

The Push and Pull of Product Demand on Supply Chain Models

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Abstract

In business we strive to satisfy our customers in economically efficient ways. As we drive inefficiency out of our internal organization, we may realize that our ability to fully satisfy demand as efficiently as possible is constrained by our suppliers or our distribution channel. Supply chain management (SCM) strives to direct an organization's internal and external influence to efficiently deliver maximum value to the end customer. To this end, it is wise to understand the nature of product offerings so that we may tailor our supply chain model to best suit our products. Once we understand key aspects of our products, such as demand characteristics, we can better design and manage our supply chain. A supply chain's focus, whether on physical efficiency or market responsiveness, determines its primary purpose, manufacturing process, inventory strategy, lead time targets, supplier criteria, and product design strategy. SCM balances cost efficiency objectives with responsiveness requirements by managing supply, transformation and distribution relationships. A comparison of DELL Inc. and Toyota Motor Corporation illustrates these supply chain linkages.

Key Words: supply chain management, value-chain, process strategy

SCM perspective

Supply chains are like rivers. As rivers spring from headwaters and empty into seas, products flow from sources, intersect and mix, and ultimately arrive at their destinations. This is why we refer to our input providers as upstream members of the supply chain. Similarly, market or demand information flows against the currents of product deliveries from our downstream customers.

In business we strive to satisfy our customers in economically efficient ways. As we drive inefficiency out of our internal value-adding activities, we eventually realize that our capabilities are limited by those of our upstream and downstream channels of supply or distribution. While our motives may remain local, our perspective broadens from a local one to a global one. To be globally effective, managers must take a systems view of our activities. And our activities, where appropriate, should be visible to our supply chain partners. With this in mind, we adopt a supply chain perspective. With this perspective we are not only managers of purchasing, quality assurance, line production, logistics, marketing, or information systems; we are managers of supply chains as well. Every link in the chain of value-adding activities influences the effectiveness and efficiency of the whole. So, we must direct

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our internal and external influence to achieve or maintain advantages over our competitors.

Supply chain management strives to balance an organization's internal and external influence to efficiently deliver maximum value to the end customer. This capability itself may be a source of competitive advantage. This is certainly true for DELL Inc. It seems that many major companies are striving to be more like DELL. What these companies are seeking is the capability to mass customize. Mass customization delivers wide product variety on a large scale at prices comparable to mass-produced products. DELL's supply chain management capabilities are the foundation of its direct business model. However, there is no single best supply chain model. What is best suited for DELL may not be best suited for General Motors, Ford, and Toyota.

The famous economist Adam Smith described the workings of the free market as an invisible hand [4]. Supply chain management strives to put a visible glove on that hand so that we can identify our system of value creation and better understand the form we employ to meet market demands. Once we know the functions required to meet market demand, we can form a supply chain to support those functions.

Strategic Fit

A supply chain model is the structure or form of a supply chain strategy. Naturally, strategy and structure perform best in harmony. The architect or developer of the supply chain model is commonly referred to as a channel captain. When choosing or developing a supply chain strategy, a channel captain must first consider its own business model. The business model provides strategic direction by answering questions such as:

- Who are our customers?
- What products do we offer?
- How do we create and deliver value?

A value chain is composed of value adding activities that can be categorized as either physically transforming (production related) or market mediating (marketing related). By mapping its value chain a company defines its business model and pieces together the appropriate supply chain to support value-adding activities. An organization's supply chain model should at least reinforce the organization's competitive position; at best it can provide competitive advantages. A supply chain should efficiently support the chosen business strategy of its constituent companies.

The end objective of any supply chain is efficient demand satisfaction. To perform the right activities, to be effective, a supply chain model should achieve strategic fit with the business model. That is to say that it should be driven by the target market, efficiently deliver product offerings, and strive to integrate value-adding activities to create greater value for the stakeholders of the chain. Ultimately, it should enable, or even constitute, the channel captain's business model.

Product and SC Fit

As previously mentioned, determining the product or products to offer customers is central to a business model. Similarly, building capabilities consistent with critical product

attributes is central to a supply chain model. Marshall Fisher develops a framework to craft fit between attributes of products and supply chain focus in his 1997 Harvard Business Review article titled, “What is the right supply chain for your product?” [1]. In particular, Fisher states that effective supply chain strategy hinges on understanding the nature of demand for one’s products. Important demand aspects include product life cycle, contribution margin, variety, demand predictability and lead time expectations.

Fisher found that based on demand patterns, products can be categorized as either primarily innovative or primarily functional. Functional products tend to have low contribution margins [defined as $(\text{price} - \text{variable cost}) / \text{price}$], little variety, and their demand is relatively predictable. While innovative products are higher in contribution margin, their demand is less predictable; so they suffer greatly from stockouts and markdowns due to large forecast errors. For example, if the contribution margin on an item is 40% and it is out of stock 25% of the time, this represents a 10% loss in profit before taxes.

These two differing product types require distinctly different supply chains. Fisher notes that supply chains perform the two previously mentioned value-adding functions: a physical function and a market mediation function. Physical functions transform raw materials into finished goods and transport them from link to link. Market mediation matches supply to demand by allocating the desired quantities and varieties to the appropriate markets at the right time.

A supply chain’s focus, whether on physical efficiency or market responsiveness, determines its primary purpose, manufacturing process, inventory strategy, lead time targets, supplier criteria, and product design strategy. Physically efficient supply chains primarily strive to meet demand at the minimum cost possible through high utilization of productive capacity, minimum inventory investment, cost efficient lead time reductions, and by choosing suppliers based on standards of quality and low costs. Essentially this is consistent with a low cost business strategy. A market responsive supply chain primarily strives to minimize stockouts and obsolete inventory by responding quickly to unpredictable demand. To accomplish this a flexible production process is employed, chain inventory acts as a buffer, lead time reduction is aggressively pursued, supplier criteria focus on quality, speed and flexibility, and modular product design helps postpone product differentiation. This is consistent with a quick-response business strategy.

Fisher develops a *match* table for the two types of products and two types of supply chains discussed. Further, he states that many causes of supply chain problems stem from a mismatch between product and supply chain types. Due to the low margin nature of functional products and the significant investments necessary for responsive capabilities, it is rare that a functional product is serviced by a responsive supply chain. Therefore, most mismatches occur with innovative products serviced by cost efficiency focused supply chains. To correct the mismatch, one can make its product more functional or make its supply chain more responsive. The appropriate option to pursue depends on the product category.

However, this two-by-two matrix is a simplification of reality. Even within product categories certain models may be best classified as functional while others may be best classified as innovative. For example, Toyota produces rather functional or basic passenger cars like the Corolla and simultaneously offers the innovative hybrid fuel Prius. Both the Corolla and Prius are considered economy cars, but they require distinctly different supply chain capabilities to meet distinctly different demand patterns.

Herein is a real challenge of supply chain management. Channel captains typically produce or provide a mix of multiple products. Therefore its supply chain strategy should accommodate various types of product lines and within those product lines various product

models or brands. Thus the supply chain must be at once efficient for functional products and responsive for innovative products. In order to accomplish this we must create a portfolio of supply chain capabilities by wisely choosing the most appropriate upstream and downstream partners for each product. To deliver responsiveness efficiently and efficiency responsively supply chain managers can use a mix of tactics. If we can develop a supply chain that is at once highly responsive and highly efficient, we have mass customization capabilities.

Push and Pull

What we respond to determines our tactical approach to managing the supply chain. However, our ability to respond to the market may be limited by our distance from the market and / or our suppliers' responsiveness. We can think about our distance from the market in terms of our trigger for production. What drives us to produce? Is it actual demand or a forecast for demand? If we produce in response to actual demand, then we make-to-order (MTO) or assemble-to-order (ATO). If we produce based on forecasts, then we make-to-stock (MTS) or assemble-to-stock (ATS). In this case we try to anticipate demand or respond to a forecast.

Primarily functional supply chains may tend to use a push process strategy, where relatively accurate forecasts drive production. A pure push strategy makes- or assembles-to-stock based on downstream orders rather than end demand, and it pushes end products into the market place. Alternatively, responsive supply chains tend to use a pull process strategy, where actual end demand drives production. A pure pull strategy produces only after orders are placed and therefore products are pulled into the market. In most supply chains a mixture of push and pull strategies is used to manage the conflicting objectives of efficiency and responsiveness. This is classified as a push and pull process strategy [3].

The point in the supply chain where push processes meet pull processes is the push-pull boundary. Each supply chain may have multiple push-pull boundaries. The position of these boundaries has significant implications for inventory management. If we have a push-pull boundary close to the end consumer, say at the retail level, we must stock finished goods. So we produce end-items based on a forecast. Since aggregate forecasts are more accurate than disaggregated forecasts, the accuracy of forecasts is hindered by the breadth of end-item variety. One way to mitigate this inherent uncertainty is to try to reduce the risks of inaccurate forecasts by designing modular products or end-items with common components in their bill of materials. In this way risk or demand variability is reduced by risk-pooling.

Other ways to mitigate forecast uncertainty are to practice postponement or buffer demand with safety stock. Postponement is a way of delaying product differentiation. The classic example involves Hewlett-Packard (HP) printers. By allowing regional distribution centers to bundle power supplies and instruction manuals rather than bundling them at the factory, printer differentiation is postponed or performed closer to end demand. This allows the supply chain to be more flexible or responsive while still leveraging scale economies for core components. The success of this tactic is often enabled by modular design. Here HP stocks generic printer modules that are modified at a point in the supply chain where demand is more certain.

Inventories tend to accumulate for various functional reasons at push-pull boundaries. So it stands to reason that if we can minimize the number of push-pull boundaries, we may be able to reduce inventory investment. Additionally, since the supply chain adds value to products as they move from raw materials to end items, the costs of holding inventory increases

as we move products from upstream sources to downstream end-users. Therefore, if we can position our push-pull boundary as far upstream as possible, the supply chain balance sheet should benefit.

Push-pull boundaries are critical links in the supply chain. Therefore, channel captains want to control them. However, lead time expectations or consumer behavior, and legacy structures of supply and distribution channels may prohibit direct channel captain control of push-pull boundaries. Supply chain management in these instances is as much or more the art of managing relationships and judicious exertion of influence as it is the science of global optimization.

The greater the number of distinct constituencies in the supply chain or the greater the number of links, the more difficult is the challenge of supply chain management. This is because supply chain management seeks to obtain system-wide optimality and if the proper incentives are not provided, portions of the supply chain may become estranged.

Bullwhip Effect

The economic principal agent problem frequently arises between the channel captain and each supply chain link. The bullwhip effect illustrates several complications that arise in multi-echelon supply chains. Even when demand is stable, the variability of orders placed between various levels of the supply chain distorts demand information and causes excess inventories or stock outs. As orders travel upstream, this variability is amplified. We refer to this upstream propagation of variability as the bullwhip effect. Lee, Padmanabhan, and Whang [2] attribute the bullwhip effect one or more of the following causes:

- *Demand forecasting*

The problem here is that each link in the supply chain places orders based on its own forecast and ordering policy. Therefore if safety stocks are embedded in forecasts, we wind up with compounded safety stocks. Additionally, forecast errors may be compounded by updating or smoothing forecasts as more recent order information arrives. By sharing point of sale information and engaging in collaborative planning forecasting and replenishment (CPFR) initiatives, supply chains can dampen the impact of this inter-organizational ineffectiveness. Vendor managed inventory (VMI) is another tactic used to reduce or eliminate compound effects of serial forecasts.

- *Lead times*

Lead times are delays between need recognition and need satisfaction. In supply chains there are both physical and information process delays. The greater the number of transfer points between demand and supply, the longer the total lead time from producer to end customer. Physical tactics for reducing lead times include drop-shipping and cross-docking. Drop shipping is typically employed by resellers and reduces lead times by shipping finished goods from a central inventory source directly to an end-user. Cross-docking reduces lead times by eliminating storage or warehousing of products. Implementing shared information technologies and systems can significantly reduce information related delays.

- *Batch ordering*

Demand may be smooth but orders are lumpy. Downstream orders are often in batches or lot-sizes that exceed true demand. Several channel forces are at play here. The first is the periodic nature of sales quotas and other incentives based on calendar deadlines. The final day's push to meet performance goals urges our human nature. Another force causing batch

ordering is that of fixed transaction costs. These arise as production set-up costs, or ordering and transportation costs. Still another cause of batch ordering is the use of unit price discounts based on individual order quantities to achieve economies of scale.

- *Price variability*

Price promotions may also add to the bullwhip effect by encouraging forward buying. Here downstream supply chain members tend to purchase more than is immediately required to take advantage of lower costs for satisfying future demand. Wal-Mart's everyday low pricing avoids this type of buyer behavior.

- *Gaming Rations*

If supply shortages are anticipated and suppliers ration supply as a proportion of order quantities desired by buyers, buyers may game the system by inflating their true requirements in an attempt to receive a rationed delivery that meets their true requirement. In these cases, suppliers can mitigate gaming by basing rations on historical order information.

Each of these causes may compound serially throughout the supply chain. Therefore, the more links in the chain, the more distorted actual demand becomes.

Comparison of DELL and Toyota

Regardless of the actual length or number of upstream and downstream links in a supply chain, the chain's leading original equipment manufacturer (OEM), like Toyota or DELL, has three basic interfaces or linkages. There is the suppliers-to-OEM link that determines the input attributes and provides the basis for the OEM's cost structure. There is the internal link or in-house transformation processes that actually create the finished goods. Finally, the OEM-end user link allows us to categorize products as innovative or functional and ultimately determines revenues.

The internal processes of an OEM set the efficiency and responsiveness standards for its supply chain. Its supplier management practices define the level of intimacy or connectedness it desires from its supply base. The OEM's role as a large buyer or customer of components provides it with great influence over its supply base. Supply chain decisions in this domain center on supplier qualification criteria, types of supplier relationships, supply diversification and component inventory management.

As a company's location in the supply network or distribution network gets farther removed (in terms of levels or links in the chain) from the OEM, the OEM's influence is stretched thinner or becomes more diluted. This seems especially true on the distribution side since the OEM is the seller and downstream members between the OEM and end customers may also be viewed as customers. One of the core ideas in supply chain management is to optimally produce and deliver based on the system-wide margin (meaning retail price – manufactured cost), rather than each link optimizing based only on its own margin. Suboptimal supply chain performance due to multiple mark-ups is referred to as double marginalization.

Let us consider two different industry leading supply chains. The DELL and the Toyota supply chain model are designed to produce and deliver innovative products. Therefore, they are geared toward responsiveness.

DELL's supply chain is very compressed. This is in large part due to its direct sales to end customers. Since DELL produces from actual demand, DELL's model allows it to assemble-to-order. This positions DELL itself as a pull process in the supply chain. The push-pull boundary for DELL's supply chain is between DELL and its component suppliers. At this

boundary, DELL pioneered virtual integration, which substitutes information for inventory. DELL component suppliers deliver just-in-time (JIT) to trim inventory on hand down to a couple of hours.

DELL is also capable of directly influencing demand with real time promotion of components that suppliers may have overstocked. This practice is known as demand shaping. In terms of cash flow, DELL also enjoys a competitive advantage. DELL has a negative cash-to-cash (C 2 C) cycle. C 2 C is the amount of time between raw materials expense and end-item payment. DELL typically receives payment from end consumers before producing their orders, and does not take component ownership until at most hours before assembly. DELL has great influence over not only its suppliers, but also its end customers. Therefore, DELL directly controls each of the three major supply chain interfaces.

Toyota's supply chain is built upon the responsiveness of its supply base. Toyota's keiretsu based supplier management is a hybrid of purchasing and vertical integration. These partnerships enable Toyota to direct a highly synchronized and flexible JIT inventory policy. Toyota also possesses great capabilities in flexible and efficient automobile assembly. And although Toyota pioneered the component pull system, Toyota largely produces based on forecasts of demand and therefore end-items are made-to-stock. Thus Toyota's production system is itself, in supply chain terms, part of the push process.

The push-pull boundary for Toyota automobiles in the U.S.A. occurs at retail dealers. According to Fisher's article 90% of new automobiles in the U.S.A. are purchased from dealer stock [1]. These products are delivered to dealers from Toyota through two links of distribution and so there are three supply chain stages between Toyota and end consumers. This elongation in distribution limits Toyota's ability to directly influence or shape demand.

The supply chain models of DELL and Toyota are similar in terms of supply-side capabilities and efficiency. There are clearly differences between the two due to attributes of product demand. Automobile consumers prefer to "kick the tires" or test drive before purchasing. Also, automobile consumers have low lead time tolerance, and producing and transporting automobiles for final delivery requires weeks. By contrast, computer consumers are at least patient enough to wait several days for a custom computer to be delivered to their door. Further, there is no *last mile problem* for computers since they are readily handled by express package companies like UPS.

So will DELL's supply chain model work for Toyota? Obviously if we eliminate links in distribution, we can reduce the suboptimal effects of double marginalization and better influence demand. If Toyota sold directly to consumers, it could directly control the push-pull boundary. So why not compress the supply chain and simply eliminate the links between end customers and the OEM? Why doesn't everyone sell directly to end-consumers like DELL?

The answer is because we can eliminate the middle man, but we cannot eliminate the value adding activities that the middle man performs. Product demand attributes and our business model dictate our most appropriate supply chain model. In the business model we state the value we intend to create. We indicate our core competency. So unless we are capable of adding the value as efficiently as our existing downstream supply chain members, end customers are better served, demand is better satisfied, with additional stages in the supply chain.

Concluding Remarks

The bursting of the dot-com bubble can be attributable in large part to this realization that

middle-man value added activities must still be executed. Simply generating revenue or building market share does not generate profit. Economic value is created by efficiently executing all value added activities while meeting or exceeding expected customer service levels. Supply chain models seek to integrate value adding activities from raw materials to production to distribution to after sales activities. This is the value proposition of supply chain management, global optima can be no worse than local optima. Finding the balance between cost efficiency and responsiveness may require management science, but achieving that balance requires artistry in relationships management.

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