Designing a flexible supply chain for new product launch

by

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Abstract

This thesis examines how companies tactically design flexible supply chains for new product launches. The research focus is on different strategies and tactics used by original equipment manufacturers to improve supply chain flexibility through their engagement with contract manufacturers. Five case studies regarding successful product launches were documented and analyzed, and the successful strategies and tactics were then categorized according to the characteristics of the situation. Finally, the findings from the analysis were applied to a startup company to develop its contract manufacturing engagement plan.

Thesis Supervisor: Dr. Chris Caplice
Title: Executive Director, Master of Engineering in Logistics Program

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Biographical Note

Wai-kwan Benjamin Ha is a Master of Engineering in Logistics candidate at Massachusetts Institute of Technology. Concurrently, he is working on a Master of Business Administration at Harvard University. Prior to attending MIT, he was the Director of Corporate and Business Development at NetEase.com, an online media company based in Beijing, China. Benjamin holds a Bachelor of Science in Engineering (System Engineering) from the Engineering School and a Bachelor of Science in Economics (Decision Science) from the Wharton School, both from University of Pennsylvania.

Table of Contents

List of Tables

List of Figures

1 Introduction

When launching new products, companies have historically tried their best to forecast product demand and design an optimal supply chain strategy. Different methods have been developed to forecast demand scientifically. However, the accuracy of these forecasting results varies, and for product launches without relevant historical product demand data, forecasting results can be very unreliable. Because of the unreliability of these forecasts, companies are trying to find new methods to make the supply chain more responsive to uncertain demand.

Since World War II, when the study of operations research began, academia has spent years of research effort on the topic of optimizing supply chains—that is, reducing the overall supply chain costs using different mathematical optimization methods. Many supply chains have now been sufficiently optimized using operations research theories, and companies have started to realize that their supply chains are lean, but not flexible enough to accommodate uncertain demand. The topic of flexible supply chains, which started to draw academic and industry attention in the 1980s, is a relatively young discipline; the lack of tactical approaches to building a flexible supply chain is one reason to examine the topic.

In addition, with technology advancement and increasingly demanding consumers, more new products are introduced every year. Launching new products effectively has become a core competence of many businesses, ranging from information technology equipment manufacturers to fashion designers. As a result, flexible supply chain strategies to manage new product launches are becoming more important. This is another reason to study the topic.

The reminder of this thesis is organized as follows: Chapter 2 is focused on reviewing current academic literature regarding flexible supply chain design and its relationship with new product launch. Chapter 3 is an introduction of the contract manufacturing industry. In Chapter 4, five case studies are presented to show how companies achieve successful product launches through flexible supply chain arrangement with contract manufacturers. The results of the case studies are then analyzed in Chapter 5. The learning from the case studies is then applied to a company with a new product launch in Chapter 6. Chapter 7 completes the thesis with concluding remarks and future research suggestions.

2 Literature Review

To understand the current research efforts on supply chain flexibility and its relationship with new product launch, academic literature was reviewed. Research on supply chain flexibility was generally found in supply chain management and operations research journals, while research on new product launch was mostly found in the product development literature.

There were different, but similar definitions of supply chain flexibility. Terms such as flexibility, responsiveness and agility were used in this context. DeMeyer (1989) and Gerwin (1993) saw flexibility as the ability to react to changes in external environment. Christopher (2000) defined an "agile supply chain" as the ability to respond rapidly to changes in demand, both in terms of volume and variety. Fisher (1997) said that the primary purpose of a responsive supply chain was to respond quickly to unpredictable demand in order to minimize stockouts, forced markdowns, and obsolete inventory.

There is much literature on the topic of matching different classes of supply chain with different products. Christopher (2000) summarized that an agile supply chain is suitable for a less predictable environment where demand is volatile and high variety is required, while a lean supply chain is suitable for high volume, low variety, and a predictable environment. Fisher (1997) said that a responsive supply chain is suitable for products with unpredictable demand, while an efficient supply chain is suitable for products with predictable demand. However, contrary to Christopher (2000) and Fisher (1997), Randall (2003) believed that the hypothesis —

a responsive supply chain is better than an efficient supply chain for a demand uncertain and technologically uncertain products — could not be proved scientifically. Moreover, Vickery (1999) concluded that greater uncertainty did not strongly correlate with greater emphasis on supply chain flexibility by managers in the furniture industry.

Besides stating strategically which type of product needs flexible supply chain, current research did not provide many tactical advices to achieve supply chain flexibility. However, postponement was suggested to increase supply chain flexibility. Zinn (1990) and Zinn (1988) suggested two methods of postponement: time and form. Time postponement is achieved by shipping exact product quantities from a central location, while form postponement is achieved by assembling and keeping intermediate products in a neutral form. Bowersox (1999) said that time postponement provided inventory positioning flexibility and form postponement provided product variation flexibility. Christopher (2000) described the role of the de-coupling point in a supply chain; the material de-coupling point, where strategic inventory is held in as generic a form as possible, should lie as far downstream and as close to the final marketplace as possible. The information de-coupling point, where demand information is used, should lie as far upstream as possible.

During a new product launch, a number of decisions have to be made. Bowersox (1999) categorized these into strategic and tactical decisions: strategic decisions are related to the planning activities for the launch, and tactical decisions are the operational steps for the launch. Guiltinan (1999) listed all the key tactical activities and placed them under promotion, distribution, pricing, product and timing. The supply chain was only addressed very briefly in the distribution activities.

Searching for success factors for a new product, Montoya-Weiss (1994) suggested there were 18 key factors. The factors were placed under the categories of market environment, new product strategy, development process execution, and organization. None of the factors are directly related to the supply chain. After researching new product launch literature, Bowersox (1999) summarized his findings into two main strategies: traditional anticipatory launch strategy and lean launch strategy. In a traditional anticipatory launch strategy, inventories were placed based on demand forecast. In a lean launch strategy, minimum inventories were committed and a flexible logistics system was deployed to respond to early sales success. Again, broad strategies were stated, but tactical operational steps were not mentioned.

In conclusion, research has been conducted on strategic frameworks regarding the type of product that flexible supply chains are suitable for. However, academic literature has not provided many tactical advice beyond the strategic framework, with the exception of postponement. In current product launch literature, supply chain flexibility strategies during product launches were found, but not tactical operational steps.

3 Contract Manufacturing

During the rapid development of the electronics industry in the 1990s, original equipment manufacturers (OEMs) have been increasingly outsourcing non-strategic manufacturing activities to contract manufacturers (CMs). OEMs that plan to launch new products with unknown demand often use CMs to mitigate the downside risk by avoiding fixed cost investment. Most startup OEMs, with even less resources, do not have enough money to build manufacturing operations. Dealing with CMs means that OEMs outsource some of their supplier decisions, inbound logistics decisions, manufacturing decisions, distribution decisions, and outbound logistics decisions. There are different degrees of outsourcing. For example, if an OEM elects to have the CM source its components due to the CM's strong bargaining power with suppliers, most of the supplier-related decisions will be made by the CM. However, if an OEM is interested in directly sourcing some non-standard, proprietary components to secure supplies, most of the supplier-related decisions will be made by the OEM. When OEMs outsource the manufacturing operations, most of their abilities to improve the supply chain flexibility are also outsourced.

3.1 Overview of the contract manufacturing industry

Since the 1960s, there has been a small electronics subcontracting industry in high tech centers such as Silicon Valley. These subcontractors were small and provided simple assembly service of printed circuit boards and standard electronic components for manufacturers. Small companies, which did not have the capital to invest in manufacturing facilities, worked with these subcontractors to build prototypes and low volume runs. Large companies regarded manufacturing as their core competence and building better manufacturing facilities as their competitive advantage.

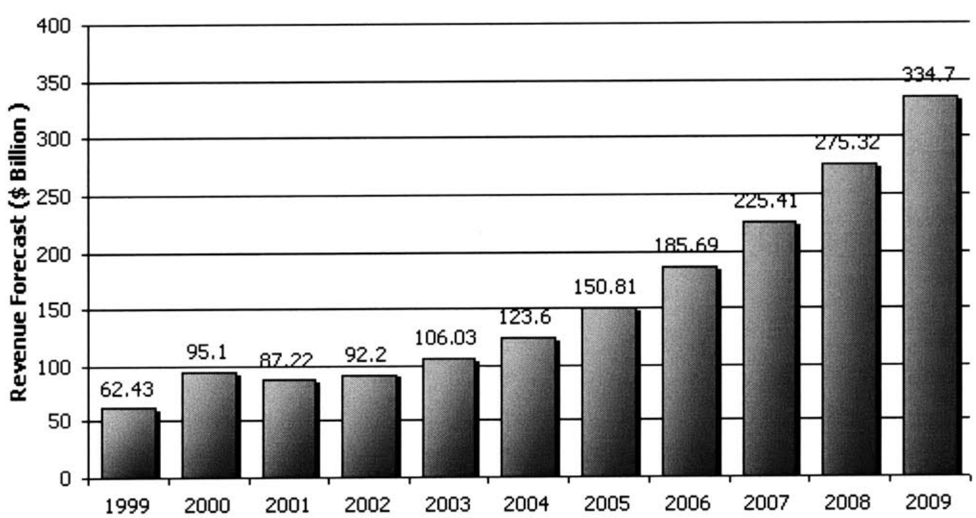
In the 1980s, the growth of IBM PC compatible computers stimulated the vertical disintegration of the electronics industry. The previously tightly vertically integrated supply chain was replaced by horizontal-focused industry specialists. There are specialized players in each component space such as microprocessors, memory chips, hard drives and computer motherboards. Computer manufacturing increasingly became simple assembling of standardized parts and components supplied by various suppliers. With less value-added in the manufacturing process, the computer industry started to subcontract its manufacturing operations to third party manufacturers, initially just a few of the low value-added steps but ultimately the whole manufacturing process. These trends rippled through other sub-segments of the electronics industry.

In the 1990s, a new type of subcontracting firms, contract manufacturers (CM), started to gain growth momentum and dominate the electronics manufacturing sector. CMs, which tend to be larger in scale and global in scope, provide integrated manufacturing services not only for small companies, but also for large companies. Compared with traditional subcontractors, CMs provide all elements of manufacturing including product engineering, highly automated assembly of printed circuit boards, final assembly and configuration of devices.

In the 2000s, trying to grow revenue from their customer base, CMs extended their service offerings to product design, components purchasing, distribution logistics and even customer-facing after-sales services. In addition, CMs also grew aggressively through acquisition of customers' manufacturing facilities. For example, Solectron paid $900 million to acquire Nortel Networks' North American and Asian product assembly assets with over 4,000 employees. The companies then signed a 4-year $10 billion contract manufacturing agreement (Source: Nortel Networks (2000) Press Release.)

The contract manufacturing industry is projected to grow rapidly in the near future. The following is a forecast of the global electronics contract manufacturing market:

Figure 1: Global Contract Manufacturing Revenue Forecast



Source: Frost and Sullivan (2003) Report.

3.2 Types of contract manufacturers

At present, contract manufacturers are generally categorized into three tiers:

Tier-1 CMs are large in scale and global in scope. At present, five CMs are large enough to be considered tier-1.

Table 1: Tier-1 Contract Manufacturers

Company	2004 Sales (US$)	Sales - International Exposure
Flextronics	$13.4B	America – 14%, Europe – 43%, Asia – 47%
Sanmina	$12.2B	America – 27%, Europe and Asia – 73%
Solectron	$11.6B	America – 43%, Europe – 14%, Asia – 42%
Celestica	$8.8B	America – 41%, Europe – 20%, Asia – 39%
Jabil Circuit	$6.3B	America – 35%, Europe – 37%, Asia – 28%

Source: Credit Suisse First Boston (2005) Report.

These tier-1 CMs offered the whole range of services to their clients ranging from component procurement, product manufacturing, outbound logistics to even customer service. In recent years, these players also provided other value-added services such as design for manufacturability and design for procurement, to help their clients to improve the product design. Because of their large component purchase volume, they have strong bargaining power against component suppliers and often obtain the best price and experience less frequent product shortages. Procurement cost savings are in turn shared with customers, which makes tier-1 CMs more competitive. In addition, tier-1 CMs have significant global presence in terms of customer concentration and manufacturing facilities. Most players have manufacturing facilities in North America, South America, Asia and Europe. Because of the standardized manufacturing procedures globally, clients can request CMs to switch manufacturing from one region to another without experiencing serious problems in product quality. Among the facilities around the world, the major differences are level of labor cost (lower in Asia and Eastern Europe) and transportation lead time to customer site (depending on end-customer location). Most customers of tier-1 CMs are larger OEMs with significant global presence.

Tier-2 CMs are smaller in scale and focus on certain market segments, such as fiber optics component assembly. Selected US-publicly listed tier-2 CMs are:

Table 2: Tier-2 Contract Manufacturers

Company	2004 Sales (US$)	Market Focus	Sales – Int'l Exposure
Benchmark	$2.0B	High end computing - 58%	US – 77%
Plexus	$1.0B	Networking - 37%, Medical - 30%	US – 80%

Source: Credit Suisse First Boston (2005) Report.

Tier-2 CMs offer similar services as tier-1 players. However, the range of service offered is more limited. Most tier-2 players do not provide after-sales customer service and design advisory services such as design for procurement and manufacturing. In addition, tier-2 CMs have less global exposure – most of their revenue is derived in the geographical region they focused on and their facility footprints are more concentrated in one geographical region. In addition, because of the niche market focus and smaller economy of scale, tier-2 can only demand premium component pricing from selected suppliers. However, because of their niche focus, tier-2 CMs can provide superior service for clients in their industry of expertise. Most customers of tier-2 CMs are smaller in scale, focused in one product category and one geographic region. There were only approximately 30+ CMs considered tier-2 at the moment, but the definition of tier-2 is not as clear-cut as tier-1.

Tier-3 CMs are the smallest in scale generally, operate only one facility and focus geographically. Compared to tier-1 and tier-2 players, tier-3 CMs offer its clients lower service level and less variety of service offering. For example, some tier-3 CMs do not even offer full component procurement services. Without large purchase quantity, they do not get much discount from component suppliers and likely to experience component shortage when supply is tight. Tier-3 customers are usually the smallest in scale and very locally focused. There are hundreds of tier-3 CMs around the world. Most tier-3 CMs generate less than $250 million in sales.

4 Case Studies

Executives from five different original equipment manufacturers (OEMs) were interviewed to understand how OEMs achieved supply chain flexibility through their partnership arrangements with contract manufacturers (CM) for new product launches. All five companies had successfully launched new products within the past ten years, and all five had different arrangements with various CMs. The scale of the product launch successes varied: one became a billion-dollar business, one was recently acquired for hundreds of millions of dollars, and the other three are in earlier stages of development. Due to the sensitivity of the information provided, the company names and product categories of these five OEMs were disguised, but key lessons can still be learned from these five case studies. In summary, these five case studies verify the importance of contract manufacturing agreement terms and the enforcement of these terms during the execution phase.

4.1 Case Study: Company A

Company A is a California-based original equipment manufacturer of storage-related networking switches. The company was founded in 1995, raised several rounds of venture capital and then went public in 1999; it has over $500 million in revenue, and its market capitalization is over $1 billion.

The first product was launched in 1998. Before 1998, various prototypes were sent off to customers for evaluation and testing. The 1998 design was the first production unit that went through a customer's full qualification cycle. In the beginning of 1998, the product had a very complex electrical hardware design and relatively unstable software, and the company decided it was too early to outsource all of the manufacturing and testing functions to a contract manufacturer. Most of the initial product assembly and testing was done in-house, although the printed circuit board assembly was outsourced.

In mid-1998, the senior management changed its view on outsourcing and hired a new manufacturing vice president to execute the strategy. The change was largely to avoid investment in manufacturing assets when the company prepared for an initial public offering. The manufacturing vice president, who had outsourcing experience, published a "Request for Proposal" and encouraged several tier-1 and tier-2 contract manufacturers to submit their proposals. Several contract manufacturers participated in the process, including a leading tier-1 contract manufacturer (CM-A1), which submitted a bid with competitive terms. As a result, Company A, a promising startup company, signed an agreement to work with CM-A1 to launch its first product in late 1998.

Throughout most of 1998, Company A had only one customer (Customer-A1), a leading information technology consulting business that designed and installed storage solutions using Company A's products. Customer-A1 provided the initial cash flow to sustain the company's early cash needs. In late 1998, Company A signed a supply agreement with a Fortune 500 computer manufacturer. Although the company did not make much profit from this well-known customer, their agreement rapidly increased production volume and helped the company to sign up with other computer manufacturers, exponentially increasing Company A's revenue from this product over the next three years. These major partners resold Company A's products under their own brand names, and over 80% of the company's revenue came from these partners. With a wholly outsourced manufacturing model, Company A provided the product design, while CM-A1 manufactured the product and shipped the product directly to customers. Company A did not physically handle the product.

Because the product used a number of cutting-edge technologies, over 60% of the components (including semiconductors, mechanical parts, and power supplies) were custom-made and could only be sourced from one supplier. The remainder consisted of standard semiconductors and printed circuit boards that could be sourced from two or more vendors. To make sure the possible shortage of proprietary components was well managed, in 1998 Company A hired material procurement managers for each key component area to negotiate prices with suppliers and handle flexibility planning; the company procurement staff ordered these key components from suppliers and had them shipped to CM-A1's factory floor. However, off-the-shelf components that could be multi-sourced were handled by CM-A1, since CM-A1 could obtain better prices due to its procurement volume. Contrary to most contract manufacturing arrangements, Company A invested in material procurement capability and kept the procurement of key components in-house, partially because senior management and the manufacturing vice president had experience in manufacturing complex products.

Over the years, the material handling responsibilities for this product were gradually transferred to CM-A1, with proprietary components slowly displaced by commonly used components. Company A's in-house procurement staff began to work on proprietary components for the company's next-generation products. With the gradual transfer of the procurement process to CM-A1, more specific terms related to carrying costs of component and finished goods inventories were added to their contract in subsequent amendments. However, even with the contract signed, there was a lot of negotiation about how individual procurement and inventory situations would be handled.

In addition, because of the complex manufacturing and testing process, the company made significant investments in designing and purchasing special manufacturing tools for CM-A1 to ensure a smooth transfer of manufacturing capabilities. The process and tools were transferred to CM-A1 in late 1998. The early investment paid off, because manufacturing and testing did not have significant capacity problems, even with a rapid volume increase.

The outsourcing arrangement faced some early problems with product shipment because of the direct shipment arrangement from CM-A1 to the customers. Company A believed that the direct shipment option could reduce the lead time to customers. However, CM-A1's factory, primarily a board assembly facility, did not have the process or the tools to manage hundreds of different ship-to addresses, and many shipments were delayed because of this problem. Eventually, CM-A1 moved the latter part of the product assembly to a facility that had box building experience, and the shipment lead time became more predictable.

When Customer-A1 was the only customer, the demand forecast was relatively accurate. However, when more partners signed up afterwards, the demand forecast was off by an order of magnitude, since management did not expect the technology to take off so rapidly. The volume ramp-up was exponential: $20+ million in 1998, $70+ million in 1999, $300+ million in 2000, and $500+ million in 2001. However, because management had built flexibility into the contract manufacturing arrangement to prepare for possible rapid volume increases, the supply chain successfully kept up with the dramatic increase in demand for the product.

One lesson that the executive learned from this was that tier-1 contract manufacturers have great capabilities in many aspects, but they usually cannot afford to allocate enough resources to smaller partners. A company with $500 million sales is only considered a medium-sized partner by a tier-1 contract manufacturer. There were constant battles between Company A and CM-A1 regarding how many resources CM-A1 was willing to provide to the company. As a result, the company is planning to move its business to another Asian-based tier-2 contract manufacturer for better service and pricing.

4.2 Case Study: Company B

Company B is a California-based original equipment manufacturer of wireless network equipment. It was founded in 2001 and was acquired by a large competitor in the same industry in 2005. Within 4 years, the company became a market leader in its niche and grew its revenue from zero to $100 million.

Company B's first product was launched in late 2002. The product, manufactured by the company's manufacturing infrastructure, went through alpha and beta testing in 2001 and early 2002. These prototypes were built and sent to customer and government agencies for different kinds of testing. In 2003, the company signed up three well-known telecommunications equipment manufacturers (one Japanese, one French, and one Canadian) as customers and partners. The company provided these partners with equipment that bore the partners' brand names; although the electronic circuitry was the same, every branded product had a different physical box design and different embedded software. Because of the new partners' strong distribution channels, the production volume grew from a 20-box batch for testing in 2002 to 50 boxes per month in 2003, 100 boxes per month in early 2004, and more than 1,000 boxes per month in late 2004.

In 2002, Company B successfully raised money from venture capitalists, but it had limited financing resources, so it decided to outsource its manufacturing operations to a contract manufacturer because of the low capital requirement. In 2002, after the burst of the Internet bubble, contract manufacturers were worried about startup companies, and only tier-2 and tier-3 contract manufacturers would consider working with a startup like Company B. As a result, Company B signed an agreement to work with its first contract manufacturing partner (CM-B1), a tier-2 contract manufacturer, in late 2002.

During the early ramp-up phase in 2002, the company worked exclusively with CM-B1. However, the working relationship became increasingly strained due to problems with CM-B1's manufacturing facility. For example, CM-B1 did not build enough production flexibility to ensure on-time product delivery, even when the outsourcing agreement included specific terms on the acceptable date of product delivery after the purchase order. Company B was so worried that it hired four full-time staff members to station at the manufacturing facility to make sure there would not be issues with manufacturing commitment and scheduled product delivery. Finally, Company B decided to terminate its contract with CM-B1 because of CM-B1's lack of commitment.

In 2003, Company B invited various contract manufacturers that fit its preliminary selection criteria to submit proposals for the company's business. The management team devised a set of criteria to evaluate the proposals:

- cost of the product (including component cost, manufacturing cost and CM's margin)
- quality of the product (product reliability, manufacturing yield and other quality measures)
- on-time delivery commitment (penalty that CM compensates OEM for late delivery)
- flexibility plan (how many changes in purchase order are allowed within how much time)
- history with other OEMs (whether CM has good reputation with OEM-size customers)
- proximity of the contract manufacturer's manufacturing locations to the company
- personal relationship between the contract manufacturer's sales staff and the company

Senior management assigned a weight to each criterion, scored the proposals based on the criteria, and used the weighted scores to rank the proposals in a formal decision-making process.

Company B selected a tier-1 global contract manufacturer (CM-B2) that had a manufacturing facility in the same city as the company's headquarters.

To ensure flexibility commitment from CM-B2, a purchase order flexibility schedule was included in the contract to codify the flexibility given to the company. These terms defined the maximum monthly purchase order increase (or decrease) allowed by the contract manufacturer and the commitment of the contract manufacturer. In this case, the terms were approximately as follows:

- within 4 weeks, maximum volume increase is 30% above current monthly forecast
- within 3 months, maximum volume increase is 50% above current monthly forecast
- within 1 year, maximum volume increase is 100% above current monthly forecast

These terms made sure that the contract manufacturer had enough component inventory and manufacturing capacity to fulfill any rapid production volume increase requested by the company. In cases where a larger increase was needed, the issues were solved through case-by-case negotiations.

Because the product had approximately 70% single-sourced components, availability of these components was the major issue for maintaining flexibility. The company picked a set of industry-standard terms—"load and chase" —to improve responsiveness. "Load and chase" terms detailed the actual steps that the contract manufacturer would follow to expedite the component procurement process when demand increased rapidly: (i) the contract manufacturer would "load" the new demand information into its enterprise resource planning system within a certain period of time (around 5 days); (ii) the contract manufacturer would use its best effort to procure, or "chase," key components to ensure the timely delivery of final products; and (iii) the contract manufacturer would promptly inform the company with the premium price of each rush-order component. Because of these arrangements, Company B and CM-B2 could respond quickly to a surge in demand by rapidly processing the new demand information and procuring key components. The arrangement also improved flexibility by giving the company the option to make a real-time trade-off and elect to pay premium for rush-order components for an important sales order.

On the other hand, the demand forecast by Company B's sales and marketing group was extremely inaccurate; the forecast numbers were off by an order of magnitude because the sales team was either too conservative in the beginning or too aggressive later. The monthly revenue of the company grew from approximately $0.5 million at the end of 2003 to over $10 million by the end of 2004. Because of their flexibility arrangement, the company's relationship with CM-B2 was smooth in light of the extreme stress on the partnership. In many instances, especially after closing unexpected sales deals, the demand was instantly loaded into the system, the proprietary components were quickly found, and the final products were delivered on schedule.

The executive learned that it was difficult to enforce most of the terms in the manufacturing agreement (as seen with CM-B1). He suggested that it was better to treat the agreement as a strong letter of intent and communicate the intent clearly in the beginning. After the contract is signed, the relationship is probably too strained if someone needs to reread and enforce a specific term in the contract.

4.3 Case Study: Company C

Company C is an Illinois-based original equipment manufacturer of web hosting products. It was founded in 2000 and raised over $20 million in three rounds of venture capital financing. Within 5 years, it grew into a leading company in its niche market and generated approximately $15 million in revenue.

Company C's first product was launched in late 2002. The management decided to launch the product after receiving favorable feedback from several potential customers who beta-tested the product. In order to become the first commercially available product in its field, the product was rushed into the marketplace. As a result, the engineering team selected the components that fit the specifications of the product, and a number of components could only be bought from one supplier.

Since its first day in business, Company C had believed that it would focus on designing and selling the product. Most of its early employees were in engineering and sales. In early 2002, the company tried to find a contract manufacturer to manage its component procurement, product manufacturing, and final product shipment operations. However, because of its small volume and limited financial resources, the company could not find even a tier-2 contract manufacturer that was willing to provide a comprehensive and reasonably priced proposal. Desperately trying to launch its product, the company found a US-based tier-3 contract manufacturer (CM-C1) to manage its manufacturing operations during the beta-testing and launch phase.

Since the company totally relied on CM-C1 to perform component procurement, manufacturing, and product shipment functions, it did not invest in the capability to perform those tasks. During the beta-testing phase, CM-C1 was effective in getting the 10 beta-testing products out to the customers quickly. However, problems started to surface after the commercial launch phase, with the initial order of 50 boxes for the forecasted first three months of sales. CM-C1 did not assign a strong team to manage that first order, and the whole process was badly organized. First, there was a problem with procurement; two key components took longer than expected to deliver, which held up the whole manufacturing schedule. Secondly, the manufacturing function had quality problems. After the components arrived late, the manufacturing facility rushed through the batch of products, but it took even longer to complete because they had to fix the faulty products.

Due to CM-C1's lack of process orientation, Company C decided to terminate its partnership with CM-C1 in 2003. Learning from the painful experience, the company decided to pick a more capable contract manufacturer to continue its outsourcing strategy. With better funding and a more experienced operations executive, Company C eventually signed an agreement with a global tier-2 contract manufacturer (CM-C2) that had strong sourcing relationships with Intel and Motorola. At the same time, because of the problem with proprietary components, Company C's engineers worked with new procurement staff to reduce the portion of single-sourced components from over 70% to below 20%. One of the tricks they used was to put more functionality into the software and use a commonly-used integrated circuit (IC) instead of putting all functionality into an application-specific integrated circuit (ASIC), which could only be sourced from one semiconductor foundry.

In 2003, Company C was optimistic about its sales due to favorable customer feedback and the strong momentum of the new niche market. The senior management believed that building volume flexibility with the contract manufacturer was important to the success of the product.

The company added two key clauses to the contract with CM-C2 that addressed demand responsiveness by establishing constant and frequent communications and a scheme to reduce lead time.

As written in the agreement between Company C and CM-C2, the two parties were obliged to assign teams to have a monthly meeting. Company C assigned a product manager, an engineer, and a marketing representative to its team, while CM-C2 assigned a manufacturing manager, a procurement specialist, and a customer representative to its team. These groups met every month to exchange up-to-date information on forecasted product demand, possible engineering changes, manufacturing constraints, and component availability. The teams also evaluated the performance of CM-C2 in terms of product quality, delivery punctuality, and supply chain flexibility. As a result, each team clearly understood the needs and the constraints of the other side, and both sides could respond quickly during any sudden change in production volume. In addition, the team members developed strong personal relationships with each other, resulting in faster responses and easier negotiations when the company asked CM-C2 to accommodate last-minute requests.

In addition, the contract included a joint effort to reduce the overall lead time from the company's purchase order to the shipment of the product. This effort covered the following:

- communication of finished product purchase order from Company C to CM-C2
- communication of component purchase order from CM-C2 to component suppliers
- order-to-deliver lead time of components
- dock-to-dock lead time of finished goods from CM-C2 to the company
- product manufacturing lead time

Company C promised to give CM-C2 a monetary reward for any approved steps to reduce lead time that did not increase costs significantly. The reward was in proportion to the days saved against base case lead time and the production volume during the period. Most of the ways to reduce lead time cost money—for example, increasing buffer inventory level or investing in manufacturing and communications tools. However, there were other ideas, such as quicker supply ordering and better manufacturing preparation, which did not cost much money, but had a significant impact on lead time. As a result of this effort, the total lead time decreased from 60 days in 2003 to 50+ days in 2004, then finally to 50 days in 2005. With the reduction in total lead time, Company C paid an undisclosed amount for CM-C2's effort.

As expected, Company C's forecast proved to be unreliable. In 2003, volume grew from 10 boxes per month to 30 boxes per month, which was slower than the forecast. However, in 2004, the volume grew from 30 boxes per month to 300 boxes per month, which was much higher than expected. Due to the reduction in proprietary components, however, there was no component shortage. In addition, because of the periodic team communications and lead-time-reduction scheme, CM-C2 was able to run on a shorter lead time and react more quickly to the changing demand of Company C. These measures were so effective that CM-C2 did not miss any scheduled deliveries, even after experiencing a tenfold volume increase in 2004.

4.4 Case Study: Company D

Company D is a Massachusetts-based original equipment manufacturer of intelligent thermostats. The company was founded in 2003; it has experienced strong volume growth since its first product launch, and will generate approximately $30 million in revenue in 2005.

Company D's first product was launched in mid-2004. By early 2004, the company had successfully begun alpha- and beta-testing with several customers. Trying to generate revenue quickly, the founders of the company decided to expedite the product development and started to look for a contract manufacturer to produce the product. With the small initial order quantity, a US-based tier-3 contract manufacturer (CM-D1) was soon identified, and a relatively simple agreement was signed to cover the initial product run.

Since the company intended to move into volume production quickly, the engineering team was pressured to rush through the design and test phases. However, due to inadequate design review and testing, the company ended up giving CM-D1 a number of engineering change orders (ECOs) throughout the life of the product. These ECOs not only increased the cost of the product, but also delayed the launch date. After a number of ECOs, the company had reduced the proprietary components to approximately 50% of the total bill of materials (BOM). The key proprietary components were an application-specific integrated circuit (ASIC) and a small LCD that fit into the product's design. These proprietary components had a long lead time, for example, the ASIC they used had a lead time of over 25 weeks.

An initial production run of 100 units was ordered in mid-2004. To make sure CM-D1 had enough inventory to work with if the product volume increased rapidly, Company D initially purchased enough components to build up to 1,000 units, which was the expected volume in the first 6 months. The total number of units produced was actually close to the forecast of 1,000 units during that period. Since the volume ramp-up was moderate, the company did not have many problems with CM-D1 in the first 6 months.

In late 2004, the company hired a consultant to improve the flexibility and efficiency of its contract manufacturing arrangement. Understanding the product characteristics and the projected growth in volume, the consultant initially focused on two areas to improve flexibility: 1) replace components with a long lead time, and 2) reduce lead time in every step of the process.

The consultant met with Company D's engineering team and CM-D1's procurement staff to analyze the characteristics of the items with long lead times. The team compared the functionality of these items with alternative shorter-lead-time components. In addition, since Company D did not understand the performances of its vendors in the approved vendor list (AVL), the procurement staff from CM-D1 was asked to provide delivery reliability information on suppliers from the AVL. After the analysis, in the new product design, some proprietary components were replaced by off-the-shelf components with a high degree of functional compatibility. The new AVL also consisted of only vendors with a history of reliable product deliveries. As a result, the proportion of proprietary components was further reduced from approximately 50% to less than 20%, with the ASIC as the only single-sourced item. The total BOM was also reduced by 10% because of the increased use of common parts.

After reducing the amount of proprietary components, the consultant suggested the company should work closely with CM-D1 to aggressively reduce overall lead time. The consultant frequently contacted CM-D1 employees who worked on Company D's account in order to understand CM-D1's operational procedure, explore CM-D1's relationship with component vendors on the AVL, and find out possible ways to improve the lead time of the manufacturing process. The analysis suggested that additional staff commitment from CM-D1 alone would reduce the lead time by a week. With that information, Company D then negotiated with CM-D1 to obtain higher-priority treatment from CM-D1 staff and improve the responsiveness of the arrangement; in return for the improved service level, Company D guaranteed more volume to CM-D1. Finally, the company chose suppliers that were willing to deliver products faster without a significant increase in costs. With all these lead time reduction measures, the lead time from purchase order to product delivery decreased from 12 weeks to 10 weeks.

Company D went through exponential growth in late 2004 and early 2005. The production volume increased from 250 units per month to 1,000 units per month within four months. By late 2005, the volume is forecast to reach 2,000-2,500 units. Because of the reduction in unnecessary proprietary components, Company D saved money by keeping a high level of buffer inventory. The reduction in lead time also greatly improved the responsiveness of the supply chain and contributed to the smooth ramp-up in production volume.

4.5 Case Study: Company E

Company E is a Britain-based original equipment manufacturer of specialized computer servers. The company was founded in 1996. In 2001, when it was the leading player in its niche, the company generated $15 million in revenue. An executive in its manufacturing operations was interviewed in 2005.

Company E's first product was launched in 2000. The prototype testing in 1999 had such a favorable response from customers that a leading computer manufacturer (Customer-E1) partnered with Company E and marketed the product as an integrated part of its own product offering. Customer-E1 required the company to work with a tier-1 contract manufacturer to guarantee the quality of the product and process performance. As Company E did not have the production volume to secure a deal with any tier-1 contract manufacturer, Customer-E1 asked its global tier-1 contract manufacturer (CM-E1) to work with Company E. Since Customer-E1 basically provided a financial guarantee to cover Company E's low creditworthiness, Company E was able to obtain reasonable manufacturing terms that it could never obtain by itself.

Company E had two classes of servers in its product line: a high-end 128-port server and a low-end 8-port server. These two product lines had very different characteristics. The 128-port server was a lower-volume product with a complex manufacturing process that sold mainly through Company E's channel, while the 8-port server was a higher-volume product with a less complex manufacturing process and sold mainly though Customer-E1's channel.

For the high-end 128-port servers, approximately 70% of the total bill of materials (BOM) was made up of single-sourced components such as application-specific integrated circuits (ASICs). Although the procurement of all components was outsourced to CM-E1, the company worked closely with the procurement staff of CM-E1 to develop a component procurement and inventory plan. In order to ensure the availability of these proprietary components, the company required a weekly inventory report of the proprietary ASIC components, in addition to a monthly report of all components. The company maintained a strong working relationship with the ASIC vendor to keep a direct information channel on the inventory situation. In summary, the primary focus of the high-end server product manager was to monitor the proprietary component situation.

Moreover, the contract included a set of "load and chase" clauses to help ease the pressure of proprietary component shortage. These terms made sure that any sudden change in demand would be "loaded" into CM-E1's enterprise resource planning system within 2 working days. In addition, if component availability was questionable, CM-E1 was obliged to use its best effort to "chase" its vast supplier network to procure the necessary proprietary components. With the high price tag of the servers and the targeted niche market, the production volume grew relatively moderately, from zero in 2000 to 10 servers per month in 2001. With the extra attention paid to proprietary components, CM-E1 was able to deliver the servers with a 14-week lead time in most cases.

For the low-end 8-port servers, only 30% of the total BOM was made up of single-sourced components. The primary focus of the low-end server product manager was to constantly monitor the process of ordering, manufacturing, and delivering the product. The lead time for each step was continuously recorded and analyzed by the company. If there was any sudden increase in lead time, the company would meet with CM-E1 to determine the reason for the change and to search for possible solutions. With Customer-E1's distribution network, adoption of Company E's low-end product grew rapidly. The volume grew from 2 servers per month in 2000 to 100 servers per month in 2001. For the low-end product, CM-E1 achieved an almost perfect product delivery time record and kept a 5-week lead time, partly because of the ongoing monitoring of the process lead time.

All these measures were highly successful during the rapid increase in production volume in 2001. In 2002, Customer-E1 was acquired by another computer manufacturer, and the new entity did not provide as much sales support to Company E's product as before. To make things worse, Company E's second-generation products were not competitive against other new products. As a result, the overall production volume dropped significantly in 2002. With layoffs at Company E and less attention from CM-E1, the parties had difficulty keeping all the flexibility in place. After they stopped closely monitoring the contract manufacturing process, the production lead time became less predictable. At present, Company E is considering switching to a smaller contract manufacturer that will give their account the appropriate management attention.

5 Analysis

The five case studies illustrated the problems different companies faced, the key tactics used by management to improve supply chain flexibility, and the results of these tactics. By comparing these five cases, conclusions can be drawn about sustainable types of contract manufacturing partners at various sales and growth levels, the accuracy of demand forecasting, and the level of proprietary components used in the initial run of a product. In addition, companies with products that used different proportions of proprietary components had different constraints to improve supply chain flexibility. As a result, companies set different priorities and used different sets of tactics to achieve their objectives. Only important observations and analyses from the case studies were commented in the following sub-sections. Other factors, such as number of customers of equipment manufacturers, were not significant in product launch supply chain decision.

On the other hand, only five companies were selected and responded to complete the case studies. In each case, one current executive was interview by phone. The interviews on average lasted for 90 minutes for the first time and 15 minutes for follow-on interviews if further clarification were needed. These interviews only focused on collecting information on the background of companies and products, the relationship between the companies and their contract manufacturers and the key measures that the companies used to ensure supply chain flexibility.

5.1 Revenue level and contract manufacturer type

Each company had a different experience with its contract manufacturer (CM) throughout its lifecycle. The following table summarizes the types of contract manufacturers used by the five companies:

Table 3: Revenue Level and Contract Manufacturer Type

Company	Peak annual revenue (year)	First CM	Current CM	Future CM
A	$500M (2001)	Ticr-1 (1998)	No change	Tier-2 (2005)
B	$100M (2004)	Tier-2 (2002)	Tier-1 (2003)	No change
C	$20M (2004)	Tier-3 (2002)	Tier-2 (2003)	No change
D	$30M (2005)	Tier-3 (2004)	No change	No change
E	$15M (2001)	Tier-1 (2000)	No change	Tier-3 (2005)

Timing played a role in the type of CM a company could partner with in its startup phase. After the Internet bubble burst in 2001, tier-1 CMs were worried about the health of startup companies, so the startup companies only had the chance to work with tier-2 and tier-3 CMs. Companies B, C, and D illustrated this observation. Before the Internet bubble burst, startup companies had the chance to work with tier-1 CMs; Company A, a pioneer in outsourcing, successfully partnered with a tier-1 CM in 1998, while Company E was able to outsource its service to a tier-1 CM with the financial backing of its large computer manufacturing partner.

There is also a relationship between revenue and sustainability of CM type. A sustainable relationship with a tier-1 CM requires high revenue growth or sizable production volume. Company A, with $500 million in revenue since 2001, could sustain a close relationship with a tier-1 CM, but Company A was unhappy about its treatment and planned to switch to a tier-2 for better service. Company B, with its high growth trajectory, was able to maintain a healthy relationship with a tier-1 CM. Because Company B's new parent uses the same tier-1 CM, its production partner will not change. Company E's low revenue and negative growth forced it to switch to a smaller CM, as the tier-1 CM could not afford to provide enough attention to a smaller customer. For smaller companies, it is more sustainable to use a tier-2 or tier-3 CM. Companies C and D were satisfied with their tier-2 and tier-3 CMs because they provided the appropriate types and levels of service for companies of their size. That is also why Company E is looking for a tier-3 CM—to obtain the right level of attention and service. In short, only large and high-growth companies can sustain tier-1 CMs; tier-2 and tier-3 CMs are better fits for smaller and lower-growth companies.

Moreover, as we saw from these five companies' changing contract manufacturing partnerships, it is common practice to switch from one CM to another. When Companies B and C were not satisfied with the quality of service they were getting, they moved to higher-tier CMs. When Companies A and E had problems with the amount of attention they received from their CMs, they moved to lower-tier CMs. Only Company C found the right mix of service level and attention from its CM. However, it is the youngest company of the five.

5.2 Growth pattern and demand forecast

All five companies experienced different growth patterns. The following table summarizes their growth patterns and comments on forecast accuracy:

Table 4: Growth Pattern and Demand Forecast

Company	Growth pattern	Comment on forecast accuracy
A	- high growth in year 1-3 - no growth in year 4-6	Very inaccurate
B	- high growth in year 1-3	Very inaccurate
C	- medium growth in year 1-3	Quite inaccurate
D	- medium growth in year 1-2	Moderately accurate
E	- medium growth in year 1-3 - decline in year 4-6	Quite inaccurate

These five companies experienced different levels of success during their rapid-growth phases. Company A was the most successful one, but it stopped growing after 2001. Company B, a pioneer in a rapidly growing field, grew exponentially within 3 years. Companies C, D, and E targeted niche markets, so their revenue growth was relatively moderate. Company E also experienced a rapid decrease in revenue due to loss of support from a key customer and an uncompetitive product offering. While most startup companies survive long enough to experience some growth phase, these five companies belonged to a select group of successful startups.

Four of the five operation managers expressed that their demand forecasts were unreliable. With the exception of Company D, their comments on forecast accuracy ranged from "quite inaccurate" to "inaccurate by an order of magnitude." At Companies A and B, the sales and marketing staff were too conservative in the beginning when the market developed rapidly and too aggressive afterwards when the market growth started to plateau. In the case of Company C, the forecast was too aggressive when the niche market developed slowly and too conservative when the market started to develop rapidly. To further complicate the situation, in the case of Company E, forecasts were too conservative or aggressive for the high-end and low-end product types. Since it is very difficult to estimate when these new markets take off, building a flexible supply chain is the best way to hedge against forecast inaccuracy.

5.3 Proportion of proprietary components

All five companies designed different types of products. The proportion of proprietary components in the total billing of materials varied as follows:

Table 5: Proportion of Proprietary Components

Company	Product description	Initial proprietary component %	Final proprietary component %
A	Storage-related network switch	60%	< 60%
B	Wireless network equipment	70%	< 70%
C	Web hosting server	70%+	20%
D	Intelligent thermostat	50%+	20%
E	Specialized computer server	70% / 30%*	70% / 30%*

** 70% for high-end servers and 30% for low-end servers.*

All five products, except the low-end servers of Company E, included a high proportion of proprietary components in the initial phase. Because of pressure to launch the products quickly, the engineering teams usually picked existing components or designed new components that performed specific tasks without much regard for the sourcing consequences. Over time, with the involvement of procurement staff from companies or CMs, more common components were included in the new product designs to reduce reliance on long-lead-time components. The trade-off is essential time to market and the manufacturing complexity or product cost. At Company C, problems with component shortages drove significant changes in product design to allow the use of more common components. In the case of Company D, the consultant aggressively pushed for a new product design that reduced the proportion of proprietary components.

5.4 Strategies and tactics to improve flexibility

Each company focused on different areas to improve flexibility in its arrangement with its CM. The five operations managers believed that the following tactics best improved supply chain flexibility:

Table 6: Key Flexibility Tactics

Company	Proprietary component %	Key tactics
A	60%	- hire staff to manage procurement in-house - transfer manufacturing tools and knowledge to CM
B	70%	- purchase order flexibility schedule - "Load and chase" provision
C	20%	- formalize communications between the parties - give CM incentive to reduce overall lead time
D	50%+ (initial)	- keep large component inventory buffer
	20% (final)	- closely work with CM to reduce overall lead time
E	70% (high-end)	- closely monitor proprietary components - "Load and chase" provision
	30% (low-end)	- closely work with CM to reduce overall lead time

In the case of Company D, the proportion of proprietary components was reduced from 50%+ to 20% after the consultant pushed for more commonly-used components. In these two different scenarios, the company used different tactics to achieve supply chain flexibility. In the case of Company E, the high-end product had a different component mix compared with the low-end product. For these two different product lines, the managers focused on different ways to improve flexibility.

To understand these tactics, their characteristics were studied and then they were categorized by their objectives:

Table 7: Objectives and Tactics

Objectives / Strategies	Related tactics
Reduce impact of long-lead-time components	- hire staff to manage procurement in-house - "Load and chase" provision - keep large component inventory buffer - closely monitor proprietary components
Reduce overall process lead time	- formalize communications between the parties - give CM incentive to reduce overall lead time - closely work with CM to reduce overall lead time
Others	- transfer manufacturing tools and knowledge to CM - purchase order flexibility schedule

A number of tactics—for example, active management procurement and building an inventory buffer—reduced the risk of component shortage. Other tactics, such as lead-time monitoring and formalized communications, helped to reduce the lead time of the outsourcing process. Combining the categorization of the strategies and the proportion of proprietary components, another conclusion can be drawn:

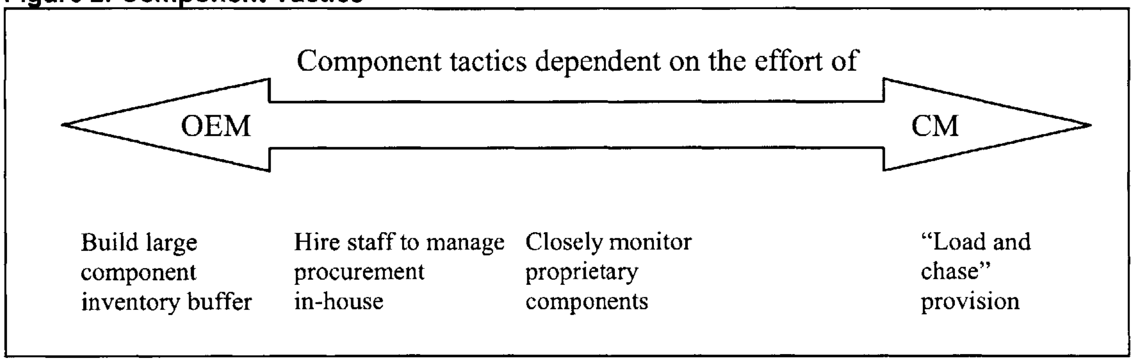
Table 8: Proprietary Components and Tactics

Proprietary component %	Strategies	Related tactics
High	Reduce impact of long-lead-time components	- hire staff to manage procurement in-house - "Load and chase" provision - keep large component inventory buffer - closely monitor proprietary components
Low	Reduce overall process lead time	- formalize communications between the parties - give CM incentive to reduce overall lead time - closely work with CM to reduce lead time

A relationship between the proportion of proprietary components and the strategies used could be derived from these five case studies.

When the proportion of proprietary components was high, as in the cases of Companies A, B, D (initially), and E (high-end products), management focused on managing the availability of long-lead-time components to avoid any shortage. In these four cases, managers deployed different tactics to achieve this objective.

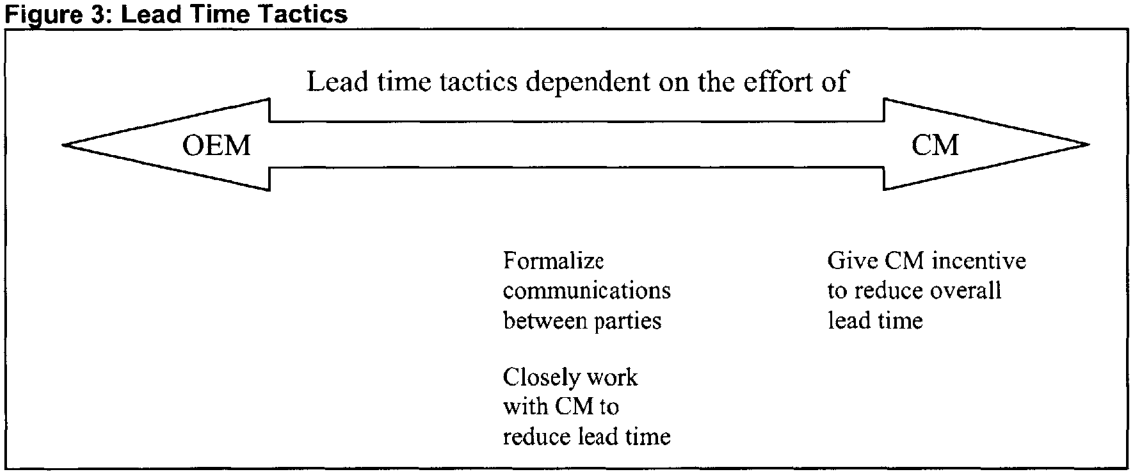
Figure 2: Component Tactics



The above figure shows the different component tactics' dependence on the effort of the parties. The most extreme way was to keep a high buffer of component inventory, as in Company D's case initially. Although component shortages were largely avoided, the company had to keep a high level of inventory, which could potentially be costly. Another aggressive tactic was to hire a dedicated procurement staff to manage the procurement decision in-house, as in Company A's case. Although this may be an expensive solution for a startup company, the company may find this investment worthwhile. A less involved tactic was to assign product managers to work closely with the CM's procurement staff in every aspect of proprietary component procurement and inventory decisions, as Company E did. Getting involved in the CM's procurement decisions would generally have a positive impact on flexibility, but the degree of improvement would depend on the level of communications between the parties. As shown in the cases of Companies B and E, the cheapest tactic was to include a "load and chase" provision in the contract manufacturing agreement to make the CM responsible for "chasing" long-lead-time components from its vendor network. These standard terms should ideally improve supply chain flexibility, but their effect depends on the actions of the CM. These four tactics each have their strengths and weaknesses; it is advisable to find the optimal combination of tactics for each high-proprietary-component situation.

When the proportion of proprietary components was low, as in the cases of Companies C, D (final), and E (low-end products), management focused on reducing the overall lead time to make the supply chain more responsive. In these three cases, managers deployed different tactics to achieve this objective.

Figure 3: Lead Time Tactics



All three tactics required active involvement from both the OEM and the CM, but the degree of involvement required from each party varied, as illustrated above. The CM was the most involved when the company provided the CM with incentives to reduce overall lead time, as in the case of Company C. While the CM might try its best to find creative ways to reduce lead time, it does not have the incentive to fully disclose the tradeoff needed to achieve the results. On the other hand, there were two tactics that required similar involvement from both parties: formalizing communications and regular meetings, as in the case of Company C, and working closely with the CM to reduce overall lead time, as in the cases of Companies D and E. Although frequent meetings might help the parties understand each other's concerns and constraints to improve responsiveness, they require both parties to openly discuss their corporations' limitations in order to be effective. Having both parties discuss ways to reduce the lead time could be helpful, but the CM does not have a strong incentive to help the company reduce the lead time. Like the component tactics, these three lead-time tactics each have strengths and weaknesses; it is advisable to find an optimal combination of these tactics for each low-proprietary-component situation.

6 Application

The knowledge derived from the case studies will be applied to a startup company (BoxCo) that is considering its contract manufacturing options. BoxCo is a Massachusetts-based original equipment manufacturer of wireless networking equipment. The company was founded in 2003 and successfully raised several million dollars from a local venture capital firm in 2005. The founder of the company was interviewed in 2005.

The company has just finished its prototype alpha-testing phase. It plans to start beta-testing by mid-2005. If the results from beta-testing are satisfactory, the company will consider launching the product in early 2006. With the backing of investors and advice from other entrepreneurs, the founder decided not to invest in manufacturing capabilities and to outsource its manufacturing operations to contract manufacturers. As in most new product launches, the company cannot accurately predict the demand for this product. As a result, it is important to devise a contract manufacturing engagement plan with consideration of supply chain flexibility. Besides a team of 10 engineers, BoxCo's other employees are the CEO and the founder, who leads product development and will deal with the contract manufacturer in the future. The alpha-testing prototype consists of more than 80% proprietary components, but the company has set a target of 70% proprietary components for the beta-testing prototype.

In short, BoxCo is an ideal case to apply what we learned from the five case studies and develop a flexible contract manufacturing engagement plan.

6.1 Choose the right contract manufacturer

As illustrated in section 5.1, the contract manufacturer that will offer a reasonable proposal to BoxCo is likely to be a tier-2 or tier-3 player. Since BoxCo is operating in a sector similar to that of Company B and aiming for a similar exit strategy, its growth prospects may be similar to those of Company B. With that growth objective, therefore, BoxCo should work hard to convince a tier-2 CM to take its business. It would not be advisable to approach tier-1 CMs because of the mismatch between BoxCo's size and the demand of tier-1 CMs; even if an agreement is signed, the relationship will not be sustainable, as BoxCo will not get enough attention from the tier-1 CM.

Nevertheless, BoxCo should perform full due diligence on its contract manufacturing candidates, learning from the experiences of Companies B and C when they switched to higher-tier CMs. Due to its unstable product design, BoxCo will likely submit several major engineering change orders to its CM during the production phase. To prepare for the intense communications required by such changes, BoxCo should try to find a CM that has a local manufacturing facility. If it has not recruited a manufacturing manager when the decision is made, BoxCo should consider hiring an external consultant to help evaluate the options.

6.2 Manage proprietary components

Since the alpha- and beta-testing prototypes consist of 80% and 70% proprietary components, the volume production unit will likely have a high proportion of proprietary components. The largest constraint on supply chain flexibility will be the availability of these proprietary components. To improve its ability to handle proprietary components, BoxCo should apply the component-related strategies and tactics summarized in the first half of section 5.4. Firstly, BoxCo should analyze the availability of all long-lead-time components and create a limited buffer inventory of the longest-lead-time components. Secondly, a "load and chase" provision should be included in the contract manufacturing agreement, so that BoxCo can communicate its intent to make its CM responsible for quickly solving component shortage problems.

In terms of BoxCo's involvement in the procurement process, BoxCo should do further cost-benefit analysis to evaluate its return on investment. BoxCo should compare the net benefit of handling procurement in-house (the component costs in this case net in-house procurement expenses) with the net benefit of outsourcing procurement (the component costs in this case net outsourced procurement staff expenses.) If the cost-benefit analysis determines that high involvement makes sense and its budget allows, BoxCo should hire a procurement manager to handle component procurement decisions in-house, at least during the period when the product still includes a high proportion of proprietary components. However, if the cost-benefit analysis determines that high involvement does not make sense or its budget is too tight, BoxCo should at least assign a product manager to work closely with the CM's procurement staff and regularly monitor proprietary component procurement and inventory decisions.

6.3 Reduce the proportion of proprietary components

As indicated in the cases of Companies C and D, the engineering team can find creative ways to reduce the proportion of proprietary components with a new product design. If the volume production unit has a high proportion of proprietary components, BoxCo should create a task force to concentrate on this effort, made up of BoxCo engineers and procurement staff from BoxCo and the CM. The task force should analyze component lead time, compatibility of alternative components, and vendor reliability to search for the optimal product design. In addition, the task force should continuously evaluate the product design to respond to changes such as the introduction of new components and the obsolescence of old components.

An even better idea is actually hiring a procurement expert to participate in the initial design of the beta-testing and volume production units. If the proportion of proprietary components can be lowered at this early stage, BoxCo will save not only the cost of making engineering change orders, but also most of the costs related to management of long-lead-time components in Section 6.2. However, an early effort may not be feasible because of the trade-off between brining the product to the market as soon as possible and making an effort to use less proprietary components. In BoxCo's situation, one of the milestones from the venture capital investor is the product launch date, so engineering team will not likely have enough time to reduce the proportion of proprietary components with a tight product launch deadline.

6.4 Reduce the overall lead time

After minimizing proprietary components and executing the component-related tactics in Section 6.2, the availability of proprietary components will no longer limit supply chain flexibility. BoxCo should then turn its focus toward reducing the overall lead time of the contract manufacturing arrangement. BoxCo should apply the lead-time-related strategies and tactics summarized in the second half of section 5.4.

BoxCo should explore the possibility of providing the CM with an incentive to find creative ways to reduce lead time at every step, from confirmation of the purchase order to delivery of the finished product. A fair incentive structure using measurable metrics should be jointly developed by both parties. For example, the measurable metrics should include the initial overall lead time, the current lead time and the total cost of products during the period. In addition, the product manager of BoxCo should work closely with the CM to learn the inner workings of the CM. The product manager will then better understand the consequences of each suggestion made to reduce lead time. As illustrated in the case of Company D, BoxCo may be able to negotiate a higher service level to reduce lead time if BoxCo is comfortable with offering a higher volume commitment in return.

7 Conclusion

The research was motivated by the need to have flexible supply chains for new product launches by startup companies. Current literature addresses how to design a flexible supply chain at the strategic level, but not at the tactical level. With the increase in manufacturing outsourcing, original equipment manufacturers have found that the way to improve supply chain flexibility is to develop a flexibility-based engagement plan to work with contract manufacturers.

Executives from five original equipment manufacturers with successful product launches at their startup phase were interviewed to explore the strategies and tactics that improved supply chain flexibility. The key findings from these five case studies were analyzed, and the successful strategies and tactics were categorized by the proportion of proprietary components.

The findings were then applied to a startup company, BoxCo, that is currently working on a contract manufacturing strategic plan for its product launch. To make sure that BoxCo's management is focused on the most pressing issues affecting supply chain flexibility at each stage, a four-step process was developed and applied to BoxCo:

1. choose the right contract manufacturer,
2. manage proprietary components,
3. reduce the proportion of proprietary components, and
4. reduce the overall lead time.

In the future, more researches should be done to understand various ways to design a flexible supply chain for new product launch. For example, additional case studies will help researchers (a) to collect more valuable tactics used by OEMs, (b) to understand more about the situation OEMs and CMs faced during the decision making process, (c) to derive stronger causality between different tactics and situations, and (d) to develop better frameworks for decision making. Moreover, other innovative practices such as using contract manufacturers to perform postponement and engaging third party logistics providers with contract manufacturers to handle outbound logistics should be studied to help companies to manage these new tools to improve supply chain flexibility during product launch.

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