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Supply Chain Management and Demand Uncertainty

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SUPPLY CHAIN MANAGEMENT AND DEMAND UNCERTAINTY

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ABSTRACT

The global marketplace has brought increased competitive pressures on manufacturers. This increased competitiveness and market demand uncertainty has made it difficult for U.S. manufacturers to compete with traditional production planning methods that seek to maximize efficiency and utilization within a customer-centered world. Supply chain management has emerged as a mechanism to improve competitiveness and flexibility in addressing demand uncertainty by the physical and conceptual integration of the customer into the supply chain. Through improved information flow through the supply chain, uncertainty is reduced and greater flexibility and reliability is achieved in response to customer and market volatility demand factors.

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INTRODUCTION

The global marketplace of today has brought increased competitive pressures. In addition, market demand uncertainty has made it difficult for manufacturers to compete with traditional production planning methods that seek to maximize efficiency and utilization within a customer-centered world. Traditionally, the response to uncertainty has been to hold excess inventories or spare capacity; neither of these are now viable; the response now must be to eliminate the negative effects of uncertainty through flexibility, while providing a quality product in a timely and reliable manner. Manufacturers wanting to compete successfully must look to new concepts, processes and technologies to help them adapt and ensure that their production processes deliver customer satisfaction while retaining efficiency. U.S. manufacturing has recently looked to techniques pioneered in the Toyota Production System (TPS). In addition to lean and just-in-time manufacturing, supply chain management has emerged as a mechanism to improve competitiveness and flexibility in addressing demand uncertainty. Supply chain management seeks to achieve the goal of better performance through the physical and conceptual integration of the customer into the supply chain. This takes the form of improved information flow through the supply chain. This has two general mutually reinforcing advantages: the reduction of uncertainty, and the integration of supply chain entities, both internal and external to the firm. Reducing uncertainty and integrating functions allows for greater flexibility and reliability in response to customer and market volatility demand factors. This paper will examine the effects of this strategy on the U.S. manufacturing function in contrast with tradition responses to demand volatility.

SUPPLY CHAIN BASICS

The supply chain has been defined as the entire value-adding process from raw materials to the ultimate consumption of the finished product linked across supplier-user companies (Fredendall and Hill, 2001). The term is dynamic, used to describe various emphases of the concept. For example, supply chain management is used to describe supplier relationships, information exchange, or the entire process. In addition to supply chain management, such terms as materials management, keiretsu, logistics, and resource planning are often used interchangeably in actual business practice (Langley, 1992). Generally, however, the term supply chain management refers to a total systems approach to managing the entire flow of information, materials, and services involved in the production, addition, and delivery of value to an end user (Chase, Aquilano, and Jacobs, 1998).

There are four basic enablers to supply chain management (Marien, 2000):

1. Organizational infrastructure
2. Technology
3. Strategic alliances
4. Human resources management.

Organizational infrastructure is how the functional areas of the business are coordinated and integrated. This is the key; all business success will flow from the firm's ability to coordinate all it's activities such that the processes of the organization are optimized (Burt & Doyle, 1993). This prevents conflicting activities resulting from local optimizations (Goldratt & Cox, 1992). Technology is the means of a company's operational strategic supply chain processes; it includes information technology and the physical materials management technologies for material design, operations, materials handling and transportation (Marien, 2000). Strategic alliances refer to how external companies, such as customers, suppliers, and logistics services are selected as partners or business allies. Intercompany relationships are built and managed so that information flows through the whole chain and activities are coordinated appropriately for mutual advantage (Bhote, 1989). The final enabler, human resources management, goes beyond the traditional job design and compensation issues. It also recognizes the human behavior implications that will affect the design of communication links and strategies that will bring the supply chain together, such as the ergonomic issues of information display and communication styles that increase the efficiency and reliability of the communication system (Gattorna, 1998).

Supply chain management is derived from traditional logistics, which deals with the activities of a business that involve management of raw materials to the delivery of the final product (Christopher, 1992). Supply chain management can be considered an extension of logistics beyond the confines of the organization with an emphasis on a strategic approach that links activities to corporate strategy (Lamming, 2000). The goals of supply chain management are to reduce uncertainty and risks in the supply chain to optimize the system by positively affecting inventory levels, cycle time, processes, quality and end-customer service (Chase et al., 1998).

The current manifestation of supply chain management in the United States has evolved as a response to increased global competition, the development of enabling technologies, and in part as an emulation of successful Japanese management concepts, especially the Toyota Production System (TPS). TPS, from which the concepts of lean manufacturing, just-in-time manufacturing (JIT) and many aspects of supply chain management (SCM) are derived, is a manufacturing philosophy that shortens the time line between the customer order and the shipment by eliminating waste (Shook, 1998).

The Need for Supply Chain Management

Supply chain management has become an important managerial issue in the United States in the 1990's. This has come about for several reasons, but mainly includes: a change in markets; changes in customer demand; changes in technology; and the success of other companies' supply chains.

Markets have provided a multitude of challenges as national and international competition has increased. In addition, cost of capital increases coupled with uncertainty due to market swings have made investment decision in capacity, systems, and inventories risky, as less reliable information is available to make informed capital investment decisions (Oliver & Webber, 1992).

Increased competition has fundamentally changed customer demand; with global competition, customers have multiple sources from which to choose to satisfy demand (Lummus, Vokurka, & Alber, 1998). Because of this, traditional competitive advantages of cost and quality are not enough; they are no longer order winners (the criterion that favorably differentiates one firm from another), but order qualifiers (the screening criterion that permits a company to even be considered a candidate in competition) (Mahoney, 1997). Companies need to compete on cost and timely delivery. Low-cost variety and quick response times are now fundamental competitive differentiators; to customers, total time to deliver a low-cost, high-quality product or service is essential (Liker, 1998). Improvements in technology, especially in information processing and the

Internet, has offered opportunities for rapid communication between traditional organizational boundaries (Marien, 2000). This has enabled the strategy, supply chain management to emerge.

The success of this strategy for companies such as Wal-Mart, Coca-Cola and Dell Computer has aroused the interest of U.S. manufacturers. In the period of 1988-1996, Wal-Mart, Coca-Cola, and Dell have implemented supply chain strategies and exceeded industry growth average by 250, 500, and 3000 percent respectively (Evans & Danks, 1998). The phenomenal success of Japanese manufacturing in the 1970's and 1980's, especially in the automotive sector as exemplified by Toyota, has gained the full attention of manufacturers in the U.S. (Cox, 1999). The ability of these manufacturers to weather recessions in 1977 (Liker, 1998) and in 1991 (Lamming, 2000) have added further interest. It can be argued that a great deal of manufacturing and supply chain management practice today appears to be an attempt to emulate the approach to management pioneered by Toyota's approach of lean manufacturing and external resource management (Cox, 1999).

To meet these changes and allow for success in good times and bad, several management concepts have evolved in terms of improving customer service through improved quality and flexibility. The Massachusetts Institute of Technology (MIT) Commission on Industrial Productivity identified firms that were responding successfully to the opportunities and constraints of the new competitive environment and compiled six key similarities among best practice firms (Dertouzos, Lester, Solow, 1989):

1. Simultaneous improvement in quality, cost, and delivery
2. Staying close to the customer

3. Closer relationships with suppliers
4. Effective use of technology for strategic advantage
5. Less hierarchical and less compartmentalized organizations for greater flexibility
6. Human resource policies that promote continuous learning, teamwork, participation, and flexibility.

These comprise an integrated, mutually reinforcing system as a part of a single, integrated strategy (Dertouzos, et al., 1989). Further, John Shook, director of the Japan Technology Management Program at the University of Michigan, who worked for Toyota and was involved in transferring TPS to the U.S., says the implementation of lean manufacturing has several problems that continue to confound U.S. manufacturers. A significant part of these problems is that the way manufacturing works with sales makes scheduling and running the plants difficult, which is compounded by the way they order from suppliers (Shook, 1998).

Manufacturing is just one part of this total, but it must be optimized first; in terms of its position in the entire process and its relationship to other functions, manufacturing can give the whole process great competitive advantage (Drucker, 1990). Lean manufacturing, JIT, agile manufacturing, and other concepts can provide advantages in manufacturing. Supply chain management incorporates these concepts and extends this beyond the confines of the factory floor and provides integration between functions to achieve best practice. To compete in the market, each segment or function must realize that they are not stand-alone entities, but should work in close coordination to optimize process flow through the entire organization and supply chain (Mohanty & Deshmukh, 2000). For a manufacturing firm to stay competitive in a globally oriented market of today, the understanding of strategic, tactical and operational issues concerning the links between markets, products and production is fundamental (Olhager & Wikner, 2000).

UNCERTAINTY

Uncertainty can refer to quantity (i.e. quantity of product demanded) or to time. Uncertainty in time may occur in the form of yield losses due to quality problems, shortage of materials needed, or of equipment required. Uncertainty can be classified or defined in several ways; essentially, uncertainty is variance. The terms variability, variance, uncertainty, and volatility can be used interchangeably. This paper will examine demand uncertainty as it pertains to the manufacturer; i.e., the question of how much to produce to meet demand, either demand by customers within the supply chain or by the consumer at the end of the process.

Demand Uncertainty

Demand uncertainty complicates planning and generally reduces the ability of a company to respond to customers. It can be characterized in several ways, but a common approach is to classify demand as intrinsic, which is true demand from the market not controlled by the company (i.e. consumers), and extrinsic demand, which is controlled or induced by the company, especially as associated with marketing, sales, and manufacturing (Mahoney, 1997). As supply chain management concerns itself with the process of the entire chain, customers within the chain will be considered extrinsic for the purpose of this discussion; the term consumer will refer to the ultimate consumer at the end of the chain.

Intrinsic, or economic uncertainty in the market presents difficulties in matching production for demand, especially in terms of market shifts in and out of recession. For example, automobile sales typically change up to 25% between years; orders for machine tools can increase by up to 75% or decrease by 50% from one year to another (Anderson, Fine, and Parker, 2000). Generally, market volatility can be cyclical, seasonal, trend, or random. Volatility in consumer demand can be much the same, but is generally considered driven by rational choice based on income, tastes, expectations and the prices of other goods (Dolan & Lindsey, 1988). Demand volatility affects the manufacturer by increasing working capital costs and variable costs associated with safety stock, buffer inventory, stock outs, increased lead times, variable staffing, etc. (Bolton, 1998).

Bullwhip Effect

Responses to demand volatility by the manufacturer and/or the supply chain itself often induce or magnify the impact of such changes (Oliver & Webber, 1992). Evidence has indicated that variance of plant production is often greater than the variance of manufacturer sales (Baganha & Cohen, 1998) and that variability of demand will be amplified in a type of "ripple effect" through the supply chain (Fransoo & Wouters, 2000). Evidence of this is found in various functions all along the supply chain, and is referred to as the bullwhip effect (Lee, Padmanabhan, & Whang, 1997).

The bullwhip effect is increasing or amplified variability of demand upstream in the supply chain. The farther a company is upstream in a supply chain (the farther it is from the consumer), the more demand variance becomes distorted as the distortion propagates through the chain. Generally, the bullwhip effect is an outcome of the strategic interactions among rational supply chain members due to skewed information in the supply chain as each successive upstream process overreacts to accommodate the increasing variability in customer demand (Lee, et al., 1997).

More specifically, the bullwhip effect is caused by four major factors (Fransoo & Wouters, 2000): order batching; price fluctuations; rationing and shortage gaming; and demand forecast updating. Order batching and price fluctuations are factors that can be induced by the company (terms of sale, policy, etc.). This can be controlled through reduction of promotions and other means of stabilizing order behavior, such as by stable pricing.

Rationing and shortage gaming occurs as product demand exceeds supply. The supplier needs to ration its product to customers; knowing this, customers may order more than they need. This results in decreasing orders when the shortages are later eliminated. Rationing methods based on past sales rather than on orders placed takes away the incentive for customers to inflate order sizes (Fransoo & Wouters, 2000).

Demand forecast updating is the amplification of demand forecasts based on increasing order size upstream in the chain. This can be solved by making appropriate data on consumer demand, such as electronic point of sale data (EPOS) available directly to all companies in the chain. Further, a single source of forecasting data can be determined for the entire supply chain (Lee, et al., 1997). For example, companies upstream often do not have access to direct consumer data, (i.e. EPOS); they base their order decisions on the incoming orders from the next downstream company. This can lead to distortion if not coordinated throughout the chain. Any member of the chain could hold a different level of finished goods or components inventory equal to a number of periods of expected demand based on downstream data; if these demand periods are different, distortion will occur upstream (Anderson, et al., 2000). Each process creates a buffer in the form of excess capacity, longer lead time, or greater inventory; in any case, the overall result is higher production costs and/or poorer customer service.

Effective communication (including information exchange) is key to addressing the problems associated with the bullwhip effect. Information sharing is not enough. However, measurement of the bullwhip effect and the use of EPOS data in supply chains itself has proved problematic (Fransoo & Wouters, 2000). This is generally due to limitations of the current information systems, and measurement issues. The way the data is accrued and measured can yield different demand determinations. A correct, well - defined measurement must be used by all in the chain. Of course, demand data and determination will always be incomplete (as is forecasting) as conceptually, any part of a supply chain is part of a greater supply web; certain product line demand determinations may not be possible as a particular web subset does not exist in isolation (Fransoo & Wouters, 2000).

RESPONSE TO UNCERTAINTY

Companies have attempted to deal with demand uncertainty in many ways. Many traditional responses to uncertainty are reactive and have been found to be detrimental to the company, either in terms of trade-offs at the expense of another function, or in inducing and amplifying the volatility. However, some proactive approaches to addressing the uncertainty problem, such as forecasting, have served only to exasperate the problem. As will be seen, many of these methods are related and mutually reinforcing. For facilitation of discussion, these have been arbitrarily divided between marketing and sales, and manufacturing production and inventory.

Demand Management

Demand planning processes include any means a company takes to anticipate customer demand and ensure sufficient product is available (right time, right place, right price). It includes such activities as demand forecasting, inventory management, capacity planning, production planning and scheduling, and materials requirements planning (Bolton, 1998). These processes have developed rapidly in the last decade. For example, lean manufacturing and JIT were developed to improve customer service through reduced lead times from smaller batch-size (to one-piece flow). Quick response (QR), an extension of JIT used in manufacturer-retail channels (Iyer & Bergen, 1997), was developed to shorten lead times. Efficient consumer response (ECR) is a supply chain management technique used to link all members of a supply chain to fulfill customer demand more effectively. It integrates four key elements: efficient store assortments, efficient replenishment, promotions, and new product introductions (Sharpe & Hill, 1998).

All these approaches can successfully reduce lead times and costs in a supply chain. They all make the assumption however, that demand volatility is a given input into the process. The strategic supply chain management process concept of demand management, by contrast, proactively attempts to smooth demand volatility (Bolton, 1998). In general, variance can be addressed by eliminating it, reducing it, or adapting to it (Standard & Davis, 1999). This is important, as volatile customer demand can have detrimental effects on performance in terms of the cost and complexity of business operations. Demand volatility can increase working capital cost through increased inventory levels, and variable costs as a result of increased labor costs. Complexity is also increased, which must be managed; this can be in the form of increased uncertainty in the supply chain, risk of stock outs, increased lead times, increased risk of obsolescence, and reduced customer service levels (Bolton, 1998).

Demand management from a supply chain perspective refers to actively producing and supplying customers with precision according to actual demand rather than the more traditional indiscriminate production according to forecast demand (Gattorna, 1998). This is analogous to a pull versus a push production system with the pull being generated by the customer. However, it should be noted that this is not an all pull system (which would be ideal). Generally, it is realized in demand management that an all pull system is an ideal; an all pull system makes the assumptions that supplies are highly flexible and unlimited, and that there are no costs tied to instant supply. It is often economically unwise in terms of working capital investment, capacity usage, total costs, and margins. Therefore demand management attempts to synthesize production planning, inventory planning, manufacturing capacity planning, inventory planning, and deployment such that uncertainty is smoothed and the system is flexible enough to address unforeseen problems (Tyndall, Gopal, Partsch, & Kamauff, 1998). By understanding the causes of these demand spikes, companies can either eliminate them or manage their production and supply chain processes to accommodate them.

Marketing and Sales

Marketing and sales can do much to address competitive issues through such activities as market segmentation, product mix and demand-planning activities to increase customer demand. Demand-planning activities will be discussed, as they will have the greatest impact on the manufacturing function in terms of planning production. Market segmentation and product mix are considered beyond the scope of this discussion.

In terms of marketing and sales, traditional responses to demand volatility have included demand-planning processes such as: terms of trade (credit terms); company policies; and promotions and pricing, and sales quotas. These responses, intended to increase customer demand, can lead to unintended volatility and uncertainty if not coordinated with the manufacturer.

Terms of trade (credit) can result in demand swings when customers make the rational decision to order at certain times of the month to maximize credit terms. Similarly, company policies such as minimum order quantities distort consumer ordering behavior (Bolton, 1998). Promotions (i.e. bulk discounts or sales) are generally intended to increase sales; however, unless a sustainable increase in market share is achieved following the promotion, consumer buying behavior is distorted. This will result in a production-demand mismatch if production planning has not factored this in (Bolton, 1998). However, if a promotion or policy is properly coordinated between all parties (including the customer, such as by advance information of customer needs) benefits can be realized throughout the chain (Gilbert & Ballou, 1999). The time periods for which the achievement of sales quotas are measured will induce significant variability into the underlying intrinsic demand pattern. Demand will peak at the end of the measured quota period, resulting in the hockey stick phenomenon, or demand curve (Chase, et al., 1998). This volatility can be reduced by coordinating efficiency and financial performance measurements (Chase, et al., 1998), and rewarding the sales force for leveling factory orders and penalizing variability induction (Mahoney, 1997). This can be achieved through improved functional integration.

TRADITIONAL MANUFACTURING RESPONSES TO DEMAND VOLATILITY

Traditional approaches to production planning and control systems, seeking to maximize efficiency and utilization, are no longer adequate, and are even detrimental in a customer-centered environment (Maskell, 2001). Firms wanting to compete successfully need to look to new concepts, processes and technologies to help them adapt and ensure that their production processes to optimize the balance between customer satisfaction and efficiency (Evans & Danks, 1998).

In terms of manufacturing, SCM possesses similar characteristics to other popular management concepts, including lean manufacturing, just-in-time production (JIT), quick response manufacturing, and other terms such as agile manufacturing. All of these philosophies or concepts share the same core goals: increased success (profit) through improved customer service by eliminating waste from the system. This waste can include money, time, materials, or described in terms of flexibility and improved quality.

Manufacturing attempts at addressing uncertainty have focused on improving forecasting, and optimizing production and inventory planning through production process methods to reduce throughput times, lead times, and cycle times (Raman, 1998).

Forecasting

Much of production planning is based, at least in part, upon forecasts. Forecasts are necessary to allow reduced aggregate customer and supplier lead times by building ahead to meet demand (Mahoney, 1997). Forecasts can be considered an indirect link to the customer, as opposed to a direct link that can be considered a customer order

(Olhager & Wikner, 2000). It is generally understood that forecasting is more accurate for larger groups over shorter time periods, and are always wrong anyway. Most manufacturers thus realize the need for planning and manufacturing techniques that eliminate forecasts or make them more accurate, especially lean manufacturing or JIT (Williams, 1996). Many companies that face unpredictable demand have found that they can decrease lead times by reducing their dependence on forecasts that tend to be volatile and thereby improve their responsiveness to demand. Indeed, the performance of JIT ordering systems that do not utilize demand forecasts (the order release for each process is determined on the basis of actual demand) has been shown to have better performance than other ordering systems such as Material Requirements Planning, or MRP (Takahashi & Nakamura, 2000). Advances in information technology, e.g. electronic-point-of-sale (EPOS) and electronic data interchange (EDI), and new software technology have sometimes led to an increased level of (misplaced) trust in forecasting (Raman, 1998). In addition, the bullwhip effect and other sources of inaccurate information can distort perception of demand. For example, inaccurate recording of sales data impedes the implementation of data-based forecasting in some companies, as when only one of two different products with the same price are scanned, e.g. a can of regular Coke and a can of Diet Coke scanned as two Diet Cokes (Raman, 1998). In terms of demand management through forecasting, the ideal situation is to eliminate forecasts. When this is not possible, the forecasts must be improved.

<u>Production and Inventory Planning</u>

Within its sphere of influence, the manufacturing function can address demand uncertainty in two major ways: inventory and production process. These two areas are obviously interrelated. This discussion demarcates manufacturing processes into two main groups: push and pull. Push systems tend to generate high inventory levels; pull systems tend to reduce it.

Inventory

Inventory management has received much attention due to its significant cost: firms can have millions or billions of dollars invested in on-hand inventories (Norek, 1998). Freeing up even a small percentage of inventories held can free substantial capital for use in other areas of the company.

Inventory is kept by all firms (including companies that use lean, or JIT) for several reasons: to maintain independence of operations (reduce setup times at workstations); to allow flexibility in production scheduling; to provide a safeguard for variation in raw material deliver time; to take advantage of economic order size; and to absorb variations in demand (Chase, et al., 1998).

One of the principal reasons used to justify investment in finished-goods-inventories (FGI) is its role as a buffer, or safety stock, to absorb demand variability. Buffer inventories can serve a valuable purpose, even in a synchronous or JIT environment (Krupp, 1997). Safety stock can be seen as a lower bound inventory level used to hedge the risk of stock outs. Safety stock or buffer inventory may be needed in certain situations, i.e. with unreliable suppliers, when demand exceeds production plans, etc. In many manufacturing environments, failure to provide product on demand will result in lost sales and customer goodwill. In most cases, inventories can destabilize material flow patterns; this contributes and is reinforced by the bullwhip affect.

However, under certain demand and industry conditions, econometric models have shown that inventories can have a stabilizing effect, or no effect at all (Baganha & Cohen, 1998). To determine if safety stock should be carried (and at what level), cost/benefit analysis should be undertaken. More specifically, the net marginal benefit must be determined by comparing the profit realized from the recouped lost sales and goodwill to the cost of carrying the inventory (Krupp, 1997). Any investment in safety stock beyond what is absolutely required to support this is considered waste.

Inter-process buffer inventory, or work in process inventory (WIP) is used to reconcile an imbalance between supply and demand within the locus of internal production disruptions that occur in the short term (and may even be expected), as opposed to intrinsic or extrinsic external demand variability. In this case, it is used to increase the capacity and flexibility of the production system; to address problems associated with disruptions such as processing time variability, machine breakdowns, machine preventive maintenance, repair, unplanned absenteeism, poor supplier quality, etc. This is especially true in a multistage, serial flow, high-mix, low-volume manufacturing environment (Mahoney, 1997). This is usually based on strong economic incentives for reducing fluctuations in production levels, such as fixed set up costs, as well as protection against stock outs, which can adversely affect revenue.

JIT, the core principle behind lean manufacturing, is often perceived (and often defined) as activities designed to achieve high-volume production using minimal inventories of all types (raw materials, WIP, FG); any inventory held over the absolute minimum needed (ideally zero) is waste (Chase, et al., 1998). However, reducing inventory per se is not an explicit goal of JIT, rather it is a beneficial consequence of reducing variability in the system (Standard & Davis, 1999). Indeed, when instituting a pull production system, it is recommended by some to keep initial WIP levels high to ease introduction of the system in a relatively risk-free manner (Standard & Davis, 1999). Generally, inventory (especially WIP) is not in itself a problem, but an outward manifestation of other problems in the factory; a high WIP level indicates improper conditions. Typically, inventory will accrue due to long setup times; large batch production; frequent equipment breakdowns; cancelled or preempted orders; unavailable components, bottlenecks, or absenteeism (Standard & Davis, 1999).

Poor or nonexistent planning and scheduling strategies will inflate inter-process buffer inventories as well as create the need for inter-process buffer inventories that otherwise would be unnecessary. A failure on the part of management to understand and recognize the causal relationship between planning and scheduling to the supply and demand imbalance problem will perpetuate the creation of excess inventory and reduce the ability to compete. Many managers use inflate FGI levels to mask the effects of poor or nonexistent planning and scheduling strategies. It has been suggested that buffer inventory makes explicit the implicit assumptions of managers and thus serves as a measure of managerial competence (Mahoney, 1997).

An alternative to safety stock is to use safety lead time. Studies have suggested that when possible, safety lead time is preferable to safety stock when demand is known with certainty, and that the choice of methods is inconsequential when knowledge of demand is unknown (Standard & Davis, 1999).

In the absence of a holistic system, the role of inventory is viewed differently by separate functional areas within the company. For example, traditional manufacturing prefers longer production runs of like units to spread fixed costs of setup and changeover; sales and marketing would prefer high finished goods inventory so stock outs do not occur; purchasing departments often have incentive to buy in larger quantities to achieve a lower price per unit; in contrast, inventory –management personnel and JIT or lean manufacturing prefers inventory as low as possible (Norek, 1998). Opposing views must be reconciled for optimum inventory levels in line with company strategy; this can be achieved through a holistic approach of common, cross-functional performance incentives and measures. Supply chain management methods can improve or eliminate problems associated with buffers and other traditional inventory responses to uncertainty. Communication throughout the supply chain, by shared appropriate EPOS data, EDI, or common forecasts, can eliminate surprises and overreactions.

Traditional production and inventory planning has generally involved trade-off analyses such as economic order quantity (EOQ). A pitfall of most of these planning methods is that they are static, ignoring the possibility of continuous improvements. For example, the classic EOQ model calculates optimal order quantity based on the trade-off between set-up costs and inventory carrying costs (Williams, 1996). This assumes that set-up costs are fixed and cannot be altered by management practice; this assumption is unrealistic in the long term and thus reduces it relevance (Raman, 1998).

Mass Production

Traditionally, U.S. manufacturing has been based on mass production. Mass production involves the assumption that the following practices were most efficient (Cusumano, 1988): high levels of worker and equipment specialization that are constantly active; extensive automation; long production runs requiring long setup times;

large manufacturing scales with buffer inventory; "push" production control; and inspection as defect control.

The thinking behind this is that cost or time efficiencies are gained by eliminating setup and changeover times. Further, perhaps the large lot size items have a higher profit margin; this large lot may be used to reach or surpass production quotas; finished goods inventory will accrue, which is treated as revenue by most accounting systems. This revenue may be applied to that department, which makes it continue to appear profitable later in the month when the more difficult or less profitable jobs are produced.

Push production control systems schedule the factory based on orders or forecasts using material requirements planning (MRP) or a related algorithm. In a push system, the orders or forecasts are analyzed, and production material is procured and scheduled to arrive when needed. The factory is scheduled to produce necessary components and subassemblies for timely production of the finished goods. This type of system would work extremely well if demand were perfectly predictable and within the capacity constraints of the factory. In such an environment, an MRP-type system would actually result in just-in-time production (Standard & Davis, 1999). The problem comes from unexpected problems and unsatisfied assumptions that are unavoidable in any manufacturing environment: the forecast is always wrong, schedules always change, and nothing goes according to schedule anyway, i.e. Murphy's law (Shook, 1998).

This approach tends to put excessive, sporadic demand on all of the resources. It may result in long production lead time and long customer waiting time depending on the batch sizes. The larger the batch or lot size, the longer is the lead time.

MRP, or material resource planning, a common production and inventory control software technique. Manufacturing Resource Planning (MRPII) is a computer-based system that attempts to integrate all the facets of a manufacturing company. It is often used in high-mix, low-volume manufacturing environments. The fundamental potential flaw with these systems is that production schedules are based on sales forecasts and generally do not provide a mechanism to accommodate for uncertainty (Guide & Srivastava, 2000). Most MRP and MRP II production planning is performed on a monthly basis for a one-year time horizon (Mahoney, 1997); this could also be source of volatility if this time schedule is out of sync with other entities in the chain. Reduction of uncertainty in this case is usually addressed in one of two ways: frequent rescheduling, or safety buffers (safety stock and safety time). Frequent rescheduling is not preferred, as it is not responsive to the marketplace, and it leads to increased nervousness in the system, which could in turn cause higher system costs and lower service levels (Guide & Srivastava, 2000). While not much is known about the effects of buffering in an MRP system and its interaction with other subsystems, buffering appears to be the most viable option with MRP or MRP II. Improved integration and information exchange could improve upon this.

However, MRP causes problems when used to control production rather than to plan materials. The assumptions and models underlying MRP are fundamentally flawed. For example, MRP algorithms assume incorrectly that the time required to procure an item from an internal or external supplier is independent of the quantity ordered. MRP also assumes that the time required to produce an item is independent of the status or loading of the plant (when the opposite is true). The result of all this is shortages and late deliveries to customers. Without buffers, MRP has an inability to contend with uncertainty in production schedules, production modes other than batch and queue; and changes in customer demand (Standard & Davis, 1999).

Because push systems often result in a large amount of finished goods inventory, a common result when demand is reduced is to suspend production. Thus, workforce reductions have been common. Workforce reductions have also played an integral role in the restructuring strategies of many companies. While some empirical studies have shown that workforce reductions significantly improved subsequent financial performance (based on growth in sales and market capitalization) in the short term (Wayhan & Werner, 2000), other companies (especially those involved in JIT or lean production) have been successful in de-emphasizing workforce reduction in lieu of more people-oriented approaches. For example, Donnelly Corporation has a no-layoff, no time clock policy (Liker & Allman, 1998).

Pull Systems

As noted above, there has been a major movement in the U.S. to incorporate successful tactics used by Toyota with the Toyota Production System (TPS), especially in terms of JIT and lean manufacturing. These methods focus on a process perspective with emphasis on throughput reduction. Throughput is the time through process, and is further discussed below in terms of lead time and cycle time. Throughput time reduction has several side benefits that are helpful: good quality, low inventories, and quick market response, or flexibility (Schmenner, 1988). Flexibility, in terms of reduced throughput, lead time, or cycle time, is a key factor in meeting demand volatility, the most obvious of which is quick market response (Schmenner, 1988).

Pull systems, such as with JIT, Lean, and TOC, are inherently more flexible, require less inventory, and are generally more profitable than scheduled systems such as MRP; (Standard & Davis, 1999). A pull system responds in real time to the status of the factory; it is self-correcting and self-regulating. The most notable advantages of a pull system are that stock outs are eliminated and inventory drops markedly; other benefits include a streamlined flow of material and information, shorter cycle time and lead time, greater flexibility, higher revenues, lower production cost, and ultimately higher profit (Standard & Davis, 1999).

In a pull system, signals are sent upstream more frequently, as the objective is to provide all processes with real-time information about the timing and quantities of material required. A pull signal is not based on a schedule or a forecast; it is a reaction to material that has been consumed; therefore, production material is released only to replenish what has already been used. In contrast, a push system releases material to the next process to satisfy a pending demand. Pull is responsive; push is anticipatory (Standard & Davis, 1999). Real-time information about timing and quantities is crucial. Just as this works within the manufacturing function, this can be extended through the supply chain.

Another aspect of lean or JIT systems is Heijunka. Heijunka is the TPS term for leveled, mixed production by both volume and variety (Shook, 1998). This is related to *takt* time, which links production to the customer by matching the pace of production to the pace of actual final sales. For example, Toyota takes their forecasted orders for the month and creates a leveled schedule with a preset sequence that spreads out parts over the scheduling period. Suppliers in the chain do not produce directly to what Toyota is assembling every hour; rather, they take develop an internal leveled schedule based on the leveled schedule of Toyota. A major goal of leveling is to avoid making large batches of any one item (such as all blue or all red widgets) and mix up production to have a smooth flow and minimize inventory (Liker & Allman, 1998).

Heijunka is a tool for scheduling production quantity and product mix based on customer demand; as a result, the factory produces at the rate of customer demand, making what the customer wants when the customer wants it (Standard & Davis, 1999). Therefore, for a given time period, such as a day or a week, all the orders for one product are combined and distributed evenly through the production schedule and combined with an evenly spread schedule for another product until all products in the daily schedule are thoroughly mixed (Williams, 1996).

Mathematically, this is equivalent to reducing the variability in the production schedule; the demands on suppliers and on the production operation are evenly distributed, and variability in demand for materials, equipment, and effort is minimized (Standard & Davis, 1999). Commonly in mass production, customer orders are consolidated into huge orders by product type. These huge orders produced in a single production run tend to deplete supplies and overload equipment and personal such that processes cannot keep up with sporadic increases in demand (Jung, Ahn, H., Ahn, B., & Rhee, 1999). Instability forces suppliers to react to unexpectedly changing requirements, which increase the variability of processing time, which increases cycle time and lead time; cost increases through increased overtime, undertime, inventory, premium freight, changeovers, material handling, record keeping, and disruptions in quality (Inman &

Gonsalvez, 1997). The effects of uneven scheduling also propagate upstream in the manufacturing process.

Another type of production mixing is in-line sequencing. This resembles level, sequential flow because it also involves mixed-model production. Schedules and sequences of production are sent to suppliers; the suppliers send the necessary materials just in time to meet production requirements. However, this system can be inflexible. Once the schedule is set, it is difficult to change. This inflexibility magnifies the impact of suppler tardiness, parts shortages, equipment downtime, and any production line difficulties (Mahoney, 1997).

In the manufacturing environment, the customer requirements change radically and frequently, and therefore scheduled production rarely goes as planned. In most manufacturing companies, the uncertainty about customer demand and the variability in production operations preclude successful in-line sequencing; level, sequential flow is adaptive and responsive to demand fluctuation. The responsiveness and even mix results in a steady utilization of production resources which helps eliminate the bullwhip effect (Standard & Davis, 1999).

Reducing lead times, the total time from raw material to market (Chase, et al., 1998) is another common response to changes in demand. Demand volatility can lead to internal scheduling problems, which results in poor customer service. A traditional response has been an attempt to reduce total lead time by eliminating constraints or bottlenecks (as in TOC). However, supply chain management investigations have revealed instances where the consumer need was greater reliability – not necessarily shorter lead times (Oliver & Webber, 1982). However, lead time has been shown to be directly related to cost and inversely related to total revenue (Standard & Davis, 1999). Lead time reduction can be reduced by reducing cycle time.

Reduction of cycle time can result in reduced lead time, allowing better flexibility in meeting uncertainty. Generally, cycle time can be reduced by: examining inventory to look for production problems; keep production material flowing to the customer; synchronizing production; keeping workload steady; and reducing variability (Standard & Davis, 1999). Cycle time is the time between two identical units completed on a line (Chase, et al., 1998); it can also comprise any waiting times; i.e. processing time, setup time, conveyance time, queue times, etc. (Williams, 1996). Reduction in cycle times can lead to: shorter lead times; less impact on the factory when orders are canceled; less reliance on forecasts about future demand; greater manufacturing flexibility to respond to changing customer demand; fewer disruptions due to changes in product design; less need to expedite special rush orders (Standard & Davis, 1999). Synchronizing production processes and smaller batch sizes can reduce cycle time and lead time.

In general, small, frequent order releases yield short queues, maximum flexibility, short cycle time, and, consequently short lead time (Mahoney, 1997). The key in the manufacturing equation then is ultimately to reduce variability. A longer and more variable cycle time means that longer lead times will be needed to achieve a given customer service level or percentage of on-time deliveries.

SUPPLY CHAIN MANAGEMENT AND INTEGRATION

Uncertainty, especially in terms of demand, will always be present. How a company addresses this uncertainty is critical to success. It has been suggested that many traditional methods, such as forecasting and holding buffer inventories, are costly and inefficient, and disastrous if not appropriately matched with true demand. The efficient exchange of information, within the company and the supply chain, hedges this risk and allows companies to meet demand needs in a timely fashion. Supply chain management principles of integration and information sharing for furthering a common strategy is one possible mechanism of addressing the inevitability of uncertainty.

In order to design an efficient production planning system, a thorough understanding of the environment in terms of markets, customers, products, and transformation processes is a must (Olhager & Wikner, 2000). This is especially important in planning for uncertainty. Thus, it has become increasingly important to link the production planning and control process to the strategic level of decision making in order to meet priorities of quality, delivery speed and reliability, price and flexibility; it provides the framework for translating the strategic intent into concrete tactical and operational plans (Olhager & Wikner, 2000). A holistic strategy thus involves three key elements: internal functional integration; external integration (between entities in the chain); and the supporting infrastructure that makes this integration possible.

Internal Integration

Manufacturing can be a formidable source of competitive advantage if it is equipped and managed properly. To achieve this, a company must have the correct alignment of manufacturing and organizational strategies, especially with marketing; indeed, aligning marketing and manufacturing strategies can make a company more responsive to changing customer demands (Weir, Kochhar, LeBeau, & Edgeley, 2000). A coherent manufacturing strategy must be developed which is in line with the other functional strategies of the company with close linkages to other functional areas. A study by Tracey, Vonderembs, & Lim (1999) has shown that firms with high levels of manufacturing managers involvement in strategy development had high levels of "competitive capabilities" which translated into high performance as measured by market share and sales. These competitive capabilities were represented by price, quality, and reliability.

In order for integration to be achieved, communication and commonality must be achieved. Commonality is the alignment of all business functions to a common, strategic goal. In addition, performance measures and accountability must be the same; i.e., each function cannot be managed as an isolated, discrete function, unaware of how their actions affect each other, while each is measured and rewarded for different and sometimes conflicting goals (Beech, 1998). Local optimization must be eliminated in favor of system optimization.

External Integration

In supply chain management, this concept of system optimization in lieu of local optimization is extended beyond the confines of the organization to customers and suppliers within the chain. Similar core processes of the chain can be managed (to a degree), in concert. By considering each of the processes as they flow from one end of the supply chain to the other, companies at different points along the chain can synchronize their activities to maximize efficiency and returns; this has the greatest benefit of understanding demand and being better able to address demand uncertainty (Beech, 1998).

Supplier performance is intricately tied to organizational performance. If suppliers are unreliable, deliver sporadically, deliver variable (especially large) batches, or delivered parts are of poor quality, the factory will be danger of having disrupted production. This has the negative effect of lowering customer service. Thus, supplier performance has a profound influence on factory performance; it is therefore advantageous to treat suppliers as partners for success and integrate them into the overall process (Bhote, 1989). There are different levels of integration across the chain; this can range from sharing bits of information (up to a coordinated information flow in which the same EPOS or EDI data streams to all those in the chain), to a strategically aligned chain with coordinating plans, forecasts, etc. (Tyndall, et al., 1998).

<u>Supporting Infrastructure</u>

The foundation that makes all this possible is correct and appropriate information exchange; i.e. communication. As discussed, a sharing of demand data from EPOS can be shared across links and functions to develop a coordinated forecast so as to eliminate the bullwhip effect; preferably, demand information can be exchanged in such a manner that forecasts are not needed. One advantage of a tightly communicative supply chain is that the production plans can be based less on forecast and more on actual demand; in this type of environment it is much more likely that all sources of demand have been accounted for and there will be no (or at least minimized) surprises that upset production (Fredendall & Hill, 2001). If the entire supply chain is viewed as one entity driven by the actual market demand rather than each element operating in isolation, variability can be absorbed.

CONCLUSION

Supply chain management provides a means of reducing uncertainty and volatility in order to optimize a system for strategic advantage. It is not an answer to everyone's problems. As with other popular management concepts and tools, it is not a one-size fits all solution, nor should it be. All firms face different situations through their particular market, environment, culture, and product. Indeed, a one-size fits all solution to manufacturing problems could conceivably reduce any strategic or competitive advantage. For any manufacturer, the determination of management technique must come from the need itself.

The true value of supply chain management lies in its way of thinking. Supply chain management issues force a company to view the entire process or system, not only within the company, but also with its suppliers, competitors, and customers. Manufacturing does not lie in a vacuum. Events on the factory floor affect, and are in turn affected by, events all through the chain. Supply chain management calls attention to this and attempts to provide a means by which to utilize this information.

REFERENCES

Anderson, E. G., Fine, C. H., & Parker, G. G. (2000). Upstream volatility in the supply chain: The machine tool industry as a case study. Production and Operations Management, 9 (3), 239-261.

Baganha, M. P., & Cohen, M. A. (1998). The stabilizing effect of inventory in supply chains. Operations Research, 46 (S3), S72-S83.

Beech, J. (1998). The supply-demand nexus: From integration to synchronization. In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp. 92-103). Brookfield, VT: Gower.

Bhote, K. R. (1989). Strategic supply management: A blueprint for revitalizing the manufacturer-supplier partnership. New York: AMACOM.

Bolton, J. (1998). Effective demand management: Are you limiting the performance of your supply chain? In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp.138-156). Brookfield, VT: Gower.

Burt, D. N., & Doyle, M. F. (1993). The American keiretsu: A strategic weapon for global competitiveness. Homewood, IL: Business One Irwin.

Chase, R. B., Aquilano, N. J., & Jacobs, F. R. (1998). Production and operation management: Manufacturing and services (8th ed.). New York: Irwin McGraw-Hill.

Christopher, M. (Ed.). (1992). Logistics: The strategic issues. New York: Chapman & Hall.

Cox, A. (1999). Power, value and supply chain management. Supply Chain Management, 4 (4), 167-175.

Cusumano, M. A. (1988). Manufacturing innovation: Lessons from the Japanese auto industry. Sloan Management Review, 30 (1), 29-39.

Dertouzos, M. L., Lester, R. K., Solow, R. M., & The MIT Commission on Industrial Productivity. (1989). Made in America: Regaining the productive edge. Cambridge, MA: The MIT Press.

Dolan, E. G., & Lindsey, D. E. (1988). Economics (5th Ed.). New York: The Dryden Press.

Drucker, P. F. (1990). The emerging theory of manufacturing. Harvard Business Review, 90, (3), 94-102.

Evans, R., & Danks, A. (1998). Strategic supply chain management: Creating shareholder value by aligning supply chain strategy with business strategy. In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp. 18-37). Brookfield, VT: Gower.

Fransoo, J. C., & Wouters, M. J. F. (2000). Measuring the bullwhip effect in the supply chain. Supply Chain Management, 5 (2), 78-89.

Fredendall, L. D., & Hill, E. (2001). Basics of supply chain management. New York: St. Lucie Press.

Gattorna, J. (Ed.). (1998). Strategic supply chain management: Best practice in supply chain management. Brookfield, VT: Gower.

Gilbert, S. M., & Ballou, R. H. (1999). Supply chain benefits from advanced customer commitments. Journal of Operations Management, 18 (1), 61-73.

Goldratt, E. M., & Cox, J. (1992). The goal: A process of ongoing improvement (2nd ed.). Great Barrington, MA: The North River Press.

Guide, V. D. R., & Srivastava, R. (2000). A review of techniques for buffering against uncertainty with MRP systems. Production Planning & Control, 11 (3), 223-233.

Inman, R. R., & Gonsalvez, D. J. A. (1997). The causes of schedule instability in an automotive supply chain. Production and Inventory Management Journal, 38 (2), 26-31.

Iyer, A. V., & Bergen, M. E. (1997). Quick response in manufacturer-retailer channels. Management Science, 43 (4), 559-570.

Jung, H., Ahn, H., Ahn, B., & Rhee, S. (1999). Impacts of buyers' order batching on the supplier's demand correlation and capacity utilization in a branching supply chain. Production Planning & Control, 10 (5), 472-485.

Krupp, J. A. G. (1997). Safety stock management. Production and Inventory Management Journal, 38 (3), 11-18.

Lamming, R. (2000). Japanese supply chain relationships in recession. Long Range Planning, 33 (6), 757-778.

Langley, C. J. (1992). The evolution of the logistics concept. In Christopher, M. (Ed.), Logistics: The strategic issues (pp. 17-28). New York: Chapman & Hall.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: The bullwhip effect. Management Science, 43 (4), 546-558.

Liker, J. K. (Ed.). (1998). Becoming lean: Inside stories of U.S. manufacturers. Portland, OR: Productivity Press.

Liker, J. K., & Allman, K. (1998). The Donnelly production system: Lean at Grand Haven. In Liker, J. K. (Ed.), Becoming lean: Inside stories of U.S. manufacturers (pp. 200-245).

Lummus, R. R., Vokurka, R. J., & Alber, K. L. (1998). Strategic supply chain planning. Production and Inventory Management Journal, 39 (3), 49-58.

Mahoney, R. M. (1997). High-mix low-volume manufacturing. Upper Saddle River, NJ: Prentice Hall.

Marien, E. J. (2000, March/April). The four supply chain enablers. Supply Chain Management Review, 60-68.

Maskell, B. (2001). The age of agile manufacturing. Supply Chain Management, 6 (1), 5-11.

Mohanty, R. P., & Deshmukh, S. G. (2000). Reengineering of a supply chain management system: A case study. Production Planning & Control, 11 (1), 90-104.

Norek, C. (1998). Inventory management: Keeping costs down while lifting customer satisfaction. In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp.381-392). Brookfield, VT: Gower.

Olhager, J., & Wikner, J. (2000). Production planning and control tools. Production Planning & Control, 11 (3), 210-222.

Oliver, R. K., & Webber, M. D. (1992). Supply-chain management: Logistics catches up with strategy. In Christopher, M. (Ed.), Logistics: The strategic issues (pp.63-75). New York: Chapman & Hall.

Raman, A. (1998). Towards finding the perfect match: Matching supply with demand in supply chains. In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp.171-187). Brookfield, VT: Gower.

Schmenner, R. W. (1988). The merit of making things fast. Sloan Management Review, 30 (1), 11-17.

Sharpe, D., & Hill, R. (1998). Efficient consumer response: From harmful competition to winning collaboration in the grocery industry. In Gattorna, J. (Ed.), Strategic supply chain alignment: Best practice in supply chain management (pp. 104-122). Brookfield, VT: Gower.

Shook, J. Y. (1998). Bringing the Toyota production system to the United States: A personal perspective. In Liker, J. K. (Ed.), Becoming lean: Inside stories of U.S. manufacturers (pp. 40-69).

Standard, C., & Davis, D. (1999). Running today's factory: A proven strategy for lean manufacturing. Dearborn, MI: Society of Manufacturing Engineers.

Takahasi, K., & Nakamura, N. (2000). Reactive logistics in a JIT environment. Production Planning & Control, 11 (1), 20-31.

Tracey, M., Vonderembse, M. A., & Lim, J. (1999). Manufacturing technology and strategy formulation: keys to enhancing competitiveness and improving performance. Journal of Operations Management, 17 (4), 411-428.

Tyndall, G., Gopal, C., Partsch, W., & Kamauff, J. (1998). Supercharging supply chains: New ways to increase value through global operational excellence. New York: John Wiley & Sons.

Wayhan, V. B., & Werner, S. (2000). The impact of workforce reductions on financial performance: A longitudinal perspective. Journal of Management, 26, (2), 341-363.

Weir, K. A., Kochhar, A. K., LeBeau, S. A., & Edgeley, D. G. (2000). An empirical study of the alignment between manufacturing and marketing strategies. Long Range Planning, 33 (6), 831-848.

Williams, B. R. (1996). Manufacturing for survival: The how-to guide for practitioners and managers. Reading, MA: Addison-Wesley.