY VMI?**

Success in supply chain management usually derives from understanding and managing the relationship between inventory cost and the customer service level. The most attractive projects yield improvements along both dimensions, and this is certainly the case with VMI. To begin, we examine how each partner in a VMI relationship reduces cost and improves service.

### **Reduced Cost**

Demand volatility is the key problem facing most supply chains, eroding both customer service and product revenues. In traditional retail situations, sales fluctuations are made worse by management policies. Ordering patterns may be aggravated by demand uncertainties in general, conflicting performance measures, planning calendars used by buyers, buyers acting in isolation, and product shortages that cause order fluctuation.

Many suppliers are attracted to VMI because it mitigates uncertainty of demand. Infrequent large orders from consuming organizations force manufactures to maintain surplus capacity or excess finished goods inventory, which are very expensive solutions, to ensure responsive customer service. VMI helps dampen the peaks and valleys of production, allowing smaller buffers of capacity and inventory.

Buyers are attracted because VMI resolves the dilemma of conflicting performance measures. End-of-month inventory level for example, is a key performance measure for retail buyers, but customer service level (tracked by some sort of out-of-stock measure) is also applied. These measures are contradictory. Buyers stock up at the beginning of the month to ensure high levels of customer service, then let inventory drop at the end of the month to “meet” their inventory goals (disregarding the effect on service level measures) The adverse effect is even more pronounced when end-of-quarter incentives are tied to financial reporting. The combined result of this behavior is a monthly order spike to the supplier.

With VMI, the frequency of replenishment is usually increased from monthly to weekly (or even daily), which benefits both sides. The supplier sees a much smoother

demand signal at the factory. This reduces costs by permitting better resource utilization for production and transportation; it also reduces the need for large buffer stocks. The vendor can make replenishment decisions according to operating needs, and also has heightened awareness of trends in demand. The consuming organization benefits from legitimately lower cycle stocks, not just low end-of-month inventories intended to make performance lead the reward system. Even if the buyer has surrendered ownership to the supplier, many benefits arise from improved transportation and warehouse efficiencies. Moreover, service levels will go up at the end of the month or quarter.

In the scheduling domain, unevenly distributed order can result from variations in retail planning calendars. Retailers commonly divide their annual calendars by weekly increments, so that the “month” always has the same number of weekends. This facilitates period-to-period comparisons of sales, revenues and so forth. Alternatives include thirteen four-week “months” to a year; quarters comprised of four week, four week and five week months (4-4-5); and quarters comprised of four-week, five week and four week months (4-5-4).

A buyer who uses a 4-5-4 planning scenario and places orders on a monthly needs to order 25 percent more for the second month of the quarter, even if end user demand remains constant on a weekly basis. If the supplier is unaware of the buyer’s planning calendar, then these surges may come as surprises. Worse yet, the supplier may misinterpret them as a reflection of increased user end demand and make incorrect forecasting and purchasing decisions. VMI safeguards against these errors.

In retail supply chains, there is seldom any coordination of orders from the different buyers; it is even more rare to stagger orders from the same buyer for different distribution centers. Orders often arrive simultaneously, making it impossible to fulfill all delivery requests at on time. With VMI, greater coordination supports the supplier’s need for smoother production with out sacrificing the buyer’s service and stock objectives.

Finally, transportation costs are reduced with VMI. Managed properly, the approach helps increase the percentage of low-cost full truckload shipments and eliminate the higher-cost less than truckload (LTL) shipments. This is achieved by allowing the supplier to coordinate the resupply process instead of responding automatically to orders as they are received. Another attractive option is more efficient route planning; for example, one dedicated truck can make multiple stops to replenish inventories for several near by customers.

### **Improved Service**

From the retailer’s perspective, service is usually assessed by measuring product availability. This is rooted in the simple notion that if a product is not there when the customer walks into the store, then a sale is lost. The consequences are particularly severe when a promotion is running; simply the cost of the lost sale may be compounded by the loss of goodwill. When planning, therefore, a retailer looks to the supplier for

dependability. In their merchandising plans, retailers favor their best suppliers with more, and more attractive shelf space. Thus, a supplier known for reliability benefits from higher revenues. All else being equal everyone gains from improved service.

With VMI, coordination of replenishment orders and deliveries across multiple customers helps to improve service. A non-critical delivery can be diverted for a day or two to enable a critical delivery to another customer. Similarly, a smaller than usual replenishment to one customer may enable a larger than usual shipment to a customer in dire need. With the ability to balance the needs of all partners, the supplier can improve the system's performance without jeopardizing any individual customer. Customers benefit from the assurance that they are assured that their most critical needs will get the most attention. Without VMI, the supplier has a difficult time prioritizing customer shipments effectively.

Service can be improved further by widening the scope of available solutions to a given problem. For example, in times of crucial shortage, inventory balancing across one customer's distribution centers (or even between customers) may be necessary. In some cases, rebalancing among customers may even be the most economical approach. This is not usually an option with out VMI, for neither suppliers nor customers can see the widespread disposition of inventory. With VMI, stock balancing can be achieved when customers return product to the supplier, who can send it to another customer. At worst, this approach can result in excessive transportation cost.

The rich get richer, too. When service improves and customers regard the supplier as dependable, two things happen. First, fewer crises occur. Second, when they do occur, customers are less likely to inflate orders in an attempt to seize a larger share of limited supply. The supplier has a more accurate view of demand and can plan more effectively, which leads to better service.

As an additional benefit, the rollover to a replacement product can be facilitated by VMI. There would be less old inventory to flush through the system, so the customer can avoid such drastic measures as a "fire sale". Moreover the new product will be on the shelf sooner. With shared information, the rollover takes place with less upset to merchandising plans and helps the retailer maintain a reputation for being current.

The transportation process used with VMI improves customer service even more. Without VMI, shipments are sometimes rejected by distributors because of communication gaps between centralized buyers and dispersed distribution centers. This problem also appears with overcrowding on receiving docks on busy days. With VMI, however, the supplier typically schedules replenishments and deliveries in advance, hoping to ensure more predictable delivery schedules.

## **Technology Requirements**

Successful implementation of VMI often depends on computer platforms, communications technology, and product identification and tracking systems. In many cases, these systems are already in place at both the retailer and supplier. Software systems are the most likely areas of deficiency and are important because they facilitate such discussions as replenishment quantity and timing; safety stock levels, transportation routing and inter facility transshipments.

Many commercial systems are available to address these problems, and strategic decision systems can be used to determine, for example, the best location for a new distribution center or the advantages and disadvantages of bringing another retailer into a supplier's VMI system. Bar coding for product identification is also helpful at distribution centers, so information warehouse withdrawals can be captured; many retailers already have this capability.

Electronic data interchange (EDI) is an enabler, but not a requirement for VMI. For example, Frito –Lay used VMI techniques long before establishing EDI. Interestingly, research has shown that EDI alone provides little improvement in warehouse stockouts or inventory levels but coupled with VMI has been found to be very effective. Various transactions sets are used to communicate the following: retailer warehouse withdrawals, retailer warehouse on hand inventory, supplier replenishment plans, and advance shipments notices.

For standardization, transactions known as Uniform Communication Standards have been defined by the Uniform Code Council (UCC). Warehouse withdrawal and inventory information is transmitted via UCS 852 (product activity data). Supplier replenishment decisions transmitted via UCS 855 (purchase order acknowledgment). Advance shipment data is transmitted via UCS 856 (manifest). With VMI, UCS 855 is used to acknowledge a purchase order actually sent. It serves as a signal of the supplier's decision to replenish the retailer with a specific quantity at a specific time.

While decision support systems, product information technology, and EDI are often associated with VMI, they are not absolutely necessary, especially when the number of stock keeping (SKUs) is low. For example, a retailer could send a supplier a batch of valid purchase order numbers, so the VMI manager at the supplier's corporate headquarters can make replenishment decisions for the retailer. These purchase orders would be entered into the supplier's order management system and the system and the system would respond as though the retailer had sent that order. Note that no special support system is needed; the VMI manager simply uses a stock level approach to replenishment. In a week the VMI manager can use the difference between on-hand

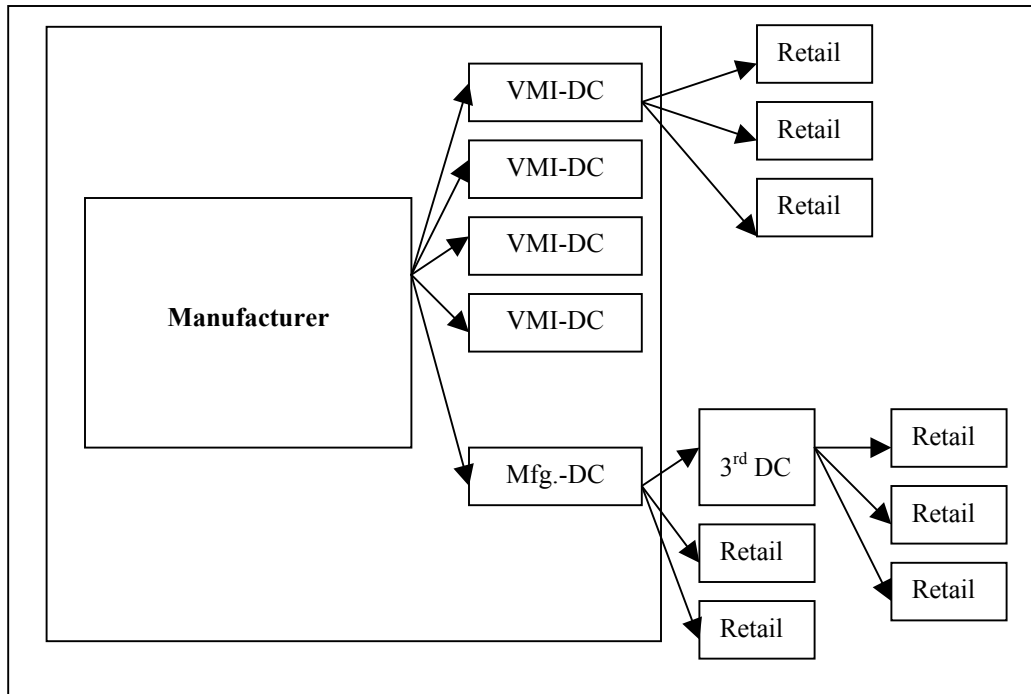
inventory in the retailers distribution center, along with the target stock level, to make replenishment quantities decisions. Also, considered to the extent possible, are supply, demand, capacity, and transportation issues facing the supplier. This approach is prudent for pilot projects because it postpones investments in information technology until the cost-effectiveness of the technology has been demonstrated. This, initially allows both parties, especially in a start-up mode, to assess their true needs.

## **EVALUATING THE VMI APPROACH**

To evaluate the effect of VMI on supply chain inventories, we evaluated a comprehensive group of scenarios as part of an investigation at Hewlett-Packard. Using simulation techniques, we generated our supply chain model to represent a large variety of industries. We made sure to include key components of supply chains and home computer industries: high demand ability and multiple distribution channels. Other recent research on VMI has concentrated on grocery and apparel industries. For example Cachon and Fisher examined forecasting and inventory management under VMI for Campbell's Soup. Using simulations of their ordering rules they found both retailer and manufacture's inventories could be reduced while improving service. They did consider cases with limited manufacturing capacity and issues related to allocating inventory across retailers. In another study, Narayanan and Raman developed a simple analytic inventory model to examine the benefits of VMI when product demand is influenced by product availability. They found that transferring stocking decisions to the manufacturer can lead to increased channel profits. Finally a number of studies have established and characterized the value of centralizing inventory in a supply chain. In our research, we have established the effect of VMI in environments with different levels of demand variability, limited manufacturing capacity and partial channel adoption.

Figure 1 shows our supply chain. It includes one manufacturing plant that supports all retailers through distribution centers of several types: manufacture owned (Mfg.- DC), retailer owned (VMI-DC) and 3rd party owned (3rd DC). Large customers with there own DCs are supported by direct shipments from the factory: they are likely VMI candidates and we include several of them. The relative size and frequency of orders from these customers were key variables in the analysis. In our scenarios, we examined the effect of reducing order frequency from every four weeks (traditional in many industries) to once every two weeks, every week, or even daily (under VMI).

**Figure 1**  
**Supply Chain Model**



Our manufacture also maintained its own DC, which supported a mix of small and medium sized customers. According to our scenarios, these customers depend on direct-to-store shipments or third-party distributors (as shown).

Figure 1 depicts the channels through which products move from manufactures through DC's to retail outlets. Each retailer owned DC faces a daily demand from the retailer's stores. The manufacture receives daily orders from the customer and places delivery replenishment orders to the factory. The daily demand faced by all DC s is normally distributed, with relative variability being another point of our analysis.

Inventories at each DC were adjusted to achieve a 90 percent item fill rate in each scenario. The factory produced enough to meet orders received daily. When these orders exceeded capacity, the orders from major customers were filled on a first-come, first-served basis. Daily priority was given first to major customers, then to the internal DC. Upon completion of a major customer order, the product was packaged and transported to the retailer's DC. Transportation time varied from two to four days and was randomly generated according to discrete distribution (25 percent two days, 50 percent three days, and 25 percent four days).

The boxed area in the figure indicates our scope of interest. We tracked demand and inventory at the manufacturer's DC and the retailers DC; We omitted third party DC or store level inventories from the analysis since we were concentrating at VMI on the first-tier DC level. Our baseline scenarios were simulated with average total demand representing 85 percent of manufacturing capacity. The total plant capacity was 1,970 units/day (with no overtime permitted), so the average daily demand was 1674.5 units. This demand was split among the seven DCs (30 percent and the manufacturer's DC (70 percent)).

The key dimension for our simulation scenarios was the order frequency from major customers. Ordinarily, retailer DCs placed orders every one, two, or four weeks to restore inventory to the target level (one delivery per order). With our model of VMI, by contrast, replenishment quantities for seven major retailers were computed daily (retailer orders were filled in their entirety). Only full trucks were used, with stop-offs at each DC, as needed. The amount shipped to each customer was upward or downward to ensure that full trucks left the manufacturer. When the seven DCs together did not require at least half a truckload no shipment was made at all.

The model was implemented using the SIMAN simulation language. We ran the simulation for 20 iterations of 1,500 days for each scenario, truncating the first 150 days to mitigate warm up effects that do not represent normal operating conditions. Statistical comparisons between the scenarios were facilitated using the well-established approach of common random numbers.

### **The Effect of Demand Variability**

To understand variability that has the greatest influence on supply chain inventories, we first examined how variability of demand affects the benefits achieved with VMI. For each scenario, we specified three levels of variability faced by the DCs; this variability was measured by the coefficient of variation (CV), the standard deviation of daily demand divided by the mean.

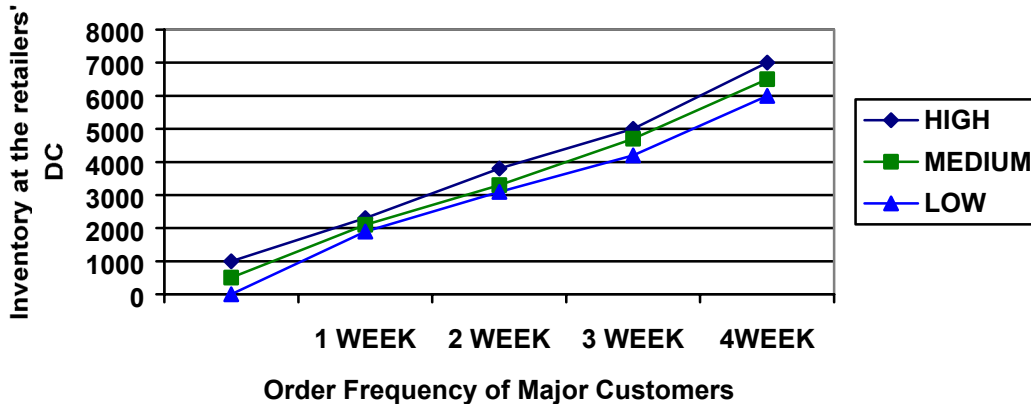
Demand variability ranges widely in different industries. For example, daily demand variability may be low in consumer products but significantly higher in electronics due to the short product life cycles. At Hewlett Packard, product CVs of 1.0 are common and sometimes are as high as 2.0. For modeling purposes, we specified a range of demand variability from low (CV=0.1), to medium (0.5), to high (1.0).

Figure 2 shows, for all seven large customers, the average inventory required to ensure 90 percent fill rate at each DC. Notice that the inventory reductions were very large (greater than 85 percent) for all three levels of demand variability. This striking benefit was achieved through dramatic reductions in cycle stock arising from more frequent deliveries as well as a modest reduction in safety stock. There is no particular advantage gained with low or high demand variability: simply shortening the order review period accounts for most of the benefit. We observed the same results for both higher (95 percent) and lower (85 percent) fill rate targets.



FIGURE 2

AVERAGE INVENTORY AT MAJOR DISTRIBUTION CENTERS



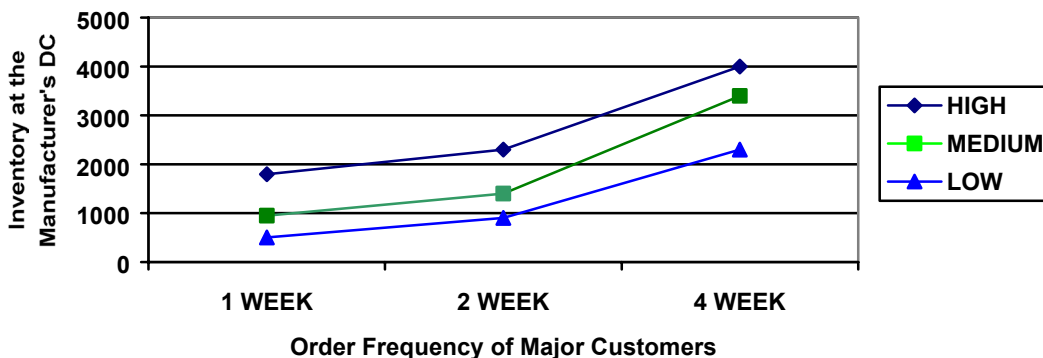
Note that moving from four-week intervals to weekly or daily intervals would require many product shipments to be shifted from more economical full truckloads to partial truckloads (LTL). With medium demand variability, for example, the percentage of LTL shipments for four-week order intervals was very low (4 percent). It grew to nearly 16 percent with weekly shipments. Without careful management, shipments twice a week could mean nearly 100 percent LTL. With VMI however, the replenishment needs of all customers can be managed to ensure full loads, with stops at each customer. On days with little demand, shipments can be postponed; on heavy demand days it may be possible to ship two or more truckloads.

While inventory reductions were expected for participating customers, an unexpected side effect is shown in figure 3. *There were significant inventory reductions at the distribution centers supporting only non-VMI customers.* Bringing customers into the VMI program clearly improves the supply chain for customers who have not adopted the approach. These reductions result from production smoothing, which yields reductions in safety stock; the order frequency was not changed for customers of this DC.

This conclusion is supported by figure 4, which shows that as the order frequency of major customers decreased, the average production backlog decreased. Backlog represents the total number of units in the production process at the beginning of each day. Eliminating large, infrequent orders from some customers allowed the plant to become a more reliable supplier to all its customers.

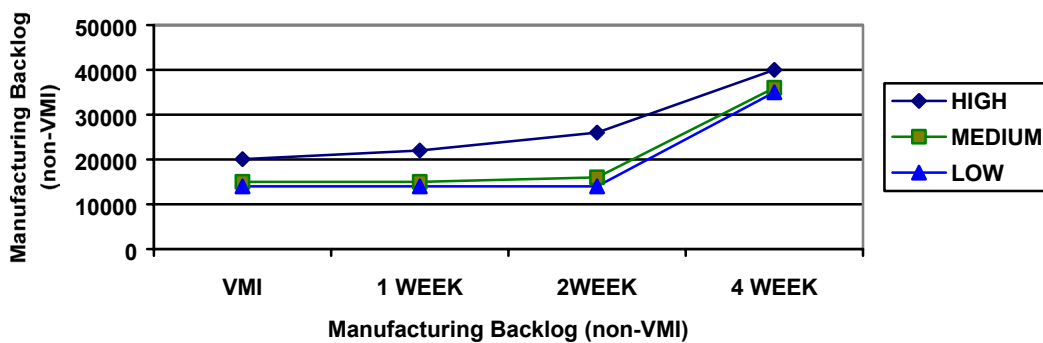
**FIGURE 3**

**AVERAGE INVENTORY AT THE MANUFACTURE'S DISTRIBUTION CENTER**



**FIGURE 4**

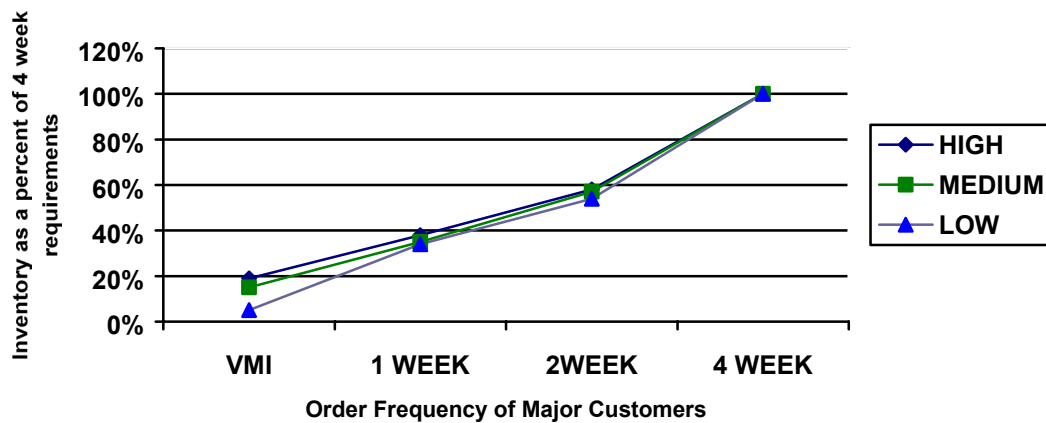
**AVERAGE MANUFACTURING BACKLOG  
Order Frequency for Major Customers**



In figures 2 and 3, inventory reductions are similar for all three demand variability cases. In figures 5 and 6, we see the relative inventory reduction for major retailer DCs and for the manufacturer's DC (inventory requirements are a percentage of four week requirements). In every case, the largest reductions occur in the low variability cases. With VMI, retailers required only about 5 to 15 percent of the inventory needed for a

four-week order cycle. Lower variability cases showed greater relative reduction because the unit cycle stock reductions were the same for both high and low variability cases; these reductions constitute most of the savings (safety stock is a small portion of the total inventory). Likewise the manufacturer's own DC (which supports only non-VMI customers) was able to reduce inventory to only 20 percent of four-week requirements. Again, the greatest reduction occurred in low variability cases, since improving manufacturing delivery performance for these cases nearly eliminated the need for safety stock (cycle stock is not affected because the manufacturer's DC places daily orders). Reductions for medium and high demand variability's cases, while slightly smaller, are still dramatic.

**FIGURE 5**  
**INVENTORY REDUCTION AT MAJOR RETAILER DISTRIBUTION CENTERS**



**The Effect of VMI Adoption Rates**

Our second set of experiments examined partial channel adoption of VMI. Potential adopters often are concerned about the “critical mass” required for success. Clearly, the adoption decision of each retailer is based on the cost and benefits of such an initiative. Our objective is not to examine the drivers of the adoption but the system wide benefits of different levels of adoption (15 percent) and widespread adoption (60 percent). For this analysis, we assumed medium demand variability.

**FIGURE 6  
INVENTORY REDUCTION AT MAJOR RETAILER DISTRIBUTION  
CENTERS**

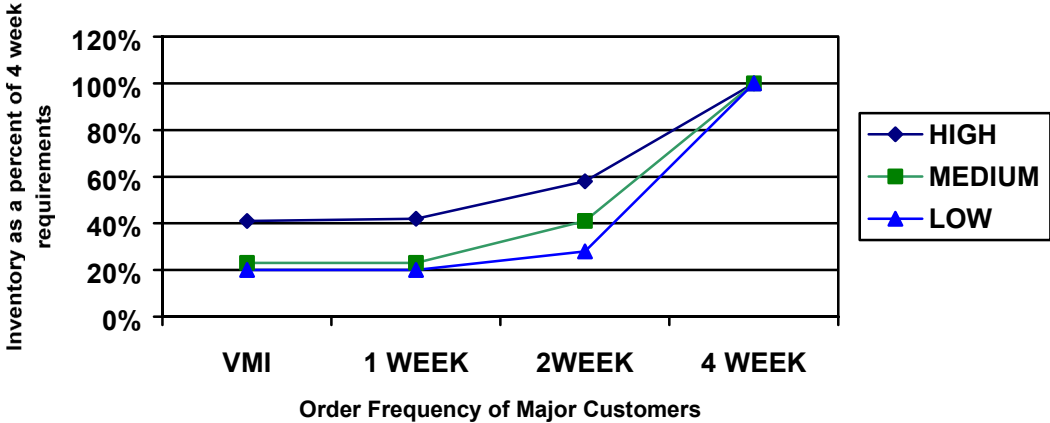
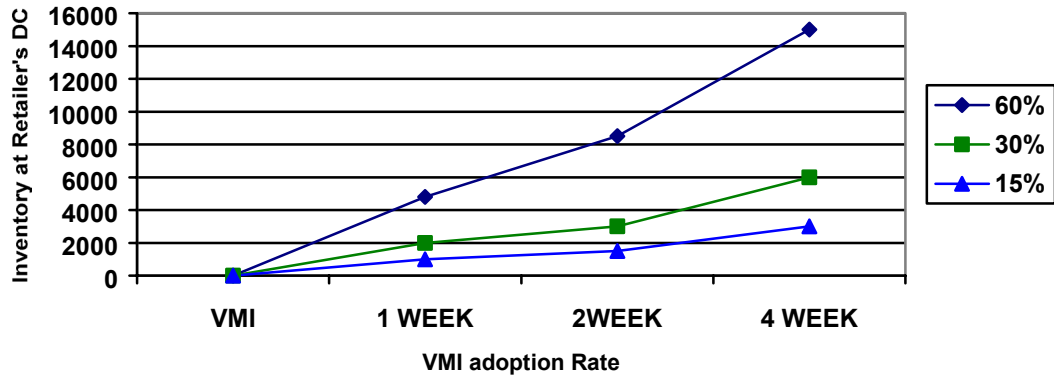


Figure 7 plots inventory of major retailers at the three adoption levels. When major retailers constitute 60 percent of total daily demand, they require more inventory than when they only constitute 15 percent, which comes as no surprise. But Figure 8 reveals that the relative benefit of VMI (and of more frequent ordering in general) is the same *regardless* of the adoption rate. From a retailer's perspective, therefore, the decision to adopt VMI can be made without concern for the supplier's relationship with other customers.

Less obvious is how VMI adoption rates affect the manufacturer's DC supporting non-VMI customers. Figure 9 shows that when major retailers consume 60 percent of the demand and operate under the traditional four-week ordering policy, the inventory requirements for the manufacturer are higher than when the manufacturer's DC services 85 percent of the market. When the major retailers are large and batch their orders, it creates chaos in manufacturing. More inventory is required to protect against uncertainty associated with the factory's ability to deliver on demand.

Figure 10 shows the relative inventory requirement with changing order frequency. The key lesson from this analysis is that the benefits of bringing the major retailers into the VMI program are substantial, regardless of how widespread the adoption rate is, although the benefits are greatest when adoption is widespread.

**FIGURE 7**  
**RETAILER INVENTORY AN VMI ADOPTION RATE**



**FIGURE 8**  
**RETAILER INVENTORY AND VMI ADOPTION RATE RELATIVE BENEFIT**

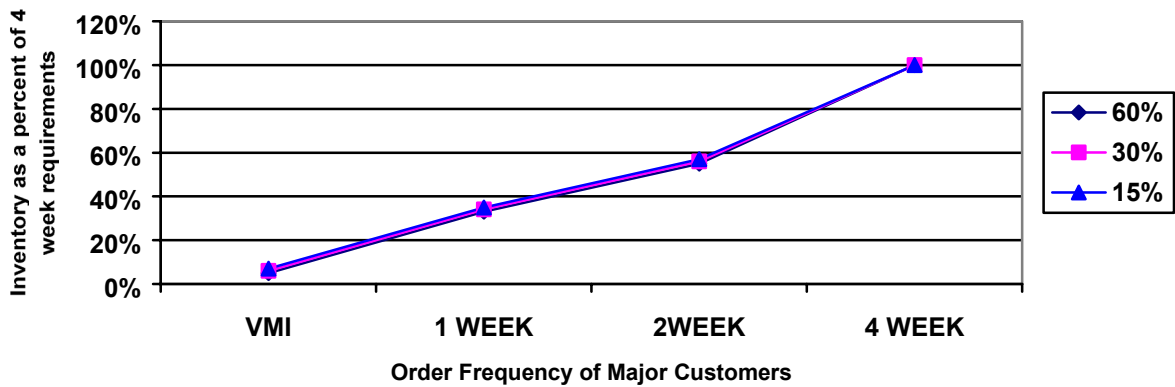


FIGURE 9

MANUFACTURER'S INVENTORY AND VMI ADOPTION RATE

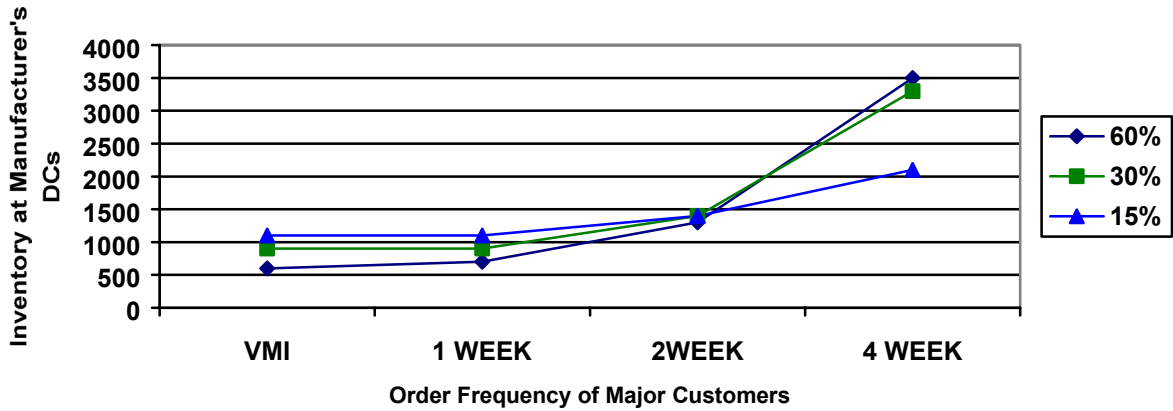
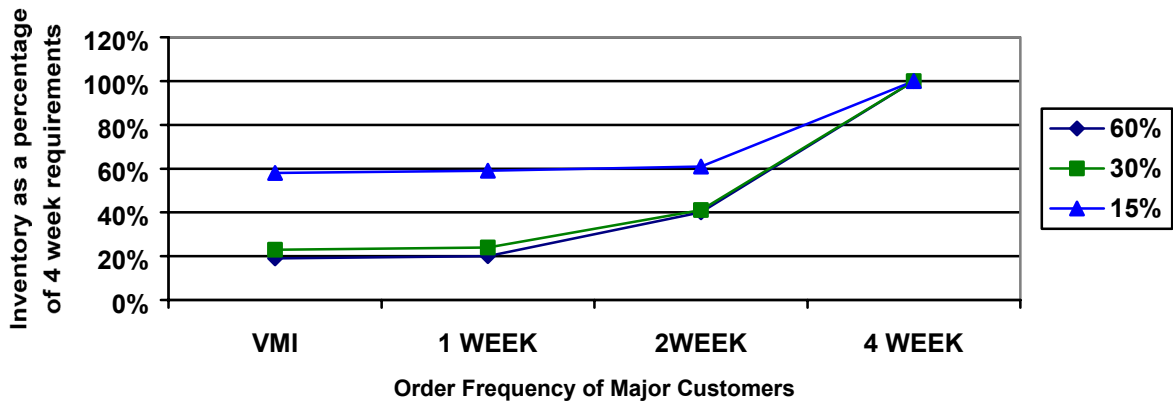


FIGURE 10

MANUFACTURE'S INVENTORY AND VMI ADOPTION RATE (RELATIVE BENEFIT)



The Effect of Limited Manufacturing Capacity

Our last set of scenarios involves the relationship between manufacturing capacity and inventory requirements. Like inventory, excess capacity represents a buffer against demand uncertainty. As capacity utilization increase, therefore, one would expect more inventory to be required (hence trading one buffer for another).

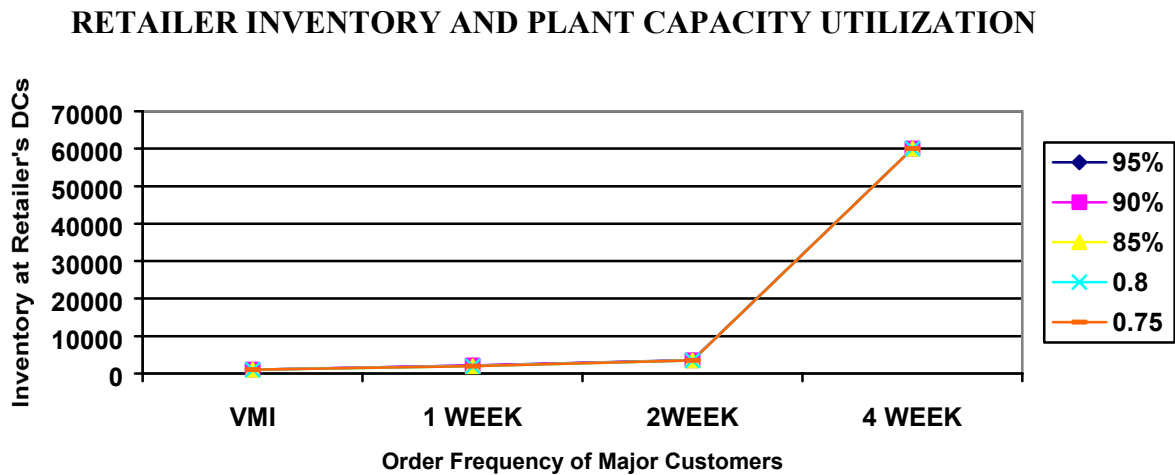
We modeled five plant utilization scenarios ranging from 75 percent to 95 percent. These were developed by adjusting the production capacity of the plant while maintaining the same demand process. Again, the scenarios were all examined under

medium demand variability and with the major retailers representing 30 percent of the total demand.

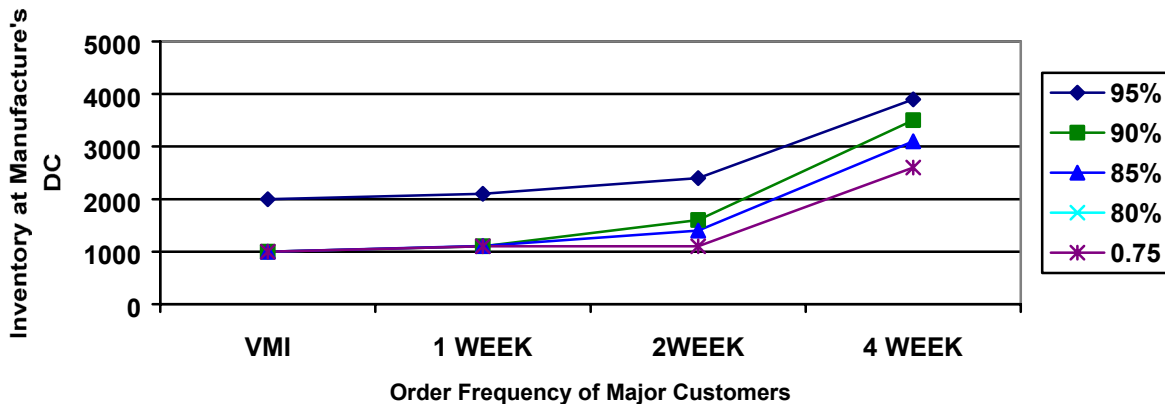
Figure 11 shows that with the higher plant utilization, the inventory requirements of the major retailer DCs actually increase slightly under any replenishment plan. Because the major customers are given priority at the manufacturing plant, the increased inventory needs are small.

Figure 12 reveals that the manufacture's DC pays the price for reducing excess capacity at the factory. As plant utilization increases, requirements for inventory at this DC increase, with the largest jump occurring as utilization climbs above 90 percent. This figure also reveals another hidden benefit with VMI. With VMI, inventory requirements change very little until plant utilization becomes high. In fact, inventory needs at utilization levels increase steadily with higher plant utilization. The lesson that VMI is even more important for manufactures with little excess capacity. To put it differently, VMI allows the manufacturer to diminish excess capacity and achieve high production efficiencies without increasing inventory or reducing order fulfillment objectives.

**FIGURE 11**



**FIGURE 12**  
**MANUFACTURER INVENTORY AND PLANT CAPACITY UTILIZATION**



### CONCLUSION

The management of inventory by the supplier continues to draw attention in many industries. We have addressed the benefits attributed to VMI by describing the practice and by applying rigorous simulation analysis. Our scenarios were designed to demonstrate the effect on VMI of demand variability, partial adoption of the approach, and limited manufacturing capability.

The operational benefits of VMI are very compelling. The costs of implementing VMI include investment in technology and in creating the organizational structure. Many of the technology costs associated with VMI are declining. For example, implementing EDI with trading partners is becoming dramatically less expensive with the availability of Internet EDI software. Our analysis shows that the approach greatly reduces inventories for all participants in the arrangement, without compromising service. Moreover there is a surprising “trickle down” benefit to non-VMI customers of a manufacturer.

Most of the inventory reduction achieved with VMI can be attributed to more frequent inventory reviews, order intervals, and deliveries that characterize this approach. Opportunities for greater coordination of activities among supply chain participants can be exploited in sophisticated ways to increase the value created by VMI. Demand volatility does not play role in determining likely benefits; businesses with low and high volatility of demand benefit to more or less equal degree.

Customers participating in VMI partnerships benefit under all conditions we examined and additional benefits accrue to the manufacturer under certain conditions. For example, while benefits are greatest with widespread adoption of VMI, they are likely to be significant for manufacturers even at low rates of adoption. Likewise, the manufacturer can expect to increase capacity utilization, for the VMI approach enables greater production smoothing.



VMI has been widely touted in recent years. Our analysis shows that this heightened attention is merited on the strength of operational benefits from this partnership arrangement. Yet, we found that successful implementation depends heavily on sound business processes and interpersonal relationships. A purely technical solution without regard for the people involved is unlikely to deliver the benefits we have described. Effective teamwork is required, with strong participation by both manufactures and retailers. Moreover, trust between supply chain partners is critical. Both must experience (and recognize) clear benefits, or the relationship is doomed. Finally, organization incentives and metrics must be aligned with VMI goals. For example, sales bonuses are often tied to short-term sales goals that are inconsistent with VMI. Clearly VMI relationships will fail without necessary relationships, metrics, and organizational structure. Interesting future research might examine the effect of team development on VMI success. Also, research on methods to manage benefits sharing among members of the supply chain would also be helpful.

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