Achieving Supplier Integration through Implementation of Supplier Managed Inventory Programs

by

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Abstract

Competitive market pressures and new dynamics in manufacturer-supplier relationships have led to the development of collaborative initiatives between manufacturers and suppliers that result in improved inventory management and material ordering practices. While these types of initiatives are known by different names in different industries, "vendor managed inventory" (VMI) and "supplier managed inventory" (SMI) are designations typically used in traditional industrial settings. Similar programs have been successful in retail and grocery environments. This research seeks to determine the appropriateness of supplier managed inventory programs for use in industrial settings and the conditions under which their use offers significant benefits. A review of current literature regarding collaborative manufacturer-supplier initiatives is conducted as well as interviews with fifteen industrial companies regarding their experience with supplier managed inventory programs. Just-in-time (JIT) production and change management emerge as key supporting elements of an SMI initiative and are also discussed.

The results from this research show that supplier managed inventory programs are being utilized in many different industrial settings with positive results. These results include improved inventory turns, higher service levels, reduced operating costs and mutually beneficial manufacturer-supplier partnerships. Benefits may vary between manufacturer and supplier companies. This research documents significant benefits associated with the implementation of SMI programs. A framework for implementing an SMI program is also provided.

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Chapter 1. Introduction

Motivation

The industrial world is changing at a seemingly exponential rate. Rapid technological advances have resulted in shorter product life cycles in many sectors. The use of customer focus as a competitive strategy has led to a proliferation in product variety, thus spawning the emergence of mass customization[1]. Availability of competing products on a wide scale, and increasing customer expectations, require that a company provide shorter lead-times with better service. And as if these pressures weren't enough, price competition remains an intense battleground. This combination of shorter product life cycles, increased product variety, shorter lead-times and price competition require a company to be more flexible and more responsive, while continually lowering costs. Within this fast-changing market environment, however, traditional inventory and operations management practices can insulate company functions from market actions, sustain activities that may no longer be needed, and result in excessive inventory that is prone to obsolescence.

The need to be flexible, responsive and cost competitive has forced companies to reevaluate how much they do themselves, and how much they rely on their supplier base to develop and manufacture products. Manufacturing firms have outsourced many activities previously considered fundamental to the success of the company. Companies understand that attempting to reorient their factory workers and undertake significant capital projects for each new product development effort is inconsistent with the need to be nimble. Manufacturers are becoming assemblers, while their suppliers are providing more finished components and subassemblies. Also, companies are consolidating their supplier base, doing more business with fewer suppliers. As a result, manufacturers have grown

[1] Mass customization is the ability to prepare on a mass basis individually designed products to meet each customer's requirements.

increasingly dependent on suppliers and have started to form closer relationships with them. Manufacturers and suppliers are becoming more interdependent than ever before.

Along with these market dynamics and changing manufacturer-supplier relationships come significant risks. There is great uncertainty in demand for a company's products. It is difficult to predict how successful a product will be and when it will be displaced by something new or less expensive. When forecasts are inaccurate sales are lost or excess product inventory can become obsolete. As manufacturers make fewer of a product's components, purchase transactions with suppliers are increasingly for higher dollar value items that are ready to assemble into to products or ship directly to the end user. This leads to inventory that is less "flexible" and more expensive, as it is already configured into final form and costs more than raw materials traditionally held in storage. In light of these considerations, companies have placed more focus on improving responsiveness through the use of supply chain management and logistics.

Amidst the more competitive and risk intensive environment companies face, they are held to high expectations regarding financial results in order to satisfy demanding shareholders. They have become more aware of the impact inventory assets have on the balance sheet. Andel (1997) put it this way: "The goal of every supply chain should be to eliminate non-productive assets from the balance sheet". Assessment of a firm's overall performance invariably includes mention of its inventory turnover ratio.[2]

There has been increasing focus on benefits to be gained from effective inventory management as companies look for new frontiers in which they can gain competitive advantage. Yet there are influences embedded in current practices that may impede progress toward achieving greater efficiency gains, such as volume discount pricing and maintaining an internal focus. The dynamics in the manufacturer-supplier relationship in industry, against the backdrop of competition and risk pressures, provide opportunity for manufacturers and suppliers to collaborate for mutual gain. There are areas to avoid

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[2] Inventory turnover is defined Chapter 2.

duplication of tasks traditionally performed by each company. A typical example is inspection. In the past, a supplier may have inspected a part prior to shipping it, only to have the manufacturer inspect it again when it was received. This is a simple example and, in many cases, this type of obvious redundancy has been eliminated. There are, of course, additional opportunities for collaboration for greater mutual gain. Programs such as "efficient consumer response" (ECR) have been successfully used in retail and apparel since the late 1980's to reduce demand volatility by directly connecting suppliers to the actual point-of-use[3]. Another such program, known as "supplier managed inventory" (SMI), is being adopted by an increasing number of industrial companies. SMI is a process in which a supplier will monitor a manufacturer's inventory, and, using previously agreed-upon guidelines, continuously replenish the items required by the manufacturer directly at the point-of-use. All non-essential effort and transactions are eliminated. The potential payback is lower system-wide inventory and better utilization of the workforce. In an effort to respond to rapidly changing market dynamics, SMI appears to offer participants dramatic benefits and warrants a closer look.

Objective

The objective of this thesis is to explore "supplier managed inventory" (SMI) programs and evaluate potential benefits to participants in the context of traditional industrial settings. While inventory and workload reduction are both inherently appealing, this research seeks to discover if SMI is a worthwhile approach that can benefit manufacturers and suppliers as they respond to the day-to-day pressures of shipping products. Although at first glance benefits may seem to favor the manufacturer, this work seeks to discover what types of tangible benefits can accrue to the suppliers as well. Additional goals are to define the conditions under which an SMI program should be adopted, and to understand what fundamental principles would help support the success of an SMI program. Further,

[3] See Chapter 3 for examples.

this thesis attempts to determine specific elements that are critical to a successful SMI program and develops a framework for implementation.

Thesis Overview

Chapter 2 reviews traditional inventory management and operations practices in order to understand what can cause a company to find itself with excessive inventory and potentially inefficient processes.

Chapter 3 provides a summary of the information related to SMI programs found in current literature. The chapter provides insights gained from types of programs similar to SMI that have been implemented in various industries. It describes the concept of SMI, as well as practices that can be considered foundational elements of a successful SMI program: JIT and EDI.

Chapter 4 summarizes the results from interviews with key representatives of manufacturers about their SMI experiences.

Chapter 5 summarizes the results from interviews with key representatives of suppliers about their SMI experiences.

Chapter 6 contains an analysis of the insights gained from interviews with representatives of both manufacturers and suppliers. It summarizes the important insights gained from current SMI practitioners and offers what are considered the key success factors for an SMI program. It finally provides a suggested implementation framework, based on a synthesis of the insights gained from both the interviews with industry practitioners and the existing information found in the literature.

Chapter 7 provides the overall conclusions of the thesis and suggests what areas might benefit from additional research.

NOTE: For clarity of presentation this thesis is written from the perspective of a manufacturer-supplier relationship. The manufacturer, also referred to as the buyer, represents the entity, such as an OEM, that performs final assembly and test of the product or system being supplied to the market. The supplier represents one of the many types of firms that supply components or subassemblies to the manufacturer. When used to describe these types of relationships, the word buyer refers to the company (manufacturer) that is procuring items from the supplier. It is not meant to refer to the individual company representative (e.g., senior buyer) who may be performing a purchasing transaction on behalf of the buyer company.

Chapter 2. Traditional Theory and Practice

Holding inventory is important to businesses for a variety of reasons. There are traditional views and practices that influence the amount of inventory a business holds and the methods by which companies obtain and manage materials. Demand patterns, and how businesses react to those patterns, also play a key role in determining inventory levels in a supply chain.

Inventory

Inventory allows an activity to proceed without being directly dependent on any preceding activities. It provides the buffer that is needed when linked activities are not, or cannot be, perfectly timed or instantly performed. For example, a product can be sold immediately when it is stocked on the shelf and the consumer does not have to wait the 12 weeks it takes to manufacture and transport the product. As another example, a machining operation for a metal component can take place as one sequential step in manufacturing, without being dependent on when the mill will roll the steel being used as raw material. Inventory for manufacturing operations can be classified as follows (Nahmias, 1997):

- *Raw materials:* production or processing resources.
- *Components:* items not yet complete, subassemblies.
- *Work-in-process (WIP):* waiting for processing or being processed.
- *Finished goods (FGI):* final products or end items.

Traditional views simply consider inventory as a necessary activity, common to all enterprises, which is kept for several reasons. These reasons include protecting against variations in demand, allowing smooth production flow by de-coupling stages of production, lowering material cost by taking advantage of quantity discounts, and optimizing operation of a bottleneck stage (Buffa & Sarin, 1987).

Although holding inventory provides certain benefits (e.g., eliminating disruption in production operations) it also brings with it important costs. Inventory ties up scarce capital and results in unrecoverable storage and handling costs. It must typically be paid for prior to being resold, and must be disposed of at a loss when obsolete. It has opportunity costs associated with it and continually begs the question: How could the financial and human resources expended to acquire and manage this inventory have been better utilized to benefit the company? Many influences shape the amount of inventory a company carries. At the same time, these very same influences could often have serious consequences in terms of inefficient practices that have increasingly become more significant to business performance than ever before.

There are different ways to view the many characteristics of inventory. Each offers insight into the practices evidenced by the traditional approach to inventory management. Some of these views are presented below.

Motivations for holding inventory (Nahmias, 1997), (Gattorna & Walters, 1996):

- *Economies of scale:* amortizing fixed set-up costs over a larger number of units in manufacturing, or achieving purchasing or transportation rate discounts.
- *Uncertainties:* uncertainty of supply (resources, labor, cost), lead-times, or external demand due to customer preferences.
- *Speculation:* anticipation of future events, such as an expected price increase.
- *Transportation:* inventory that is in-transit, or in the pipeline.
- *Smoothing:* producing in a steady-state manner, without responding to all changes in demand patterns due to seasonal influences or unforeseen events.
- *Logistics:* issues such as minimum lot, package or shipment sizes.
- *Specialization:* enables businesses to specialize within a manufacturing facility and then ship to distribution centers for the assortment process.
- *Improved customer service:* assumes that demand for a product, once created, requires availability if sales are to be made.

- *Control costs:* the cost of maintaining the inventory control system (for example, an inexpensive component, while not worth tracking on an ongoing basis, may be worth keeping in large quantities).
- *Inventory as a buffer:* here the issue of interdependencies within the procurement-manufacturing-distribution-consumption process is highlighted. Because channel members are distanced geographically, philosophically and financially, often 'buffer stocks' are held at critical interfaces.

The basic elements of inventory: From the perspective of a retailer or similar party, inventory might be viewed as consisting of three basic elements[4]:

- *Cycle stock:* inventory that is drawn down and subsequently replenished while responding to expected demand (see Figure 2-1).
- *Safety stock:* inventory that is kept in reserve in case demand or lead-time exceeds expected values that were planned for (see Figure 2-1).
- *Pipeline, in-transit stock:* inventory that is on order but has not reached the location from which it is considered available for use.

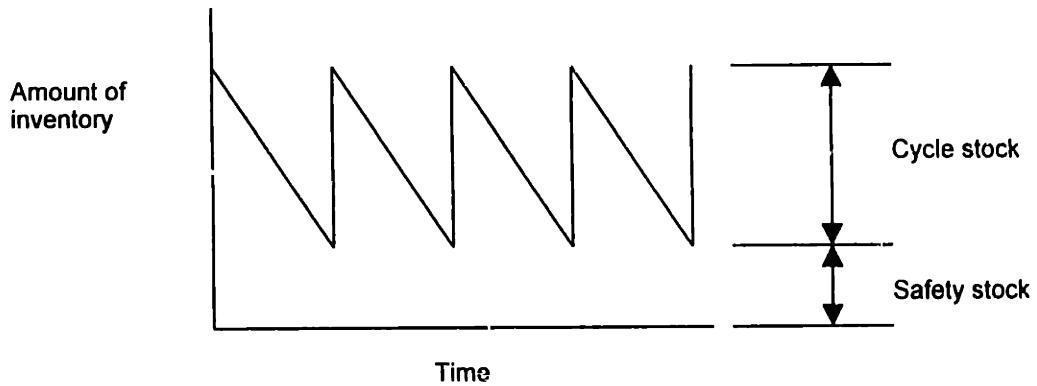


Figure 2-1: Cycle and Safety Stock

Gattorna and Walters (1996) also list speculative stock, seasonal stock and dead (or obsolete) stock as additional types of inventory.

[4] Based on class notes from 1.261J - 15.771J Case Studies in Logistics and Supply Chain Management taught by Dr. Jonathan Byrnes, Fall 1998.

A textbook perspective on the relevant categories of inventory costs (Nahmias, 1997):

- *Holding cost (also known as carrying cost):* the cost of physical storage space; taxes and insurance; breakage, spoilage, deterioration and obsolescence; and opportunity cost of alternative investment.
- *Order cost:* the fixed cost (transaction expenses) and variable cost (per-unit) associated with inventory that is ordered.
- *Penalty cost:* shortage or stock-out costs. This includes "loss-of-goodwill" intangible costs. For back-ordered items this is the bookkeeping and/or delay cost. For lost sales it includes lost profit.

Additional items to be considered with holding cost are the labor and equipment costs related to storage and retrieval of inventory.

The Procurement and Production Cycle

Ideally, materials and components should be available to the production process when they are needed. In order for a part provided by an external supplier to be ready for assembly into a system at the right time, the need for the part must be established and communicated to the supplier, it must go through the supplier's production process, and must then be transported to the proper location. The activity of planning material needs and performing the associated purchasing transactions is known as procurement. The manufacturer's procurement and production cycles trigger similar processes at the supplier. All in all, for the multitude of components involved in a system, many parts must be procured by the manufacturer and produced by its suppliers. This results in a tremendous amount of activity that continually ripples throughout the manufacturer and its network of suppliers.

A representation of a traditional procurement and production cycle is shown in Figure 2-2. This diagram provides the basis for two subsequent discussions. The first is an overview of each of the many influences on this cycle and how inventory and workload levels are affected. The second is a consideration of the implications due to traditional practices used in this cycle, and a look at which steps directly contribute to value creation and those that do not.

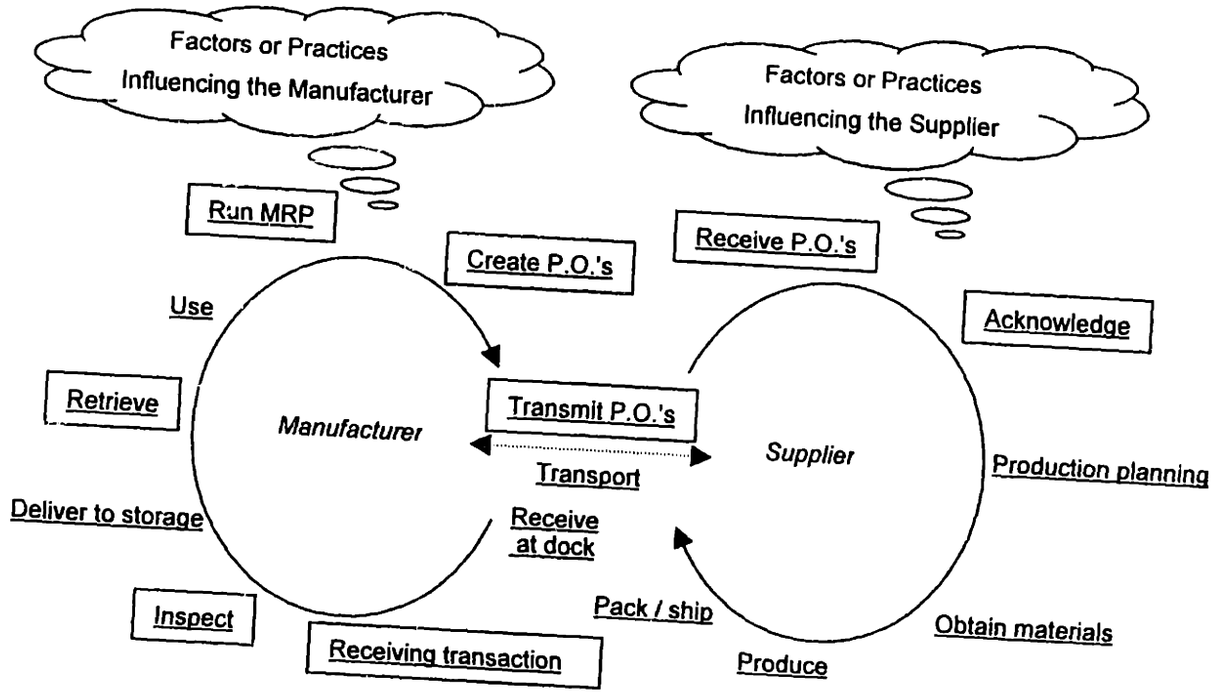


Figure 2-2: The Procurement and Production Cycle

There are internal as well as external factors or practices affecting the manufacturer, and still others affecting the supplier organization, which influence the procurement and production cycle. The influences acting upon the manufacturer are shown in Figure 2-3 and those impacting the supplier in Figure 2-4. Many of the influences upon the manufacturer also apply to the supplier, since the supplier becomes the manufacturer from the perspective of its sub-suppliers. In order to avoid confusion, the respective influences are shown only once in the diagrams.

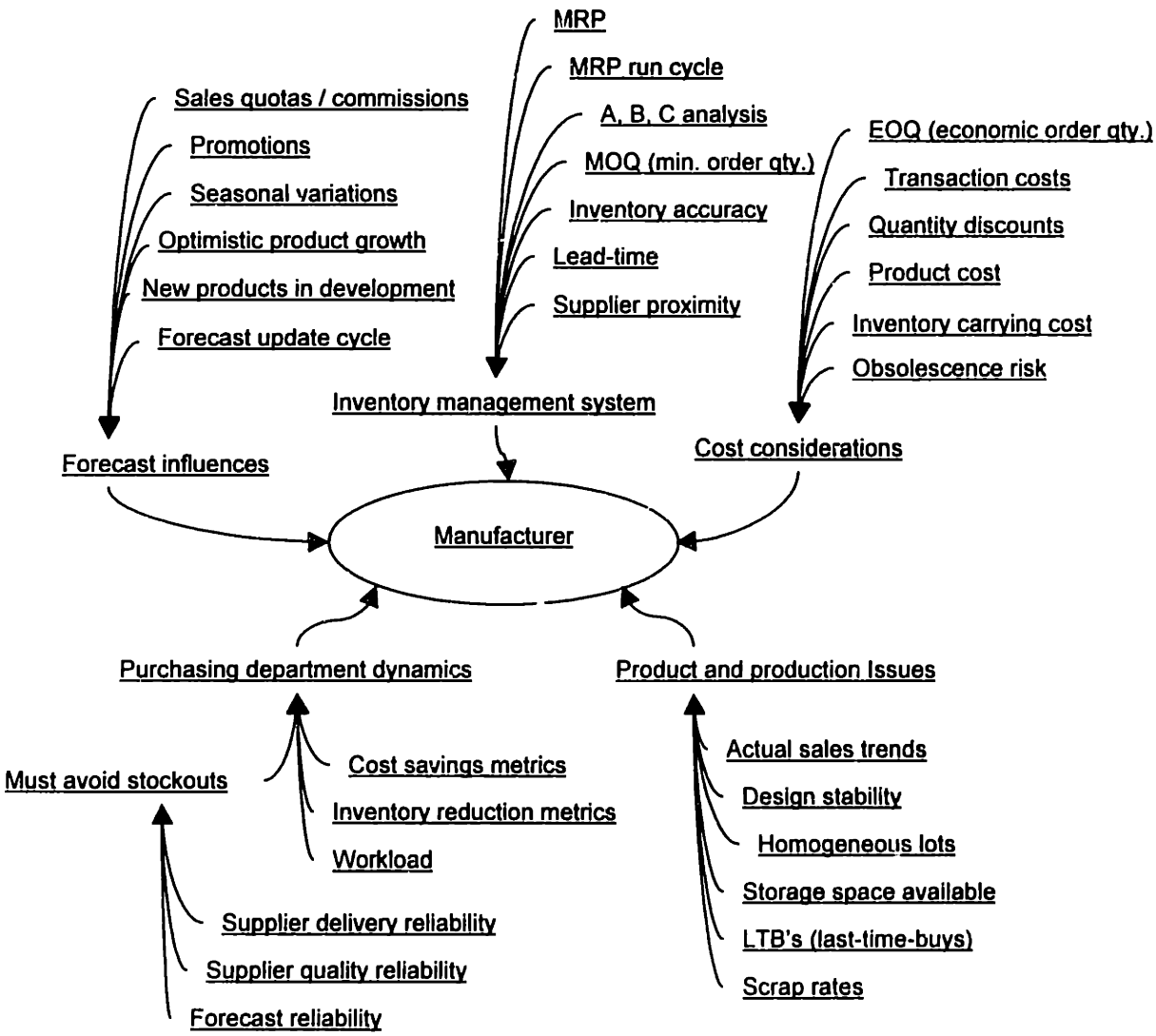


Figure 2-3: Factors or Practices Influencing the Manufacturer's Procurement and Production Cycle

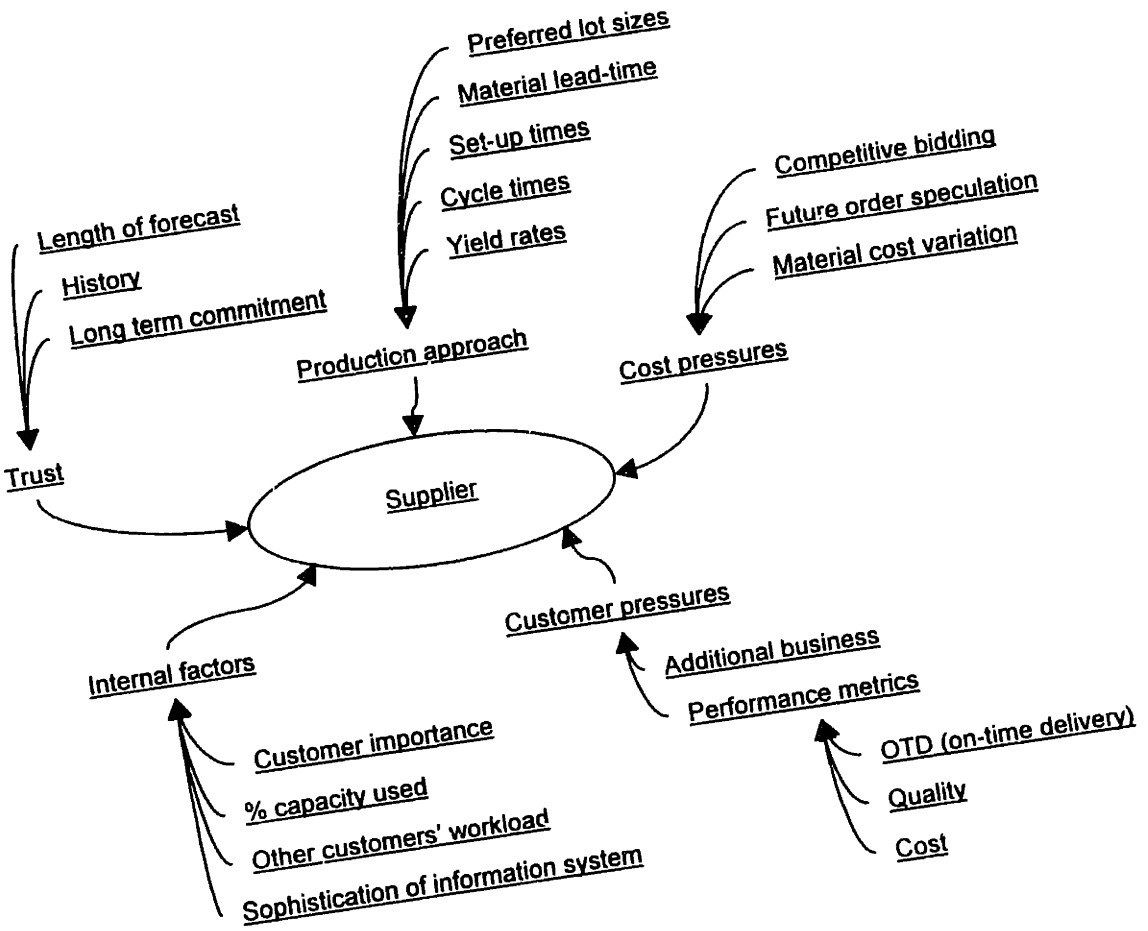


Figure 2-4: Factors or Practices Influencing the Supplier's Procurement and Production Cycle

An overview of the factors or practices influencing these procurement and production cycles is given below. The respective factors or practices are presented individually in order to:

- provide a brief description of the specific factors or practices to serve as a common reference point, since there are variations in actual industry perception and practice, and,
- suggest how this factor or practice can lead to higher inventory levels and an assortment of other non-value-adding activities.

Factors or Practices Influencing the Manufacturer

There are a number of factors or practices that influence manufacturers throughout the procurement and production cycle, primarily due to market, product and internal issues. They can be divided into five major categories that provide insight into the wide range of, and sometimes conflicting, requirements placed on the people and systems involved. An overview and brief description of each of these five categories of factors or practices influencing the procurement and production cycle is given below.

Inventory Management System - The inventory management system comprises the decision assisting techniques and processes that determine how frequently materials will be replenished to the production system and when purchase orders are placed. It consists of:

- *MRP (material requirements planning):* MRP is a computerized top-down planning system that utilizes demand forecasts and product structures to drive production and schedule decisions for items that make up a product. Information such as bills-of-materials and lead-time estimates are entered into the system along with quantity forecast, actual usage and inventory information. The MRP system facilitates creation of the detailed production schedule and determination of procurement needs. MRP systems, while providing many benefits, have difficulties responding to frequent changes in demand and schedule inaccuracies. Higher inventories can result from inefficiencies due to over and under ordering, or excessive use of safety stocks or safety lead-times. Depending on the level of detail a company goes to, providing information to the MRP system, such as multi-level product structures or numerous schedule changes, can be very time consuming.
- *MRP run cycle:* MRP systems receive information from numerous sources, such as the marketing department for sales forecasts. In order to determine the requirements schedule for various product components, MRP users have to coordinate the gathering of the required data and then run a batch job to perform the MRP update. The time period between MRP runs varies, but can be a week or more in many companies. This causes a delay in integrating the latest market

information, and leads to perturbations that ripple through the production system, causing rescheduled production runs and associated inefficiencies.

- *A, B, C parts analysis:* This is a technique used to help determine the appropriate amount of effort to expend on managing inventory in order to balance costs and benefits. Typically a large portion of the total dollar value of purchased items is accounted for by a small number of items as shown (designated as "A") in Figure 2-5. Another consideration is the impact of various factors on production, such as that of shutting down an entire assembly line if a part were not available in stock. Parts are placed in the "A" category if they are in the group that forms the largest total purchased dollar value, or if they are considered critical to production. Parts are placed in the "C" category if they are in the smallest total dollar value group or are considered not critical to production. B-parts are those parts in between these two categories. More monitoring and sophisticated control methods are used to manage A-parts, while minimal control is applied to C-parts. While this can be an appropriate method to prioritize efforts, companies sometimes assign the code based on a casual perception of part cost or value, and end up with much more "C" dollar value than expected when adding up aggregated demand. Inaccurate categorization can lead to more inventory dollars being controlled by using the less sophisticated methods, resulting in higher average inventory levels, since C parts for example, might only be ordered twice per year.

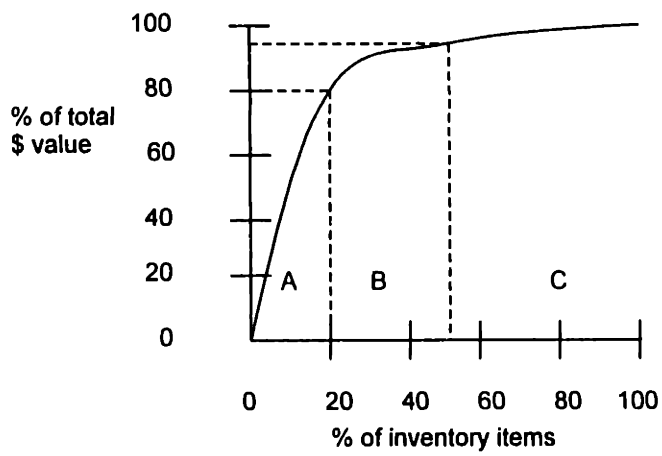


Figure 2-5: A, B, C Parts Classification

- *MOQ (minimum order quantity):* Suppliers establish minimum order quantities for a number of different reasons. The supplier may be amortizing a fixed set-up cost over the quantity of parts made during the production run, and may want to assure itself a minimum level of profit. There may be process inefficiencies in small lots thus encouraging large lots, or there may be preferred shipping container sizes that accept a certain quantity of parts. A mismatch between actual usage and the MOQ can result in inventory being held in excess of desirable levels.
- *Inventory accuracy:* Planning for production requires that an accurate inventory count is available. If not, production plans generated through an MRP system will lead to incomplete orders or production overruns, both of which result in excess WIP or FGI. In order to assure itself that inventory counts are accurate, a company typically practices cycle counting (performing routine physical counts of inventory) in order to assure accuracy. This requires physical labor to count or weigh the items.
- *Lead-time:* Lead-time from realization of need, to part availability for use, includes the time for purchase order generation and transmission, supplier production, shipment transit and receipt processing. Long lead-times force a company to plan far in advance of anticipated needs, making it unlikely actual consumption will equal planned production. Since lead-time prevents a company from reacting quickly to unanticipated demand, companies plan conservatively and can have excess inventory as a result. In addition, longer lead-times lead to more order monitoring and expediting activities.
- *Supplier proximity:* The geographic location of a supplier relative to a manufacturer influences the time required for transportation of goods between the two companies. This distance also affects the amount of packaging materials needed to protect items in transit. Clearing customs, if necessary, can also add to transit time. Product shipments that will travel long distances with multiple carriers tend to have longer lead-times, higher MOQ's, and more expensive packaging. In addition, unpacking these items can require more time when compared to local shipments.

Cost Considerations - Direct and indirect cost considerations regularly impact the decisions made by individuals and managers regarding ordering items and holding inventory. These cost considerations include:

- *EOQ (economic order quantity)*: The basic inventory model attempts to balance costs of holding inventory with the costs of preparing each order by use of the EOQ equation:

  $$EOQ = \sqrt{\frac{2RC_P}{C_H}}$$

  Where R = annual requirements, C_P = cost of placing an order, and C_H = inventory carrying cost per unit per year. If individuals responsible for placing orders to suppliers perceive a high cost of ordering, they are likely to order in higher quantities. High ordering costs can be attributed to transaction costs as outlined below. (Note: See below for additional descriptions of C_P, under transaction cost, and C_H, under inventory carrying cost.)
- *Transaction cost (C_P):* Many companies include time to prepare, review, transmit and monitor purchase orders in order placement costs, as well as costs to perform the receiving and payment transactions. These costs can be difficult to determine due to the number of individuals and functional areas that are involved in processing these transactions. As the perceived or actual cost of placing an order goes up, typically the quantity ordered goes up as well, in a desire to get more "mileage" out of each transaction cost incurred, which inevitably results in higher levels of inventory.
- *Quantity discounts:* Suppliers frequently offer a manufacturer a lower unit cost when buying in larger quantities. Larger production quantities allow the supplier to spread the cost of equipment set-up over more units. When set-up times are high relative to unit production time, there is a larger discount for higher volume. This can motivate a manufacturer to buy more components and hold them in inventory. These savings can be very tangible and appealing to a buyer, as compared to inventory carrying costs that may seem more like "bookkeeping" and somewhat abstract. Purchasing in larger quantities leads to a higher value of average inventory for a given rate of usage.

- *Product Cost:* Product profitability is influenced by direct material cost as well as indirect costs. Since direct costs are very visible when evaluating product profitability, there is pressure to keep the cost of components low despite changes in sales volume or other factors. In an effort to keep these costs low, individuals may take advantage of quantity discounts, resulting in higher volume purchases and higher inventory levels.
- *Inventory carrying cost (C_H):* Inventory carrying costs include the cost of physical storage space; taxes and insurance; breakage, spoilage, and deterioration; labor and equipment costs related to storing and retrieving inventory; and opportunity cost of alternative investment. Although significant, many of these costs are accounted for as indirect costs and can lose visibility in the day-to-day activities of individuals making the buying decisions.
- *Obsolescence risk:* When a product is no longer desired by the market or has been replaced by a new product, it may have to be sold at a discount or scrapped. Similarly, an obsolete product's component parts that do not have alternative uses may need to be scrapped as well. The longer an item is held in inventory, the higher the chance it will be displaced by a newer version or technology, and, therefore, become obsolete.

Product and Production Issues - Issues specific to the product and its associated production processes are:

- *Actual sales trends:* Material and component lead-times dictate that forecasts are made well in advance of actual sales. Also, companies and its individuals are averse to the risk of running out of stock and therefore generally order items conservatively, insuring there will be adequate inventory to cover forecasted production levels. When actual sales are below forecast, inventory levels increase.
- *Design stability:* If market forces or quality issues force a product to undergo design changes, materials in inventory may not be able to be used after the change is implemented and, therefore, may become obsolete.

- *Homogeneous lots:* Due to regulatory or process related reasons, some products must be made in homogenous lots. If technologies are changing rapidly and re-qualifying replacement components requires extensive effort, a company may choose to produce in large lots and keep high levels of component or finished product inventory on hand between production runs.
- *Storage space available:* When items are physically small and considered easy to store, or when ample warehouse space is available, individuals may decide to order in larger quantities for convenience sake. When items are physically large, or when inadequate warehouse space is available, items may have to be stored off-site and incur multiple handling operations prior to use or sale.
- *Last time buys (LTB):* Companies frequently have to provide customer support for many months or years after trade shipments of a product have ceased. In order to provide this support, the company may have to purchase multi-year quantities of components that suppliers plan to discontinue. For these situations, forecasted needs estimates typically are conservative and err on the high side, leading to high levels of slow moving inventory.
- *Scrap rates:* If a production process at a supplier or manufacturer has uncertain yield, then excess materials will be purchased in order to cover the lower yield scenarios. When high production yields are realized, the extra materials or finished goods become additional inventory.

Purchasing Department Dynamics - As suggested by Johnson, Davis and Waller (1998), end-of-month inventory is a sometimes a key performance measure for individuals buying products, as is customer service level (tracked by an out-of-stock measure). The individuals may tend to stock-up at the beginning of the month to ensure high service levels, then let the inventory level drop at the end of the month to "meet" inventory reduction metrics (temporarily disregarding the impact on customer service). The adverse effect can be worse if end-of quarter incentives are tied to financial reporting. The combined result can be a monthly order spike to the supplier. Dynamics for purchasing department individuals can be summarized as:

- *Avoiding stockouts:* No one wants to be the person that stopped the production line or negatively affected customer shipments because of a lack of inventory. In addition to the points discussed above, a supplier's delivery and quality reliability, as well as the inherent knowledge of internal forecast accuracy, will influence the individuals making the buying decisions as they decide on purchase quantities. In general, these individuals may tend to err on the conservative side, resulting in higher levels of inventory.
- *Cost savings metrics:* Companies try to motivate purchasing department individuals to save the company money by tracking cost savings activities. By purchasing a larger quantity of components at a lower price (quantity discount), an individual can get recognized for a cost savings that is equal to the cost difference between the higher and lower price, multiplied by the quantity ordered.
- *Inventory reduction metrics:* (Note: Discussed above.)
- *Workload:* As an individual's workload increases due to downsizing or other factors, one "easy" solution is to buy items less frequently. Buying less frequently for the same consumption rate results in larger purchase quantities and higher average inventory.

Forecast Influences - Product sales forecasts are developed due to business pressures such as preparation of yearly budgets and company growth expectations, as well as various material and capacity planning needs. Influences to forecast accuracy are:

- *Sales quotas / commissions:* Since reaching specific revenue or volume goals frequently drives sales compensation, sales may be "pulled-in" to meet a particular threshold or deadline. This may result in a demand spike, followed by a demand lull, which can create inefficiencies due to production and inventory level fluctuations.
- *Promotions:* When a company plans a promotion they may build product ahead of time, thus raising inventory levels, in order to be able to satisfy anticipated peak demand during the promotion.

- *Seasonal variation:* Similar to what occurs for promotions, it may be necessary to build products ahead of time, thus raising inventory levels, in order to be able to satisfy anticipated peak demand during the season when the product is popular.
- *Optimistic product growth:* As a new product is introduced and ramped up, the company is optimistic that it will be successful and wants to ensure its availability. Since the company may have forecasted revenue growth as well, additional incentives abound to plan conservatively and have adequate inventory to support the growth.
- *New products in development:* When a new product is scheduled for introduction, and the product will replace another product, production planning requires adequate overlap in inventory coverage for both items. If the new product is delayed, inventory levels rise because many of the product's materials will already be on hand due to lead-time concerns.
- *Update cycle:* The frequency of updating the product sales forecast can be limited by other more urgent responsibilities of sales and marketing departments. Those responsible for buying materials may rely heavily on historical trends after the latest forecast gets out of date. Actual usage trends may be slow to filter through demand smoothing algorithms, thus masking any demand slow-downs.

Factors or Practices Influencing the Supplier

Suppliers are influenced by many types of factors or practices throughout the production and procurement cycle, mainly due to customer, competitive and internal issues. They can be divided into five major categories that provide insight into the wide range of, and sometimes conflicting, requirements placed on the people and systems involved. An overview and brief description of each of these five categories of factors or practices influencing the procurement and production cycle is given below.

Production Approach - The basic philosophy that the supplier adopts toward its manufacturing strategy plays a key role in determining the level of inventory carried in this

portion of the supply chain. The supplier must decide if it will make to order or make to stock. It must choose between relying on large batch sizes and the perceived economies of scale, or using a just-in-time approach. Production approach factors or practices are:

- *Preferred lot sizes:* The lot size chosen by the supplier, when compared to the actual consumption rate at the point of actual product use, determines the level of inventory in this part of the system. As manufacturers provide conflicting pressure to reduce cost and reduce inventory, the supplier must pick between larger and smaller production runs.
- *Material lead-time:* If material lead-time is long compared to the production cycle, suppliers will be forced to order conservatively (increased amounts) to ensure adequate material in case of unexpected demand.
- *Set-up times:* Similar to the dynamics caused by the EOQ equation, long set-up times (higher "order cost") will lead to long production runs and the associated excess inventory. Set-up time can occupy significant portions of productive capacity, either in equipment or people.
- *Cycle times:* Long cycle times can lead to conservative production planning (additional safety stock), since the impact of reduced yield or other shortages is more significant.
- *Yield rates:* Processes with yield variation will force the supplier to plan for the worst case scenario and store the excess materials or finished items when yield is better than worst case results.

Cost Pressures - Although many issues are related to cost, factors or practices that have a very direct impact on cost pressures are:

- *Competitive bidding:* Suppliers competitively bid for business, often based on rough estimates of production yields and processing times. If estimates are off unfavorably, the supplier may consider buying material and producing in large lots in order to gain the perceived advantages of quantity discounts and economies of scale.

- *Future order speculation:* In order to "get ahead" or be better prepared should its customer request additional product on short notice, a supplier may order excess material or overproduce. Without a long-term forecast or other collaborative mechanism, the supplier will make these choices based on historical order pattern data and risk excess inventory, which could occur if market demand is decreasing, for example.
- *Material cost variation:* Suppliers may purchase excess raw material in advance of an impending price increase in order to avoid the unpleasant task of having to notify its customer of a cost increase.

Customer Pressures - Manufacturers can impose direct and indirect pressure on suppliers to be responsive to varying order patterns. It may be necessary for a supplier to maintain high levels of inventory in order to meet this expectation. These customer pressures include:

- *Additional business:* A supplier will naturally want to grow its business and manufacturers are the source of this potential. The prospect of additional business can lead a supplier to hold excess inventory in order to prove itself reliable for the manufacturer.
- *Performance metrics:* Many manufacturers have supplier management programs that measure supplier performance in discreet numbers such as on-time-delivery, quality and cost performance. Suppliers may compromise their inventory and operations management practices in order to satisfy the manufacturer and the measurement system. Effective inventory management at the supplier is sometimes considered secondary.

Internal Factors - A supplier's business strategy and a manufacturer's business strategy are not necessarily aligned, even though they do business with each other. This can create different internal priorities for each company. Factors or practices that influence the supplier due to internal issues are:

- *Customer importance:* Depending on how important a particular customer is, a supplier may tolerate inaccurate forecasts and unpredictable ordering patterns and may hold the extra inventory that is needed to overcome these deficiencies.
- *% capacity used:* If a supplier is operating near capacity it may paradoxically choose to extend production runs to take advantage of the investment in set-up time, prior to changing over to the next production run. This can result in high levels of inventory held at the supplier.
- *Other customers' workload:* Pressures created by production requirements and priorities of other customers impact how much attention a supplier can devote to one customer. A supplier may have to frequently reschedule production runs due to erratic demands of different customers. This can lead to inventory and operations inefficiencies such as excessive set-ups.
- *Sophistication of information systems:* A supplier must contend with many different types of information systems used by its customers, in conjunction with its own business system. Small suppliers may not have the financial or human resources to invest in information systems that could provide better visibility into inventory status and movement.

Trust - Trust between a manufacturer and a supplier is established in two ways. The first way is through formal terms and conditions, agreements, and other business and legal documentation that formalize the relationship. The second way is through the intangible feelings and understandings that develop between individuals from both parties as they conduct business together over time. Influences to trust include:

- *Length of forecast:* The longer the forecast the easier it is for a supplier to make capacity decisions and allocations, and potentially stock up on materials and finished components in advance.
- *History:* The history of negotiation outcomes, trading partner responses to unforeseen events, and the extent of mutual benefit derived from the relationship all shape the feelings that each party has toward the relationship. There may be negative feeling if one party has not lived up to previous agreements. A supplier

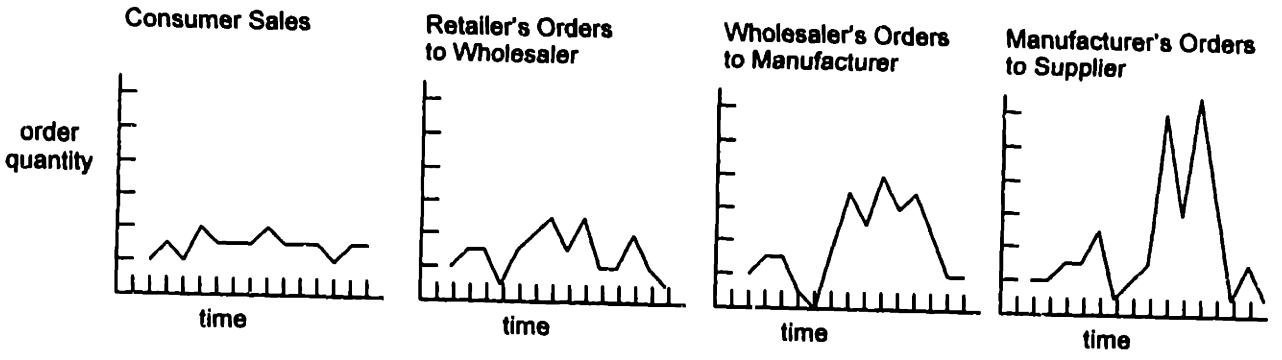
will be more flexible and accommodating for a manufacturer that has historically honored its commitments

- *Long term commitment:* The types and duration of contracts and agreements that are formed between a supplier and manufacturer may determine how much material purchasing and production occurs in advance of actual purchase orders.

Implications of Traditional Practices

The previous discussion illustrates the extreme complexity embedded in the procurement and production cycles of a manufacturer and its suppliers. The realities of financial pressure, time, and uncertainty with regard to future demand combine to create the need for buffer inventory at numerous locations in the supply chain. In addition, by focusing only on its own internal issues, these companies limit the potential to eliminate inefficiencies and redundant activities that exist in the manufacturer-supplier network.

Lee, Padmanabhan & Whang (1997) describe what happened when logistics executives at Procter & Gamble (P&G) studied the order patterns for diapers. Although consumption was steady and retail stores sales fluctuated slightly, orders to distributors showed much higher levels of variability. When they looked at orders to material suppliers, they discovered even greater swings. P&G labeled this phenomenon the "bullwhip effect" (it is also known as the "whiplash" or "whipsaw" effect). Hewlett-Packard observed a similar situation when executives examined the supply chain for printers. This pattern of increasing variability in demand is shown in Figure 2-6. Lee, Padmanabhan & Whang (1997) describe the symptoms of large variations in demand as excessive inventory, poor product forecasts, insufficient or excessive capacities, poor customer service due to unavailable products or long backlogs, uncertain production planning (i.e. excessive revisions), and high costs for corrections, such as for expedited shipments and overtime.



Source: Lee, Padmanabhan & Whang (1997)

Figure 2-6: Increasing Variability of Orders up the Supply Chain

Byrnes and Shapiro (1991) found similar results when they studied intercompany operating ties. In one case that they considered typical, a high-volume product was being consumed steadily but there were erratic ordering patterns to the supplying company as well as its suppliers. Upon closer inspection, the supplying company found that a few large customers dominated the order patterns and were causing most of the problem. These large, infrequent orders created demand spikes that were amplified as each company in the channel ordered from the next.

Lee, Padmanabhan & Whang (1997) describe the best illustration of the bullwhip effect as the "beer game". In the game, participants play roles of customers, retailers, wholesalers and suppliers of a brand of beer. They cannot communicate with each other and must make order decisions based only on orders from the next downstream players. The ordering patterns share a common recurring theme: the variation at an upstream site is always greater than that at the downstream site. Lee, Padmanabhan & Whang (1997) cite research that suggests human behavior, such as misconceptions about inventory and demand information, may cause the bullwhip effect.

Lee, Padmanabhan & Whang (1997) identified four major causes of the bullwhip effect:

- *Demand forecast updating:* Each company in a supply chain typically does its own forecasting for production scheduling, capacity planning, inventory control and materials requirements planning. These activities are influenced by many behavioral factors, such as perceptions and mistrust. When a downstream operation places an order, the upstream manager processes that information as a signal about future product demand. Based on this signal, the upstream manager readjusts demand forecasts and in turn, places orders with the suppliers of the upstream operation. The effects of exponential smoothing algorithms and safety stock policies can further influence these dynamics.
- *Order batching:* Periodic ordering and push ordering are two forms of order batching. Due to concerns about order placement costs, companies will order weekly, biweekly, monthly, or will base orders on MRP run cycles, resulting in periodic ordering. Push ordering can result from salespeople who are trying to meet quotas.
- *Price fluctuation:* Manufacturers and distributors periodically have special promotions such as price discounts, quantity discounts, coupons, and rebates that result in price fluctuations. The result is that customers buy in quantities that do not reflect their immediate needs; they buy in larger quantities and stock up ahead of time. Subsequently, a period of low ordering activity will follow.
- *Rationing and shortage gaming:* If an item is in short supply, a company may choose to order more than they need to try to get additional safety stock, or a larger shipment, if products are being rationed based on a percentage of order quantity. Once the shortage is over, excessive inventory in the channel must be consumed and as a result, order levels may decrease for a time.

The principles of just-in-time (JIT) production lead to consideration of manufacturing activities in terms of "adding value" and "not adding value" with regard to the output of the production system. This is discussed in more detail in Chapter 3. For now, consider that value is added only by actual work on a product. Refer back to Figure 2-2, and note the activities that are outlined by a rectangular box ("Run MRP" for example). It is

worthwhile to consider that these activities are currently necessary in the traditional production system, but they do not add value to the product. As seen in the following chapters, it is possible to reduce or eliminate activities such as these when companies adopt a more integrated approach to supply chain management.

Additional Information

The following definitions provide information regarding terms used in this thesis:

Inventory turnover - Inventory turnover is a popular measure used to assess effectiveness of asset management. Tersine (1988) defines it as:

$$\frac{\text{annual cost of goods sold}}{\text{average inventory}}$$

He cautions that an effort should be made to determine a true average inventory level, since the value of inventory is a point in time measure that could distort the figure if, for example, the value was determined at a time when inventory was abnormally high or low. He also suggests having specific turnover ratios for each type of inventory: raw materials, in-process inventory and finished goods to provide visibility into inventory composition.

Supply chain - Nahmias (1997) describes supply chain management as "the logistics of managing the pipeline of goods from contracts with suppliers and receipt of incoming material, control of work-in-process and finished goods inventories in the plant, to contracting the movement of finished goods through channels of distribution".

Chapter 3. Exploring an Integrated Supplier Network

Supply chain management and purchasing performance is increasingly recognized as an important determinant of a firm's competitiveness (Dyer, Cho & Chu, 1998). Historically, companies have oscillated between controlling costs (lowering inventory) and managing customer service (lowering stock-outs which leads to higher inventory). Gattorna (1998) points out that using a traditional approach, buyers merely place orders for items when they are needed, with no early warning of needs. Suppliers carry safety stock as a buffer in order to be able to be responsive. Buyers carry safety stock in case the supplier is unable to respond quickly. This arms-length approach results in higher levels of inventory and paradoxically lower levels of service and responsiveness. In a collaborative relationship between buyers and suppliers, the buyer shares actual usage data and expected future needs data on a continuing basis. The supplier can now plan and schedule production and transportation more efficiently with this information. Duplicate inventories are reduced, service levels improve, and the cash flow of both the manufacturer and the supplier is enhanced because product is paid for when used. Thus, these collaborative relationships encompass win-win, value-creating activities and practices.

Lee & Ng (1997) claim that the distinction between supply chain management and traditional operations is organizational integration and flow coordination. They consider organizational integration to be intracompany (within the company) as well as intercompany (between companies), overcoming traditional functional and company boundaries. They present flow coordination along three interdependent areas: materials, information and finance.

The elements of organizational integration and flow coordination are embedded in the just-in-time (JIT) methodology that was initially made popular by the success of Japanese automobile manufacturers. In addition, electronic data interchange (EDI) has proved to be an enabling technology for companies undergoing the transition to better intercompany

integration. Following an in-depth discussion of manufacturer-supplier integration initiatives, the basic elements of JIT and EDI are presented at the end of this chapter.

Counteracting the Bullwhip Effect

The phenomenon of increased demand variation moving up the supply chain is described as the bullwhip effect in Chapter 2. Lee, Padmanabhan & Whang (1997) characterize various initiatives and other possible remedies to counteract the bullwhip effect based on the following underlying coordination mechanisms:

- *Information sharing:* Sharing actual demand information throughout the supply chain.
- *Channel alignment:* Coordination of pricing, transportation, inventory planning and ownership between upstream and downstream sites in a supply chain.
- *Operational efficiency:* Activities that improve performance, such as reducing costs and lead-time.

Lee, Padmanabhan & Whang (1997) propose the following four specific ways to counteract the bullwhip effect:

- *Avoid multiple demand forecast updates:* Encourage all sites in the supply chain to update their forecasts based on the same raw data. Another approach is to allow an upstream site to control re-supply for a downstream site.
- *Break order batches:* Reduce order costs through such initiatives as electronic data interchange[5] (EDI). This allows more frequent demand data communication. Reduce dependencies on large shipment quantities through more innovative approaches to transportation such as third party logistic providers that can coordinate smaller shipments.
- *Stabilize prices:* Reduce the frequency and level of price discounting and consider practices such as everyday-low-price (EDLP).

[5] EDI is described in detail at the end of this chapter.

- *Eliminate gaming in shortage situations:* When facing a shortage a supplier could allocate shipments based on past order history rather than excess order quantities. Sharing capacity and inventory information with customers can alleviate shortage fears and lessen their need to engage in gaming.

Successful Supplier Integration Initiatives in Other Fields

The factors or practices that influence the procurement and production cycle of manufacturers and suppliers, as discussed in Chapter 2, produce similarly high inventory levels and associated work practice inefficiencies in many different industries. Since the late 1980's and early 1990's initiatives have been underway in the retail and grocery supply chains to address these inventory and inefficiency issues. Current literature contains numerous stories of successes that have been realized in various fields. The concept of information sharing between manufacturers and suppliers, and allowing suppliers to assume responsibility for replenishment decisions, has been approached and defined in a number of different ways.

The following overview summarizes these initiatives and the context in which they were developed (Simbari, 1996) and (Anonymous, 1997):

- *Quick response (QR):* Initially conceived by a group of apparel and soft-goods manufacturers in the late 1980's to revive the U.S. apparel industry, quick response (QR) was originally associated with EDI and data collection technologies. The strategic value of this initiative was, however, the vision to gain advantage by leveraging across the supplier network that supported the manufacturers.
- *Efficient consumer response (ECR):* Efficient consumer response (ECR) is used as an umbrella term for a set of goals and practices that the grocery industry developed in the early 1990's as a means to combat "alternative format" stores, such as Wal-Mart, by lowering costs and increasing customer satisfaction. ECR has four goals:
    - Efficient assortment: The best products to customers that want them.

- Efficient product introduction: The best sales environment for success of new product.
- Efficient replenishment: The most efficient distribution of products from manufacturer to store shelf.
- Efficient promotion: To provide supply chain cost savings by making promotional activities more efficient.

These goals are supported by the following concepts:

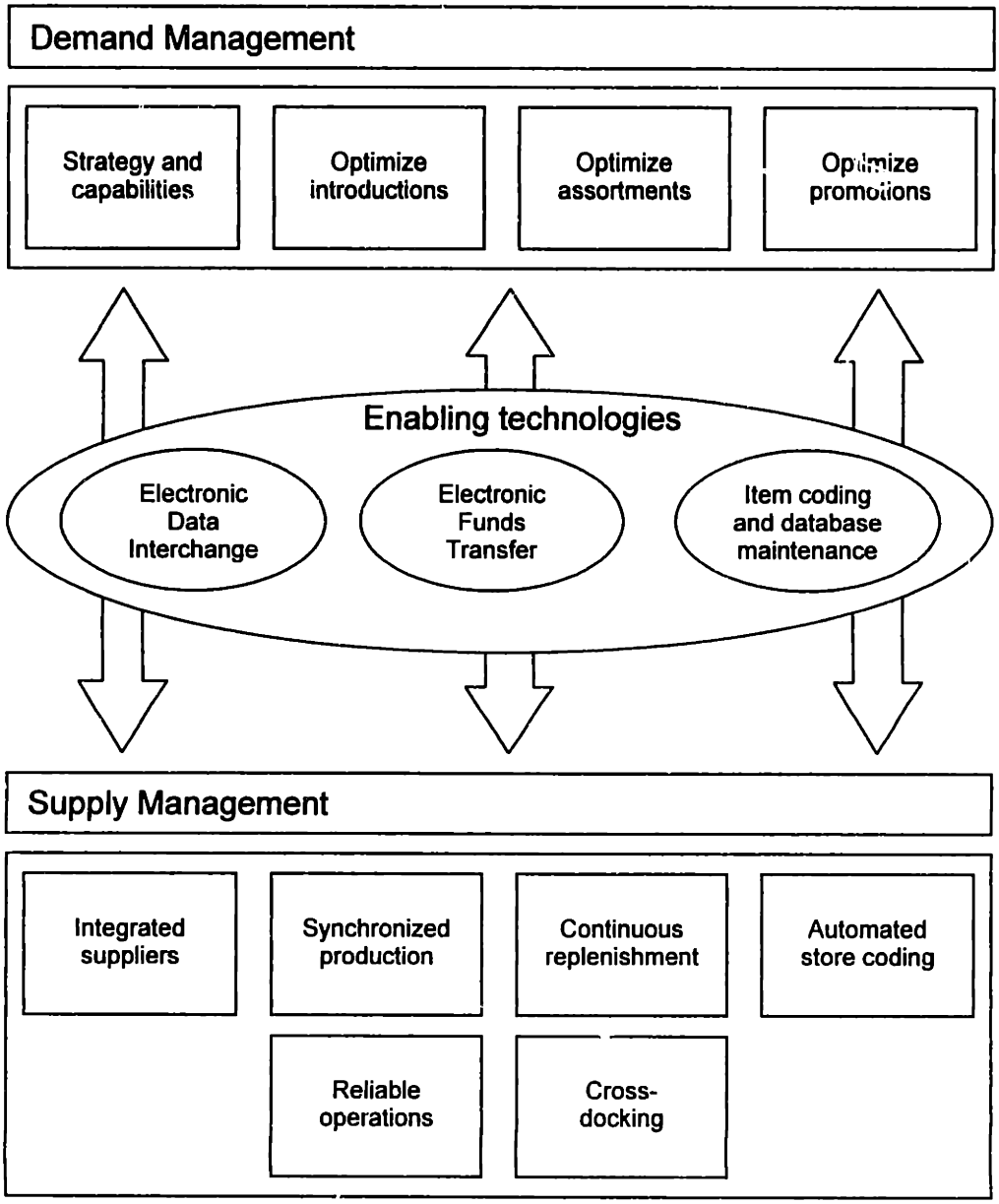
- Category management: Using categories as an organizing unit for business practices.
- Continuous replenishment: (see below).
- Vendor managed inventory: (see below).

- *Continuos replenishment programs (CRP):* Typically associated with retail industries, continuous replenishment programs (CRP) involve the practice of replenishing stock based on actual consumer demand. Scanner level sales data are used to drive warehouse fulfillment and shipping. The goal is to make this as automated as possible, thus reducing ordering and item stocking costs. In this type of program purchase orders are generated by the retailer (the "manufacturer", to be consistent with the terminology used in this thesis) and sent to suppliers.
- *Vendor managed inventory (VMI) or vendor managed replenishment (VMR):* Vendor managed inventory was originally developed by mass merchandisers with their suppliers, such as Wal-Mart and Proctor and Gamble, in the late 1980's. VMI takes the CRP concept one step further by making the supplier responsible for managing the retailer's inventory. The retailer communicates product movement information and suppliers use this to forecast needs and generate orders, which are then accepted or adjusted by the buyer. This arrangement typically utilizes EDI. The buyer provides the supplier with product usage and stock level information. The supplier uses this information to develop production and shipping schedules in order to replenish the buyer on a regular basis.
- *Customer managed replenishment (CMR) or retailer managed replenishment (RMR):* This is similar to the vendor managed replenishment concept, except for

the fact that the buyer is responsible for planning and sending a schedule of planned replenishments to the supplier. The buyer would use movement data and on hand inventory and calculate future, long range replenishment plans and send these to the supplier.

- *Jointly managed inventory (JMI), distributor managed inventory (DMI), synchronized consumer response (SCR):* These are additional initiatives, specific to certain industries or originators that are based on the basic CRP / VMI concepts but may enhance them in some way.
- *Supplier managed inventory (SMI):* There does not appear to be a standard accepted definition in the literature for the VMI type of relationship when used in more traditional industrial settings. The term "supplier managed inventory" (SMI) is sometimes used interchangeably with VMI. For the purposes of this thesis, supplier managed inventory (SMI) will refer specifically to collaborative inventory management relationships between manufacturers and suppliers in industrial settings where, similar to VMI, the supplier assumes responsibility for most inventory management efforts on behalf of the manufacturer in order to generate system-wide improvement in asset management and customer service.

The essence of SMI is captured by much of the literature pertaining to ECR or VMI. Gattorna (1998), who presented the structure of ECR as outlined by *The Official European ECR Scorecard* (shown in Figure 3-1), indicates that the ECR improvement concepts are not easy to achieve and they deliver the greatest benefit when implemented as an integrated whole rather than as a set of individual best practices. They further need to be considered from the perspective of their impact on all trading partners, and not just as one link in the total supply chain.



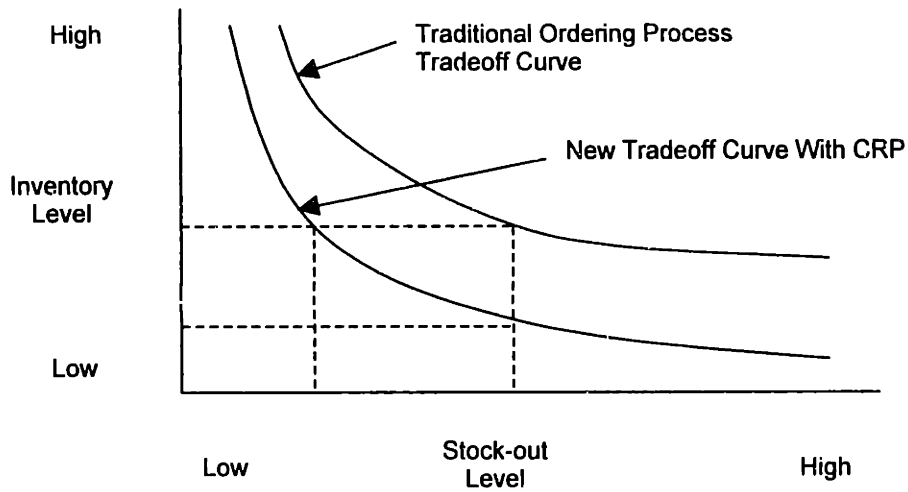
Source: Gattorna (1998)

Figure 3-1: Concepts of Efficient Consumer Response (ECR)

Cachon & Fisher (1997) have documented concrete benefits that were derived by Campbell Soup Company which illustrate the potential benefits of ECR for companies that may be considering such programs: inventory levels were lowered by 50%, while the service level was increased from 98.7 to 99.5%. They described the key features of an

ECR program to be: every-day-low-price (EDLP) (to avoid promotion induced buying), daily EDI inventory status transmissions, and daily re-supply determination and shipments. Landvater (1997) presents the success achieved by Heinz Canada from its "customer linking" (getting early access to future forecast data) activity: inventory turnover increased from 3 to 45 turns, forecast accuracy improved from 20% to 60%, fewer shipments were required, and there was 30% higher truckload weight utilization.

Clark & Hammond (1997) present inventory level and stock-out level as performance tradeoffs for grocery retailers as shown in Figure 3-2. They discuss the cost implications of stock-outs (opportunity cost associated with lost sales and customer dissatisfaction) and inventory (handling, storage, damage, obsolescence and financing costs). They propose that technological and process innovations, such as those made possible through the implementation of continuous replenishment programs, can shift the cost tradeoff curves inward as shown in the figure. Their research also shows that the benefits of continuous replenishment programs to companies increases with an increase in the number of participants as well as with an increase in the transaction volume. They found that retailers experienced a 50% to 100% improvement in inventory turns.



Source: Clark & Hammond (1997)

Figure 3-2: Inventory and Stock-out Performance Tradeoffs

Landvater (1997) describes a typical VMI application, which works as shown in Figure 3-3.

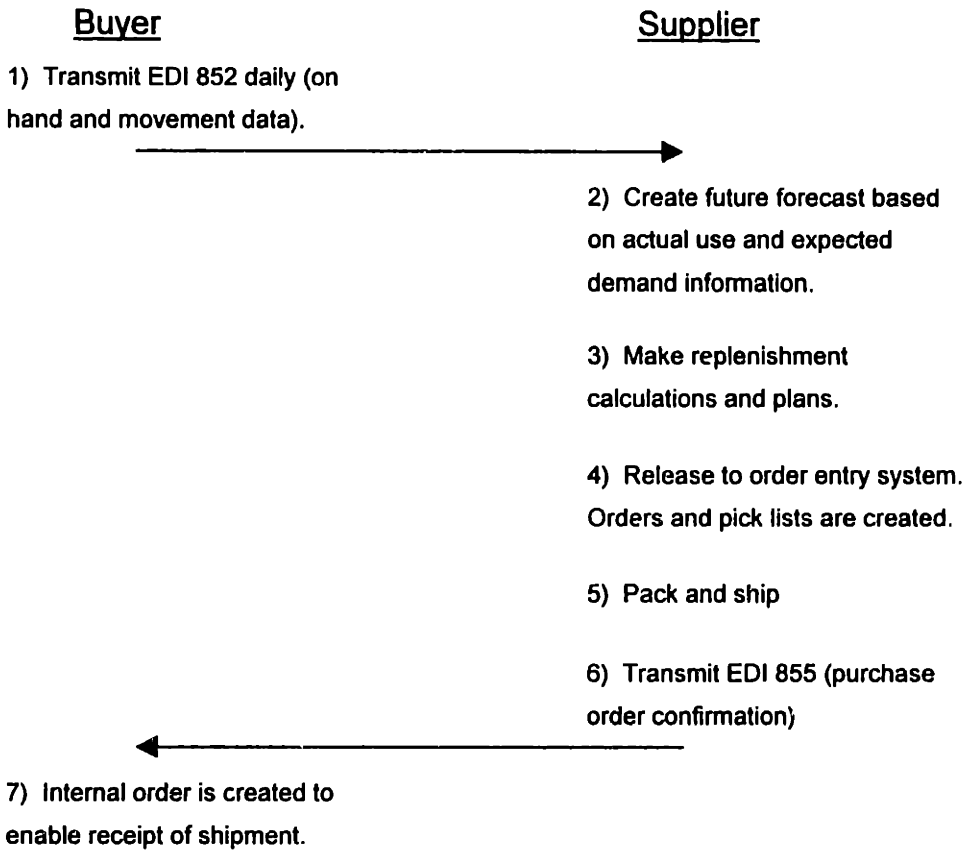


Figure 3-3: Typical VMI Application

As a comparison, Landvater describes a typical CMR application, shown in Figure 3-4, where the supplier's customer (i.e. the buyer) performs the bulk of the inventory management activities.

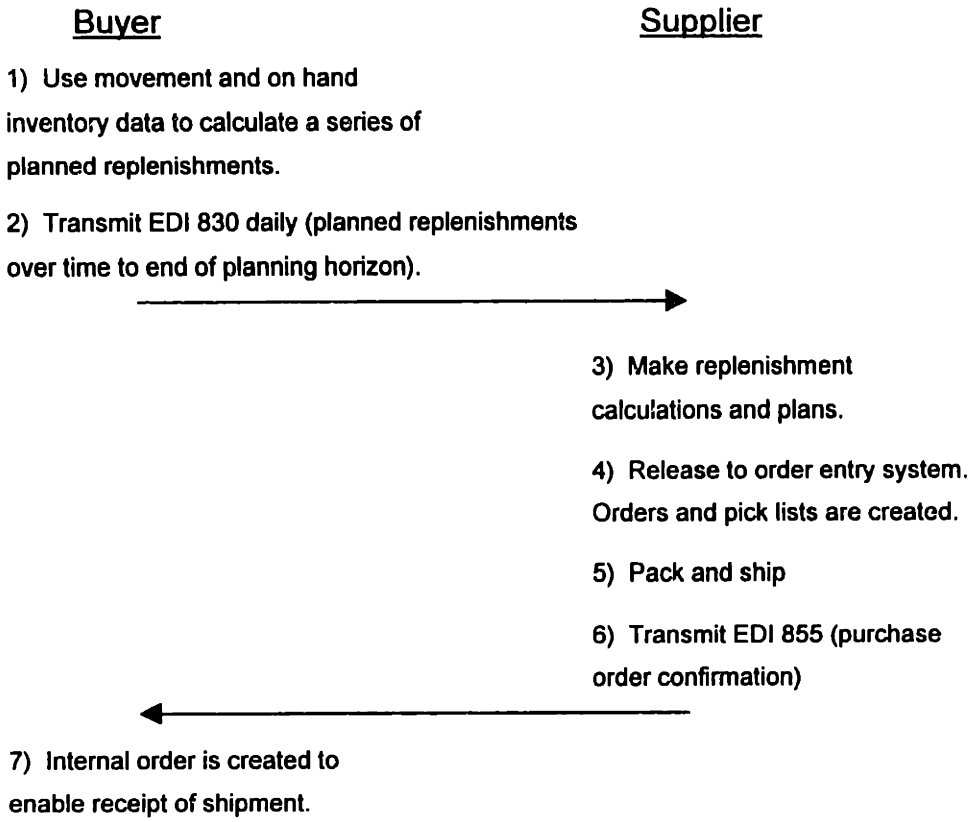


Figure 3-4: Typical CMR Application

These diagrams illustrate two of the methods used for continuous replenishment programs. Note that the VMI application diagram illustrates that the supplier makes all replenishment decisions for the manufacturer based on frequent transmissions of inventory movement information.

Supplier Managed Inventory in Industrial Settings - A Closer Look

In the personal computer industry, Dell Computer is considered an innovative leader in supply chain management. In March of 1997 Dell's inventory turns were reported as 32, compared to IBM's 12. Dell is using familiar initiatives such as customer focus, supplier partnerships, mass customization, and JIT, but using them in concert with technology to

achieve new levels of supply chain performance. This technology enables Dell to communicate actual customer demand directly to their suppliers to achieve high inventory velocity (the speed at which inventory moves through the system) and a negative cash-to-cash cycle (the time between when customers pay the manufacturer, in this case Dell, and when Dell's suppliers are paid). Dell utilizes SMI programs and utilizes JIT practices on its manufacturing floor to pull material from its suppliers (Magretta, 1998), (Hayes, 1997), (Minahan, 1997).

Northwestern Steel and Wire Company, a steel service center, implemented SMI during 1996 and 1997 with an initial group of four key customers. One of these customers doubled its inventory turns and significantly reduced its stock-out days in the first six months on the program (Nolan, 1998).

Newton (1998) describes a typical SMI arrangement used in the electronic distribution industry:

- The buyer's system tells the supplier of any change in net available inventory of any product that has been affected by sale, transfer, return, receipt or count correction.
- The supplier's system scans this input to determine if any product has reached reorder point.
- When a pre-agreed shipping point is reached (minimum dollars, weight, day) the buyer's system is notified that a purchase order has been created, using PO numbers issued by the buyer. Then, the buyer's system knows what is on order and when it will be shipped.
- When the shipment is made, the supplier issues a detailed shipping and billing notification to the buyer.
- Upon receipt of the shipment, the buyer sends back an EDI receiving advice, thus completing the replenishment cycle.

SMI programs can be implemented in various ways. The following list outlines some examples found in the literature (Byrnes and Shapiro, 1991), (Minahan, 1997), (McKeefry, 1998):

- *Consignment:* Inventory is placed at the manufacturer's site and is replenished by the supplier to predetermined, agreed upon levels. In some cases the supplier performs internal distribution within the manufacturer's facilities. The manufacturer does not pay until material is withdrawn for use.
- *Supplier Logistics Centers (SLC's):* The manufacturer establishes a relationship with a third party logistics provider that provides local warehouse space and interfaces with the manufacturer's suppliers for SMI replenishment activity. Frequent shipments are made to the manufacturer's plant from the SLC with the precise quantities of materials needed for immediate manufacturing needs. This allows the manufacturing plant to operate with essentially no on-site inventory and avoids receiving dock congestion due to frequent supplier shipments.
- *"Pull-in" or "Push-in":* In these types of systems, the supplier frequently receives (usually electronically) information on the manufacturer's usage and inventory levels and is responsible for "pushing-in" stock. The supplier has full authority to schedule deliveries of its product, without receiving an order. This type of system can also run on various types of Kanban "pull" signals, typical of JIT type programs. Typically, the manufacturer issues blanket or standing purchase orders to the supplier on a yearly basis.

A Look at the Types of Benefits Being Achieved - A manager at a large electronic products manufacturer, when reflecting on the impact on the company of its consignment program with suppliers stated: "We don't pay for inventory until we use it, and we never run out of stock. We no longer even have to think about on-time delivery" (McKeefry, 1998). The types of benefits being realized by SMI or VMI program participants in industrial settings mentioned in various journal articles include (Gresh, 1998), (Burke, 1996), (Stratman, 1997):

- *Improved inventory turns:* The average improvement is 30% to 50%. Obsolete or slow moving inventory is eliminated and new or promotional items can be accommodated.
- *Reduced transaction costs:* Typically the number of purchase orders and invoices is reduced by 50%.
- *Improved service levels:* VMI ensures that, for a distributor, inventory is at the right mix and levels to enhance customer service levels. For a production operation, it ensures materials will be available when needed.
- *Increased sales:* As a result of higher availability and a closer working relationship with customers, suppliers realize sales increases of 6% to 10%.
- *Improved production flexibility:* Work-load is scheduled to match customer demands and production capacity is not wasted by over-producing.
- *Shorter lead-times:* Information moves between partners faster and with accurate forecast data, the supplier can produce just what is needed to satisfy demand. These factors can result in shorter lead-times from the time a need is recognized to when the item is available for use at the manufacturer or distributor.
- *Lower operating costs:* For example, one firm experienced productivity improvement throughout the order to remit process.
- *Improved buying efficiency:* Buyers are able to spend less time on basic stock replenishment issues and can concentrate instead on planning, supporting sales staff and working on product management issues.
- *Improved accounting efficiency:* The invoice reconciliation process can be eliminated since in most cases, the invoice is automatically posted into the partner's accounts payable system, with payment schedules determined during the VMI agreement negotiations.
- *Improved receiving efficiency:* With improved communication between companies and EDI, more information can be exchanged. For example, stock location can be communicated to the supplier and be printed on the shipping label.

- *Improved forecast information to the supplier:* The supplier benefits from knowing actual demand at the point-of-use and having access to longer-range forecast information, which it can use to drive its manufacturing process.
- *Increased business to suppliers:* As a supplier becomes recognized as the low transaction cost supplier, the manufacturer is likely to increase volume with that supplier.
- *Improved manufacturer-supplier relations:* When companies are long-term partners, they learn more about each other's business. Being tied together electronically forces the companies to learn each other's business processes, which is critical to reducing transaction costs.

Byrnes and Shapiro (1991) have observed a "snowball effect" among companies developing intercompany operating ties, both in numbers of companies participating and benefits being realized. They find that once a buyer begins to benefit from a successful intercompany tie, it is likely to spread the initiative to other suppliers. These suppliers then recognize the advantages and encourage other customers to establish such programs. As other companies recognize a competitive disadvantage from not participating, they become involved as well. When companies begin to realize benefits from intercompany operating ties, such as lower levels of inventory, they experience other unexpected and favorable changes as well. One such benefit is that sales representatives can focus on more strategic selling activity, rather than trying to resolve customer service problems. Byrnes and Shapiro (1991) also find that the most effective initiatives could be self-financing. The largest gains are produced early and release substantial capital invested in inventories. Subsequent activities require little investment in new assets.

Johnson, Davis and Waller (1998) have found that when service improves through VMI initiatives, and a buyer regards the supplier as dependable, two things happen. First, fewer crises occur. Second, when they do occur, buyers are less likely to inflate orders in an attempt to seize a larger share of limited supply.

Identifying and Selecting Opportunities - Creating and managing the strategic buyer-supplier relationships inherent in an SMI program requires that a company think in new and innovative ways. A company has to develop the capacity for adapting to a new environment that also requires letting go of some long held practices. Byrnes and Shapiro (1991) identified three impediments to realization of the untapped benefits that are available:

- *Lack of awareness:* Companies measure performance in terms of internal cost efficiencies and service levels, and can miss opportunities to create new efficiencies for both the manufacturer and supplier. Many times, a company will accept the order and replenishment pattern as a given. Only when a company "challenges everything" is it able to recognize potential system-wide improvements.
- *Lack of data:* Despite sophisticated information systems, companies may lack data that is needed to understand many of the costs of product flows between companies. The lack of such data may require gathering new information and building new cost models to effectively analyze the situation being considered.
- *Existing organizational barriers:* Barriers between functional departments and a lack of a cross-functional perspective can prevent the close working relationships within a company, as well as between companies, that can lead to innovation. When communications are established between companies at new levels, rather than just between their respective sales and purchasing departments, for example, new opportunities for improvement can develop.

Byrnes and Shapiro (1991) propose that the most effective operating ties are created by companies that develop a deep understanding of the types of collaborative arrangements available, the context in which each works best, and the internal changes in systems and procedures necessary to carry out such an initiative. They point out that achieving the benefits of these ties is not as easy as it might seem. They identify five areas that provide insight into intercompany operating ties:

- *Benchmarks:* Knowing what innovative companies are doing and the results they are achieving.

- *An external view:* Looking beyond traditional boundaries to develop a perspective of product flow throughout the channel.
- *Fit:* How well specific operating ties fit with channel structures.
- *An interfunctional perspective:* Understanding the significant change required within the company and the role of each function in ensuring success.
- *A strategic view:* An appreciation of the new strategic directions that ultimately result.

SMI programs can be designed to achieve a number of different results. The manufacturer and its suppliers can agree on goals and then tailor a program to meet them. They may choose, for example, to concentrate on inventory turns, sales, profit margins, service levels or inventory investment (Gresh, 1998). Dell, for example, uses a two-tiered strategy, one for custom parts and one for commodity parts (Minahan, 1997).

Preparing for the Initiative - Prior to embarking on an SMI initiative and seeking out partners with which to establish the relationship, a company should spend the necessary time to determine the proper initial direction of the program. With adequate preparation, a company will have the required information and understanding for later discussions and development efforts with channel partners. Byrnes and Shapiro (1991) identify three areas on which a company must reach consensus:

- *Selection:* Analysis of coordinating mechanisms in the context of particular participants. For example: Which customers will be involved? Which suppliers? What types of intercompany operating ties?
- *Performance goals:* The choice of suitable performance measures and rough approximations of potential gains.
- *Internal changes:* Changes in operations, organization and administrative systems (e.g., performance measurement and compensation) needed within the company and within other channel members.

Byrnes and Shapiro (1991) stress the importance of developing an understanding of the issues facing both customers and suppliers through close communications with them.

They recommend creating a "channel map" that provides a broad view of consumption patterns, channel operating structure, and actual channel performance. This map is developed by tracing product flow through the channel from point-of-origin to point-of-consumption. They present the channel map as having three important components: (1) a diagram of information and product flow (with all activities and transactions); (2) a quantitative analysis of product accumulation and movement over a typical time period; and (3) rough estimates of the costs at each stage. With the knowledge gained from the channel map, appropriate prioritization of subsequent program development activities can take place. They claim that a large portion of the potential benefits can be provided by a small number of well-designed initiatives.

Significant cultural changes are required on the part of SMI program participants. For example, companies may have to abandon or relinquish control of some traditional activities. Ray and Swanson (1996) present a sampling of some of the necessary cultural changes:

- *New performance indices:* For example, on-time delivery, days early and days late no longer have the same significance, since the buyer does not know exactly when product will be delivered.
- *Supplier management of manufacturer inventories:* Manufacturers must learn to trust their suppliers. Suppliers must learn to inform manufacturers of critical shortages or potential supply problems.
- *Limited formal feedback to the manufacturer on specific ship schedules or quantities.*
- *Mutual supplier-manufacturer responsibility for the success of the process.*
- *Traditional lead-times lose most of their significance:* The concept of lead-times driving PO releases loses most of its significance.
- *Merging organizational boundaries:* The supplier can start to really understand how the manufacturer's production system really operates.

It is important to identify cultural and historical differences in industries, markets or geographical areas that may help or hinder successful implementation of SMI. In order to

overcome internal resistance to a new initiative like SMI, Byrnes and Shapiro (1991) stress the importance of the need to change incentive compensation and provide focused education. They describe focused education as needing to evolve as the program gets underway: first on why the initiative is necessary; then an explanation of the company's new direction, expected benefits and required changes; and finally, individuals' roles and responsibilities. They also recommend framing the benefits in the language of top management, in order to generate and maintain the support required for such major change.

Partner Selection is Important - The importance of the buyer-supplier relationship in SMI programs is underscored in much of the current literature. Many authors consider this relationship as a partnership, critical to the success of the program. Although there are many tactical considerations when establishing an SMI program, selecting the right partner is clearly one of the key aspects of any initiative. Gattorna and Walters (1996) suggest that companies consider the following indicators when evaluating the level of interdependence between prospective partners:

Buyers	**Suppliers**
% business involved	% of business this buyer represents
Level of risk if supplier fails	Impact if business is lost
Cost of changing suppliers	Strategic significance of business
Availability of alternative suppliers	Number of direct competitors
Strategic significance of business	Degree of differentiation of product / service
This supplier annual cost vs. other suppliers	Price advantage / disadvantage compared to competitors
Total category cost as a proportion of sales	

He recommends that each party develop an understanding of the level of interdependence between their respective companies, high or low, before embarking on strategic initiatives. For the purposes of an SMI relationship, a relationship characterized by low-low would not be recommended. The optimal situation is when there are high levels of mutual

interdependence. Gattorna and Walters (1996) present research that uncovers three fundamental aspects of strategic business relationships:

- They must yield immediate, short-term, benefits for both partners, but also extend into the future.
- The relationships must be collaborative, creating new value together, rather than just exchange (a return for what is input to the arrangement). Partners must value the skills that each brings.
- The relationship cannot be controlled by formal systems alone, such as detailed procedures. It requires an elaborate arrangement of interpersonal connections and internal infrastructures that enhance learning.

Gattorna and Walters (1996) go on to present eight criteria that are necessary for organizational relationships to meet if they are to be successful:

- *Individual excellence:* Each partner is strong and able to contribute value. Both have positive motives for entering the relationship.
- *Importance:* The relationship is congruent with strategic objectives of both partners.
- *Interdependence:* There is mutual need, and complementary skills and assets.
- *Investment:* Each invests to signify stake in each other and a long-term commitment to the prosperity of the venture.
- *Information:* Shared information across the spectrum is essential: goals and objectives, performance data, and information on changed circumstances.
- *Integration:* Partners develop linkages and shared ways of operating to facilitate their working together easily.
- *Institutionalization:* The relationship is formalized, with clear responsibilities and decision processes. It thereby extends beyond the originators.
- *Integrity:* Partners behave towards each other in ways that justify, and enhance, mutual trust. They do not abuse confidences they are privy to, nor do they undermine each other.

Byrnes and Shapiro (1991) describe partner selection criteria by citing the importance of the relationship (as measured by potential payoffs), potential partner's attitude toward innovation and change, and operating fit of the relationship.

With regard to distance, Dyer (1994) claims that as distance between suppliers and auto manufacturers decreases, the auto manufacturers' inventory as a percentage of sales decreases as well. Close proximity makes transportation easier and fosters more face-to-face interaction for improved communication.

Establishing the Required Coordinating Mechanisms - Establishing an SMI program requires joint operating strategies between companies. While the specifics of each program may vary, those participants in SMI arrangements acknowledge that the supplier needs to be provided information that will allow it to determine true usage and future needs (Lamb, 1997). Burke (1996) offers the following steps:

- *Establish and synchronize electronic transfer of information capability:* In a well coordinated SMI partnership, various types of information are needed by each party in order to make decisions and provide necessary data for internal processes. Figure 3-5 shows an example of information exchanged.

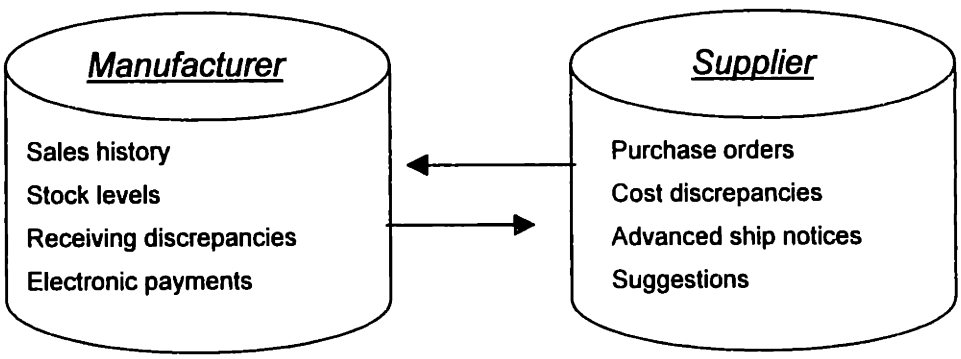


Figure 3-5: Electronic Transfer of Information

- *Develop a stocking strategy:* Strategies must be developed for A, B, and C items, fill rates and inventory turns. These strategies will have to be periodically revisited and updated.

Clark and Hammond (1997) show that channel transformation involving adoption of EDI and the redesign of the replenishment process (using VMI) enables performance improvements more than an order of magnitude greater than implementation of EDI alone. This research supports claims by Byrnes and Shapiro (1991) that "success requires a major shift in perspective and broad changes in operations, both within a company and its channel partners". Cachon and Fisher (1998) claim that while information exchange is important, reducing lead-time and cutting batch sizes reduces supply chain costs to a much greater extent. This research suggests the principles of just-in-time production (reduced lot sizes and shorter lead times) to be presented later in this chapter, provide significant benefit when extended to supply chain inventory management.

Stratman (1997) suggests the following information needs to be transferred between partners using EDI or a direct computer to computer interface:

- Stock levels and usage rates are transmitted from the buyer to the supplier.
- The supplier informs the distributor of shipping schedules, lead times, quantities shipped, product verification and invoicing.

It remains the manufacturer's responsibility to inform the supplier of any unanticipated changes or major changes in usage rates that are not reflected on system generated data transfers. Gattorna and Walters (1996) claim the following choices must be made when establishing an SMI program: who holds inventory and where, how much inventory will be held, how orders are placed, and how orders are delivered.

Forecasting future demand becomes an important element in an SMI program. Byrnes and Shapiro (1991) recommend identifying historical events and characterizing them so they can help predict future demand in relevant situations. They propose that there are three channel types and each has unique characteristics:

- *Steady:* Ultimate product consumption is very stable, yet companies ordering patterns can create large swings in channel ordering patterns. Efforts should be made to create a smooth pipeline flow.
- *Fluctuating:* Product consumption is variable and unpredictable, but usually within a known range. Historical patterns can be used to establish meaningful boundaries. Efforts should be made to bring channel partners activities into phase to avoid persistent overstock and understock situations.
- *Ramp:* When a new product moves into the supply chain, channel partners can over order to ensure availability. This can create distorted signals throughout the supply chain. The objective is to coordinate all channel members' activities based on actual consumption levels and real growth trends to provide as much stability as possible.

Gattorna (1998) suggests that suppliers need about 60% to 70% of volume on VMI to allow smoothing of production. This would provide adequate visibility into future demand and allow suppliers to plan production better so as to avoid spikes in times of high consumption. In addition, demand slowdowns would be noticed in advance, thereby allowing a reduction in excess or obsolete inventory.

Establishing appropriate metrics to monitor the performance and health of the SMI program is an important aspect of any implementation. Basic measures such as customer service level, inventory turns, and return on investment can be established in concert with the primary goals of the program, if desired. Metrics can be tracked for categories of products managed by individuals on the purchasing staff. Gattorna and Walters (1996) provide the following suggestions for metrics that can be used in order to maintain inventory investments at cost-effective levels:

- Financial performance:
    - Return on inventory investment
    - Inventory investment / working capital investment
    - Percentage of inventory increase (decrease) versus percentage of sales increase (decrease)

  - Percentage of inventory increase (decrease) versus percentage of cost of sales increase (decrease)
  - Stock "write-off" and markdowns
- Operational performance:
  - Customer service levels over time
  - Inventory turnover performance; product groups, rate of sale categories, etc
  - Inventory accuracy: actual count / indicated
  - Number of customers not supplied from stock
  - Number of SKU's out of stock / number of days
  - Number of trading periods in which stockouts occurred
  - Number of stockouts per year (or other significant period)
  - Number of SKU's out of stock at month end
  - Probability of stockouts / product group, rate of sale categories, etc
  - Percentage of demand supplied from stock

Gattorna and Walters (1996) also present additional performance measures based on work by the Council of Logistics Management (CLM):

- Productivity:
  - Total dollar ($) value inventory managed / inventory holding cost
  - Total SKU's managed / inventory holding cost
  - Total dollar ($) value inventory managed / costs attributable to inventory management activity
- Utilization:
  - Stock value / working capital
  - Stock turns by relevant category
- Performance:
  - Actual dollar ($) value inventory / planned dollar ($) value of inventory
  - Actual inventory management cost / budgeted inventory management cost

Information Systems are an Integral Element - The level of information system sophistication used by companies to implement and support SMI programs varies significantly. The following list gives examples:

- *File transfers:* Exchanging information extracted from the information system of one company, formatted in a standard format such as a database or spreadsheet, and e-mailed or sent by modem to the partner company.
- *EDI:* The use of standard EDI protocols. (Explained later in this chapter.)
- *Fully integrated inter-enterprise coordination applications.* As businesses adopt Enterprise Resource Planning (ERP) applications, sophisticated software packages are now available to facilitate integration of information system networks of trading partners.
- *Internet / extranet:* Companies are increasingly utilizing, or making plans to utilize, supplier specific web sites for quick access to information. Minahan (1997) describes plans that Dell Computer is planning to implement.

Some Cautionary Steps to Consider - Clark and Hammond (1997) claim that stable or reasonably predictable products are needed for continuous replenishment programs. In one article, a distribution consultant expressed concern that manufacturers are the ones with the closest knowledge of consumer takeaway patterns and are therefore best positioned to manage the inventory. Also, as a supplier takes on more and more SMI accounts, it becomes difficult to be "all things to all people". Lyons, Krachenberg and Henke (1990) point out that most manufacturers, enthusiastic about making strategic moves toward more intimate buyer-supplier relationships, tend to overlook disadvantages they may eventually face. In contrast, suppliers often tend to focus on disadvantages and overlook potential advantages. The authors presented the following potential risks:

- *Increased dependence:* "Likened to placing more eggs in one basket, for a longer period of time." As manufacturers outsource more, they lose in-house people who understand the dynamics of supplier relationships.

- *New negotiating style:* The manufacturer must transition from a competitive win-lose style, to a collaborative win-win style and restructure previously awarded attitudes, habits, and skills.
- *Less supplier competition:* Since there is a tendency for fewer suppliers and larger long-term agreements, relationships become more intimate and suppliers have more access to inside customer information.
- *New sources of added costs:* Purchasing department roles become more complex and sophisticated. Manufacturers have to balance short-term reduced prices against higher prices that will provide revenues that will help support research and development by the supplier. Manufacturers may have to provide more technical support to develop suppliers.
- *Loss of channel control:* As the manufacturer hands off more transactions to the supplier, the manufacturer loses control of second-tier suppliers. The first-tier supplier may not exercise control over second-tier suppliers with the same degree of concern and intensity as the manufacturer.
- *Pressures to improve and expand services:* Suppliers are typically left with a choice between expanding the scale and complexity of their operations or being relegated to second-tier status.

Landvater (1997) points out that without appropriate systems changes for receiving and logistics, the system could get overloaded. He recommends using supplier inspection, barcode technology, and utilization of labels with more information to speed handling.

Just-in-Time Production: A Key Element

This section provides a detailed explanation of just-in-time production methods. As a key element of lean manufacturing, JIT offers both a philosophy and a methodology that can be used in a variety of settings to increase competitiveness throughout the supply chain. The principles and activities associated with JIT are directly and indirectly applicable to SMI initiatives, in both the manufacturer and supplier operations.

Just-in-time production can be defined as a production strategy whose aim is continuous improvement of overall productivity and elimination of all waste (Tersine, 1988). It has also been defined as an inventory control and purchasing system that attempts to reduce the inventory of incoming parts as well as the size of delivered quantities to their absolute minimum, using small lots delivered on demand (Nahmias, 1997), by synchronizing the timing of supplier deliveries with when they are needed by the customer company's production process. JIT is a pull system that is about producing the necessary parts, in the quantities needed, at the time they are needed. It's main focus is to reduce lot sizes while continuously improving operations. It's essence is simplification and elimination through problem solving.

Background

Just-in-time is a methodology that originated out of the Japanese approach to organizing manufacturing operations. JIT is sometimes synonymous with the Toyota Production System (TPS) and the kanban system that is an essential feature of TPS.

The initial intent of JIT was to provide a means for moving material in a plant, but it has grown into an overall philosophy aimed at eliminating waste (e.g., eliminating inefficient material movement and defective parts). In addition, supplier relationships and quality control systems are now part of fully integrated JIT systems (Nahmias, 1997). Although frequently labeled a kanban system, the Toyota Production System has been categorized as 80% waste elimination, 15% production system, and 5% kanban (Shingo, 1989).

Application and Benefits

Many JIT principles are applicable to activities throughout a company when the intentions behind the concepts are understood and appropriately applied. Although typically considered within a production context, JIT has applications in areas such as product design and service as well. JIT, and the kanban system of inventory control, is considered ideal for situations where standardized parts are manufactured repetitively. Low volume or highly variable output requires some form of supplemental control, such as MRP.

Application of JIT is not ideal when there is variation inherent in the production process or in equipment. In addition, low-value items with high fixed order costs may be inappropriate for JIT.

JIT is a pull system that initiates production as a reaction to present demand, while a push system (MRP) initiates production in anticipation of future demand (Karmarkar, 1989). JIT is a long-term approach that cannot be installed quickly. Inventory and lot sizes are reduced incrementally (month after month). The result is sustained productivity and quality improvements with greater operational flexibility and delivery responsiveness (Tersine, 1988).

The JIT approach requires implementation of a number of interrelated practices that seek to reduce inventory and production cycle times while eliminating defects. Utilizing JIT can provide numerous benefits in the production environment. Some of the benefits related to inventory reduction and operations improvements are that:

- capital can be utilized more productively,
- additional space becomes available without having to invest in new facilities,
- there is reduced opportunity for material damage while handling,
- there is a lower risk of losses due to obsolescence,
- there is reduced work force effort needed for handing and production,
- the need for complicated inventory management systems is eliminated,
- a company can be more responsive to product and market changes,
- quality problems are detected quickly before significant quantities accumulate,
- manufacturing velocity increases (i.e. the "dock-to-dock" time[6]), and,
- there is reduced tracking of individual items between steps.

Excessive work-in-process (WIP) inventory can be caused by erratic process yields, unreliable equipment, long changeovers and set-ups, and suppliers who don't deliver on time (Hayes, Wheelwright & Clark, 1988). Proper application of the JIT methodology, in

[6] "Dock-to-dock" time is the time between receipt of component material to shipment of finished products.

the context of production smoothing, directly addresses these causes in order to achieve reduced WIP, lower overall inventory and higher productivity. In addition, JIT provides opportunities for more productive relationships with suppliers.

JIT does not use automation and robotics until all that can be done to rearrange, synchronize, and balance operations is completed. Initial savings are in overhead reduction of indirect labor (stockroom, personnel, material handlers, planners, controllers, inspectors, etc.). Direct labor reductions take place later when automation takes place. JIT makes automation easier and more effective, but automation is not the primary initial thrust (Tersine, 1988).

Principles

The fundamental principles of just-in-time are embedded in the Toyota Production System. Toyota believes that the way to achieve profit is through cost reduction and productivity improvement (Monden, 1998). Hence, the primary goal of the Toyota Production System is reducing cost and improving productivity. This is achieved by eliminating various kinds of waste, such as excessive inventory and excessive workforce, that lie concealed within a company. This waste is exposed and eliminated by JIT. Toyota focuses on four kinds of waste that, it is claimed, can be found in manufacturing production operations (Monden, 1998). The interrelationship of these wastes is shown in the following table:

Type of Waste	**What the Waste Causes or Includes**
excessive production resources (work force, facilities and inventory)	superfluous personnel costs, facility depreciation costs and inventory interest charges
overproduction	excessive inventory
excessive inventory	more work force, equipment and floor space to transport and stock the inventory
unnecessary capital investment	extra storage warehouses, handling equipment, inventory management systems

In order to eliminate waste, it first has to be understood. Tersine (1988) classifies activities as:

- pure waste,
- operations without value added, and,
- net operations to increase value added.

Value is added only by actual work on a product. Machining, assembling, painting and packaging add value. Moving, storing, counting, sorting and scheduling add cost but not value. Fork trucks, expediters, and safety stocks add cost but not value. Inspections, backup sources, and safety time add cost but not value. Cost without value is waste and therefore should be minimized or eliminated. Similarly, Womack and Jones (1996), advocate that value stream[7] analysis will show that three types of actions occur. They are:

- value creating,
- creating no value but unavoidable, and,
- creating no value.

Developing an understanding of this type of analysis creates a better appreciation of the motivation behind many JIT practices.

In the JIT system, inventory is considered bad, as opposed to good for smoothing production as other production control philosophies advocate. Inventory covers up problems. When inventory is removed, problems are discovered so they can be solved (Tersine, 1988).

There are inherent expectations embedded in the JIT approach that apply to workers within the company, as well as to suppliers. It is expected that:

- every item is correct when received,
- machines are available when needed to produce (no downtime), and,
- the delivery commitment is expected to be honored at precisely the time it is scheduled.

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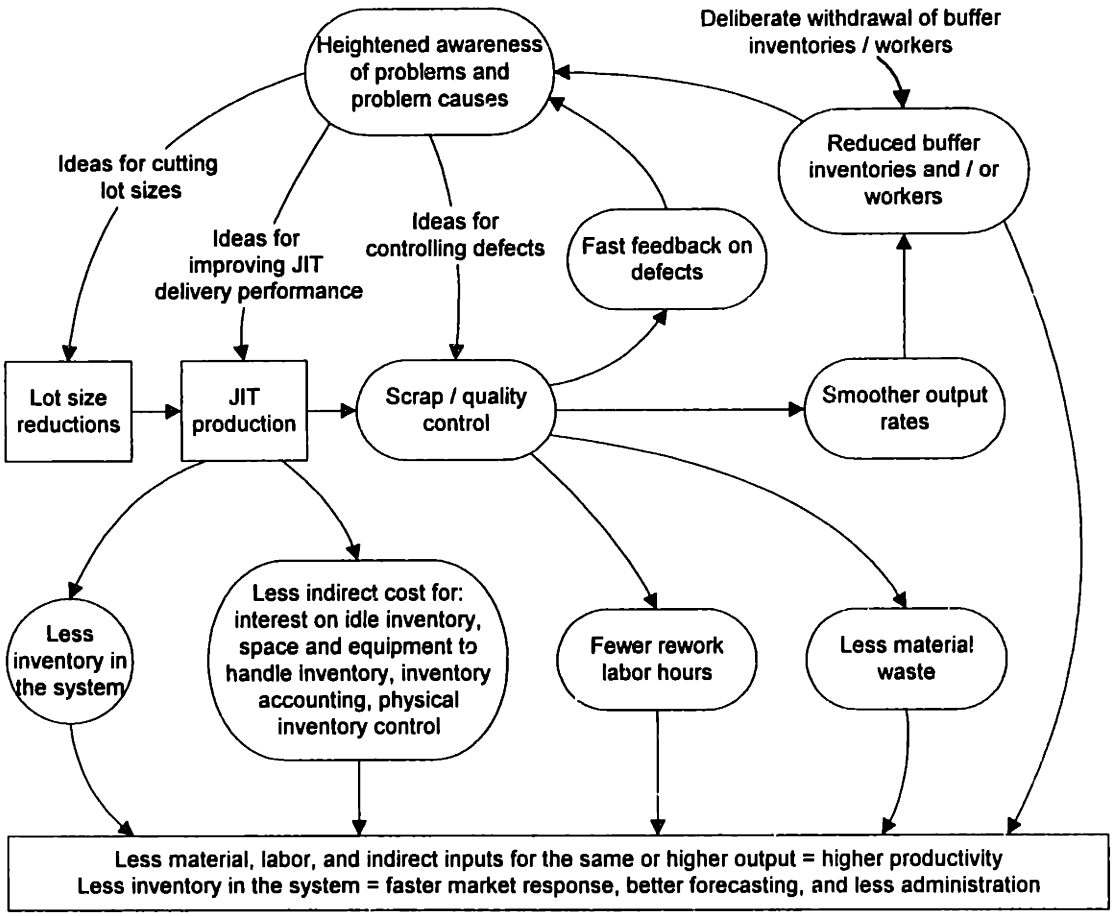
[7] Womack and Jones (1996) identify the value stream as the set of all actions required to bring a product through concept and design, ordering and delivery, and physical transformation from raw material to a finished product.

Therefore, there is an emphasis on quality, preventive maintenance and mutual trust throughout manufacturing network.

Toyota's approach is to produce at the velocity of sales. They accomplish this by calculating a "tact time", or throughput time for one unit in production based on the daily salable quantity, and using kanban to pull units through production. These concepts will be discussed later in this section. Secondary goals of the Toyota Production System are quantity control, quality assurance and respect for humanity. Through these primary and secondary goals, the foundation and approach for JIT production is established.

Schonberger (1982) offers the following diagram (Figure 3-6) to illustrate the interrelationships between the main elements of JIT.



Source: Schonberger (1982)

Figure 3-6: Effects of JIT Production

The main elements of JIT, as shown above, are interrelated and self-reinforcing. They are:

- *Eliminate inventory:* Tersine (1988) illustrates the consequences of producing more items than what is immediately required. He points out additional needs for these excess items: containers to hold them, trucks to move them, warehouse space to store them, money to finance operations until they are sold to customers, extra workers to cycle count them, accountants to track them, and schedulers to indicate when to produce more. Shingo (1989) proposes the following three strategies for "non-stock" production:
  - reduce the production cycle dramatically,
  - eliminate breakdowns and defects through detection and response, and,
  - reduce set-ups to allow small lot production and rapid demand response.
- *Produce according to market demand:* JIT is a pull system that waits for a demand signal from the end use point to trigger production. As a unit is used, demand "pulls" ripple back up through the production system and triggers each station to replenish what the next station just used. In this way only items that are needed are actually produced. Various studies (Byrnes & Shapiro, 1991), (Lee, Padmanabhan & Whang, 1997) have indicated that demand spikes typically do not reflect actual end user demand but are caused by other dynamics, such as quantity discounts. By understanding the true consumption rate at the point-of-use and by taking steps to level demand, such as establishing standing purchase orders or long-term contracts, the production system can produce at a more steady state. For production of multiple products, the concept of mixed-model assembly is utilized. In mixed-model assembly, the plant produces according to actual daily or weekly demand for each product. For example, rather than producing 5,000 of product A for two weeks, then 10,000 of product B for the following two weeks to satisfy monthly demand, the plant would plan to produce 250 of product A and 500 of product B daily. The JIT system does long range planning via mixed-model master scheduling and MRP, and produces based on orders received. This type of small lot production requires significant attention to dramatically reducing set-up times.

- *Improve quality, eliminate defects:* Because a JIT system operates without the safety net of extra inventory, it is imperative that each item that is made is acceptable. By producing 100% good parts, the wastes associated with scrap and overproduction are avoided. JIT relies heavily on the idea that the manufacturer or manufacturing process itself is responsible for quality control. It relies on immediate detection of defects by either the producing station or the subsequent station. JIT utilizes the concept of autonomous defect control, or autonomation. Autonomation prevents mass-production of defective work by either automatic defect detection to stop machines or the ability of production workers to stop the line when abnormalities occur.
- *Continuously improve productivity:* In order to pursue the goals of minimal set-up time and zero defects that are critical to JIT, it is necessary to continually improve operations. Improvement activities concentrate on (Monden, 1998):
    - refinement of manual operations to eliminate wasted motion,
    - introduction of new or improved machinery to avoid uneconomical use of manpower, and,
    - improved economy in the use of materials and supplies.

  Improvements are implemented by small groups, such as quality control (QC) circles, using a suggestion system.
- *Utilize visual control:* The JIT system relies on involvement of all workers to achieve production and improvement goals. In order to create awareness and build a shared consciousness, visual systems are employed. Examples of visual systems are:
    - labeling of wasted items, such as scrap, for immediate disposal,
    - indicators for proper location of tools and materials,
    - standard operations sheets used in production, and,
    - indicator boards, known as Andon, to call attention to production status.
- *Create a flexible, involved and motivated workforce:* In order to achieve the goals of JIT production, it is necessary to have a multi-skilled and flexible workforce. Workers are cross-trained, help each other in order to balance various production

steps and may run several different machines. Because JIT relies on instantaneous detection of defects, employees have heightened awareness of the cause, and have ideas to prevent reoccurrence. By providing employees the opportunity to improve operations, they are motivated to participate and provide suggestions (Butfa, 1987).

- *Extend JIT to suppliers:* It is extremely important to a well functioning JIT system to have close relationships with reliable, long-term suppliers. Freeland (1991) gives a list of characteristics contrasting conventional and JIT purchasing behavior. Some of these include:

Conventional Purchasing	**JIT Purchasing**
Large, infrequent deliveries	Small, frequent deliveries
Multiple suppliers for each part	Few suppliers; single sourcing
Short-term purchasing agreements	Long-term agreements
Minimal exchange of information	Frequent information exchange
Prices established by suppliers	Prices negotiated
Geographic proximity unimportant	Geographic proximity important

Tersine (1988) provided a contrast of conventional and JIT attitudes that provide an overall summary of JIT principles:

Conventional	**JIT**
Some defects are acceptable	Zero defects are necessary and attainable
Large lots are efficient, more is better	Ideal lot size is one, less is better
Fast production is efficient	Balanced production is efficient (faster production is a waste)
Inventory provides safety	Safety stock is a waste
Inventory smoothes production	Inventory is undesirable
Inventory is an asset	Inventory is a liability
Queues are necessary	Queues should be eliminated
Suppliers are adversaries	Suppliers are partners
Multiple supply sources lead to safety	Fewer sources of supply lead to control
Breakdown maintenance is adequate	Preventive maintenance is essential

Long lead time is better	Short lead time is better
Set-up time is a given	Set-up time should be zero
Management is by edict	Management is by consensus
Work force is specialized	Work force is multifunctional

Specific Practices

The following are specific practices of JIT production:

Reduction of Set-ups - In order to achieve reduced work-in-process by using smaller lot sizes, it is necessary to reduce process set-up times. Toyota formalized a program known as single minute exchange of dies (SMED) that became well known for achieving dramatic set-up time reductions, from several hours to minutes or even seconds. In theory, the goal is to have an EOQ[8] equal to one. In addition to the benefit of allowing smaller lot sizes, reducing set-up time can increase equipment utilization, which is equivalent to capacity expansion since the equipment can have more "uptime". Gattorna (1998) offers the following steps:

- analyze current time taken for set-up, perhaps by taking a video,
- identify internal and external components of the set-up, that is, steps that are performed while the equipment is operating (external) and steps that are performed when the equipment is stopped (internal),
- convert as much as possible of internal to external, and,
- streamline both internal and external steps.

Shingo (1989) offers additional suggestions:

- eliminate adjustments, and,
- perform clamping without screws.

[8] EOQ = economic order quantity and is used to calculate the size of an order that minimizes total inventory cost. It is calculated using the purchase cost, the order cost (i.e. setup time), and the holding cost. See Chapter 2 for more detail.

In general, intelligent tool design, quick clamping devices and standard procedures help to reduce set-up times. Additional items are quick-change tooling, quick disconnects, hinged bolts, oil or air-assisted clamps, roller platforms, and tool carousels.

Produce to Demand - The goal of the JIT system is to produce immediate (e.g., daily) requirements. There are two important definitions that support this goal (Monden, 1998).

- *Tact time:* The tact time shows how many minutes or seconds are needed to produce one unit when considering the daily customer requirement (salable quantity). It is calculated by dividing the planned operating hours by the customer requirement for the product during that time.
- *Cycle time:* The total time necessary for performing manual operations for the process described by the standard operations sheet (including walking time).

During the planning stage the cycle time is determined so that it does not exceed the tact time. The intention is to balance production steps as much as possible while planning operations. Because each process step does not just feed the subsequent step (it waits for a pull signal), those who finish early help those who haven't and system tries to balance itself. The intention is not to try to run equipment at rated speed for high efficiency, rather it is to produce daily requirements, intermixed with other products. The following guidelines give insight into the production planning and control methodology of JIT (Silver & Peterson, 1985):

- a rough-cut master schedule is developed for a 3 month to 1 year horizon,
- re-planning occurs one to four times per month with the schedule to the next re-planning time firmed up,
- the detailed final assembly schedule, determined by actual customer orders, is set for something on the order of one to a few days in advance, and,
- minor deviations of ~+/-10% in actual demand (vs. planned) are allowable without jeopardizing effectiveness.

Standardization of Operations - To effectively communicate production information, standard operations routines and standard operations sheets are used. These are defined as follows:

- *Standard operations routine:* Instructions for the worker to communicate what process actions are to be taken within a given cycle time, including quality and safety checks.
- *Standard operations sheet:* This specifies the cycle time, standard operations routine, and standard quantity of WIP. It is posted in the factory for all to see.

Cell Manufacturing - In order to facilitate smooth and uninterrupted work-flow, JIT gets away from batch production and grouping of similar types of equipment. Instead equipment is dedicated to groups of parts, and group technology cells are created (Tersine, 1988). With the cell layout, equipment is set-up according to process steps so when one operation is complete parts can be handed or conveyed to the next step for immediate processing. In this way, transit time and queue times are reduced or eliminated. Guidelines for adopting this methodology are:

- arrange equipment to product flow,
- reduce space between operations, and,
- eliminate stocking points.

Kanban System for Production and Inventory Control - Kanban[9] is a simple, self-regulating and paperless system for scheduling and shop floor control. It provides JIT production without the use of work orders for parts. In the Toyota system two types of cards are used along with standard containers to move parts. Withdrawal (or conveyance or move) kanban are used as a ticket to allow parts to move from a supplying workstation to a using workstation. Production kanban are used to authorize a workstation to produce the specified number of units to replace those that have been used (Tersine, 1988).

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[9] Kanban is a Japanese word meaning card.

Supplier kanban are another form of withdrawal kanban. See Appendix A for a description of the system. There are two types of systems that can be used. These are:

- the constant order quantity system (typically used internally) where kanban are moved when a predetermined quantity of items have been used, and,
- the constant order cycle system (typically used if there are supplier delivery scheduling issues) where kanban are retrieved at a fixed interval of time, independent of quantity used.

In the kanban system the level of WIP can be controlled through the planning of how many kanban cards are in the system. As operational improvements are implemented, cards can gradually be removed from the system to lower inventory until a problem is experienced, thus exposing the next opportunity for improvement. The function of the kanban cards can be achieved in many different ways. Some examples are: squares on the floor, carts, boxes, colored flags, lights, parts boards, clips and cards. Even golf balls imprinted with part number and quantity rolling down a chute between stations can be used (Landvater, 1997). Containers are popular because they protect and help handle material, and act as authorization to produce so visual contact is not required between stations. The typical kanban card contains the following information: kanban number, part number, name and description, place where used (two associated places for move card, single place for production card), and the number of units in the container. Standard rules for operating the kanban system are (Silver & Peterson, 1985):

- the standard container must be filled with the prescribed number of parts,
- a container must not be forwarded until authorized by receipt of a move card, and,
- a container of parts must not be produced until authorized by a detached production card.

Note that large parts and irregular parts require special attention. In the Toyota system additional types of kanban are used such as express, emergency, job-order and through kanbans in order to handle emergency and other unusual situations (Monden, 1998).

Eliminate Machine Breakdowns - An important element of stabilizing production and being able to produce only what is needed, when it is needed, is assuring the availability of equipment. For this reason, preventive maintenance programs are used.

Limit Production of Defects - In order to ensure that only acceptable quality is forwarded to subsequent areas, it is imperative that any defects that are produced are discovered quickly and the cause of the defect is eliminated. In the JIT system there is a focus on quality control at the source. Each worker is responsible for his or her own work. If there is a problem, everyone focuses on it and production is not resumed until it is corrected. The underlying philosophy is that:

- defect-free output is more important than output,
- defects, errors and breakdowns can be prevented, and,
- prevention costs less than doing it over.

Machines utilize automatic stopping devices that detect defects, stop the machine and signal (through use of andon) the operator of the problem. For manual inspection, various techniques are used to emulate 100% inspection. For example, the operator might look at the first and last parts of a batch, if both are okay, the batch is acceptable; if the last part is bad, then the whole lot is inspected. The primary intent of inspection is not to find defects, but to prevent them (Shingo, 1989).

Process Improvements - Continuous improvement is a cornerstone of JIT. In order to constantly reduce set-up times, reduce the number of defects, have more efficient machine layouts, reduce inventory and prevent machine breakdowns, operations are continually improved. Shingo (1989) recommends focusing on five elements when making process improvements:

- *Process:* Improve the product through value engineering[10]. Improve manufacturing methods to reduce materials and labor.

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[10] Value engineering is a method used to break down costs of design features and stages of production, and to then look at these for ways to lower cost.

- *Inspection:* Use control charts, self and successive inspection, and enhanced self-inspection. Enhanced self-inspection can be achieved through physical detection ("poka-yoka"), such as by utilizing a limit switch to detect a hole that should be in a certain location.
- *Transport:* Eliminate transport through equipment layout improvements.
- *Process delays:* Take steps to eliminate lots waiting to be processed due to: unbalanced flows, cushions to avoid delays if there's a problem, and safety stock to feel secure.
- *Lot delays:* By locating processing steps adjacent to each other, parts made first can proceed to the next step without waiting for rest of the lot.

Extend to Suppliers - Methods to extend JIT practice to suppliers include:

- using EDI[11] for electronic links between warehouses, suppliers and manufacturers,
- use fewer but better suppliers,
- form long term partnerships with a few suppliers,
- certify suppliers and eliminate incoming inspection,
- use local suppliers to reduce lead times,
- have frequent delivery of parts directly to the point-of-use, and,
- establishing longer, larger contracts (with fewer suppliers) to achieve lower costs.

Additional Aspects

Toyota considers "respect for humanity" to be a key element of the Toyota Production System. Toyota seeks ways to encourage employee involvement, motivation and mutual trust between workers and management. As productivity improves or demand decreases, there may be times when workers are not fully occupied with production work. Shingo (1989) offers the following suggestions for tasks that can be done during these times:

- plant repairs,
- machine repair and maintenance,

[11] Electronic Data Interchange. It is described in the next section of this chapter.

- practice tool and die changes,
- make fixtures for planned improvements, and,
- in-source items made by outside suppliers.

Electronic Data Interchange (EDI)

EDI is used in many SMI applications discussed in the literature. Gattorna and Walters (1996) define Electronic Data Interchange (EDI) as the electronic intercompany transfer of business documents in a standard format. They add that:

- *Intercompany* implies the interchange of documents between separate commercial entities, using unique computer operating systems.
- *Business documents* implies not simply electronic mail messages, but formal business documents and transactions of commercial and legal significance.
- *Standard format* implies a universally agreed electronic format.

They also state that EDI takes its form in four areas of business:

- *Electronic funds transfer:* electronic funds transfer at point-of-sale (EFTPOS), banking clearing.
- *Trade data interchange:* purchase orders, delivery advices, and invoices.
- *Technical data interchange:* technical drawings, scientific data.
- *Interactive query / response:* travel bookings, customers' access.

Gattorna and Walters (1996) also list the potential key benefits of EDI as:

- More accurate and timely information flows.
- Administrative savings / improved efficiency.
- Closer trading relationships (a new spirit of working together).
- Improved cash flows.
- A move closer to the final customer and therefore a reduction in forecasting errors.

They suggest that realization of these benefits is dependant upon the number of EDI documents exchanged and the number of EDI trading partners up and down the supply chain.

There are a number of different ways to utilize EDI, from proprietary protocols between trading partners, to the use of standard protocols. Standards were developed within industries, such as the Uniform Communication Standards (UCS) by the Uniform Code Council (UCC) utilized by the grocery industry. After EDI use became more widespread, it was recognized that a more universal standard was needed that could be used both within and between industries. In 1979 ANSI chartered a new committee called the Accredited Standards Committee (ASC) X.12, to outline a standard for the electronic exchange of business documents. They approved the first version of the ANSI X.12 in 1983 (CTRC, 1992). In 1994, 85% of EDI transactions in the United States used this protocol (SSCI, 1994). EDIFACT (EDI for administration, commerce and transport) is slowly being adopted as the international standard and is the defacto standard in Europe. Efforts are underway to make the syntax of both the X.12 and EDIFACT standards compatible (SSCI, 1994).

Information can flow between a manufacturer's business system and a supplier's business system through their respective EDI management systems and either direct communication (modem-to-modem) or a third party value-added-network (VAN) as illustrated in Figure 3-7.

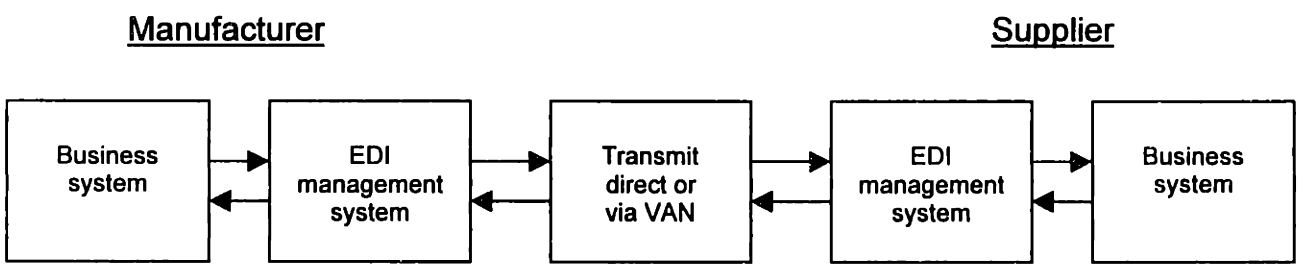
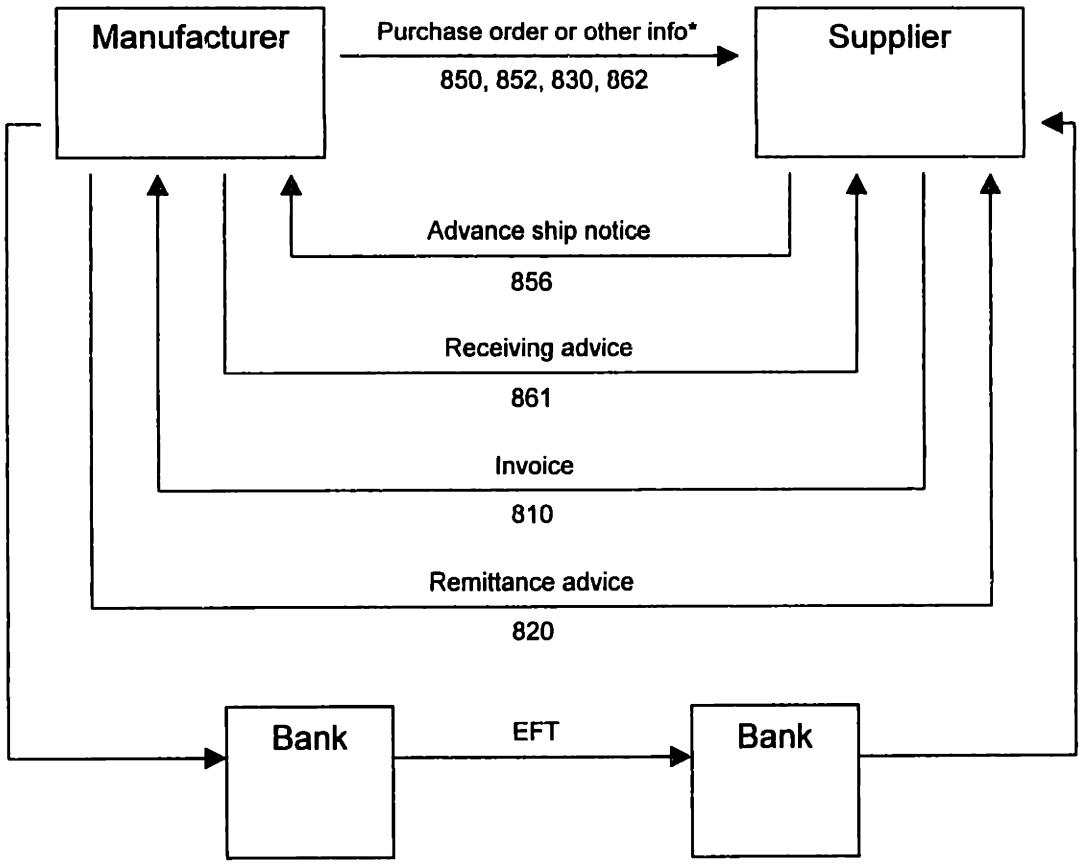


Figure 3-7: EDI Information Flow

A basic EDI transaction cycle is illustrated in Figure 3-8:



Source: Gattorna and Walters (1996)

Figure 3-8: Basic EDI Transaction Flow

* Note that as well as purchase orders, the manufacturer can transmit other information that is conducive to supplier managed inventory applications.

The EDI message includes (CTRC, 1992):

- *Headers:* Units of information attached to the message that are used to control delivery of the message.
- *Headings:* Information typically found at the top of business documents, such as the billing address.
- *Transaction details:* Description of what is being ordered, shipped, etc.
- *Link control data:* Information that helps identify transmission errors.

The basic unit of an X.12 EDI message is called the "transaction set". Transaction sets contain standardized, application specific information. Some of the more common ANSI X.12 transaction sets used for SMI programs, as well as traditional purchase order based applications are (SSCI, 1994) (note the arrow indicates typical flow, i.e. (M>S) = manufacturer to supplier):

- Ordering Transactions:
  - *850 Purchase Order (M>S):* Used to order product and/or services.
  - *855 Purchase Order Acknowledgement (S>M):* Used to provide early confirmation or notification of changes to a Purchase Order previously placed. For SMI applications it can signal the supplier's decision to replenish, the manufacturer does not send the Purchase Order.
  - *860 Purchase Order Change (M>S):* Used to make changes to or cancel a Purchase Order.
  - *865 Purchase Order Change Acknowledgement (S>M):* Used to confirm order changes, reject changes, or give notification of further changes to the Purchase Order as a result of receiving a Purchase Order Change request.
  - *869 Order Status Inquiry (M>S):* Used to check on the status of the order in conjunction with the Order Status Report.
  - *870 Order Status Report (S>M):* Used by supplier to report to customer.
- Materials Management Transactions:
  - *830 Planning Schedule /* Material *Release (M>S):* Used to provide material release against blanket purchase orders, or to provide forecasts of anticipated purchases from manufacturer to supplier. The manufacturer may choose to allow the forecasted purchases to automatically convert to orders. Used in many CR/SMI type programs.
  - *852 Product Activity Data (M>S):* Provides current on hand balance and movement data (inventory status and warehouse withdrawals); typically used in VMI applications.
  - *856 Advanced Ship Notice (S>M):* Used by supplier to provide a detailed description of the contents/configuration of a shipment and/or carrier

information to let the manufacturer know what, when and how materials are being shipped.

- *862 Shipping* Schedule *(M>S):* Used by the manufacturer to provide the supplier more detailed, product dependent information than what is available in the Planning Schedule / Material Release. This transaction set is product dependent and generally used in a JIT environment.

- Shipping/Receiving Transactions:
  - *861 Receiving Advice (M>S):* Used by manufacturer to provide to a supplier confirmation of receipt and condition of products shipped.
- Inventory Management Transactions:
  - *846 Inventory Inquiry / Advice (M<>S):* Used by a manufacturer to inquire on available inventory from the supplier and by the supplier to respond to the inquiry. Also used within organizations to communicate inventory levels from one branch to another.
  - *867 Product Transfer and Resale Report (M<>S):* Used to report information about product that has been transferred from one location to another; to report sales of a product from one or more locations to a customer and demand beyond actual sales (lost orders).
- Financial transactions:
  - *810 Invoice (S>M):* Used to bill for products and/or services provided. In some industries, invoices are no longer being used. Payment is generated by the manufacturer through matching product received to a Purchase Order. This technique is called Evaluated Receipts Settlement.
  - *820 Payment Order / Remittance Advice (M>S):* Used for Electronic Funds Transfer (EFT) and related payment information. The timing of payments is typically adjusted slightly from traditional payment terms to allow for "float".

Chapter 4. Manufacturer Survey Results

In order to develop an understanding of practices and issues related to supplier managed inventory programs, individuals from fifteen companies were interviewed regarding their specific experiences with SMI. Approximately half of these companies offer the perspective of manufacturers and the other half offer the supplier perspective. The questions in Appendix B were used to guide the interview. These questions were sent to interview participants in advance to allow time for preparation. Then, a 45 to 60-minute telephone or personal interview was conducted. This chapter contains results from the interviews with representatives from manufacturers. The following chapter contains results from the interviews with supplier representatives.

The following summary contains illustrative excerpts from interviews conducted with manufacturers. Participant responses are grouped according to the order of the interview questions presented in Appendix B. Each bullet represents a response from a company. Duplicate comments are not repeated. Interview participants are listed in Appendix C.

Background Information

Question	Illustrative Responses
1. Primary business of company.	• See company information in Appendix C.
2. Size of company.	• Examples: $900 million to $2.0 billion annual revenue. 3,000 to 10,000 employees.
3. Extent involved in SMI programs.	• Examples: 0.5% to 50% of purchase dollars. 20% of purchase transactions, 5% of dollars.
4. SMI system function (with supplier).	• "We use dedicated in-plant storage of consigned inventory. The supplier owns the inventory until we take it out to use it. The supplier agrees to keep four weeks of inventory in the in-

	plant warehouse. Some of the suppliers have dedicated people in our plant who managed the inventory and do buying from the supplier company. We use standing P.O.'s. Receipt is done against P.O. when parts are removed from storage for use." • "We use Kanban system with two containers. When the second container is opened, that becomes the signal (via bar-code scan) to replenish one container. The containers have one-month supply. Projected monthly volume initially based on our yearly forecast (sometimes way off!), but now supplier calculates replenishment based on actual usage and other inputs from manufacturer (such as new product impact, etc.). Supplier recalculates container size once per month. Because supplier was far away, we insisted on a local warehouse that carries an additional two bags of safety stock, in addition to the bulk inventory at the suppliers main warehouse. 2 to 3-year P.O.'s are set up. Supplier bills us based on shipments and we audit 10% of invoices." • "We provide two-year forecast with weekly, monthly and quarterly splits. Provide standing P.O.'s. Initially depended on forecasts for short-term expected usage, but now have moved to using history more and relying on Kanban for trigger." • "We use a classic VMI approach: Provide sales data to supplier daily, supplier runs the numbers and transmits P.O. to us for approval, we create a P.O. internally to allow receipt to process when parts arrive." • "We use min/max approach. Minimums and maximums are calculated with equations that include factors for A, B, C, and D parts. Frequency of replenishment is A = weekly, B = monthly, C = quarterly, and D = quarterly or yearly. Information transmitted: minimum stock level (includes two weeks safety stock), maximum stock level, quantity on hand, past due (missed shipments), and forecast information. Objective is to keep between min/max levels. Have ability to view when targets are exceeded. We issue blanket P.O.'s." • "Our supplier takes over entire supply chain responsibility. All costs are folded into part unit cost. Parts are delivered by the supplier to the point-of-use on the production line. We use a 2-bag system. When the second bag is open, the supplier shoots the barcode on the bin. Parts are replenished two days later in monthly consumption quantities. We get a daily report of usage and get billed monthly."

The Right Situations for SMI Programs and Key Enablers

Question	Responses
5. Motivation for becoming involved in SMI programs.	• "Volatile demand, product variety and short lead-times had led to excess and obsolete inventory. Stockholders disliked high inventory on balance sheet." • "New CEO four years ago decided productivity improvements were needed. An outside consultant helped us to focus on supply chain activities. Initially union issues stopped it but then they were resolved." • "The company undertook a project to map all supply chain costs in a very detailed manner. The results prompted us to look at SMI." • "A proactive VP who observed that our company was behind other competitors. He advised us to quit studying it and start implementing. There was industry peer pressure." • "To signal an opening up of the relationship. To indicate trust."
6. Appropriate components / products for SMI.	• "High-volume, industry standard components, but now moving toward customer parts such as sheet metal, plastics, and cables." • "Items that have a high number of p/n's associated with them but are standard and are relatively inexpensive such as hardware fasteners and wire." • "Items that ship at least once per quarter."
7. Inappropriate components / products for SMI.	• "SMI is not good for parts that are only used intermittently, physically large or expensive." • "We don't do with raw boards because the revision levels change so much." • "Special, low usage items." • "Items that are going obsolete are taken off the program 13 weeks prior." • "Items that have variable yield in manufacturing."
8. Effect of distance on program.	• "None." • Some manufacturers had the supplier set up local warehouse. • "Sometimes it seems that there is a lack of urgency back at the

	home office of the supplier (1,000 miles away). We've had to engage senior management more and get them more involved with designing the system. We had the supplier put in a forward stocking location with 90-days of supply (which we now feel is way too much)."
9. Motivation for first areas to implement.	• Ease of implementation. • "Started as a recommendation that was made by an improvement team that recognized opportunity to reduce costs and improve scheduling." • "The company could not add headcount so we did it with C parts first to eliminate need to manage them." • "We picked a company that had experience and we could learn from."
10. Issues related to quality.	• "None that are significant." • "Implemented dock-to-stock programs at same time. Require 10 receipts defect-free." • "Our quality department was actively involved in the program design. They drafted a new manual to provide suppliers with expectations on what we expected them to do. We have the supplier handle inspection."
11. Means for company to assess itself for readiness for SMI.	• "We chose one person to research current industry practice. Found a company to benchmark and ultimately partner with." • "We realized we were ready because of how fast our inventory was growing. We never wanted to run out so we would just always buy more parts. We'd have a bin overflowing in one place, but empty in another and think that we were out of stock. We figured we didn't have a lot to lose."
12. Means for company to assess partner for readiness for SMI.	• Presented as supplier as a way to become a "preferred supplier". • "Quality and delivery performance history, and cost." • "We chose companies that were already best in their field that we could learn from and share information." • "Did test programs and pilot programs, then production." • "We expect all strategic suppliers to be EDI capable." • "We limited the selection to suppliers that could handle the whole program and those we could trust, since they would be walking around our shop."

SMI Best Practices and How Companies Integrate SMI

Question	Responses
13. Sharing of long-term forecasts.	• Done continuously 9 months out, using the same report for short-term information exchange. • Renewed once per year. • "We send 9 months of forecast but only use four months in min/max calculations (using more than four months skews min/max excessively)."
14. Frequency of short-term usage information transfer and replenishment shipments.	• "Reports are generated once per week and e-mailed in database format or faxed to supplier (moving toward ERP system). Information transferred: - on hand quantity - recommended amount for next 4 weeks - 10 month forecast by week A second report shows pulls from prior week to supplier can invoice for use." • Supplier visits plant to check inventory status and replenish every day. • Weekly transmission.
15. Transaction communication method.	• Supplier uses its own scanner / modem system. • Fax. • E-mail of database files. • EDI 830. • "Mimics" EDI 850.
16. Issues due to pricing practices.	• None. Covered in long-term agreements. • Manufacturer had to commit to projected volumes and buy minimum when not used up in year. • "Long-term agreement gives window of commitment - guarantee to buy if do not use."
17. Impact to rest of production system from SMI activity.	• "Originally, we were buying many components directly from the manufacturer. When implementing SMI, we decided to buy components through distributors because the distributors would participate (manufacturers would not) in the SMI program. Although initially it seemed we would pay more for

	the components, the savings due to reduced inventory and the increase in leverage for the distributor with the manufacturer, resulted in a cost savings. Also, we had to change parameters in info systems, such as make material lead-time = 1 day, and create new accounts that did not list consigned inventory as assets."
18. Impact to shipping, receiving or logistics areas.	• "We no longer track on-time delivery with suppliers on program." • Try to move parts to dock-to-stock inspection status to avoid receiving delays. • "Triggered program to certify supplier (at supplier facility) so incoming inspection could be eliminated. Supplier handles all inspection." • "Had to change the way we issued the blanket P.O.'s. At first, suppliers couldn't tell when P.O.'s closed so they would ship parts, then the parts would get stuck on the dock until a new P.O. could be created."
19. Most important people issues to resolve while implementing SMI.	• "It can be very challenging to get the suppliers to understand the system. It takes a lot of explaining to them regarding report formats, etc." • "Factory was skeptical at fist, they needed to be shown that the system could work. Now there are fewer stock-outs and they love it." • "Initially some concern about losing internal jobs, but since company was growing rapidly it wasn't much of an issue." • "Prior to program, workers would take more parts than were needed in order to hoard them to avoid running out. Workers had to get used to taking only what they needed and trusting the system to work so parts would be there next time." • "Multiple business units had difficulty forecasting demand for usage early on." • Some union facilities have issues with suppliers working on the manufacturers' factory floor. • "Some people concerned about losing jobs. We finally had to tell them: 'It's just the way it's going to be'. People were transitioned to new jobs. The person running the storeroom now administers this program." • "We spent a lot of time training people. They'll listen but it doesn't really sink in with them until you go ahead and do it.

	There has been buy-in because it's working. People have transitioned to new jobs that are more strategic instead of just busy work." • "It is sometimes difficult to let go. You need to have confidence in the system." • "Some of our service people don't like it because they can't just walk up to the bins and take a handful of parts to use on an unexpected job." • "Initially it was viewed as a disguised way to lay off people. People were dragging their feet. There was distrust because there had been layoffs recently. We just had to be open and honest about what we were doing." • "Suppliers need to be much more proactive about notifying customers of impending problems. Customers only learn about problems when they run out of parts." • "It takes a huge leap of faith by the customer. It's taken many of our customers over a year to learn to trust us." • "Sometimes customers won't listen to their own purchasing people. But when we tell them they need to make a bill of material correction for example, they listen and do it."
20. SMI program performance measures.	• Monitor consumption reports; planned vs. actual. Monitor number of stock-outs. • "We try to measure suppliers' delivery performance based on meeting a replenishment time commitment. Many times it turns out the problem is with us." • Days on hand, or inventory turnover rate. • Customer service: Number of events that total quantity was not on hand for customer. • Age of investment (how long inventory has been in stock). • "We're just starting to have ability to measure and communicate over and under inventory status (min/max levels) to suppliers." • "We measure number of times over maximum inventory level." • "We measure how many bins are empty, how many are empty for more than a week, and how often there is no material in the forward stocking location. Right now, there are no penalties for poor performance."

	• "We measure inventory turns versus our goal. The goal is established by using the mid-point of the min/max levels." • Stock-outs. Number of events. • Reject rate of transactions. • Actual usage versus forecast.
21. Emergency workaround systems.	• "Still have to scramble when something goes wrong." • "Pencil and paper is the backup system."

Key Success Drivers for SMI Relationships

Question	Responses
22. Impact of SMI program on company performance.	• "Inventory has gone from 9 weeks worth to 3." • "Shipment lead-times (to customers) have gone from 55 days to 21 days." • "Has helped with vendor relationships because we sink or swim together." • Fewer stock-outs. • "Inventory has been reduced by 38% for SMI program parts." • Achieved benefits of consolidating business with one supplier and received better pricing due to more business with supplier. • Reduced costs from P.O.'s. Eliminated storeroom. Tied SMI program in with effort to eliminate inspection. Still some stock-outs but better than before. • "We were able to take on a significant amount of new business with no increase in human resources." • Improved delivery from suppliers. • "We are now carrying three days worth of inventory." • "It has exceeded expectations. We use 60% to 70% less labor to run our system now. We've remove overhead costs and made them direct costs. It makes it easier to track our profitability in certain areas." • "We've had an 80% reduction in stock-outs." • "Typical inventory turns for the industry is 5 to 8. With SMI

	we're doing 15 to 20."
23. People involved with planning and implementing. Level of upper management support.	• Extensive amount of work to develop agreements since they were new. Had to work out issues such as target inventory levels, insurance liability, who cycle counts. "Must be very clear up front who is responsible for what." • Periodic reviews are held to access how system is working for both parties. • President of supplier company involved directly at beginning and provided a lot of support. • "It took us about a year and a half to get underway. Progress was slow. It has taken about a year to get management on board." • "The logistics manager is very committed to the program and on the team." • Multifunctional team (assembly line, quality, planning, warehouse, and buyers). The big issues were which parts to do and what the service level should be. Senior management sat in once in a while and they were very supportive.
24. Extent of joint SMI strategy development and long-range planning.	• No specific responses.
25. Other relationship elements implemented along with SMI.	• 3-year long-term agreements. • One manufacturer "resurrected" its supplier partnership program in order to facilitate effective implementation of the SMI program. • The longer "window of commitment" established in the long term agreement was very helpful to establishing the trust of the suppliers. To entice the suppliers these windows have been very big - too big. We've realized that shortening these will help the supplier in the iong run. • "We agreed to accept the 90-days of local supply if we terminate the agreement."
26. Processes used for SMI and type of training.	• Suppliers are brought in for detailed training. • "We have to teach suppliers how to read reports and how to use min/max information." • "We have an implementation checklist to be sure we cover all

	the issues."
27. Most important activities for SMI.	• "Trust between companies!" • "Good" partner. • Trust of production lines that parts will be there. • "Anticipate stock-outs and keep people informed." • Accurate information to suppliers. • "You have to engage the whole company in the effort." • The system must constantly be monitored to watch for unforeseen issues - "...it won't just run itself." • "The more automated the better." • Communication. • "We still view ourselves as the process owner. It's important to not let the supplier hang. At the same time, the suppliers' responsibilities must be clear to them."
28. Least important activities for SMI.	• No specific responses.
29. Transition issues encountered while implementing SMI.	• "We had an issue regarding draw down of a few million dollars in inventory. We had the supplier take the inventory and then provide it when needed for a transaction fee." • "Had to burn off excess inventory. Some suppliers experienced reduced sales during a 6-month period. It was important to understand this up front, and we took steps to lessen the impact to them." • "We have to inspect some parts. At first we didn't include the time needed for that and we had some stock-outs." • "During test and pilot runs we had worked with suppliers IT people and everything worked well. When we started full deployment, all of a sudden we started to have problems. It turned out that the system was turned over to the suppliers' customer service people without any training." • "Internal financial software won't handle monthly billings even though that is what we prefer. We're working to change that." • "We had a tremendous amount of inventory. We transferred it all to the supplier. For parts they supply us from this group, they charge a transaction fee."

30. Rate company is implementing SMI.	• "One by one in a controlled manner, but as quick as possible. Started two and a half years ago." • "It took one year to get ready." • "Focus is on strategic suppliers. They are 45% of our supply base." • "We've restricted ourselves initially to standard hardware and some raw material. We assumed it was best for common or high volume items. But we may have narrowed our focus too much. We're looking at expanding the program based on initial success."

Other Questions

Question	**Responses**
31. Effect to product designs from SMI programs.	• "None yet."
32. Additional comments.	• One distributor said that they were very strict about only using the EDI standard with their suppliers. With their customers they were more flexible. • "Make sure you provide the supplier what they need to be successful. Don't just hand off problems. Understand the transition issues, for example, if any parts shortages will occur due to lead-times beyond their control."

The key insights derived from these interview responses are summarized in Chapter 6.

Chapter 5. Supplier Survey Results

The following summary contains illustrative excerpts from interviews conducted with suppliers. Participant responses are grouped according to the order of the interview questions presented in Appendix B. Each bullet represents a response from a company. Duplicate comments are not repeated. Interview participants are listed in Appendix C.

Background Information

Question	Illustrative Responses
1. Primary business of company.	• See company information in Appendix C.
2. Size of company.	• Examples: $12 million to $8 billion annual sales revenue. 250 to 50,000 employees.
3. Extent involved in SMI programs.	• Examples: 15% to 75% of revenues
4. SMI system function (with manufacturer).	• Manufacturer generates order releases through EDI. The SMI system is currently being used as a backup. The supplier enters a supplier specific internet website and verifies the usage and on-hand information is correct. If discrepancies are found the supplier calls the manufacturer and rectifies. The supplier ships to a warehouse local to the manufacturer where two weeks of inventory is kept. The manufacturer draws from that inventory via "milk runs". • Supplier receives weekly rolling forecast and ships to e-mail pulls from manufacturer. The supplier has one to two weeks to get parts to manufacturer. Time between e-mails and shipment quantity is variable but there is a minimum shipment quantity. • "Kanban cards kept at point of use. When parts are used, operator scans card (bar code reader). This generates a sales order to the supplier to indicate consumption, trigger replenishment, and authorize invoice. When parts are received, operator scans bar code, which authorizes payment."

	• One supplier established a customer specific electronic catalog on a website. The manufacturer personnel enter the website and order direct, provided predetermined budget constraints are not exceeded. • Each product has set stock target-quantity agreed to by each company. These are revised once per month. Customer contacts supplier twice per day for shipments. Items must be received at customer by 8:30 the next morning. Shortages get displayed on TV screen in the customer's purchasing department. Items are bar-coded and scanned in at customer production line. • Manufacturer has set-up a "Supplier Distribution Center (SDC)" (third party). Manufacturer pulls directly from SDC, SDC sends supplier a fax of pull information. Since inventory is consigned, this triggers the supplier to send more parts and invoice for those used. Kanban sizes have been calculated to include transit time, etc. • Supplier contracts with regional third party logistics provider (LP) for space in warehouses that are local to the manufacturer. LP provides a dedicated person to manage the inventory and handle basic quality issues. All costs associated with warehouse are rolled into part unit cost. Supplier is responsible for managing the partner relationship. LP operates to supplier procedures. Manufacturer does direct pulls of material requirements from warehouse via phone or fax. Two-hour delivery is guaranteed. LP electronically posts shipment data to supplier website once per day. Supplier then downloads information into information system. Use min/max stock levels, that will provide usage flexibility, agreed to ahead of time. Supplier agrees to notify manufacturer of any zero on-hand balances within 24 hours. • Basic functions of SMI system rely on "pull" theory, where consumption rather than planning drives replenishment. Safety stock is maintained to cover factory lead-time and next replenishment quantities. Floor bins are bar coded for scanned release based on a dual Kanban, or bag, FIFO rotation. This simply means that of the two bags in each bin, one is used for draw-down, the other as a back-up. When the sealed back-up has been opened it represents the signal for replenishment, which is generally conducted through a weekly sweep. • "As a supplier we see four types: 1. "True" SMI: customer provides long-term forecast and

	frequent reports of on-hand inventory and min/max levels. We decide when to ship and how much. Maximum is determined by A, B, C policy. We calculate projected inventory over horizon by using calculated consumption rate and clearing all in-transit and received shipments. 2. Shared inventory: Similar to "true SMI" except the inventory is consigned. Shorter payment cycles are negotiated. One interesting thing about this way is that it lowers overall supply chain holding costs, since a manufacturer holds inventory at purchase price and a supplier holds at cost. The disadvantage is that because the inventory is at the customers' site, it is not available for other customers. This method is best for customer specific items. 3. JIT style: Customer provides planning forecast and then pull or P.O. to ship. 4. Customer managed inventory: Customer creates blanket P.O. and provides weekly forecast that we ship to." • "We use a bin system with two-bag kanbans. We set up all the systems for the customer. We provide scanners that either the customer or we use to scan bins. The scanners plug into modems to download data into our system."

The Right Situations for SMI Programs and Key Enablers

Question	Responses
5. Motivation for becoming involved in SMI programs.	• Approached by manufacturer. • "Sometimes we become involved due to politics, to send a message that a particular sub-supplier segment needs to upgrade their infrastructure." • "To get access to large statistical base of information regarding product use to understand actual demand patterns. Then manufacturing operations can be tailored accordingly." • Customer wanted to "be more progressive" and was running out of storage space. Supplier was initially reluctant but had to participate in order to continue to be a major supplier. • Originally perceived as "a game to share ownership or inventory". Supplier was initially very apprehensive but now

	thinks the benefits are very worthwhile. • Customer initiatives were a key to early programs driven by their need to improve efficiencies while at the same time dealing with reduced staff. Some customers have a large volume of part numbers and transactions versus relatively low value. It is sometimes 80% of the bill of material items and only 5% of the value. • "Originally forced into it by customers, now we really like it because it has stabilized our production."
6. Appropriate components / products for SMI.	• "Used for high dollar, custom parts." • "Parts with high numbers of purchase transactions." • "Criteria based on: physical size (large), high $ value (A, B, C, D), high volume and constant usage." • High complexity, contract assembly parts. The advance information allows the supplier to get much of the pre-work done ahead of time, then do final assembly according to demand. • "C" class, or low value, high velocity items are best. Consistent production levels benefit most.
7. Inappropriate components / products for SMI.	• "Parts that have intermittent demand." • "Would not do any parts if customer was not big enough to justify effort."
8. Effect of distance on program.	• "The OEM's want the inventory nearby in case of problems". • It forced the supplier to contact with a third party logistics provider for stocking material close to their customer. • Not an issue due to world-wide availability of inexpensive and fast communication and transportation.
9. Motivation for first areas to implement.	• No specific responses.
10. Issues related to quality.	• "Parts must be high quality or it screws up the system." • Since supplier builds ahead, it has to watch out for engineering revision changes. • Implemented an "auto-swap" program along with SMI. If customer has any problems with parts, they just exchange for good parts with the local warehouse. Supplier handles everything from there. Data is tracked and supplier submits

	monthly quality reports to customer. • "It is extremely important that parts are delivered directly to the production line, bypassing incoming inspection. Suppliers must be totally qualified and certified for delegated inspection."
11. Means for company to assess itself for readiness for SMI.	• "Having adequate information system capability."
12. Means for company to assess partner for readiness for SMI.	• "Partner readiness is assessed by their ability to provide accurate bills of materials and forecast information and being able to separate these items from their normal procurement processes." • "The biggest roadblock is trust. If people are worried that you are taking away jobs, it can be difficult. It takes one or two years to get things operating smoothly."

SMI Best Practices and How Companies Integrate SMI

Question	**Responses**
13. Sharing of long-term forecasts.	• Two-year rolling forecast received once per week. The supplier manipulates the forecast based on previous history and other factors. • 12-month rolling forecast provided once per month. • 52-week rolling forecast (by weekly quantity), issued once per week. This includes year-to-date usage and back order quantity. Supplier account manager will adjust based on "gut feel" and additional conversations with customer prior to being incorporated into supplier's production planning. • "Forecasting is typically only used at implementation or when major production rate changes are planned. Generally calculations are made based on annual usage." • Forecasts are based on usage and other customer feedback on expected future events.
14. Frequency of short-term	• Twice per day. • One supplier received end-product forecast information from

usage information transfer and replenishment shipments.	the manufacturer and had the manufacturers bills of material on their system. The supplier would explode the bill of material and ship the appropriate amount of components. • Trigger to ship product occurs twice per day. Customer production line workers contact supplier twice per day via phone or post requirements on internet (supplier checks password protected site at scheduled times). Supplier account managers wear beepers so they can be paged for urgent demand. • "We think weekly replenishment cycles are best. Replenishment quantities (this is for a hardware supplier) average about 60 days for commodities, but high value items can turn every other week."
15. Transaction communication method.	• "Pick tickets are sent with shipment for verification. Blanket P.O.'s are used. Monthly billing is preferred." • Phone, fax. • E-mail message. • EDI (810, 830, 846, 850, 852, 855, 856, 867).
16. Issues due to pricing practices.	• "All items covered by long-term agreements. Manufacturer issues blanket P.O.'s for each p/n with annual quantity." • "Pricing is negotiated based on forecasted usage and can be adjusted based on measured consumption."
17. Impact to rest of production system from SMI activity.	• "We have decreased set-up times substantially. Now due 8 to 12 set-ups per day as compared to before, it was only a few. We have programs underway to improve the "green-to-green" (machine stop to restart) time." • When asked this question, one company responded "Yeah, we've all read 'The Goal' (Goldratt), but we still have to get product out every day" (indicating they couldn't experiment with lowering inventory levels too much). • Before SMI, supplier had high raw material, high WIP and low FGI. Now low raw material, low WIP and high FGI. Manufacturing is now smoother. Utilizing Goldratt's 'drum-buffer-rope' technique. Challenging to schedule three different types of work in shop: prototypes, discrete orders, and SMI related production. • One supplier remarked that they had always been trying to guess what was going on with their customers. Now they look directly at the customers business and know what is happening.

	• "We have initiated set-up time reduction programs." • Because of third party warehouse arrangement near manufacturer, both the supplier and manufacturer save on storage space. • "We have set up similar programs with sub-suppliers." • "It has impacted our quality department most because they now manage much of the relationship with the third party logistics provider." • "SMI works independently of 'normal' systems but utilizes same departments and processes up to a point." • "We have significantly reduced our cycle times so our customers have shorter lead times."
18. Impact to shipping, receiving or logistics areas.	• Shipments contain a lot more specific information on the bar code label. • Customer designed buggies that act as Kanbans and eliminate need to do additional packing. • "Needed specialized support staff but no major change in logistics. Becomes more customer service oriented." • "We don't send any shipping paperwork, we just keep on file."
19. Most important people issues to resolve while implementing SMI.	• "Workers sometimes ask: 'Why should we work so hard or miss a 'real' order just to build items for stock?' They are more motivated when they are trying to meet a pressing end of the day deadline to meet an urgent customer need. Initiated new metric to measure performance of building to stock to motivate production workers." • "Generally union issues from customer side." • "When we get a new contract we have to hire people local to the customer facility. We have to be very selective about who we hire because they are going into are customers site and need to be reliable."
20. SMI program performance measures.	• On time delivery, timeliness of EDI advance ship notices (ASN's), accuracy of response. • Target inventory turnover vs. actual. • Track accuracy of internal forecasts versus actual usage. • "Haven't really started yet, we're just about to put some in place". • On-time delivery is measured by whether or not inventory is in

	consignment warehouse when needed. • "Uninterrupted supply of material is the key metric. Can be measured by comparing backorders to successful replenishments, or backorders to total bins serviced."
21. Emergency workaround systems.	• "Buffer inventory is maintained to cover factory lead-time and one or more replenishment cycles for each bin." • Use manual systems.

Key Success Drivers for SMI Relationships

Question	Responses
22. Impact of SMI program on company performance.	• "Inventory levels have not changed in the past 5 to 10 years, but the manufacturers push you so you do end up better." • "Have cut down a little bit on internal lot sizes." • "Have a lot more inventory in-house than previously." • "Eliminated order entry function for SMI customers." • "Perfect on-time delivery performance for past two years." • "Enables the partnership." • "Eliminates a significant amount of cost in air-freight charges." • "SMI has given us a degree of predictability in managing our own inventory. While certain tasks are new, they replace old ones so that efficiencies are created. Overall costs of management are lower due to large degree of automation."
23. People involved with planning and implementing. Level of upper management support.	• "Contracts management leads all steps of the process form qualification, presentation, bidding, negotiation, implementation, service and analysis. This is very visible to our upper management and one they see as most important to our future." • "Upper management is involved in setting up the contracts."
24. Extent of joint SMI strategy development and long-range planning.	• "The manufacturer was very good up front building the relationship." • "Mainly additional opportunities for implementation, both production lines and commodities." • "Developing additional electronic information exchange

	capability." • "It requires a tremendous amount of up front work. Issues such as liability and insurance have to be worked out."
25. Other relationship elements implemented along with SMI.	• "The manufacturer agrees to be responsible for three weeks of finished inventory and 5 weeks of raw material in case of demand changes." • "Three-year long-term agreement with p/n's and target stocking levels." • "We try for 3 to 5 year contracts. Then we can establish long term arrangements with our suppliers as well in order to cut our overhead."
26. Processes used for SMI and type of training.	• Manufacturer provides training classes to suppliers at the manufacturer's site. • "Use documented procedures for our own staff and those of the customer, particularly when customer performs on-site functions such as put-away." • "People have to be cross-trained because we have high turnover of people in our warehouse."
27. Most important activities for SMI.	• "Trust is the big thing. We wouldn't do this with all our customers." • "The forecast is key because all manufacturing planning is done from it." • "Commitment of both parties." • "Sharing risks and benefits." • "Forecast needs to be 75 to 80% accurate." • "Integrity of forecast is number one". • "Accuracy of inventory numbers at all points in system (at warehouse, in-transit, etc.)." • "Clearly defined ownership and responsibilities." • "Consistency." • "Honesty and willingness to accept the supplier as part of the customer organization."
28. Least important activities for SMI.	• No specific responses.

29. Transition issues encountered while implementing SMI.	• When program was started, demand was highly variable and the supplier wasn't able to fulfill the material requirements. The forecasts were not very accurate. After some time went by, the supplier utilized the historical data, and was able to respond much better. Stock-outs were eliminated. • "It is critical to address customer inventory issues during transition. Identify gaps that will occur initially based on quantities and lead-times. Consignment is a good solution so that the supplier has control and visibility of existing stores immediately." • "It was a little complicated to figure out how to handle the transfer of customer inventory to our stock."
30. Rate company is implementing SMI.	• "Will implement another 25% of revenue in the next year." • "Now expanding to B and C parts." • "It took about a year learning curve to get underway." • "Our goal is to get all our business set up this way."

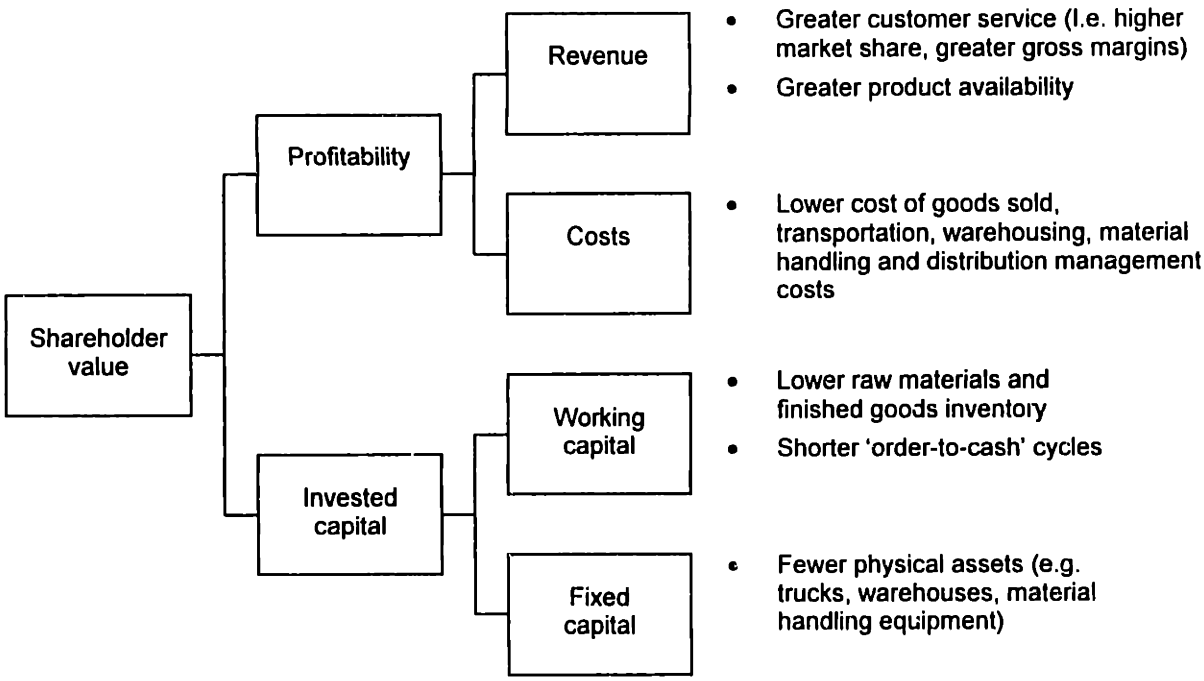
Other Questions

Question	**Responses**
31. Effect to product designs from SMI programs.	• "Have not really changed."
32. Additional comments.	• One supplier commented that the better you are, the less safety stock the manufacturer carries, which means you have to be even more responsive. It becomes a "punishment" because things get more stressful. • Three of the suppliers that were interviewed had or were establishing SMI programs with their suppliers. • "Customers (manufacturers) are typically the ones who have difficulty changing their information systems to capitalize on SMI program opportunities. Small suppliers can be more flexible."

The key insights derived from these interview responses are summarized in Chapter 6.

Chapter 6. Summary and SMI Implementation Strategies

Gattorna and Walters (1996) propose that unleashing the strategic power in the supply chain, through initiatives such as SMI, serves to increase the value of a company. The authors point out that according to value theory cash earnings must be increased in excess of the company's full cost of capital in a sustainable fashion, in order to increase the value of a company. As shown in Figure 6-1, initiatives such as SMI can directly affect both profitability and invested capital. Therefore, motivation to consider SMI is high.



Source: Gattorna (1998)

Figure 6-1: Impact of Supply Chain Management Initiatives on Cash Earnings

Key Insights from Manufacturer and Supplier Interviews

Discussions with manufacturers and suppliers that are participating in SMI programs revealed the following:

SMI programs are being implemented in many different ways. The label of "supplier managed inventory" or "vendor managed inventory" is being applied to a wide variety of joint manufacturer-supplier inventory control programs. There does not appear to be any standard methodology that is universally adopted. In all cases, manufacturers are making reasonable attempts to provide good long-term forecast information. EDI is being utilized in roughly half of the relationships. Kanban methods and utilizing min/max inventory levels are the two common approaches to short-term replenishment triggering. Consignment, third party logistics providers or warehouses, and in-plant supplier representatives are prevalent as well.

There are a number of different motivators for implementing SMI. Manufacturers are motivated by high inventory levels, a desire to shed transaction intensive management of low-value items, and industry peer pressure to pursue SMI programs. In many cases, suppliers are reluctantly pulled into SMI relationships by manufacturers. Suppliers initially comply because they assume a more cooperative supplier will displace them if they do not.

Suppliers have been pleasantly surprised by the results. Although initially reluctant to become involved in SMI relationships, every supplier interviewed was pleased with the outcome. At the very least, all suppliers felt that the SMI program provided the opportunity for a close partnership with its customer that is leading to a better working relationship and increased business, while providing an advantage over less progressive competitors. Many suppliers have enjoyed a more stable production schedule due to demand leveling and increased knowledge of future customer requirements.

Manufacturers achieve multiple benefits. Manufacturers were typically attracted to the SMI program by the promise of increased inventory turns, reduced transactions and more efficient operations. Manufacturers have realized significant improvement in these areas as well as in other areas that were not expected. In some cases, component costs have decreased due to increased purchasing leverage gained by the supplier. Stock-outs have

decreased and lead-times to customers can be shorter. By incorporating all component costs into the unit price, manufacturers are able to reduce overhead charges and achieve more accurate cost tracking.

Trust, forecast accuracy, and risk / benefit sharing are key. At one time or another during the interview, every participant expressed the importance of trust in the relationship. Both parties are incurring significant risk; manufacturers are entrusting activities they perceive as important to preventing production line stoppages due to stock-outs; and suppliers continually worry about getting stuck with excess inventory. Although new forms of contracts specific to the SMI programs are being written, there is a mutual feeling that suppliers and manufacturers will only participate with trustworthy partners. Suppliers recognize the difficulty manufacturers have in establishing accurate forecasts but nonetheless require immediate access to "the best information available" in order to make the SMI program work.

Suppliers seem more likely to modify their production approach. In order to benefit from the new dynamics of the SMI relationship, some suppliers made significant changes to their production approach. Set-up time reduction programs and a shift to lower raw material and higher FGI inventory levels were observed. Manufacturers, with the exception of elimination of incoming inspection, did not indicate significant modifications to production areas had occurred.

The distance between partners is perceived as a significant issue. Despite other elements of the partnership that were put in place, most manufacturers require that the supplier provide local storage of inventory. In most cases where the supplier facility was not nearby, manufacturers insisted that local warehousing be established.

SMI programs are influencing how companies approach quality assurance. Due to delays that typically occur when incoming items are inspected by the manufacturer, most manufacturers have established programs to certify SMI suppliers for dock-to-stock

shipments. In some cases where quality problems are experienced with a supplier, the supplier is required to pay for quality audits and other steps to re-establish confidence.

Progressive suppliers are doing SMI both ways: with their customers and their sub-suppliers. In response to the need to keep raw material and WIP inventory levels at the lowest possible levels, and recognizing the potential benefits to be achieved, many suppliers are implementing SMI programs with their sub-suppliers. These suppliers seem to be the ones that have realized the most benefit from participating in SMI programs.

Long-term agreements and standing purchase orders are common. In every case encountered in the interviews, long-term agreements and blanket P.O.'s (if needed) are being utilized by participants to avoid volume discount ordering issues and eliminate unnecessary transactions.

There are some significant people issues to overcome. Manufacturers that have a history of layoffs and downsizing experience a reluctance of employee participation and support for the SMI program. Companies in this position found that open and honest communication regarding the SMI approach was the best approach. Some manufacturers have union rules that prevent suppliers from performing in-house operations.

Existing inventory is an important transition issue. Because high inventory is a major reason for manufacturers to initiate an SMI program, and the current inventory exists for various reasons (such as forecast uncertainty or shop practice), manufacturers acknowledge that it is important to carefully deal with existing inventory in the transition to SMI. Manufacturers stated that it was necessary to understand the usage and lead-time for each item in the program in order to determine ahead of time if there will be unexpected shortages. In addition, steps may need to be taken to reduce the effect to a supplier from an unexpected lull in business, while excess inventory is used up.

Metrics are not always perfect but some track exactly what the participant is trying to achieve. There is a wide range of practices observed with participants related to metrics used to monitor the health of the SMI program. In some cases SMI programs have been initiated without any measures whatsoever. In other cases, basic metrics such as number of stock-outs, or number of times over the maximum target inventory are used. In a few cases, manufacturers with specific goals to increase inventory turnover have focused metrics to determine how the SMI program was working for them. One company calculated a target inventory turnover for the portfolio by utilizing the midpoint of the target min/max inventory level and forecasted usage, and compared it to the actual results being achieved.

Existing information systems are limiting some additional opportunities. In some cases, after experiencing initial success with the SMI program, companies could not implement additional improvements because they were restricted by information system constraints. For example, many companies expressed an interest in monthly billing but could not do so due to system limitations. Another company had to make extensive system changes in order to accommodate requirements for consigned inventory.

The Case for SMI

The case for Supplier Managed Inventory programs is compelling. Information provided by SMI practitioners, as well as successful initiatives documented in the literature, provide strong motivation for considering application of this type of program in a wide variety of industrial settings. Most sources agree that the right situations for SMI are those products that have relatively stable and consistent demand. However, innovative approaches have demonstrated that even when consumption does not appear stable, steps can be taken to level demand and reap the benefits of SMI. Situations that are plagued by high levels of inventory, inefficient ordering practices and symptoms of the bullwhip effect are suitable for SMI.

Some benefits of adopting SMI are common between manufacturers and suppliers and some are not. However, in general, there are many reasons to adopt the approach. While there are many different practices that help support the "new" SMI infrastructure (i.e. extent of written agreements, information sharing, joint strategy development, sharing of rewards, and management leadership), SMI leads to sustained gains for those willing to undertake the venture. The primary benefits of an effective SMI program are:

- *Inventory is reduced due to more frequent replenishment and shorter lead-times:* Figure 6-2 illustrates how more frequent replenishment can lead to a lower average inventory level.

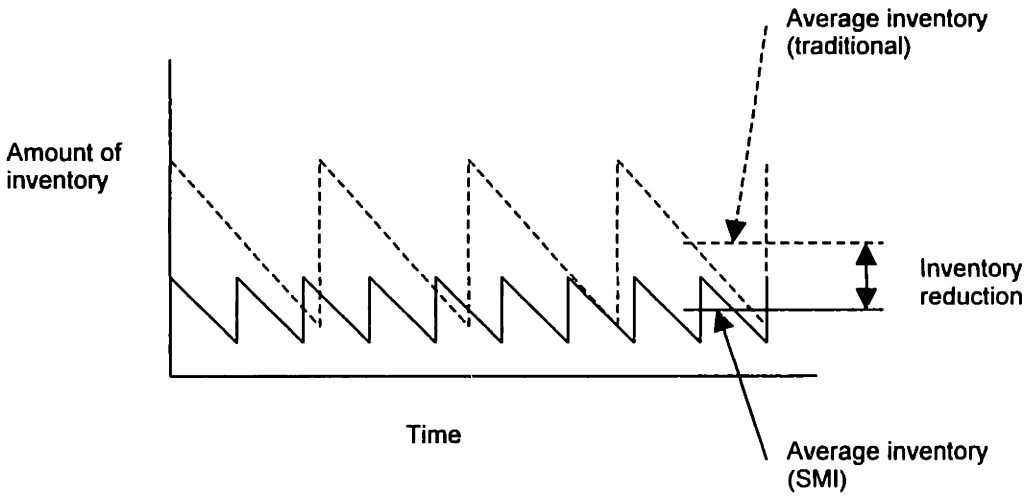


Figure 6-2: Effect of More Frequent Replenishment

When efforts are taken to shorten lead-times, through JIT improvement activities or better planning, production can more accurately track demand.

- *Non-value added work is significantly reduced:* By eliminating redundant activities and performing tasks at the most effective point in the supply chain, overall system-wide efficiency is improved.
- *Collaborative partnerships lead to new opportunities:* When once isolated functions work together, new ideas are generated and improvements are realized in areas not previously explored.
- *There is a "snowball effect" that occurs:* Success in one area leads to additional successes throughout the supply chain.

The successful implementation of a Supplier Managed Inventory program requires three critical elements: innovative and fundamental change in operating practices and attitudes, information and measurement systems to support the new initiative, and effective change management[12]. With these elements, Supplier Managed Inventory offers a new approach to achieving sustained competitive advantage.

Change Management

Change management is a critical element of the transition to SMI and warrants further discussion. Gattorna (1998) presents a framework for fast and effective management of change that is shown in Figure 6-3. The author presents these prerequisites as mutually supporting and if any one element is missing, change is likely to fail. He points out that change management encompasses building business success through managing people, and it is people in the end who provide the path to effective and sustainable change. It is necessary to move beyond cost, time, benefits and quality and become proficient at managing stakeholders and their emotions, team building, communicating, commitment building, risk management and people development.

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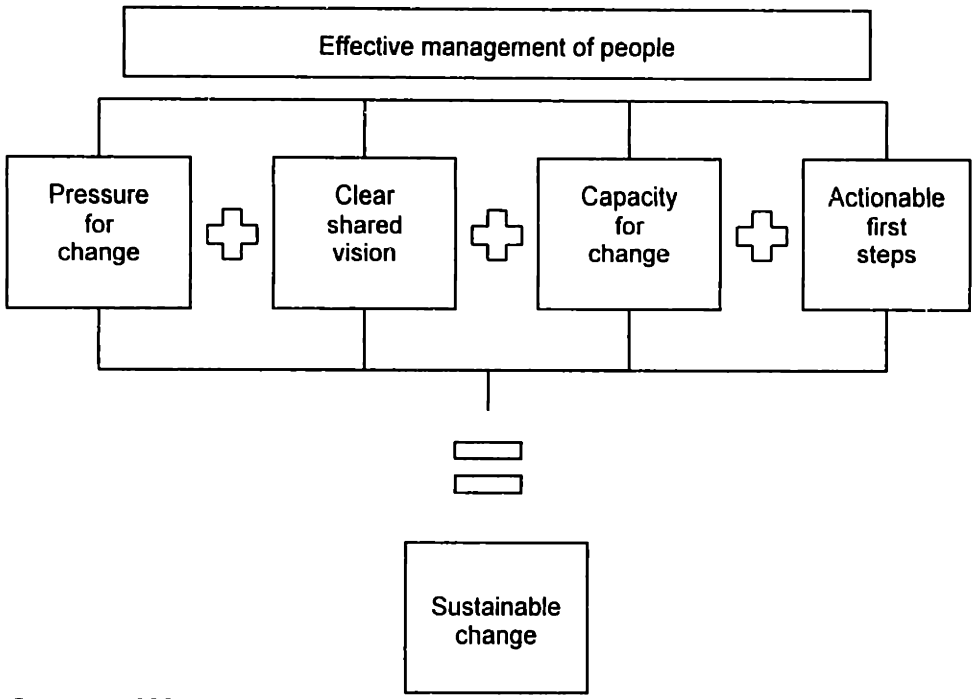
[12] Fundamental change, corresponding measurement systems, and effective change management was the theme of 1.261J - 15.771J Case Studies in Logistics and Supply Chain Management class taught by Dr. Jonathan Byrnes, Fall 1998.



Source: Gattorna, 1998

Figure 6-3: Framework for Fast and Effective Management of Change

Gattorna (1998) presents the following prerequisites for fast and effective change management:

- *Pressure for change:* The compelling need or pressure that provides the incentive and motivation for change. The pressure must be well documented and researched and must convince virtually everyone in the organization. In successful change programs the pressure for change comes from a rigorous analysis of customer needs, the company's competitive situation, its market position, financial performance, identification of the barriers to be overcome and the potential payoffs. This analysis is then dramatically communicated, often in terms of organizational survival or continued effectiveness, to convince managers and employees alike that change is imperative and desirable, not a management ploy to downsize or restructure. The pressure for change provides the basis for inspiring cooperation and motivation and pushing people out of their comfort zones, without which the program will go nowhere.
- *Clear shared vision:* A clear, compelling statement that communicates the mandate for change and the goal sought. If different managers and stakeholders have

varying perceptions of the desired outcomes, then the sought after results will not be achieved. A clear and concise statement of the goal of the change program, stated in customer focused terms which amplifies the voice of the customer, provides the essential means to harness and focus the energy of the organization in pursuit of that goal. A good vision for change should be expressed in terms of the things the organization needs to do as well as the individuals involved.

- *Capacity for change:* This capacity is derived from redesigning the organizational structure, jobs and performance measures to enable new performance and changed behaviors to occur; training and developing staff to attain the required skills and behaviors needed in the new environment; and allowing some temporary reduction in performance standards while the organization moves through the transition. It is necessary to establish and clearly communicate priorities to avoid overtaxing limited resources and to avoid differing opinions about the relative importance of each initiative. It is important to achieve small, early successes in order to build momentum, especially when resistance to change is high.
- *Actionable first steps:* These actions are needed in order to direct the efforts of the people involved. The following first actions are essential to properly focus the change in the human, technology and process areas:
    - Align culture with strategic response.
    - Appoint a process owner.
    - Reshape performance measures.
    - Develop and train the workforce.
    - Communicate and demonstrate top management commitment.
    - Involve stakeholders and gain commitment to change.
    - Implement a system to track benefits.
    - Communicate with all stakeholders.
    - Create an integration map.

An Implementation Framework

A successful and effective SMI program, as Byrnes and Shapiro (1991) point out in their discussion of intercompany operating ties, "requires a major shift in perspective and broad changes in operations, both within a company and its channel partners". The framework shown in Figure 6-4 is offered as an approach to implementation that considers the wide array of issues to plan for as an SMI program is developed and implemented in a manufacturer or supplier company.

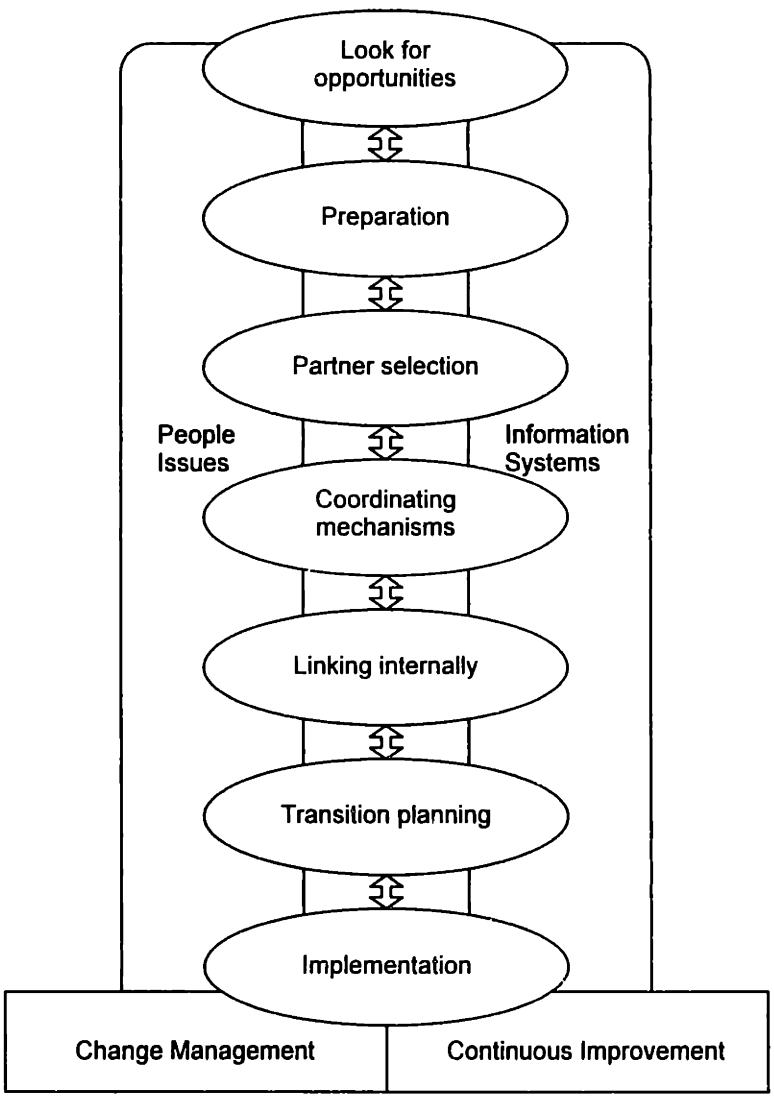


Figure 6-4: A Framework for Implementing an SMI Program

Change management and continuos improvement are fundamental to the development, implementation and ongoing activities of an SMI program. Information systems and people issues are intertwined with these as well. The following steps relate to the implementation framework shown in Figure 6-4. They are presented in a sequential order, yet as a program evolves it may be necessary to revisit items as additional factors emerge.

Look for Opportunities - In order to identify supply chain improvement opportunities, consideration should be given to issues specific to the company exploring the initiative. There may be symptoms of high demand variability. Benchmarking results may indicate inventory turns are significantly less than competitors. The company may want to lower inventory levels, increase sales, reduce transactions, free up resources or increase service levels. A change may have occurred that provides an opportunity for a new supply chain initiative. Once the motivating factor is determined, the type of products or components to involve can be evaluated. The information from the literature and participant interviews suggests that it is best to gain experience with items that have relatively steady demand. Consider commodity items or custom components with predictable usage. If a partner company has extensive SMI knowledge already, it may be worthwhile to gain experience with them first. Encourage cross-functional collaboration in order to examine areas not typically explored. Look at the whole supply chain and make the effort to get data that may expose opportunities not previously considered.

Preparation - After the initial direction for the SMI program is set, look for areas that will produce early wins in order to establish the credibility of the new approach within the company and with supply chain partners. Because the SMI program is a significant culture change, it is important that it be continually visible throughout the company during development and implementation. It is crucial to establish management support early and take steps to ensure that this support will be ongoing. Detailed process flows (the channel map) should be created in order to develop a deep understanding of existing material,

information, and financial flows. Data gathering should encompass all channel members including the end-user along these dimensions as depicted in Figure 6-5.

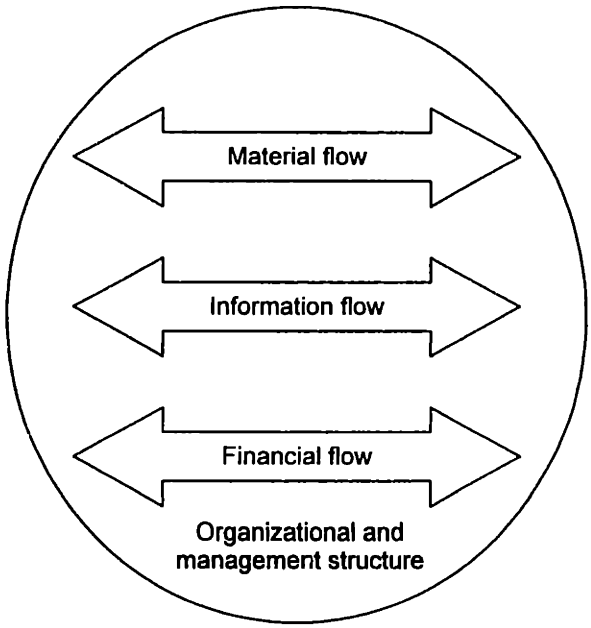


Figure 6-5: Issues and Context of the Supply Chain

Material flow refers to the physical flow of materials. Information flow includes items such as how demand is generated and communicated, and order processing information. Financial flow refers to items such as invoices and payments. As pointed out by Taylor (1997), it is important to understand organizational and management structures as well, both intracompany and intercompany. Consider business objectives and strategies of different supply chain members as well as the relative power between organizations. Understand flow across functional groups as well as management perspectives of supply chain activities and improvement. Study consumption patterns, ordering patterns, then supplier production patterns and look for opportunities to coordinate throughout the system. Identify opportunities for benefit sharing (Byrnes and Shapiro, 1991). Select appropriate performance measures, understand current performance, and make estimates of potential gains. Take the time to identify the main issues and problems. Use all of this information to prioritize efforts. In order to overcome internal resistance, provide initial education that focuses on why the initiative is necessary.

Partner Selection - Once an understanding of opportunities and current operations is developed, partners can be selected according to considerations presented in Chapter 3. For example, consider the eight criteria for strategic business relationships: individual excellence, importance, interdependence, investment, information, integration, institutionalization, and integrity. Consider other attributes of the company. It should have an ingrained philosophy of continuous improvement and set-up reduction, for example, as well as an adequate quality system. A manufacture should determine if it will be able to eliminate incoming inspection. It is important to understand what each company must do well. For example, manufacturers must provide good forecasts and suppliers must be proactive about issue notification. Look for progressive suppliers that implement SMI in both directions, with manufacturers as well as sub-suppliers, since they may offer the biggest opportunity for system-wide improvement. Consider how distance issues will be handled. Develop an understanding of the potential partner's concerns and create the appropriate contracts and long-term agreements needed to support the new relationship.

Coordinating Mechanisms - Once a partner is selected, the appropriate coordinating mechanisms can be established. In general, shorter lead-times and smaller batch sizes should be encouraged since they naturally lead to lower levels of inventory. Two dimensions need to be considered: long-term forecasting and short-term demand or usage communication. Long-term rolling forecasts should be provided, in excess of the longest lead-time component, for some mutually agreeable period. Include a mechanism to ensure suppliers are alerted of major changes in usage rates (one-time sales, add/lose a large customer, promotions, protected stock, etc.). For short-term usage and demand communication, attempt to utilize information or triggers that already occur naturally in the production process. Consider kanban techniques or the use of min/max inventory levels to drive replenishment. In order to minimize transactions, blanket purchase orders should be considered. Develop a stocking strategy and determine where inventory will be held. Decide if consignment, third party logistics providers, or in-plant supplier representatives will be used. Set targets for service levels, inventory turns, and forecast and replenishment

schedules. Identify the framework for material, information, and financial flow as depicted in Figure 6-5 and develop corresponding detailed process flows. Establish metrics that track what you are specifically trying to accomplish (i.e. increase inventory turnover). Create additional metrics to ensure that the lower level of inventory is not disrupting operations (i.e. line downs). Reference the additional metrics in Chapter 3.

Information Systems - Technology is a key enabler of SMI programs and can be utilized at many different levels of sophistication. Today's enterprise resource planning (ERP) systems hold the data needed for SMI and can be enhanced by supply chain management software applications if desired. EDI, supplier web sites, file transfer, e-mail, or simple kanban signals can all be used. Many situations require innovative changes to existing information systems in order to derive maximum benefits from an SMI program. It is advisable to have talented IT membership on the SMI team. Create a system solution that will minimize daily intervention effort, utilize existing information already in the system (so people do not need to feed in new data specific to the SMI program), and maximize information timeliness and accuracy. Consider adopting bar-coding to minimize data entry tasks.

Linking Internally - As suggested by information in the literature as well as the interview participants, coordinating the rest of the company's production system to the SMI program can yield significant gains. The production strategy should incorporate elements that compliment the SMI approach, such as JIT production. Smoothing production, taking steps to eliminate incoming inspection, and utilizing barcode technology are examples of effective linkages to the production system. Suppliers can consider utilizing SMI for sub-suppliers and perhaps shift the make-up of inventory that is held from raw material to finished goods if distance issues require. As these links are established throughout the company, education should focus on the new direction being pursued, the expected benefits and the required changes for the SMI program.

Transition Planning - The most significant issues to plan for during the transition to the SMI program are the effects of existing inventory. If suppliers will experience a lull in demand as existing inventory is burned off, then that must be planned for. If existing inventory will be transferred to the supplier, a date should be established when slow moving inventory will be considered obsolete. In addition, determine if service levels will be negatively affected during the transition.

People Issues - SMI is a significant cultural change. It requires that activities that are embedded in people's minds from many years of practice be fundamentally changed. In order to foster change, expectations and measures of performance must change as well. One key insight regarding people issues that was provided by the interview participants was that it is best to be open and honest about SMI program plans and effects. If downsizing or layoffs occur as the program is developed or launched, people will naturally be reluctant to participate. Union issues, such as in-plant supplier representatives, must be considered and addressed. Engage workers through education. Some companies that were interviewed transferred individuals displaced by the SMI program to more strategic and satisfying roles once the SMI program was underway.

Implementation - During implementation, education should focus on individual's roles and responsibilities that will combine to make the program successful. As mentioned previously, focus on early wins to build momentum and release capital to fund further efforts. Perform alpha and beta tests prior to launch to protect against unexpected declines in service levels. Adopt the spirit of continuous improvement and perform reviews for lessons learned to identify items that should be done differently as the program moves forward. Audit to ensure initial goals are being met.

Chapter 7. Conclusions and Directions for Future Research

There are new dynamics in industry and in manufacturer-supplier relationships that provide opportunities for significant system-wide improvements in asset management and operations. As manufacturers and their suppliers have become more dependent on each other, a new awareness of the benefits that can be attained from focusing on supply chain and logistics improvements has exposed opportunities not previously considered. "Supplier managed inventory" (SMI) is a collaborative program where a supplier takes on much of the inventory planning, ordering and replenishment activity for its customer. The result of these arrangements are typically benefits to both companies in the form of reduced inventory (increased inventory turns), reduction or elimination of non-value added activities, and an improved relationship that leads to additional gains.

Supplier managed inventory programs are being established between many manufacturers and suppliers. Literature research and interviews with SMI practitioners revealed that the motivations for establishing and engaging in an SMI program vary, however, manufacturers and suppliers both receive benefits. Some suppliers are initially reluctant to engage in an SMI initiative, but later become strong advocates once initial concerns are addressed and unexpected benefits are experienced. Many progressive suppliers are participating in SMI relationships with their sub-suppliers, as well as with customers, thus realizing even more benefits. The biggest gains go to those who can fundamentally change their processes and establish means to efficiently and frequently exchange information. To fully realize benefits from SMI, organizations must have effective change management capability and address the significant people and organization issues involved with such major change to current practices. SMI is typically not used in 100% of a company's purchase transactions between buyer and supplier, however there seems to be a certain level of SMI implementation that must be reached in order to realize benefits such as production smoothing. If a company establishes too many SMI relationships, overall effectiveness of SMI for the company may be diluted. Most companies start with a small

initiative in order to gain experience and develop program-specific details. These early programs tend to involve products with relatively steady demand. Then, once early programs are stabilized, the SMI initiative expands to include additional items.

The principles and methods of JIT are interdependent with SMI activities. Eliminating waste in the form of excess inventory and unnecessary operations is integral to the SMI approach. SMI enables production according to market demand, which is a key element of JIT. In addition, adopting a philosophy of continuous improvement for the SMI initiative offers additional benefits as new aspects of the collaborative relationship are discovered.

The implementation framework presented in Chapter 6 offers a methodology for suppliers and manufacturers to develop, implement, and continually improve an SMI initiative.

This research provides the basis for investigation in two other areas:

- *Optimal coordinating mechanisms:* There are numerous methods that can be used to achieve the information exchange required between manufacturers and suppliers for an SMI program. Companies use kanban signals, barcode technologies, EDI, communication via e-mail and internet, and custom supply chain management applications in conjunction with large-scale ERP systems. It would be beneficial to understand more about the specifics of these alternatives, and develop an understanding if one type of method was more effective than other methods.
- *Quantification of specific benefits achieved in industrial settings:* Currently, the literature contains more detailed information and research concerning initiatives in the retail and grocery industries than information regarding more traditional industrial settings. The research regarding grocery and retail describes specific improvements in inventory turns or service levels achieved by participating companies. Literature specific to SMI programs as applied to traditional industrial settings is more general and typically does not cite detailed information regarding improvements that were achieved. A case study involving industrial companies involved in an SMI program may provide such detail.

References

Andel, T. (1997, September). Warehousing in manufacturing: from inventory holding to product molding. Transportation and Distribution, 38(9), 80-84.

Anonymous. (1997, June). ECR primer. Software Magazine 17(6), 46.

Buffa, E. & Sarin, R. (1987). Modern production / operations management. New York: John Wiley and Sons.

Burke, M. (1996, February). It's time for vendor managed inventory. Industrial Distribution, 85(2), 90.

Byrnes, J. & Shapiro, R. (1991). Intercompany operating ties: unlocking the value in channel restructuring. Harvard Business School Working Paper No. 92-058.

Cachon, G. & Fisher, M. (1997, Fall). Campbell soup's continuous replenishment program: evaluation and enhanced inventory decision rules. Production and Operations Management, 6(3), 266-276.

Cachon, G. & Fisher, M. (1998). Supply chain inventory management and the value of shared information. Paper presented by Gerard Cachon at M.I.T, November, 1998. (Gerard Cachon is from the Fuqua School of Business, Duke University. Marshall Fisher is from The Wharton School, University of Pennsylvania).

Clark, T. & Hammond, J. (1997, Fall). Reengineering channel reordering processes to improve total supply-chain performance. Production and Operations Management, 6(3), 248-265.

CTRC (1992). Electronic data interchange - streamlining business communications. Charleston, SC: Computer Technology Research Corporation.

Dyer, J. (1994, November - December). Dedicated assets: Japan's manufacturing edge. Harvard Business Review, 72(6), 174-178.

Dyer, J., Cho, D.S. & Chu, W. (1998, Winter). Strategic supplier segmentation: the next "best practice" in supply chain management. California Management Review, 40(2), 57-77.

Freeland, J. (1991, Second Quarter). A survey of just-in-time purchasing practices in the United States. Production and Inventory Management Journal, 43-50.

Gattorna, J. (1998). Strategic supply chain alignment: best practices in supply chain management. Brookfield, VT: Gower.

Gattorna, J. & Walters, D. (1996). Managing the supply chain: a strategic perspective. London: MacMillan Press Ltd.

Hayes, J. (1997, March 24). Watch out dell. Forbes, 159(6), 84.

Hayes, R., Wheelwright, S. & Clark, K. (1988). Dynamic manufacturing: creating the learning organization. New York: Free Press.

Johnson, M.E., Davis, T. and Waller, M. (1998). Vendor managed inventory in the retail supply chain. Currently unpublished paper that is scheduled to be published in the Spring 1999 Journal of Business Logistics.

Karmarkar, U. (1989, September - October). Getting control of just-in-time. Harvard Business Review, (67), 122-131.

Landvater, D. (1997). World class production and inventory management. New York: John Wiley and Sons.

Lee, H., Padmanabhan, V., & Whang, S. (1997, Spring). The bullwhip effect in supply chains. Sloan Management Review, 38(3), 93-102.

Lee, H. & Ng, S.M. (1997, Fall). Introduction to the special issue on global supply chain management. Production and Operations Management, 6(3), 191-192.

Lyons, T., Krachenberg, A.R., & Henke, J. (1990, Spring). Mixed motive marriages: what's next for buyer supplier relations? Sloan Management Review, 31(3), 29-36.

Magretta, J. (1998, March-April). The power of virtual integration: an interview with Dell Computer's Michael Dell. Harvard Business Review, 76(2), 72- 84.

McKeefry, H. (1998, October 5). New sourcing strategies paying off. Electronic Buyers' News.

Minahan, T. (1997, September 4). JIT: a process with many faces. Purchasing 123(3), 42-46.

Monden, Y. (1998). Toyota production system: an integrated approach to just-in time. Norcross, GA: Engineering and Management Press.

Nahmias, S. (1997). Production and operations analysis. Boston, MA: Irwin, Times Mirror Education Group.

Newton, J. (1998). Why vmi? NEDA News (issue uncertain).

Nolan, K. (1998, February). With distributors in mind, Northwestern embraces vmi. Metal Center News, 38(3), 32-36.

Ray, K. & Swanson, C. (1996, May). Supplier-managed-inventory: schedule sharing. Hospital Materiel Management Quarterly 17(4), 48-53.

Schonberger, R. (1982). Japanese manufacturing techniques: nine hidden lessons in simplicity. New York: The Free Press.

Shingo, S. (1989). A study of the Toyota production from and industrial engineering viewpoint. Cambridge, MA: Productivity Press.

Silver, E. & Peterson, R. (1985). Decision systems for inventory management and production planning. New York: John Wiley and Sons.

Simbari, D. (1996, September). Competitive advantages. Manufacturing Systems 14(9), 92-96.

SSCI (1994). Electronic data interchange (EDI) business system planner. Steel Service Center Institute. Chardon, Ohio: EDI Support Services, Inc.

Stratman, Scott. (1997, June). VMI: not just another fad. Industrial Distribution 86(6), 74-77.

Taylor, D. (1997). Global cases in logistics and supply chain management. Boston: International Thomson Business Press.

Tersine, R. (1988). Principles of inventory and materials management. New York: Elsevier Science Publishing Co., Inc.

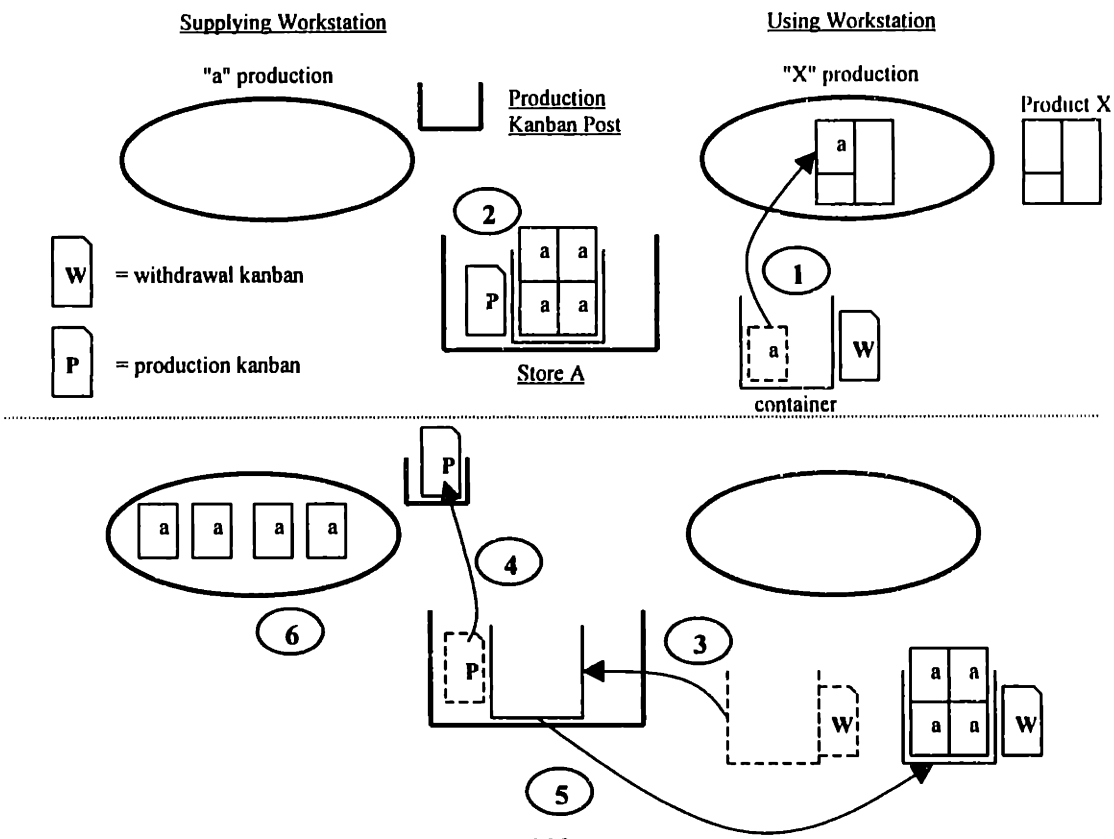
Womack, J. & Jones, D. (1996). Lean thinking: banish waste and create wealth in your corporation. New York: Simon and Schuster.

Womack, J., Jones, D. & Roos, D. (1990). The machine that changed the world. New York: Rawson Associates.

Appendix A - The Kanban System

The flow of kanbans is illustrated in the figure below. The numbers in the diagram correspond to the descriptions below. Note that in the diagram, the using workstation is making product "X" from three components, including "a". The supplying workstation is making component "a" when signaled by the production kanban.

1. The using workstation uses the last component "a" in the container.
2. Store A has a full container of "a" with the production ordering kanban attached.
3. The worker takes the empty container and withdrawal kanban to store A and leaves the empty container at store A, detaching the withdrawal kanban.
4. The worker detaches the production kanban from the full container and places it in the production kanban post.
5. The worker attaches the withdrawal kanban to the full container and returns to the using workstation.
6. The worker for the supplying workstation, upon seeing the production kanban in the post, produces the specified number of component "a", fills the container, and returns the full container and production kanban to store A (number 2 in the top diagram).



Appendix B - Survey Questions for Supplier Managed Inventory Users

A) Background information:

1. What is the primary business of the company?
2. Approximately how big is the company? (sales, people)
3. To what extent does the company utilize or participate in SMI relationships? (approximate % of purchases or sales)
4. Please briefly describe how your SMI system functions.

B) What are the right situations for SMI and the key enablers:

5. What prompted the company to initiate or become involved in SMI programs?
6. For what types of components or subassemblies is SMI used? For what types is SMI most effective? Why?
7. For what types of components do you think SMI is not appropriate? Why?
8. What affect has the distance between participating companies had on the SMI relationship?
9. How did the company decide in which areas to implement SMI first?
10. Are there any issues to consider regarding quality problems that might arise with components involved in the program?
11. How did the company assess it's own readiness for participating in an SMI program?
12. How are partner companies assessed for their readiness for an SMI program?

C) What are SMI best practices, and how companies' integrate SMI into their overall production system:

13. How and to what extent is long-term forecasting information shared? What forecast windows are provided?
14. What is the frequency of short-term communication? (part usage, inventory level, etc.) How often are shipments received or made?
15. What method do you use for transaction communication? (EDI, internet, Kanban) How are purchase orders, payment transactions, etc. handled? Is any SMI specific software used?
16. Have volume discount pricing practices created any issues?
17. How is the rest of your production system coordinated with your SMI activity? Have other programs been initiated to support the SMI activity? (For example: set-up time reduction, etc.)
18. How has your shipping, receiving or logistics areas been impacted by the SMI activities?
19. What were the most important people issues to resolve while implementing SMI?
20. How is performance of both partners measured and shared? What do you consider to be the key metrics for ongoing monitoring?
21. What types of emergency or workaround systems are in place? How much safety stock is kept? (number of days of inventory)

D) What are key success drivers for establishing and maintaining SMI relationships:

22. Describe the impact SMI has had on your organization (inventory turns, "stock-outs", delivery performance, warehouse space, human resources, etc.): What have been the most important results achieved through the use of SMI? What difficulties (expected or unexpected) have you experienced with SMI?

23. Who in the organization is involved with the planning and implementation of the SMI program? To what extent is upper management involved with and committed to the program?
24. What type of joint SMI strategy development and long-range planning takes place with the other partner(s)?
25. What other, if any, relationship elements have been implemented along with SMI? (For example: Long Term Agreements, benefit sharing, etc.)
26. What type of training is important for employees who participate in the SMI program? Do they follow a documented process for the SMI program?
27. What activities or requirements are most important to making the relationship work?
28. What activities or requirements are least important to making the SMI relationship work? Could any of these be eliminated?
29. What types of transition issues surfaced during implementation? (For example: impact of inventory draw down, etc.)
30. How quickly have you implemented SMI across your supply base?

E) Other questions:

31. How have product designs been impacted?
32. Are there any other aspects of the SMI relationship we haven't discussed that you'd like to mention?

Appendix C - SMI Program Interview Participants

Name(s)	Company
Ron Webber Account Manager	Alatec Chatsworth, California Hardware and fastener distribution
Scott Bostock Senior Project Engineer	Beach Mold and Tool New Albany, Indiana Molded plastic parts and contract assembly
Bob McQuillan Materials Manager	Cameron and Barkley Co. Charleston, South Carolina Electronic wholesalers
Mike Davies Production Manager Maggie Dervarits Account Manager	C.M.P. Ltd. Chateauguay, Quebec, Canada Sheetmetal products manufacturing
Peter Cohen President	Cosmotronics, Inc. Irvine, California PCB assemblies
Mark Zafra Procurement Specialist/Engineer	Hewlett-Packard Company Palo Alto, California Measurement, computation and communication
John Clemmons Operations Leader Manny Yi Donoy Activity Leader	Hughes Space and Communications El Segundo, California Communications systems
Randy Rosenbayger Materials Manager	Injectronics, Inc. Hudson, Massachusetts Molded plastic parts
Tom McMann Sales Engineer Joan Magrath Business Unit Director	Mack Molding Arlington, Vermont Custom injection molding and contract assembly

Keli Ray Customer Linking Operations Mgr.	Motorola, Inc. Semiconductor Products Sector Singapore Semiconductor manufacturing
Dave Atkins Material Planning and Control Mgr.	Northrup Grumman MASD El Segundo, California Military aircraft systems
Teresa Chapman Senior Buyer	Siemens Energy and Automation Johnson City, Tennessee Electronic manufacturing center
Deniz Boyd Procurement Specialist	Sunstrand Aerospace Rockford, Illinois Aerospace products
Roy Dunbar Commodity Manager	Symbol Technologies Holtsville, New York Bar code scanners, portable data terminals
David Tapia Account Manager	TriStar Aerospace Long Beach, California Distributor of aerospace fasteners