



# From supply chain to demand chain: the role of lead time reduction in improving demand chain performance

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## Abstract

To improve demand chain performance, is it better for parties in a supply chain to focus first on lead time reduction, or instead concentrate on improving the transfer of demand information upstream in the chain? Even though the theory of supply and demand chain management suggests that lead time reduction is an antecedent to the use of market mediation (i.e., adjusting production to fit actual customer demand as it materializes) [Harvard Business Rev. 75 (2) (1997) 105] to reduce transaction uncertainty in the chain, which can be conceptualized as the primary goal of supply chain management [J. Operat. Manage. 11 (3) (1993) 289], demand chain parties often are observed in practice to begin with information transfer improvement, ignoring the problem of long lead times. In this paper, we propose a framework for prioritizing lead time reduction in a demand chain improvement project, using a typology of demand chains to identify and recommend trajectories to achieve desirable levels of market mediation performance.

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## 1. Introduction

A Nordic pulp and paper producer was experiencing difficulties in managing its supply chain, which had become complex as a result of both increasing customization of its products and the company's shipping of products from its Nordic plants throughout continental Europe. The lead time from customer order to delivery averaged 6 months; hence, the pipeline

contained 6 months of inventory. Following traditional paper industry rules of thumb, the company attempted to maintain an equipment utilization level of approximately 90%. Production of various paper grades followed a standard 4-week cycle, with the sequence organized to minimize changeover disruptions. The 4-week cycle implied that a particular grade would be produced during a period of a few hours, then not produced again until the following cycle. This cycle approach resulted in large lot sizes, which caused even greater delays as they moved through the pipeline. Despite the large amount of inventory in the pipeline, stockouts were frequent because the inventory in the pipeline did not match what customers needed. The long lead times hindered the company's ability to move into custom markets, where profit margins were

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considerably higher than for standard products. With these considerations in mind, the company hired a well-known consulting firm to assist in improving the performance of its supply chain.

Management decided to begin the supply chain improvement project by forming partnerships with distributors, either by acquisition or by strategic alliance. Distributors were expected to cut paper to order, permitting increased responsiveness without needing to reduce the equipment utilization rates or the cycle period at the mills. The information flow throughout the chain was to be made more transparent through installation of an Enterprise Resource Planning (ERP) system. The main focus of the project was on improving the flow of information through use of technology and partnerships. Management believed that an improved information flow would naturally lead to an improved product flow.

Eighteen months and several hundreds of thousands of dollars later, it became clear to management that the improvement project had failed. Inventories had continued to increase as a percentage of sales. Attempts to improve the information flow in the chain had led to reductions in neither inventory nor lead time. The partnerships with the distributors and the information technology installed were unsuccessful in improving the flow of either information or physical goods. The distributors were not able to take pipeline inventory and turn it into customized products: the wrong paper grades were in the pipeline, the distributors were not committed to responding to customer orders, and the paper company had no experience in managing distributors. To make matters worse, the management time invested in the project had caused the core businesses to be neglected.

Reacting to the problem, management decided to return to focusing on their core businesses and to solve the supply chain problem by distributing manufacturing rather than by attempting to improve the performance of the existing chain. The company acquired production facilities in each major market, creating shorter and more manageable supply chains. This solution, though expensive, solved the immediate problem of poor service levels and excessive inventory investment, but it limited the company's ability to improve competitiveness through increased product customization, requiring improved market mediation in the existing chain—that is, through ad-

justing production to fit actual customer demand as it materialized (Fisher, 1997). Instead of pursuing customization supported by market mediation, the company beat a strategic and high-cost retreat into local production of standard products.

Supply chain management theory clearly addresses the limitations to improving demand chain performance through the transfer of demand information when lead times are long (e.g., Fisher, 1997; Fisher and Raman, 1996; Heikkilä, 2002; Lee et al., 1997; Mason-Jones and Towill, 1999; Perry et al., 1999). In practice, however, supply chain improvement efforts frequently are observed to implement information transfer improvements before addressing long lead times, as was observed in this pulp and paper chain. Fisher et al. (2000, p. 118) described the plight of such companies: “Many products today have such long lead times that retailers can’t call for a change in production—even if they have tracked early sales, have paid attention to product testing, and know without a doubt that a change is warranted. As one merchant told us, ‘We do pay attention to our tests. The problem is we already own the product; the test merely reveals that it will be a dog once it gets to the stores.’”

Should the Nordic pulp and paper producer have begun by reducing lead times? If so, how much should lead times have been reduced before the company invested in demand information transfer? Does the choice between investing in improving demand information transfer and reducing lead times depend on the context, or—as implied by much of the supply chain literature—should lead time reduction always come first?

In our view, such confusion results from an insufficiently articulated theory concerning the relationship between lead time reduction and demand information transfer in supply chains. Following Bacharach (1989), a theory is needed to tame the complexities and richness of the supply chain management environment—which is sufficiently complex that Choi et al. (2001; see also New, 1996) suggested modeling supply chains as complex adaptive systems—so that we can capture and understand the underlying relationships that lead to successful supply chain performance.

One approach to managing complexity of empirical data is to organize such data into a typology (Bacharach, 1989). In this paper, we develop a typology of supply chains according to relative lead

times and the demand information transferred from the customer to the manufacturer. We propose that the position of the company within this typology determines the approach that should be followed in improving performance of the chain. We begin by reviewing the supply chain management and lead time reduction literatures, then develop the typology. The typology allows us to identify attractive demand chain contexts and to recommend trajectories for reaching those desirable contexts.

## 2. Literature review

### 2.1. Literature concerning supply chain management

Supply chain management has been defined as “the integration of key business processes from end user through original suppliers that provides products, services, and information that adds value for customers and other stakeholders” (Lambert et al., 1998, p. 1). Frohlich and Westbrook (2002) divided such integration into supply and demand integration. Supply integration includes just-in-time (JIT) delivery (frequent, small lots with a reduction of buffer inventories), reduction of the supplier base, evaluating suppliers based on quality and delivery performance, establishing long-term contracts with suppliers, and the elimination of paperwork. Demand integration includes increased access to demand information throughout the supply chain to permit rapid and efficient delivery, coordinated planning, and improved logistics communication. In this paper, we will use the term “supply integration” to refer to integration that supports the efficient manufacture and delivery of goods, and we will use “demand integration” to refer to integration that supports market mediation, with the primary role of demand integration being the transfer of demand information to facilitate greater responsiveness to changing customer needs.

In the early days of logistics (the precursor to supply chain management), the focus was more on satisfying the need of the supplier for efficiency (in particular, manufacturing and distribution efficiencies) than on satisfying the need of the customer for service or speed. In the early 1980s, pull production concepts, which linked the decision to produce to evidence of downstream demand, caused a new

awareness of the value of market mediation. Sharman (1984, p. 79) wrote, “The Kanban or ‘just-in-time’ inventory systems in the Japanese auto industry provide a taste of things to come in relations between [original equipment manufacturers (OEMs)] and suppliers.”

The emphasis of much of the JIT literature in the 1980s (both theoretical and practical) focused on the pull of product from upstream operations based on the “demands” of the downstream operations, rather than true market mediation as we have defined it. Goods in a typical JIT pull system are not made to order but instead are replenished under the assumption that demand is relatively stable. The objective within JIT historically tended to be taming demand variability rather than taking full advantage of the potential of market mediation. Fisher (1997) described the unrecognized potential for market mediation in automobile sales: most automobiles are purchased from a small selection that happens to be available at a dealer, rather than having the automobile built to order. Nevertheless, JIT resulted in some initial consideration of including market mediation in supply chain management rather than only considering the efficient physical supply of goods.

A second outcome of JIT was a change in attitudes toward suppliers, moving from arms-length negotiations toward partnership. In the early days of JIT, there was considerable emphasis on improving relationships between suppliers and customers, for example through establishing close geographical proximity or increasing communication. Moving from arms-length relationships to some form of alliance was emphasized in most of the classic JIT and operations management literature (e.g., Hall, 1983; Harmon, 1993; Hayes et al., 1988; Schonberger, 1982; Suzaki, 1987).

Ellram and Cooper (1990, p. 8) were among the first post-JIT authors to issue cautions about the risks involved in integrating the supply chain (see also Bensaou, 1999). Handfield (1993, p. 291) extended resource dependence theory (e.g., Pfeffer and Salancik, 1978) to address the question of when the benefits of supply chain relationships (which he referred to as JIT purchasing, or the “social coordination of interdependent actors”) outweighed the risks. According to Handfield, this social coordination was facilitated by a reduction in the supply base combined with information sharing (including, but not limited to, demand information). The resulting model proposed

that demand uncertainty and information sharing were antecedents to supply base reduction, which was an antecedent to JIT purchasing, which in turn was an antecedent to reduced transaction uncertainty, which resource dependence theory holds to be the primary objective of supply chain management. Handfield suggested that the type of environmental and transaction uncertainty in the market would determine the nature of the relationship between buyer and supplier that would be expected to develop, with JIT purchasing relationships likely when the expected reduction in transaction uncertainty justified the loss of control implied by the partnership.

Williams et al. (2002) evaluated electronic information transfers in supply chains from a transaction cost economics viewpoint, noting that the risk of opportunism in supply chain partnerships increased with the quantity and complexity of the information to be transferred.

A survey of retailers and their suppliers sponsored by Syncra Systems in 2000 indicated significant unwillingness to share information that, in many cases, was readily available. For example, only 25% of those surveyed related that they regularly shared point-of-sale (POS) data with channel partners ([www.businessweek.com](http://www.businessweek.com), accessed, 2003).

As interest in supply chain management increased during the late 1980s and the 1990s, researchers began to focus on the speed and quality of information flow through the chain, with the Quick Response initiative in the apparel industry being one of the most visible efforts (e.g., Abernathy et al., 1999; Fisher and Raman, 1996). Lee et al. (1997) applied Forrester's (1961) concept of industrial dynamics to the flow of information in the supply chain, demonstrating that the variability of information received by the supplier is substantially greater than the variability of demand when (a) orders form the only information concerning demand that is transferred within the chain, (b) orders are batched, (c) prices fluctuate, and (d) the customer reacts to concerns about being placed on allocation by playing a rationing game (i.e., by increasing the order quantity relative to actual demand to avoid shortages). Lee et al. (1997, p. 548) demonstrated that this "bullwhip effect"—that is, the distortion of demand fluctuations, which are amplified as they move upstream—results at least in part from "strategic interactions among rational supply chain members," in

contradiction to Sterman's (1989) conclusion that the bullwhip effect arises from irrationality or misinterpreted feedback (see also Metters, 1997). Lee et al. also demonstrated that the severity of the bullwhip effect is positively related to lead times.

Fisher (1997) noted that such efforts to increase the speed of information flow in the chain often failed to improve the match between supply and demand. He concluded that a given supply chain facing demand uncertainty had to choose whether to emphasize (a) efficient physical supply of goods (risking producing goods that did not meet customer demand) or (b) market mediation (adjusting production to match actual demand, often resulting in lowered production efficiencies). Fisher proposed that the choice between efficient physical supply and market mediation as a supply chain strategy depended primarily on whether the product had functional or innovative demand. Functional demand calls for a supply chain emphasizing efficient physical supply, and innovative demand calls for market mediation. Fisher also observed that demand for many products was shifting from functional to innovative as companies saw opportunities to improve competitiveness through increased responsiveness (as exemplified by the Nordic pulp and paper producer described earlier in this paper). Fisher's work represented a radical departure from a general assumption in the supply chain management literature that market mediation plays a role in all supply chains (e.g., Ellram, 1991; Houlihan, 1985; Mentzer et al., 2001).

Vollmann et al. (2000) suggested that the term "supply chain" be replaced by the term "demand chain" to emphasize the shift in emphasis from efficient supply to meeting the needs of the customer. In 2002, the *Journal of Operations Management* published a special issue dedicated to demand chains, encouraging researchers to develop theory specific to demand chains (see Selen and Soliman, 2002). At first glance, this change in nomenclature appears undesirable: as a field, operations management has been far from parsimonious in its designation of terms, and the idea of adding the term "demand chain" to "supply chain," "value chain," and "logistics" sounds like a recipe for confusion, especially given the generally held assumption, discussed above, that market mediation plays an essential role in all supply chains.

It has become increasingly clear, however, that there is a fundamental difference between chains

that focus on market mediation and chains that focus on efficient physical supply. Just as the term “logistics” became a subset of the term “supply chain management” to denote the new strategic role of logistics (Lambert et al., 1998), differentiating between supply and demand chains is useful in emphasizing the fact that integration between supply chain parties does not necessarily imply market mediation, and that market mediation represents a trade-off between customer service and supply efficiency.

To emphasize the differentiation of chain networks into supply and demand chains, we combine Fisher’s division of supply chains (according to whether product demand is functional or innovative) with Vollmann et al.’s suggested change of terminology (from supply to demand chain management) and propose the following.

**Definition.** A demand chain is a supply chain that emphasizes market mediation to a greater degree than its role of ensuring efficient physical supply of the product.

It is possible in many chains to define a *decoupling point*, that is, a point in the chain at which inventory is held to permit an upstream focus on efficient supply and a downstream focus on market mediation (e.g., Naylor et al., 1999). In situations of production to stock upstream and to order downstream from the decoupling point, the decoupling point often serves to mark the *order penetration point*, that is, the point at which production is assigned to a given customer. Specification of an appropriate order penetration point plays a critical role in supply chain management (e.g., Sharman, 1984). In situations where goods are delivered from stock, the order penetration point is at the finished goods warehouse, but an upstream decoupling point nevertheless can be created to permit market mediation over part of the chain.

**Corollary.** A given supply chain can be decoupled into an upstream chain focused on supply integration and a downstream chain focused on demand integration (i.e., a demand chain) through a decoupling point.

Heikkilä (2002) studied attempts to improve the transfer of demand information in six demand chains experiencing difficulties with matching supply with

demand within Nokia Networks. In each case, Nokia offered a reduction in lead time from 4 months to 10 days in exchange for improved information concerning demand. Although, given the innovative nature of the products involved, market mediation was the appropriate demand chain management approach in all these cases according to Fisher’s (1997) framework, response to the overtures made by Nokia ranged from enthusiastic to negative, and the project outcomes varied considerably. On the basis of these cases, Heikkilä concluded that Fisher’s proposition—that the choice of market mediation or physical efficiency for a given chain depended essentially on the nature of demand—was too simple. Heikkilä proposed that a variety of demand and supply chain structures was required to cover the entire universe of customer needs and contexts. In his model of demand chain management, Heikkilä added constructs such as duration of relationship, trust, and customer perceptions of the support received from the supplier to the nature of product demand in determining whether a given chain should attempt market mediation (see also Mentzer et al., 2001).

Several researchers have studied the value that demand information availability holds for supply chain performance. Bourland et al. (1996) modeled a two-level supply chain to study the impact on supplier inventories that would result from access to timely demand information, demonstrating that faster access to demand improved the supplier’s fill rate at a given service level. The value of faster access to demand increased with demand variability and decreased with lead time. Croson and Donahue (2002, 2003) used experiments based on the beer game (Lee et al., 1997; Metters, 1997; Sterman, 1989) to demonstrate that exposure to POS data benefited upstream supply chain members when demand was stable and its distribution was known, in comparison to research carried out by Gupta et al. (2002), which demonstrated that POS data availability increased costs for upstream chain members when demand was unknown and nonstationary. Along similar lines, Thonemann (2002) used an analytical model to demonstrate that the transfer of advance partial demand information from customers to potential suppliers (customer intent to place an order, without specifying the supplier to receive the order or the exact product to be ordered) reduced manufacturing costs and improved service

levels when lead times were zero, but that market mediation efforts based on the advance demand information could substantially increase the bullwhip effect. Dejonckheere et al. (2003) used a control engineering approach to demonstrate that demand sharing was able to reduce but not eliminate the bullwhip effect in a supply chain in which manufacturing was able to respond to the new demand information. If manufacturing lacked the flexibility to respond, Dejonckheere et al. proposed a smoothing rule to reduce the weight of the demand information in determining the order quantity; that is, they suggested that market mediation attempts should be limited in situations of inflexible manufacturing (e.g., long lead times), with the chain focusing, instead, on efficient supply irrespective of the demand information available. Wijngaard (in press) demonstrated that high capacity utilization (implying long manufacturing, and hence supply, lead times) substantially reduced the value of advance (partial) demand information in a single-stage, single-product supply chain.

Rabinovich et al. (2002, p. 6) noted, “although there is substantial evidence that learning about demand before undertaking production acts [as] a substitute for product inventories, it is not understood what the most effective way is to achieve that substitution.” In their study, implementation of an enterprise-wide information system—hypothesized to improve demand chain performance—led instead to an increase in inventory speculation among demand chains surveyed. Rabinovich et al. concluded that improved demand chain performance was more likely to result from operational initiatives such as lean production that resulted in lead time reduction, than from direct investment in information systems to improve information flow. Along similar lines, recent experimental work carried out at the Harvard Business School, again using the beer game, demonstrated that reducing lead times—even with no transfer of demand information—lowered cost substantially more than the real time communication of end-consumer demand through the supply chain with lead times unchanged (McAfee, 2003).

In summary, literature that addresses the willingness to trade production and supply chain efficiency for market mediation began to emerge in the 1980s with JIT production. That the gains of market mediation compensated for the resulting losses of pro-

duction efficiency initially was assumed to be universally applicable but now is understood to apply to only a subset of supply chains, which subset we will refer to as demand chains. The transfer of demand information—which can be full or partial—is expected to reduce costs related to transaction uncertainty (Handfield, 1993) in contexts where manufacturing has the flexibility to respond to the new information, but adjusting the production schedule according to the new information may result in an increased bullwhip effect (Thonemann, 2002). Finally, the transfer of demand information has been shown to depend not only on the type of product demand but also on the quality of the relationship between supplier and customer, at least in some contexts.

## 2.2. Literature concerning lead time reduction

Interest in lead time reduction was also originally awakened by JIT production, even though lead time reduction was considerably less emphasized in the JIT literature than was reduction in waste—especially excess inventory (e.g., Blackburn, 1991; Hall, 1983; Monden, 1983; Schonberger, 1982; Suri, 1998; Suzuki, 1987; Womack et al., 1990). Whereas JIT is focused primarily on repetitive manufacturing, Goldratt and Cox (1984) addressed lead time reduction in a batch flow environment, drawing attention to the impact of bottleneck resources and lot sizing on lead times.

Results from lead time reductions led to identification of a competitive strategy based solely on speed, referred to as “Time-Based Competition” (e.g.; Blackburn, 1991; Holmström, 1995; Schmenner, 1988; Stalk, 1988; Stalk and Hout, 1990; Suri, 1994, 1998). Schmenner (2001) proposed his “Theory of Swift, Even Flow,” claiming that companies emphasizing flow—which implies a focus on speed and on reduction of variability—would have higher productivity than companies emphasizing productivity.

Whereas much of the literature on lead time reduction had been largely anecdotal and exploratory, Hopp and Spearman (1996) compiled a set of the mathematical principles determining lead time—based on queuing theory—which they referred to as “factory physics.” Suri (1994, 1998) simultaneously developed a manufacturing strategy (also based on queuing

theory) called Quick Response Manufacturing<sup>3</sup> that addressed implementation of lead time reduction principles in manufacturing environments. Factory physics and Quick Response Manufacturing formalized the relationships of bottleneck utilization, lot sizes, and variability to lead times. The underlying mathematical relationships had been well known in the field of queuing theory for many decades (Suri et al., 1995), but the work by Hopp and Spearman (1996) and Suri (1994, 1998) represented the first comprehensive application of these principles to the general theory of operations management.

Although the set of mathematical principles driving lead time reduction are commonly known and accepted among researchers in the field of operations management, such knowledge does not appear to have been widely disseminated to practitioners (Suri, 1994, 1998). One reason may be that these mathematical principles are not emphasized in much of the operations management literature concerning lead time reduction.

Conventional wisdom claims that lead time reduction is not possible in industries with expensive equipment—assumed to require high capacity utilization—like the pulp and paper industry, but such conventional wisdom is misleading. Upton (1995, 1997), for example, has researched flexibility (closely related to relative lead time and market mediation capabilities) in the pulp and paper industry, demonstrating the feasibility of lead time reduction.<sup>4</sup>

The mathematical principles underlying lead time reduction are axiomatic and lead to specific and concrete instructions concerning how to go about reducing lead times. Suri (1994, 1998) demonstrated empirically, however, that managers tend to be unaware of these mathematical relationships, leading to a general belief among managers that lead time reduction is difficult and costly. The lack of clarity in a large portion of the lead time reduction literature, concerning such fundamental aspects of lead time reduction, may have

hindered theory and practice development both in lead time reduction and in demand chain management.

### 3. A typology of demand chains

We propose that two primary characteristics determine the market mediation ability of a given customer–manufacturer pair<sup>5</sup> in a demand chain: demand information transfer—the demand information (partial or full) that is transferred from the customer to the manufacturer—and relative supply lead time—the supply lead time relative to the window of time during which the customer has information (partial or full) concerning actual demand.

#### 3.1. Demand information transfer

Often, a customer in a customer–manufacturer pair is able to either observe or effectively estimate demand before the end-consumer purchase. In many situations, the availability of information that would facilitate meaningful forecasts of demand increases continuously over time until the moment the exact demand is known (Fig. 1a). At the other extreme, a particular event may determine what demand will be as in Fig. 1b (e.g., an architect's plan for an apartment building with 27 units is completed, indicating the need for 27 particular refrigerators). Or, a series of such events might lead to Fig. 1c, in which demand is determined in a stepwise manner. For ease of explanation, rather than contend with demand information that reveals itself slowly and continuously over time, we will discuss the availability of demand information at three periods of time. As Fig. 2 depicts, before  $T_0$ , observations are either unlikely to lead to useful estimates of demand or are too costly to undertake. Between  $T_0$  and  $T_1$ , partial information is available to make or refine forecasts. At time  $T_1$ , full demand information is observable. Of course, as the Syncra Systems survey previously mentioned so vividly demonstrates, just because demand information is observable by the buyer does not mean that the buyer is willing to transfer it upstream.

Based on what is observable, as in Fig. 2, we define three levels of actual demand information transfer

<sup>3</sup> The resemblance in terminology between the supply chain strategy Quick Response and the manufacturing strategy Quick Response Manufacturing is coincidental.

<sup>4</sup> There are, however, cases in which manufacturers are limited in their ability to reduce lead times. Blocher et al. (1999), for example, presented an example of a pharmaceutical firm limited in its ability to reduce lead times because the Federal Drug Administration approvals specified the production lot size.

<sup>5</sup> This customer–manufacturer pair can be located anywhere in any manufacturing industry supply chain.

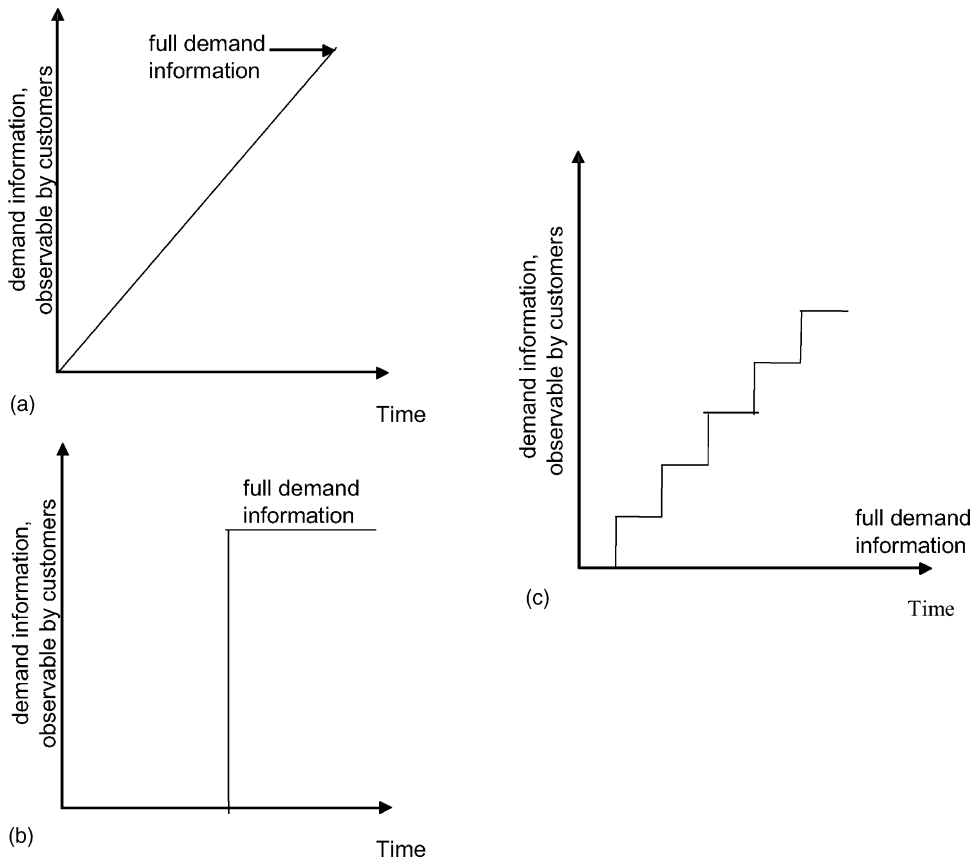


Fig. 1. The observation of demand information over time.

in a chain: (a) *full demand information transfer*, (b) *partial demand information transfer*, and (c) *no demand information transfer*. Improvement of demand information transfer must begin with eliminating the distortions arising from rationing, order batching, or price promotions that increase the bullwhip effect, as previously described.

3.1.1. Full demand information transfer

We define full demand information transfer as occurring when actual demand information is transferred from customer to manufacturer with no distortion. Full demand information transfer is an antecedent to full market mediation. The development of the Internet has greatly facilitated such information transfers

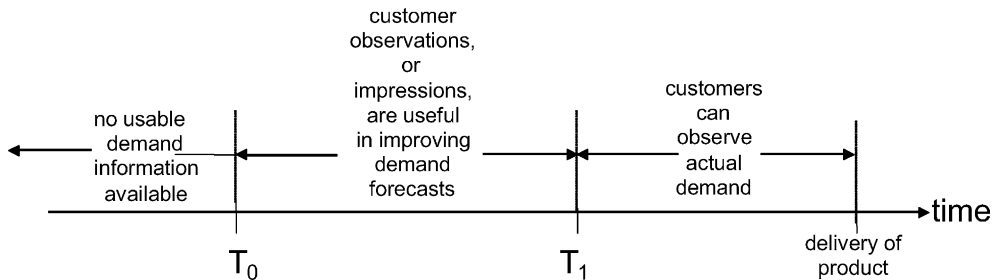


Fig. 2. Supply lead time relative to the observation of demand information.

(Frohlich and Westbrook, 2002). Examples of full information transfer can be found outside of Internet contexts, however. Consider, for example, the link between automobile assembly and seat manufacturing at Toyota Motor Manufacturing's Georgetown plant, in which automobiles exiting the paint line transmit an electronic signal to the seat supplier so that the seat that has been customized for that particular automobile can be manufactured and delivered to the Toyota assembly line by the time the automobile reaches the point in the assembly process where the seat is installed (Mishina, 1993).

### 3.1.2. Partial demand information transfer

Partial demand information transfer represents an effort to transfer early observations of demand, or information that improves the accuracy of demand forecasting, upstream in the chain while minimizing information distortion. For example, relaying POS data to a manufacturer may represent partial demand information transfer because such historical demand information may aid in estimating demand in the near future. Note that partial and full demand information transfers are not mutually exclusive. As can be seen from Fig. 2, a customer may agree to transfer full demand information when it becomes observable. The customer also may work to integrate its planning and forecasting with that of a manufacturer, as occurs in collaborative planning, forecasting, and replenishment (CPFR). As will be discussed later, whether the primary emphasis is on the transfer of full, or partial, information will depend on that manufacturer's lead times. Partial demand information transfer is an antecedent to partial market mediation. There are two primary issues involved in transferring such partial information: (a) turning historical data—or, arguably more difficult, the vague, unquantified impressions that the customer has about future demand—into usable information; and (b) the relationship between customer and manufacturer required to support the information transfer.

*3.1.2.1. Converting partial demand information into usable data.* Partial demand information often requires extensive and complex handling to transform it into usable data. Such analysis may require such sophisticated techniques that Fisher et al. (2000) referred to them as “rocket science retailing.” BMW provides

an example of the difference between using full and partial demand information. During most of the year, a BMW engine assembly plant is able to produce to order. Advance production to cover the vacation shut-down period, however, requires production to forecast. Transfer of fully observed data is handled by BMW's ERP system fairly easily, but BMW has found that transferring and analyzing partially observed demand data is much more difficult; hence, the company is experimenting with the use of Kalman filters to increase its ability to use partial demand information (Hüttmeir and Prenninger, in preparation). Sport Obermeyer uses a set of sophisticated forecasting techniques to transform into usable data the impressions that the customer and company analysts have about future demand (Fisher et al., 1994; Hammond and Raman, 1996).

### 3.1.2.2. Customer–manufacturer relationship issues.

Whereas full demand information usually is well defined (e.g., specific quantities of specific products), partial demand information often is encapsulated in impressions, forecasts, or assessments of the drivers of demand: customers may be less willing to respond positively to manufacturers' requests for such information. In addition, it is less clear with partial demand information than with full demand information how to transform the data into production schedules, and thus the benefits of transferring information at all is less clear. Hence, it is not surprising that the supply chain literature, as well as observations of practice, indicates that transferring partial demand information requires closer relationships than transferring fully observed demand information. As mentioned previously, Heikkilä (2002) demonstrated that constructs describing the strength of the relationship between customer and manufacturer (e.g., duration, trust, and perceptions of support) needed to be added to product demand characteristics in determining whether a demand or supply chain is appropriate. Most of the cases that Heikkilä studied involved partial demand information transfer.

Although leadership plays an important role in all supply chain integration (e.g., Mentzer et al., 2001), we suggest that effective leadership becomes most critical when market mediation is attempted based on partial demand information. Compounding the leadership issue is the fact that leadership within a demand chain entails that the leader is likely to be physically

distant, a situation generally believed to negatively moderate the relationship between leader behavior and performance. Distant leadership can be effective, however, if correctly enacted (Antonakis and Atwater, 2002). The topic of leadership is beyond the scope of this paper, but the idea that the transfer and use of partial demand information requires appropriate leadership—which becomes more challenging to provide with distance—supports our contention that partial demand information transfer places important demands on the customer–manufacturer relationship.

**Proposition 1.** *Partially observed demand information is more difficult to use for effective market mediation than fully observed demand information because of the difficulties in building the needed customer–manufacturer relationship as well as the difficulty of transforming partial demand information into useful data.*

### 3.1.3. No demand information transfer

In a context of no demand information transfer, the only demand information received by the manufacturer comes from the actual order. This order often represents an aggregated and potentially distorted picture of actual demand (as exemplified in the beer game). It has been well established that efforts by manufacturers to adjust their production schedules according to this distorted information result in the bullwhip effect.

**Proposition 2.** *Attempts at market mediation in a no demand information transfer context are positively related to the upstream amplification of demand variability (i.e., the bullwhip effect).*

## 3.2. Relative supply lead time

In the discussion that follows, supply lead time<sup>6</sup>—that is, the time between commitment of production and the time at which the product is available for the customer—is measured *relative* to the period

during which actual demand information is observable by the customer (whether or not this information is actually collected and transferred to the manufacturer), rather than measured in absolute terms. Again, for ease of exposition, we will follow the three time periods of Fig. 2, and we define three levels of relative supply lead time (RSLT): (a) *fully observed demand*, (b) *partially observed demand*, and (c) *no observed demand*. As an example, a manufacturer with an absolute supply lead time of 20 days would be at a fully observed demand RSLT if full demand information was available to the manufacturer 20 days or more before delivery of the product was required, but at a no observed demand RSLT if the first information concerning actual demand could be observed no sooner than 19 days before delivery.

### 3.2.1. Fully observed demand relative supply lead time

A fully observed demand RSLT requires that the absolute supply lead time be less than the period of time from when the customer is able to observe actual demand to the end-consumer purchase date.<sup>7</sup> This implies that the manufacturing organization is capable of scheduling or adjusting production to reflect the demand information so received. Thus, a fully observed demand RSLT is an antecedent of full market mediation.

### 3.2.2. Partially observed demand relative supply lead time

A partially observed demand RSLT implies that the absolute supply lead time is longer than the period of time during which the customer is able to observe full demand, but is still short enough to permit production to be scheduled based on estimates or forecasts derived from customer observations. Thus, partially observed demand RSLT is an antecedent of partial market mediation.

### 3.2.3. No observed demand relative supply lead time

When absolute supply lead times are longer than the period of time during which meaningful indica-

<sup>6</sup> Our use of the term “lead time” differs from the standard use in the literature; it often means “order lead time” in the supply chain management literature and “manufacturing lead time” in the operations management literature.

<sup>7</sup> This ignores the time it would take the buyer to actually transfer demand information to the manufacturer. To be precise, this time should be subtracted from the time period to which the absolute supply lead time is compared.

tions of demand can be even partially observed, a no observed demand RSLT results. In situations in which lead times are long, causing production to begin before demand is observed, attempts at market mediation are expected to result in a *planning loop* effect (Stalk and Hout, 1990; Suri, 1998). In such a case, when demand is observed subsequent to the time production has begun, what is in the pipeline may not match what the customer is demanding. The natural reaction of the production facility is to expedite what is actually desired by the customer, while also finishing the products already in progress. This increases capacity utilization, resulting in an increase in lead times. The increase in lead times reduces delivery performance, causing the production management to start quoting longer lead times, reducing still further the quality of demand information available when production begins.

**Proposition 3.** *Attempts at market mediation based on data that arrive after production has begun are positively related to transaction uncertainty due to the planning loop effect.*

### 3.3. Different levels of market mediation

The discussion above implies that different RSLT capabilities, coupled with different amounts of demand information transfer, dictate different levels of advisable market mediation, as illustrated in Fig. 3: (a) no market mediation, (b) partial market mediation, and (c) full market mediation.

#### 3.3.1. No market mediation

Manufacturing units of supply chains in region I of Fig. 3 will, we propose, realize higher performance by avoiding all attempts to adjust production to demand, focusing instead on supply integration (Frohlich and Westbrook, 2002), with supply/demand imbalances left to market mechanisms such as price and promotion. The same recommendation applies to all chains in region I *even though many of these have either access to demand information or relative supply lead times that permit responsiveness*. In particular, note that using actual demand information as soon as it becomes observable may not be the best option, if that information arrives after production has begun. Rather, for a manufacturer with a partially observed demand

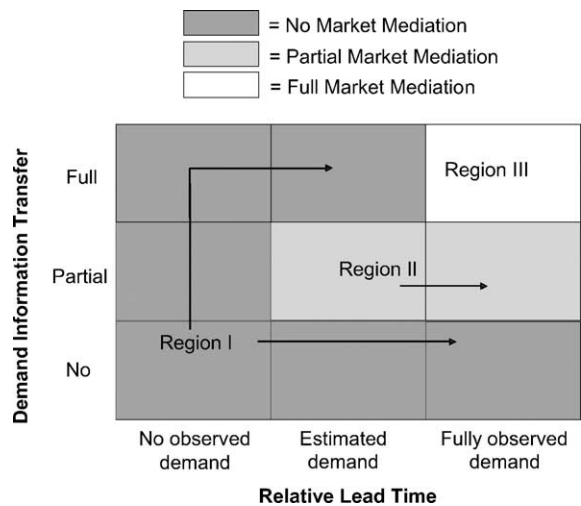


Fig. 3. A demand chain typology.

RSLT, collaborative mechanisms such as CPFR that integrate customers' and manufacturers' planning and forecasting systems are required for even partial market mediation.

A no market mediation supply chain strategy is exemplified by systems in which the transfer of information supports efficient manufacture and supply of the product, such as vendor-managed inventory systems as practiced by Barilla (Hammond, 1994), or the JIT production technique of freezing the production schedule to reduce process variability, explicitly trading market mediation opportunities for manufacturing stability (e.g., Chase et al., 2001).

#### 3.3.2. Partial market mediation

When the manufacturing part of a chain has access to at least some meaningful information concerning demand, and when its supply lead times permit it to respond to such information, then partial market mediation is feasible. Such a manufacturer can make some adjustments to its production schedule to reflect new information concerning demand, although not enough to permit building to order. Chains in region II of Fig. 3 should avoid the temptation to respond to full demand information that arrives after production has been committed. Manufacturers with adequately short lead times who find full market mediation advisable (i.e., who find full responsiveness to be more

beneficial than achieving greater production efficiencies) will want to invest in efforts to improve demand information transfer, particularly given that the transfer and use of full information is often less demanding than that of partial information.

### 3.3.3. Full market mediation

Full market mediation represents the ideal demand chain corresponding to what Towill and Christopher (2003) refer to as an “agile pipeline strategy”, in that lead times permit the chain to respond to variable demand.

## 4. Demand chain trajectories

Consider a chain at the bottom left-hand corner of Fig. 3. Suppose that demand variability makes it advisable for this chain to move to a higher level of market mediation. We now return to the question posed at the beginning of the paper: should this firm’s first movement be vertical (implying that the project begins by improving information transfer), horizontal (implying that the project begins with lead time reduction), or diagonal (implying both improvement efforts simultaneously)? Should movement over time be in a stepwise manner (alternating improvement efforts), or should a chain complete movement either horizontally or vertically before moving in the orthogonal direction?

We propose that it is better to begin the project with as much lead time reduction as possible, attempting to improve the transfer of demand information only after lead time reduction has been completed. Lead time reduction efforts involve the manufacturer only, are based on mathematical laws that are well understood, and often require substantially less investment than information transfer improvements (e.g., Suri, 1998). On the other hand, as we have argued above, information transfer requires the development of trust between channel partners, which in many industries can require time and considerable management effort. This implies that lead time reduction is a less risky undertaking than demand information transfer improvements.

**Proposition 4.** *Market mediation improvement efforts that begin with improvements in relative supply lead time are more likely to reduce transaction uncertainty*

*than those beginning with improvements in demand information transfer.*

Should a demand chain attempt to improve relative lead time and information transfer performance simultaneously? Although such “parallel processing” may appear efficient to demand chain partners, it can reduce the focus and increase the risk of the improvement efforts. In particular, in the presence of long lead times, it typically is more difficult to convince potential supply chain partners to transfer demand information, because it is more difficult to demonstrate the mutual benefits. For the same reason, if the goal of the demand chain is full market mediation, then reducing supply lead time to a fully observed demand RSLT level is likely to facilitate demand information transfer improvements.

The cases evaluated by Heikkilä (2002) that were described in the literature review give insights concerning the advantage of achieving a fully observed demand RSLT prior to attempting to improve demand information transfer. The lead time reduction from 4 months to 10 days carried out by Nokia brought one of the six cases to a fully observed demand RSLT level. In this case, benefits of demand information transfer were obvious to the customer, and improving the demand information transfer was relatively easy. In the other five cases, the lead time reduction allowed production to incorporate observed demand information partially, rather than fully. Heikkilä demonstrated that improving demand information transfer in these cases required a strong relationship between customer and manufacturer, combined with efforts to convince customers of the potential benefits of demand information transfer. We therefore propose:

**Proposition 5.** *Focusing on one improvement activity rather than attempting to improve both relative lead time and information transfer simultaneously is positively related to reduction in demand chain transaction uncertainty (implying that demand chains should not attempt to move diagonally in Fig. 3).*

**Proposition 6.** *Completing lead time reduction improvements prior to beginning demand information transfer improvements will be positively related to reductions in demand chain transaction uncertainty.*

## 5. Conclusions

We began this paper with the story of a Nordic pulp and paper producer that had failed to improve the performance of its demand chain, reverting to a series of local supply chains making no effort to engage in market mediation. According to our typology, where was this supply chain positioned? What would our theory have suggested concerning improving the supply chain performance?

The producer's relative supply lead times were at a no observed demand level; therefore, as we have proposed, any efforts to improve information flow so as to permit better market mediation would be doomed to failure. The producer had a choice of reducing lead times or simply giving up efforts to customize products. Lead time reduction could have been accomplished through applying factory physics and Quick Response Manufacturing principles to existing operations or through dedicating fast and flexible capacity to customized products.

In contrast to the pulp and paper company used to introduce the article, another Nordic pulp and paper producer made a similar effort to increase market mediation in the supply chain (i.e., become a demand chain). Following an approach similar to that suggested by Upton (1995, 1997), the second company worked to reduce the production cycle from approximately 4 weeks to 1 week, implying that all products would be made each week if needed. This required improvement in the consistency of the process after each grade change, but that improvement was accomplished without major difficulties. The 1 week production cycle meant that the lot sizes entering the pipeline were much smaller and were more likely to respond to actual customer demand. The reduced lead times encouraged chain participants to work together to exchange information. As a result, the demand chain has achieved a reasonable level of market mediation. Service levels have improved, as has profitability. The reduced cycle in paper production has facilitated a high—and improving—level of market mediation in spite of the high capital costs of the equipment. The improved performance of the demand chain has made all chain members more competitive and has permitted each chain member to set more ambitious strategies.

Our experience has been that managers in many companies believe that reducing lead times is difficult

and expensive, and that information systems will make lead time reduction easier. We have watched many companies fail. We also have watched companies begin with efforts to improve information flow, recognize that little improvement was taking place, and revert to lead time reduction, resulting in successful demand chain improvement.

If our propositions are supported in empirical testing, the following managerial conclusions can be drawn:

- (a) Not all supply chains face sufficient demand variability to warrant investment in demand integration. Such chains are better off limiting their integration to supply integration that supports efficient production and delivery.
- (b) For chains facing sufficient demand variability to warrant the considerable efforts required for market mediation, the appropriate level of demand information transfer to aim for depends on the RSLT of the manufacturer.
- (c) For chains located in the partial market mediation region of Fig. 3, relationship constructs such as trust and relationship duration are antecedents of successful demand information transfer (Heikkilä, 2002), and transforming the transferred demand information into usable data may be challenging.
- (d) Manufacturers with sufficiently short lead times should concentrate their efforts with their customers on the transfer of actual demand information as quickly as it becomes available. Manufacturers whose ability to respond to demand information is hindered by longer lead times (resulting from, for example, high capacity utilization) should concentrate their efforts on integrating their planning and forecasting with their customers.
- (e) Finally, in general, improvement of relative supply lead times should be prioritized over demand information transfer.

We recall Lewin's observation (1945, p. 129) that "Nothing is as practical as a good theory." Our goal in writing this paper has been to organize what we know about improving lead time reduction and information transfer into a typology of demand chain improvement so that we can better make sense out of the tremendously diverse and complex set of cases that have emerged from the field (Bacharach, 1989). By recognizing the importance of context in demand

chain research, we can learn more, and we also can better communicate to managers the body of knowledge that we have amassed concerning how to improve the performance of a given demand chain.

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